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Article

The sustainable development of small and midsize enterprises in China on green reverse logistics

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Abstract: In response to the increasing global emphasis on sustainability and the specific challenges faced by small and medium-sized enterprises (SMEs) in China, this study explores the integration of green reverse logistics within these enterprises to enhance their sustainability and competitiveness. The aim of this study is to understand the relationship between reverse logistics, green logistics, and sustainable development. Data analysis was conducted utilizing a combination of descriptive statistics and correlation analysis. A survey of 311 participants examined SMEs' performance in reverse logistics practices and their initiatives in green logistics and sustainable development. The empirical findings reveal significant progress in reverse logistics practices among SMEs, reducing environmental impact and improving resource efficiency. Moreover, a notable positive correlation was identified between reverse logistics promotion and advancements in green logistics and sustainable development. SMEs' investment in reverse logistics is closely linked to their efforts in environmentally conscious and sustainable supply chain management. These insights benefit SMEs and supply chain practitioners and offer a valuable reference for future research and practical applications in this field.

Keywords: sustainable development; green logistics; reverse logistics; small and medium-sized enterprises

1. Introduction

In the context of small and medium-sized enterprises (SMEs) in China, the integration of green reverse logistics has become a pivotal strategy for promoting sustainable development. As global markets increasingly prioritize environmental responsibility, SMEs must adapt by adopting practices that not only reduce their ecological footprint but also enhance their competitiveness and resilience. This study explores the significant role that reverse logistics plays in the broader framework of green logistics, emphasizing its impact on resource efficiency and environmental sustainability (Fleming et al., 2017; Pradhan et al., 2023).

The logistics field engages in a perpetual cycle of ongoing enhancements and progress. Logistics encompasses various activities, such as organization, planning, management, and execution, aimed at fulfilling market demands in a cost-effective manner, while minimizing capital expenditure (Denisa and Zdenka, 2015). The concept of green logistics encompasses a series of systematic approaches and methodologies employed in supply chain management. Its principal aim is to mitigate the adverse environmental repercussions linked to the distribution of goods, with strong emphasis placed on diverse facets, including material handling, waste management, packaging, and transportation. The term "ecosystem" encompasses varying definitions and interpretations within academic discourse. This subsystem can be classified as a logistics-oriented subsystem, as it predominantly focuses on the key elements of the logistics process, namely, the collection, storage, and transportation processes. The concept of green logistics encompasses an examination of how business activities and procedures contribute to environmental effects. The integration of environmentally friendly logistics operations within SMEs represents a means of fostering a positive perception of the organization, while simultaneously promoting long-term profitability and continuity in the business (Denisa and Zdenka, 2015; Maji, 2023). The consequent outcome of such activities is a notable augmentation in customer loyalty, bolstering brand trust and augmenting business profits (Maji, 2023). Companies can exhibit different levels of advancement in adopting green logistics practices, with certain firms being compelled to move towards a more advanced stage, whereas others tend to maintain their current level. Certain corporations may opt to curtail the extent of their ecological logistics solutions owing to a variety of factors. The attainment of complete environmental sustainability within an organization necessitates the implementation of inter-organizational collaboration with other partners within the supply chain. This collaborative effort significantly amplifies the ecological impact of the resulting green practices, surpassing the effectiveness of utilizing such practices within a single company (Zowada and Niestrój, 2019).

In addtion, the phenomenon whereby goods or products are transported from consumers to manufacturers to recover value or facilitate their environmentally responsible disposal is recognized as reverse logistics (Mugoni et al., 2023). Reverse logistics encompass all logistical operations involved in the retrieval and processing of previously utilized goods that are no longer required by consumers, ultimately rendering them suitable for reintroduction into the marketplace (Fleischmann et al., 1997). The field of business in question has garnered growing interest owing to a multitude of factors. This upward trend in consumer environmental awareness has led to a concomitant increase in the frequency of merchandise returns. Furthermore, secondary markets have flourished based on the fundamental concept of discarded merchandise. One significant rationale behind the obligatory utilization of end-of-life products lies in the implementation of rules and regulations that mandate companies to undertake proper disposal measures for returned products (Alshamsi and Diabat, 2017).

Despite growing interest in sustainability, there is limited research specifically focused on the role of reverse logistics in enhancing green logistics and sustainability among SMEs in China. Existing studies often address large corporations or broader economic trends, leaving a gap in understanding how SMEs, which form the backbone of the Chinese economy, are adopting these practices. This study seeks to fill this gap by providing empirical insights into the effectiveness of reverse logistics in improving environmental and sustainability outcomes for SMEs. The primary purpose of this study is to evaluate how effectively SMEs in China are integrating green reverse logistics into their operations and to assess the relationship between reverse logistics, green logistics, and sustainable development. The study will address the following research questions:

1) How does the promotion of reverse logistics influence the improvement of green logistics within SMEs?
2) What is the impact of reverse logistics on the overall sustainability of SMEs?

This study contributes to the literature by highlighting the practical implications of integrating green reverse logistics for SMEs in China. By examining the relationship between reverse logistics and sustainability, the findings offer valuable insights for SME managers, policymakers, and researchers interested in promoting sustainable business practices. Understanding how SMEs can leverage reverse logistics to enhance their environmental performance can inform future strategies and policies aimed at supporting sustainable development within this critical sector.

This study is structured as follows. First, a review of relevant literature on green and reverse logistics in the context of SMEs will be presented. Next, the methodology section will outline the research design, data collection methods, and analytical approach. Subsequently, the findings and discussion of the study will be discussed. Finally, the study will conclude with recommendations for future research directions.

2. Literature review

2.1. Reverse logistics and green logistics

The integration of green logistics and reverse logistics is crucial for advancing sustainability in enterprises, particularly small and medium-sized enterprises (SMEs). Research has highlighted the significant role these practices play in enhancing economic, environmental, and social sustainability. Richnák and Gubová (2021) demonstrate a positive correlation between sustainable development initiatives and improvements in green logistics, emphasizing their importance for SMEs, which are vital for economic growth and innovation (Chisala, 2008). However, there remains a need for substantial improvement in reverse logistics within SMEs to better support circular economy practices and sustainability (Dey et al., 2022a).

Green logistics involves various systematic approaches to minimize the environmental impact of logistics activities, including material handling, waste management, packaging, and transportation. The concept aims to mitigate adverse environmental effects while fostering long-term profitability and business continuity (Denisa and Zdenka, 2015; Maji, 2023). Effective implementation of green logistics can enhance customer loyalty, brand trust, and overall profitability (Maji, 2023). Despite these benefits, many SMEs face challenges such as high costs and lack of support mechanisms, which hinder their adoption of green practices (Malá et al., 2017b).

Kosacka-Olenjik and Werner-Lewandowska (2018) proposed a reverse logistics model to optimize the retrieval of value from returned items by promptly addressing issues related to customer returns. This model is particularly relevant in e-commerce, where reverse logistics play a crucial role in managing product returns and integrating circular economy principles (Nanayakkara et al., 2022). The application of decision support systems in reverse logistics networks facilitates the effective management of product returns, supporting both economic and environmental goals (Nosrati-Abarghooee et al., 2023). Additionally, Jahangiri et al. (2022) focused on reverse logistics networks for managing construction and demolition waste, while Mangla et al. (2016) developed a structural model of critical success factors for adopting reverse logistics, using methods such as Analytic Hierarchy Process (AHP) and Decision-Making Trial and Evaluation Laboratory (DEMATEL).

2.2. Reverse logistics and sustainability development

Reverse logistics refers to the processes involved in managing the return, recycling, reuse, or disposal of products from the point of consumption back to the point of origin. This process is crucial for enhancing sustainability across economic, environmental, and social dimensions (Presley et al., 2007). The strategic integration of reverse logistics into SMEs' operations can lead to significant improvements in sustainability practices by fostering new product development and enabling closer collaboration with stakeholders, thus creating additional value (Bos-Brouwers, 2010).

Empirical research supports the role of reverse logistics in promoting sustainable development. Araujo et al. (2013) demonstrate that reverse logistics is a pivotal tool in various sectors, including e-commerce, where it enhances sustainability by optimizing resource recovery and reducing waste. This integration into the e-commerce sector helps manage returns and reprocessing, which are critical for maintaining sustainability in fast-paced supply chains. Incorporating Corporate Social Responsibility (CSR) and sustainability considerations into reverse logistics systems can substantially boost both environmental and financial performance (Nikolaou et al., 2013). This integration helps firms align their operational practices with broader sustainability goals, improving their overall market position and reputation. For instance, CSR initiatives can drive reverse logistics practices that focus on minimizing environmental impact and ensuring ethical disposal of products.

Reverse logistics complements traditional logistics by enhancing waste management practices and mitigating environmental risks (de Jesus Avero and Senhoras, 2014). The integration of reverse logistics practices such as green procurement, recycling, reuse, and remanufacturing is vital for achieving environmental sustainability within the supply chain (Leigh and Li, 2015). These practices ensure that waste is effectively managed and resources are optimally utilized, thereby reducing the environmental footprint of logistics operations. A comprehensive reverse logistics network, as discussed by Yu and Solvang (2016), plays a crucial role in enhancing overall sustainability in the logistics sector. Such networks integrate various sustainability practices, including efficient resource recovery and waste reduction, contributing to a more sustainable logistics ecosystem. The development of these networks helps companies meet regulatory requirements and achieve long-term sustainability goals.

The interaction between reverse logistics and the circular economy is essential for creating value and achieving sustainability goals. Julianelli et al. (2020) emphasize that understanding and leveraging key success factors in reverse logistics can align practices with sustainability and operational efficiency goals. The circular economy framework promotes continuous resource use and waste minimization, which are facilitated by effective reverse logistics systems. Sun and Liu (2023) argue that enhancing eco-efficiency within regional logistics industries is crucial for achieving sustainable economic development and environmental conservation. Their study highlights the need for localized strategies to improve resource utilization and minimize environmental impact. This is particularly relevant for regions with specific logistical challenges or regulatory environments.

Despite the benefits, there are significant barriers to the adoption of sustainable logistics practices, especially among SMEs. High costs and lack of governmental support are major impediments (Malá et al., 2017a). These barriers hinder SMEs from implementing reverse logistics practices and achieving sustainability goals. Zhou et al. (2023) identify that while green logistics management positively influences circular economy practices, the benefits are often mediated through these practices, which highlights the need for more effective implementation strategies. Zowada (2020) finds that many SMEs, particularly in Poland, exhibit limited interest in developing "green" logistics practices due to a lack of experience with their advantages. This reluctance is often due to perceived high costs and insufficient immediate benefits. Addressing these challenges requires targeted incentives and support mechanisms to encourage SMEs to invest in sustainable practices.

3. Materials and methods

The primary objective of this study is to examine the interrelationships among reverse logistics, green logistics, and the principles of sustainable development within the context of SMEs in China. In addtions, the goal of this study is to provide an exhaustive exposition of the theoretical underpinnings of global green reverse logistics while leveraging scholarly sources as a basis for advancing bibliographic information devices.

The subsequent practical execution of the questionnaire-based inquiry and the statistical substantiation of the research findings serve as the cornerstone for deriving pragmatic insights and drawing conclusions that hold relevance for enterprises of varying sizes, encompassing small, medium, and large-scale organizations. It is imperative for enterprises to exercise judicious environmental management to mitigate adverse environmental consequences. Considering the aforementioned evidence, enterprises may attain a favorable edge over their rivals in the marketplace.

The present investigation focuses on the analysis of SMEs in China. The dimensions of SMEs in China's "small, medium, and large-sized enterprise classification standard regulations are displayed in **Table 1**.

Table 1. Size division of small, medium, and large-sized enterprises.

Indicator	Units	Large	Medium	Small
Staff headcount (X)	persons	$X \geq 1000$	$300 \leq X < 1000$	$X < 300$
Operating income (Y)	ten thousand yuan	$Y \geq 4000$	$2000 \leq Y < 4000$	$Y < 2000$

3.1. Sampling and data collection method determination

A questionnaire was used for data collection in this study. The test comprised 25 queries, encompassing both open-ended and scaled-format items. The Likert scale was utilized to generate rating scale inquiries in academic research and other related disciplines. The instrument used for data collection was digitally crafted in an electronic form. The research data gathering technique of administering and mailing surveys was employed to disseminate the questionnaires. The comprehensive development of this manuscript necessitates the utilization of traditional and specialized scholarly techniques. In classical methodologies, a variety of techniques, including literature retrieval, analysis and synthesis, induction and deduction, comparison, and scientific abstraction, are commonly employed. The employed techniques include the query method, elimination method, sorting method, materialization method, and mathematical statistics method (Richnák and Gubová, 2021). The collected survey data were subjected to descriptive statistics to discern patterns, trends, and other relevant information pertaining to the data.

The research conducted herein employed purposive sampling as the method for data collection. This approach involves the conscious selection of a sample based on predetermined research objectives or identified research inquiries. The purposive sampling method employed in this study was grounded in specific criteria: 1) the size of the firm, categorized as SMEs, 2) the industry category, which pertains to organizations engaged in logistics and supply chain management, and 3) the status of the firm regarding the adoption or intention to adopt green reverse logistics practices. Purposive sampling as a sampling method offers numerous advantages. Campbell et al. (2020) emphasizes that the utilization of sampling techniques allows researchers to intentionally choose samples that are consistent with the specific goals and inquiries of their study, thus guaranteeing the sample's genuine representativeness. Additionally, this approach has demonstrated enhanced efficiency with regards to time and resources, as indicated by previous research (Bakkalbasioglu, 2020; Rai and Thapa, 2015; Sharma, 2017). In the context of research involving a specific population or scenario, purposive sampling has been identified as better suited to meet the research needs (Jawale, 2012; Obilor, 2023). Purposeful sampling has been widely utilized in existing scholarly literature, particularly in the field of logistics (Behl et al., 2023; Halizahari et al., 2021; Halizahari et al., 2022; Sishuwa and Phiri, 2020; Valashiya and Luke, 2023).

The data collection period for this study spanned from 3 July 2023, to 15 September 2023. This study involved the distribution of 311 questionnaires to SMEs in China. Several strategies were implemented to enhance the response rate of SMEs participants. The participants were guaranteed anonymity and confidentiality with respect to their organization's involvement. Additionally, monetary incentives were employed. If the participant successfully completes the survey, he or she will have the opportunity to enter a lottery drawing for a red envelope. In conclusion, the implemented measures were based on the recommendations provided by Dillman et al. (2009) and Stoop et al. (2010).

This study obtained a total of 311 complete questionnaires, all of which contained no missing values, resulting in a recovery rate of 100%. In the present study, we implemented a multifaceted approach to enhance response rates, which encompassed the provision of incentives, the establishment of repeated contact with participants, and the assurance of confidentiality and privacy. 1) To enhance participant engagement in completing the questionnaire, we offered incentives in the form of small gifts and the chance to enter a lottery. 2) We conducted multiple follow-up engagements with participants utilizing a range of communication methods, including email and telephone calls. 3) We made a solemn commitment to uphold the privacy of participants and to ensure that all responses and data were treated with the utmost confidentiality. The participants' confidence in the study was enhanced by the expressed commitment to data protection, which subsequently served as a catalyst for their motivation to participate and to provide truthful responses to the questionnaire. The research team meticulously documented all eligible responses and organized them in a systematic manner within the Microsoft Excel software for subsequent statistical analysis. To address the potential nonresponse bias, a multivariate analysis of variance (MANOVA) was conducted in accordance with the recommendations of Clottey and Benton (2020) and Muijs (2022). The statistical analysis indicated that there were no significant differences between the test sample groups in terms of demographic variables, consistent with the findings of Vogel and Jacobsen (2021). This suggests that there is a lack of empirical support for prejudice or partiality.

The investigation was carried out in strict compliance with ethical guidelines. The participants were informed about their voluntary involvement in the study and were guaranteed the autonomy to withdraw at any time without encountering any adverse consequences. The protection of personally identifiable information for all participants will be upheld and only used as necessary for the research project. The process of data analysis and reporting will exclude the disclosure of any personally identifiable information. In order to protect the confidentiality and integrity of the research data, security measures have been put in place. The data will be securely stored in an anonymized format and will be accessible exclusively to authorized personnel within the research team.

3.2. Chi-square test

The present study employed the Pearson Chi-square test (χ^2) as a means of conducting statistical analysis. In this study, we employed statistical methods similar to those utilized in prior research, which were adeptly applied by Farida et al. (2023), Huang and Huang (2024), Martins Oliveira et al. (2023), and Saqib et al. (2023). These previous studies have provided crucial background and groundwork for our research. By adopting similar methodologies, we are able to make comparisons with prior research. The utilization of goodness-of-fit tests facilitates the examination and assessment of the null hypothesis (H_0) as opposed to the alternative hypothesis (H_1) by establishing a previously determined significance level α (Levine et al., 2013). The Pearson chi-square test, denoted as χ^2, represents an altered version of the goodness-of-fit test. In this approach, the observed frequency, represented by O_{ij}, is juxtaposed with the anticipated frequency, denoted by E_{ij}. The primary concept underlying the chi-square (χ^2) test is the comparison between the observed frequency and the expected frequency. This non-parametric method is used to detect differences between two identifiable entities (Rana and Singhal, 2015). The null hypothesis (H_0) posits the absence of any discernible relationships or associations between categorical variables, whereas the alternative hypothesis (H_1) asserts the presence of such dependencies between these variables. This assertion is substantiated through the application of a test attribute referred to as "squared chance," as documented by Levine et al. (2013), Rana and Singhal (2015), and Richnák and Gubová (2021).

$$\chi^2 = \sum_{i=1}^{n} \frac{(f_o - f_e)^2}{f_e} \tag{1}$$

where: $f_o = observed\ frequency$ of a specific cell within a contingency table was recorded; $f_e = expected\ frequency$ in a specific cell assuming the validity of null hypothesis.

The χ^2 test statistic conforms to a chi-square distribution with degrees of freedom equal to $(r-1)$ multiplied by $(c-1)$, where r represents the number of rows and c represents the number of columns in the contingency table. The restricted critical area can be expressed as a function of the inequality $\chi^2 > \chi^2_{1-\alpha}\big((r-1)\times(c-1)\big)$ in accordance with academic conventions.

To gauge the degree of contingency, this study employed statistical measures including Pearson's contingency coefficient, Tschuprow's contingency coefficient, and Cramer's contingency coefficient (Richnák and Gubová, 2021).

The contingency coefficient derived from Pearson's method was computed based on the following association (Hartmann et al., 2018):

$$C^* = \sqrt{\frac{\chi^2}{n+\chi^2}} \tag{2}$$

where: $\chi^2 = the\ \chi^2\ value$; C^* = contingency coefficient; n = sample size.

The symbol χ^2 denotes the χ^2 statistic, whereas the variable n represents the total number of observations. This statement employs the formal and conventional tone characteristics of academic writing. The absence of interdependence between the two variables can be mathematically expressed as $C^* = 0$. The maximal limit of the contingency coefficient C^* is 1, although it remains plausible for this coefficient to assume values below one, despite the occurrence of perfect correlation between a pair of variables. This phenomenon has been observed and documented in literature on contingency tables.

The contingency coefficient proposed by Tschuprow can be computed by utilizing the association between variables (Janson and Vegelius,1978):

$$\tau = \frac{\chi^2}{n \times \sqrt{(r-1)\times(c-1)}} \tag{3}$$

where: $\tau = Tschuprow's\ contingency\ coefficient$; $r = number\ of\ row$; $c = number\ of\ columns$; $n = sample\ size$; $\chi^2 = the\ \chi^2\ value$.

Cramer's contingency coefficient is derived by analyzing a mutual association or correlation (Janson and Vegelius,1978):

$$V = \frac{\chi^2}{n \times min\,((r-1)\times(c-1))} \tag{4}$$

where: $\chi^2 = the\ \chi^2\ value$; $n = sample\ size$; $c = number\ of\ columns$; $r = number\ of\ row$; $((r-1)\times(c-1))$ = the minimum number of rows or columns in a contingency table.

If the Cramer's coefficient attains values ranging from 0 to 0.3, it can be inferred that there is a weak association between the variables. The presence of a medium contingency is denoted by values ranging between 0.3 and 0.8, while a strong dependence between variables is indicated by values ranging between 0.8 and 1.

4. Results

4.1. Demographic analysis

The relevant findings are presented in **Table 2**. A total of 311 respondents participated, with 52.4% constituting men and 47.6% representing women. The demographic cohort, ranging in age from 26 to 35 years, constituted the highest percentage (34.7%), whereas the age group from 36 to 45 years accounted for 25.4% of the total population. The age cohorts of 18–25, 46–55, and over 55 years constituted 11.6%, 20.3%, and 8.0%, respectively. Furthermore, this research endeavors to scrutinize the relationship between the number of personnel in the organization and the annual financial earnings of said organization, measured in units of 100,000 yuan. In this study, companies with a workforce ranging from 50 to 100 employees represented the largest proportion, accounting for 31.5% of the total population. Those with 101–300 employees accounted for 25.4%, while companies with 0–50 workers constituted 30.9% of the sample. Furthermore, organizations employing 301–500 individuals represented 6.4%, and those with a workforce ranging from 501 to 1000 accounted for 5.8% of the study population. The study reveals that enterprises' annual income is distributed across various income brackets. Specifically, 33.1% of the enterprises reported an annual income between 0 and 500, while 30.5% fell within the range of 501 to 1000. Additionally, 18.0% of enterprises reported an annual income ranging from 1001 to 1500, followed by 12.2% with an income range of 1501 to 2000. Finally, enterprises reporting an annual income exceeding 2000 encompassed 6.1% of the sample. The small enterprise category encompasses the largest proportion of enterprises, reaching 53.4%. The medium category accommodated the second most substantial cluster of enterprises, accounting for 46.6% of the total. This study was conducted in various regions of China, comprising 20 provinces, cities, and autonomous regions. The tabulated data in **Table 3** outlines the numerical and proportional representation of the survey outcomes for every province, city, and autonomous region. Shanxi Province had the highest proportion, accounting for 20.9% of the total. Hebei Province exhibits the second highest proportion at 14.8%, whereas Liaoning Province secures the third highest proportion at 10.9%. The residual provinces, urban areas, and autonomous regions constitute 53.4% of the total.

Table 2. Demographic analysis.

Items	Frequency	Percentage (%)
Gender		
Man	163	52.4
Women	148	47.6
Age		
18–25	36	11.6
26–35	108	34.7
36–45	79	35.4
46–55	63	20.3
Above 55	25	8.0
Size of enterprise		
Small	145	46.6
Medium	166	53.4

Table 2. (*Continued*).

Items	Frequency	Percentage (%)
Does your company have an environmental protection policy?		
Yes	268	86.2
No	43	13.8
Company headcount		
0–50	96	30.9
51–100	98	31.5
101–300	79	25.4
301–500	20	6.4
501–1000	18	5.8
Annual income level of the enterprise (unit: 100,000 yuan)		
0–500	103	33.1
500–1000	95	30.5
1000–1500	56	18.0
1500–2000	38	12.2
> 2000	19	6.1
Personal monthly income level (unit: yuan)		
0–5000	168	54.0
5001–10,000	94	30.2
10,001–15,000	36	11.6
15,001–20,000	9	2.9
> 20,000	4	1.3

Table 3. Quantity and percentage of investigators in each province, city, and autonomous region.

Provices	Quantity	Percentage
Anhui	2	0.6%
Shanxi	65	20.9%
Jiangxi	6	1.9%
Shandong	4	1.3%
Henan	4	1.3%
Hubei	1	0.3%
Sichuan	22	7.1%
Hebei	46	14.8%
Liaoning	34	10.9%
Jilin	19	6.1%
Heilongjiang	19	6.1%
Jiangsu	13	4.2%
Zhejiang	8	2.6%

Table 3. (*Continued*).

Provices	**Quantity**	**Percentage**
City	**Quantity**	**Percentage**
Beijing	18	5.8%
Tianjin	16	5.1%
Chongqing	2	0.6%
Shanghai	4	1.3%
Autonomous region	**Quantity**	**Percentage**
Guangxi Zhuang	2	0.6%
Xinjiang Uygur	1	0.3%
Inner Mongolia	25	8.0%

Among the industries that were subject to analysis (Appendix A), the sector encompassing the retail industries had the highest level of representation, accounting for a substantial portion (32.8%). The subsequent electronics manufacturing category was responsible for 16.7% of the total share. The automotive manufacturing, fast-moving consumer goods, healthcare, textile and clothing, packaging, and logistics industries exhibited shares of 12.5%, 14.8%, 5.8%, 6.8%, 3.2%, and 4.5%, respectively, in their contributions to the overall economy. The present study included the representation of the aerospace industry, which contributed the smallest proportion of research participants, with a percentage of 2.9%.

Moreover, in accordance with the findings of the aforementioned survey pertaining to the adoption of environmental conservation measures by organizations, it was reported that a substantial majority (86.2%) of respondents acknowledged the implementation of environmental protection policies by companies. Nevertheless, 13.8% of participants expressed dissent from this perspective. Simultaneously, 89.1% of the participants expressed their belief in the enactment of environmental protection policies within their respective industries, whereas only 10.9% conveyed the absence of such policies in their industry (See **Table 2**).

4.2. Descriptive statistics

Climate change, which encompasses global warming and the deterioration of soil, water, and air quality, exerts significant effects on the natural environment. Environmental concerns have reached a global scale, prompting the integration of sustainable development within business operations. This integration has inspired the development of environmental strategies aimed at fostering business growth (Richnák and Gubová, 2021). This study employed a measurement of "Satisfaction" for the data collection process. Satisfaction serves as a critical criterion for assessing the extent to which small and medium-sized enterprises (SMEs) effectively align their green and reverse logistics practices with the expectations and requirements of their stakeholders, particularly their customers. Comprehending the level of satisfaction is imperative, as it is directly linked to the efficacy and success of logistics practices in advancing sustainable development goals (Jassim et al., 2020).

The relevant findings are presented in **Table 4**. A value of 4 was observed with the highest frequency, indicating that this was the mode of the recorded data. This achievement of value can be attributed to the effective implementation of environmental policies in various regions as well as the adherence of SMEs to these policies. In China, various regions exhibit considerable heterogeneity in the enforcement of environmental policies among SMEs, with mean, mode, and median values of 4 or approximately 4. Within the context of small-scale enterprises, the adoption of environmental policies is linked to a notably low standard deviation, which is measured at 0.931. The Southern region exhibited the highest standard deviation (1.014) in the context of implementing environmental policies. Among the enterprises included in the analysis, researchers found that small-scale enterprises exhibited the highest degree of implementation of environmental policies, accounting for 74.2% of the total. The satisfaction rate of the study sample regarding the implementation of environmental policies in medium-sized enterprises is 72.3%. The present study revealed a satisfaction rate of 72.3% among respondents pertaining to the implementation of environmental policies in the northern region. The findings indicate that there is a satisfaction rate of 71.3% with regard to the successful implementation of environmental policies in the southern region. The Qinghai-Tibet region exhibited the lowest percentage under examination, amounting to 68.5%.

Table 4. Descriptive statistics of the degree of implementation of environmental policy satisfaction.

Variables	Mean	Mode	Median	Std. Deviation	Frequency	
					Quantity	Percentage
small-scale enterprises	4.02	4	4.00	0.931	231	74.2%
medium-sized enterprises	4.00	4	4.00	0.940	225	72.3%
Northern Region	4.01	5	4.00	0.960	225	72.3%
Southern region	3.94	4	4.00	1.014	223	71.7%
Northwest region	3.93	4	4.00	0.966	221	71.1%
Qinghai-Tibet region	3.88	4	4.00	1.009	213	68.5%

Note: frequency represents the sum of quantity and frequency of "satisfied" and "very satisfied" for each item.

Regarding the level of contentment regarding the application of environmental policy instruments, the examined firms expressed the highest degree of satisfaction with legislation and regulations (76.2%), followed by market-entry prerequisites and labels (75.0%). The statistical summary provided in **Table 4** shows the computed measures of the central tendency, comprising the mean, mode, median, and standard deviation. Chinese SMEs have successfully attained a noteworthy average value of 4. Six through the use of environmental policy instruments, specifically legislation and regulations. The average market access requirements pertaining to environmental policies and the utilization of labels were found to be 4.04. The highest model values (5) were attained in relation to emissions standards and permits, environmental regulation and reporting, as well as market entry requirements and labelling. The median value of the environmental policy instruments in **Table 5** was 4. The variabilities observed in the values of "emission standards and permits" and "environmental supervision and reporting" in environmental policies are considerable, with standard deviations of 1.007 and 1.016, respectively. The values of legislation and regulations exhibited minimal dispersion, as evidenced by the low degree of dispersion, where the standard deviation was recorded to be 0.945.

Table 5. Descriptive statistics on the degree of satisfaction with the implementation of environmental policy instruments.

Variables	Mean	Mode	Median	Std. Deviation	Frequency	
					Quantity	Percentage
Legislations & regulations	4.06	4	4.00	0.945	237	76.2%
Taxation	3.92	4	4.00	0.975	219	70.4%
Subsidy & reward system	3.98	4	4.00	0.959	230	73.9%
Emission trading & carbon markets	3.96	4	4.00	0.984	226	72.8%
Emission standards & permits	3.96	5	4.00	1.007	221	71.1%
Education & promotional activities	4.00	4	4.00	0.954	231	74.3%
environmental supervision & reporting	3.99	5	4.00	1.016	222	71.4%
market entry prerequisites & labeling	4.04	5	4.00	0.983	233	75.0%

Note: frequency represents the sum of quantity and frequency of "satisfied" and "very satisfied" for each item.

The precise measurements obtained from the survey participants are presented in **Table 6**. The most noteworthy aspect of cruel (4.01) is acquirement coordination and conveyance coordination. The lowest esteem of the cruel (3.97) was obtained through generational coordination. Generation coordination, acquirement coordination, and conveyance coordination have the same esteem (4) of the mode and sample esteem (4.00) of the middle. The highest value of the standard deviation (0.960) was obtained by dissemination coordination. The most reduced standard deviation (0.928) was obtained by acquisition coordination. The assessed rate proposes that dissemination coordination is primarily palatable to small- and medium-sized undertakings within the coordination preparation of the analyzed ventures. This supposition was obtained in 74.5% of the respondents. The share of acquisition logs is high (74.3%). The foremost disappointed figure within the natural arrangement of undertakings within the coordination handle is generational coordination, and the fulfillment rate accounts for 72.3%.

Table 6. Descriptive statistics of logistics process satisfaction.

Variables	Mean	Mode	Median	Std. Deviation	Frequency	
					Quantity	Percentage
Procurement logistics	4.01	4	4.00	0.928	231	74.3%
Production logistics	3.97	4	4.00	0.953	225	72.3%
Distribution logistics	4.01	4	4.00	0.960	232	74.5%

Note: frequency represents the sum of quantity and frequency of "satisfied" and "very satisfied" for each item.

Table 7 presents a compilation of the descriptive statistics derived from the data obtained through the responses from SMEs in China. The degree of satisfaction of small-scale enterprises using green logistics is indicated by the highest average score, which is 4.06. Small-scale enterprises acknowledge the significance associated with adopting eco-friendly logistics practices, particularly when utilizing mode = 4. Small enterprises achieved a median score of four in the utilization of environmentally sustainable logistics practices. The utilization of green logistics in small businesses yielded a minimum standard deviation (0.914). The highest standard deviation value (0.978) is observed in the context of SMEs in the primary industry, specifically through the implementation of green logistics practices.

Table 7. Descriptive statistics of green logistics.

Variables	Mean	Mode	Median	Std. Deviation	Frequency	
					Quantity	Percentage
small-scale enterprises	4.06	4	4.00	0.914	241	77.5%
medium-sized enterprises	3.95	4	4.00	0.974	216	69.5%
Primary industry (Agriculture)	4.03	5	4.00	0.978	231	74.3%
Secondary industry (Industry)	3.99	4	4.00	0.955	226	72.7%
Tertiary industry (Service)	4.01	4	4.00	0.967	233	74.9%

Note: frequency represents the sum of quantity and frequency of “satisfied” and “very satisfied” for each item.

Table 8 presents descriptive statistics derived from the data collected through company responses. The retail industry and textile and clothing industry achieve the highest average value (4.03) when utilizing reverse logistics. The textile and clothing industry, aerospace industry, and packaging industry displayed the most notable attainment with a mode value of 5. The retail industry exhibited the most diminished standard deviation value (0.892) when employing reverse logistics. The aerospace industry exhibited the highest magnitude of standard deviation (1.013) in relation to reverse logistics.

After conducting an in-depth analysis of the application of reverse logistics in the aforementioned sample, it was found that the proportion of respondents who expressed contentment with the utilization of reverse logistics in both the retail and electronic manufacturing industries was 76.5%. The utilization of reverse logistics has been observed among respondents in the automotive manufacturing industry, wherein a notable satisfaction rate of 70.7% has been reported. The examined small and medium-sized enterprises employ reverse logistics strategies, while the satisfaction rate within the fast-moving consumer goods industry is 70.8%. The present study on reverse logistics adoption in the healthcare industry indicated a satisfaction rate of 73.3%. The present analysis observed that, within the pool of small and medium-sized enterprises assessed, a combined total of 72.7% was attributed to the textile and clothing industry, as well as the aerospace industry. The level of satisfaction within the packaging industry regarding the incorporation of reverse logistics amounted to 72.0%. The retail and electronic manufacturing industries exhibited the highest percentage (76.5%) of satisfaction regarding the utilization of reverse logistics. The automotive manufacturing industry attained a considerably low level of satisfaction (70.7%).

Table 8. Descriptive statistics of reverse logistics.

Variables	Mean	Mode	Median	Std. Deviation	Frequency	
					Quantity	Percentage
Retail industry	4.03	4	4.00	0.892	238	76.5%
Electronic manufacturing industry	3.94	4	4.00	0.952	238	76.5%
Automotive manufacturing industry	3.99	4	4.00	0.945	220	70.7%
Fast-moving consumer goods industry	3.95	4	4.00	0.991	220	70.8%
Healthcare industry	4.02	4	4.00	0.949	228	73.3%
Textile and clothing industry	4.03	5	4.00	0.983	226	72.7%
Aerospace industry	3.99	5	4.00	1.013	226	72.7%
Packaging industry	4.01	5	4.00	0.938	224	72.0%

Note: frequency represents the sum of quantity and frequency of “satisfied” and “very satisfied” for each item.

The results emanating from the empirical investigation undertaken in this study reveal that 85.2% of small and medium-sized enterprises have effectively integrated reverse logistics practices into their operational frameworks. Moreover, it is noteworthy that 70.1% of the surveyed small and medium-sized enterprises have successfully established reverse logistics channels aimed at streamlining product returns and repair processes. Hence, SMEs have acknowledged the significance of sustainable development when incorporating reverse logistics strategies.

The authors present a compilation of descriptive statistics derived from the responses provided by the respondents in **Table 9**. The highest mean score was observed in the inventory management domain, with an average value of 4.08, whereas the lowest mean score was found in the domain of material handling, with an average value of 3.94. The variable obtained a maximum mode value of 5 within the “package” dataset. An equivalent median (4.00) of the same magnitude existed. Transportation observed the highest value of the standard deviation, measuring 1.022. The response variable “investment management” was associated with the lowest observed standard deviation value of 0.923.

Table 9. Descriptive statistics of sustainability development.

Variables	Mean	Mode	Median	Std. Deviation	Frequency	
					Quantity	Percentage
Inventory management	4.08	4	4.00	0.923	242	77.8%
Material handling	3.94	4	4.00	1.019	220	70.7%
Warehousing	3.99	4	4.00	0.989	227	73.0%
Package	4.00	5	4.00	1.008	227	73.0%
Transportation	3.95	4	4.00	1.022	226	72.7%

Note: Frequency represents the sum of quantity and frequency of “satisfied” and “very satisfied” for each item.

4.3. Research hypothesis

4.3.1. Research hypothesis 1

To mitigate the adverse environmental effects of escalating industrialization, it is essential to incorporate both environmental and economic considerations into the design of supply chains (Gechevski et al., 2016). One significant strategy for combating environmental harm is the implementation of reverse logistics. Reverse logistics refers to the systematic handling and management of product returns, particularly within industries that encompass e-commerce, retail, and mail-order operations. Currently, the realm of reverse logistics has expanded significantly. The process includes the utilization of recycling and reutilization methods for both products and their corresponding packaging materials once the product surpasses its intended lifespan. Reverse logistics is a sustainable approach that seeks to minimize waste by diverting products from landfills or incineration. This methodology encompasses a range of activities including recycling, material substitution, reuse, and remanufacturing. This passage addresses the comprehensive logistical measures associated with the gathering, disassembling, and processing of utilized products, components, substances, and packaging with the intent of implementing an environmentally sound recycling approach (Kulwiec, 2006).

Legislative bodies exert pressure on enterprises by means of various statutes and regulations to adopt environmentally friendly practices and opt for sustainable approaches in the field of logistics. The adept implementation of reverse logistics can bestow a firm with a competitive edge, while simultaneously safeguarding its interests. This approach is also recognized as environmentally sustainable, falling within the realm of green logistics (Gechevski et al., 2016). Therefore, the hypothesis that was examined and rephrased is as follows:

Hypothesis 0 (H_0). There is no statistically significant difference between the promotion of reverse logistics development and the improvement of green logistics in SMEs at a significance level of $\alpha = 0.05$.

Hypothesis 1 (H_1). There is a statistically significant difference between the promotion of reverse logistics development and the improvement of green logistics in SMEs, at a significance level of $\alpha = 0.05$.

A χ^2-test of goodness of fit was conducted based on the results obtained from the administered questionnaire. Subsequently, a contingency table was constructed for this study. The observed values (f_e) (See **Table 10**).

Table 10. Observed values of hypothesis.

Observed values (f_e)	y_1	y_2	y_3	y_4	y_5	**Total**
x_1	7	2	0	0	0	9
x_2	0	5	5	2	1	13
x_3	0	2	43	14	2	61
x_4	1	1	11	81	17	111
x_5	2	0	3	13	99	117
Total	10	10	62	110	119	311

The expected values (f_o) derived from the questionnaire were computed using the following formula (Richnák and Gubová, 2021):

$$E_{ij} = n \times \frac{n_i}{n} \times \frac{n_j}{n} \tag{5}$$

where: n = total table value.

Table 11 presents the tabulated values of the expected outcomes obtained through analysis of the questionnaire data.

Table 11. Expected values of hypothesis.

Expected values (f_o)	y_1	y_2	y_3	y_4	y_5	Total
x_1	0.29	0.29	1.79	3.18	3.44	9
x_2	0.42	0.42	2.59	4.60	4.97	13
x_3	1.96	1.96	12.16	21.58	23.34	61
x_4	3.57	3.57	22.13	39.26	42.47	111
x_5	3.76	3.76	23.32	41.38	44.77	117
Total	10	10	62	110	119	311

The present research endeavor undertakes an initial examination of the aforementioned hypotheses in **Table 12**. In the examination, a comprehensive calculation was conducted to account for each individual row and column, resulting in the determination of the squared probability χ^2 value, which amounted to 509.74 specifically located in the lower-right region. The test characteristics obtained from the calculation were evaluated by comparing them with the χ^2 distribution at the 95th percentile; specifically, the $\chi^2_{0.95}$value with 16 degrees of freedom, which amounts to 341.87. Based on the calculations, it was determined that the square contingency surpassed the critical value, thereby leading to rejection of the null hypothesis. At the 95% confidence level (α = 0.05), a statistically significant association is observed between green logistics and the enhancement of reverse logistics in SMEs.

Table 12. Chi-squared of hypothesis.

Chi-Squared (χ^2)	y_1	y_2	y_3	y_4	y_5	Total
x_1	155.26	10.08	1.79	3.18	3.44	173.75
x_2	0.42	49.94	2.24	1.47	3.17	57.25
x_3	1.96	0.00	78.22	2.66	19.51	102.35
x_4	1.85	1.85	5.60	44.38	15.27	68.95
x_5	0.82	3.76	17.71	19.46	65.69	107.44
Total	160.31	65.64	105.55	71.15	107.09	509.74

The intensity of this dependence was measured based on a verification hypothesis. The calculated value of C^*, indicating a strong dependence, was confirmed to be 0.788. The Pearson contingency coefficient furnishes compelling evidence of a substantial correlation between the adoption of green logistics practices and the augmentation of reverse logistics initiatives within the realm of small and medium-sized enterprises (SMEs).

The calculations determined that τ = 0.4098, indicating a moderate level of dependence. The contingency coefficient proposed by Tschuprow revealed a moderate level of dependence between green logistics and the advancement of reverse logistics within SMEs.

The calculation yields a value of V = 0.641, indicating a moderate level of dependence. Cramer's contingency coefficient suggests a moderate degree of association between green logistics and reverse logistics advancement in SMEs.

4.3.2. Research hypothesis 2

Sustainability within the supply chain has emerged as a significant area of interest in contemporary times, primarily driven by growing societal concerns regarding environmental issues and organizations' proactive embracing of environmentally friendly approaches while acknowledging their social obligations. Furthermore, the imperative to adhere to regulatory measures designed to curtail environmental repercussions coupled with the demanding landscape of market competition and economic realities has further underscored the importance of this topic (Banihashemi et al., 2019).

The concept of reverse logistics has garnered considerable scholarly discourse and investigation over the past two decades (Haq et al., 2023). According to Banihashemi et al. (2019), RL plays a pivotal role in green supply chain management. The prioritization of environmental protection consciousness, accompanied by cost optimization and profit, is guided by principles and legal requirements. The primary objective of reverse logistics encompasses the reclamation of value, augmentation of resource utilization, mitigation of pollution, and attainment of coordinated and sustainable human and environmental development. This entails the treatment and recycling of products or packaging deemed non-compliant as well as the management of other forms of waste (Wu, 2022). Reverse logistics is an organizational approach that has the potential to mitigate or halt environmental degradation. Sustainability extends beyond environmental matters and encompasses a range of social issues. Nevertheless, there is ample scope for inquiry into the ethical and socially responsible aspects, as highlighted by Sarkis et al. (2010). Thus, the test hypothesis was as follows:

Hypothesis 0 (H_0). There is no statistically significant difference between the promotion of reverse logistics development and the improvement of sustainable development in SMEs at a significance level of $\alpha = 0.05$.

Hypothesis 1 (H_1). There is a statistically significant difference between the promotion of reverse logistics development and the improvement of sustainability development in SMEs at a significance level of $\alpha = 0.05$.

A contingency table was formed by employing the chi-square test of goodness of fit on the data derived from the administered questionnaire. The measured values (f_e) are presented in **Table 13**.

Table 13. Observed values of hypothesis.

Observed values (f_e)	y_1	y_2	y_3	y_4	y_5	**Total**
x_1	7	1	1	0	0	9
x_2	1	6	3	2	1	13
x_3	1	5	38	16	1	61
x_4	0	1	16	74	20	111

Table 13. (*Continued*).

Observed values (f_e)	y_1	y_2	y_3	y_4	y_5	**Total**
x_5	3	0	2	29	83	117
Total	12	13	60	121	105	311

In **Table 14**, the expected value (f_o) of the questionnaire was determined by applying Equation (5), as follows:

Table 14. Expected values of hypothesis.

Expected values (f_o)	y_1	y_2	y_3	y_4	y_5	**Total**
x_1	0.35	0.38	1.74	3.50	3.04	9
x_2	0.50	0.54	2.51	5.06	4.39	13
x_3	2.35	2.55	11.77	23.73	20.59	61
x_4	4.28	4.64	21.41	43.19	37.48	111
x_5	4.51	4.89	22.57	45.52	39.50	117
Total	12	13	60	121	105	311

This observation can be discerned from **Table 15**. Subsequently, the study tested the hypotheses. In this study, all rows and columns were carefully assessed, leading to the identification of a square contingency (chi-squared) value of 393.90 in the lower right corner.

The calculated testing characteristics were compared with the 95th percentile χ^2 distribution with (r−1) × (s−1) = (5−1) × (5−1) = 16 degrees of freedom $\chi^2_{0.95}(16)$ = 270.09. The calculation demonstrated that the square contingency surpassed the critical value, thereby leading to rejection of the null hypothesis. At a significance level of α = 0.05, a statistically significant relationship exists between the promotion of reverse logistics development and the improvement of sustainable development in SMEs.

Table 15. Chi-squared of hypothesis.

Chi-Squared (χ^2)	y_1	y_2	y_3	y_4	y_5	**Total**
x_1	126.35	1.01	0.31	3.50	3.04	134.22
x_2	0.50	55.21	0.10	1.85	2.62	60.27
x_3	0.78	2.35	58.45	2.52	18.64	82.74
x_4	4.28	2.86	1.37	21.98	8.15	38.63
x_5	0.51	4.89	18.75	6.00	47.91	78.04
Total	132.41	66.32	78.98	35.84	80.35	393.90

The intensity of this dependence was measured based on a verification hypothesis. The calculations substantiate the finding that C^* exhibits a value of 0.748, indicating a robust level of interdependency. The Pearson contingency coefficient reveals a substantial correlation between the advancement of reverse logistics development and the enhancement of sustainable development in SMEs.

The calculation yielded τ = 0.317, indicating a medium level of dependence. Tschuprow's contingency coefficient illuminates a moderate level of interdependence between the advancement of reverse logistics development and the enhancement of sustainable development within SMEs.

The calculation yielded V = 0.611, indicating a moderate level of dependence. Cramer's contingency coefficient revealed a moderate level of association between the advancement of reverse logistics implementation and the enhancement of sustainability practices within SMEs.

5. Discussion

5.1. Reverse logistics and green logistics

An important revelation arising from this inquiry underscores a substantial and positive correlation existing between reverse logistics and green logistics practices within the domain of SMEs. This correlation implies that enterprises that proactively embrace reverse logistics practices exhibit a higher propensity to implement green logistics strategies. This finding is in line with previous research suggesting that reverse logistics can be classified as a component of green logistics because of its ability to mitigate resource waste, conserve energy, and minimize environmental repercussions (Banihashemi et al., 2019). At present, it is evident that reverse logistics transcends resource scarcity and environmental concerns, as it can be construed as a strategic alternative that enhances the sustainability of an enterprise.

The positive relationship between reverse logistics and green logistics supports the assertion by Srivastava (2007) that reverse logistics not only aligns with but also reinforces green logistics practices by improving waste management and resource recovery. This connection highlights the strategic role of reverse logistics in fostering environmental sustainability, providing SMEs with a practical approach to enhancing their green logistics capabilities.

This discovery has yielded significant management ramifications. First, SMEs have the opportunity to incorporate reverse logistics and green logistics strategies into their operations. Companies have the opportunity to decrease expenses associated with obtaining new resources as well as mitigate waste generation and environmental impact by incorporating discarded products and materials back into the supply chain. Furthermore, this integration contributes to the enhancement of companies' environmental reputation and compliance with rising environmental regulations and consumer demands. Hence, it is strongly recommended that SMEs diligently contemplate the integration of reverse logistics into their green logistics strategies to attain sustainability objectives and gain a competitive edge.

This recommendation is supported by the Quadruple Helix model, which emphasizes the importance of collaboration among government, industry, academia, and the public. The model suggests that such collaboration can drive innovations in green logistics and reverse logistics, enhancing overall sustainability (Carayannis et al., 2012).

Furthermore, the research also revealed that, within the context of SMEs, the primary impetus behind the adoption of reverse logistics practices predominantly stems from the imperative to safeguard the environment. Government regulations and societal pressure compel corporations to implement ecologically sustainable practices, thereby contributing to the advancement of reverse logistics. This finding aligns with prior research that identified the significant influence of policies and regulations in facilitating companies' integration of environmental protection measures (Gechevski et al., 2016). The role of governmental policies and societal pressure underscores the need for a multi-stakeholder approach, as posited by the Quadruple Helix model, to support SMEs in adopting sustainable practices. This approach ensures that SMEs are not only responding to regulatory requirements but also leveraging collaborative support from various sectors to enhance their reverse logistics practices.

5.2. Reverse logistics and sustainability development

One notable finding of this study pertains to the positive correlation observed between reverse logistics and sustainability. A substantial positive correlation exists between reverse logistics advancement and sustainable development within the realm of SMEs. This finding emphasizes the significance of reverse logistics in attaining objectives related to sustainable development. The incorporation of reverse logistics holds the promise of contributing to the attainment of sustainable development goals by effectively managing waste products and materials while concurrently mitigating resource waste, environmental contamination, and carbon emissions.

These findings resonate with the work of Guide and Van Wassenhove (2009), who highlighted that reverse logistics significantly contributes to sustainable development by optimizing resource use and reducing environmental impacts. The integration of reverse logistics practices not only enhances operational efficiency but also supports broader sustainability goals, offering SMEs a pathway to align with global environmental standards.

This finding offers an explicit direction for SME managers. Organizations have the potential to attain sustainability objectives through the optimization of their reverse logistics procedures, encompassing recycling, reuse, and remanufacturing initiatives. This not only facilitates a reduction in operational expenses but also enhances the organization's corporate social responsibility perception and appeals to ecologically conscious clientele and stakeholders. Reverse logistics is an operational approach that effectively manages and repurposes products and materials. By implementing this approach, resource waste can be effectively minimized, environmental pollution can be mitigated, and resource utilization efficiency can be optimized. Therefore, the objective of sustainable development can be achieved. The importance of RL in attaining sustainable development has been corroborated by previous studies conducted by Wu (2022). Hence, it is advised that SMEs actively pursue the exploration of reverse logistics prospects and integrate them into their sustainable development strategies to attain competitive advantages in the marketplace.

This aligns with the insights provided by the Quadruple Helix model, which advocates for the active engagement of multiple stakeholders in fostering sustainable practices. By leveraging partnerships with academic institutions, industry leaders, and government bodies, SMEs can enhance their reverse logistics strategies and contribute more effectively to sustainable development goals (Carayannis et al., 2012).

6. Conclusions

This study investigates the interrelation between reverse logistics, green logistics, and sustainable development in the context of SMEs. As a consequence of the analysis, this study revealed the following findings: Our initial findings demonstrate a noteworthy affirmative correlation between small and medium-sized enterprises (SMEs), suggesting that enterprises which actively espouse reverse logistics practices are more prone towards embracing green logistics strategies. This correlation sheds light on the potential influence of reverse logistics in facilitating the adoption of environmentally sustainable logistics practices. SMEs can bolster their business sustainability and attain a competitive edge by integrating reverse logistics in conjunction with green logistics strategies. Furthermore, our research underscores the significant and beneficial correlation between reverse logistics practices and the advancement of sustainable development objectives. By efficiently overseeing the disposal of products and materials, enterprises have the ability to mitigate resource depletion, curb environmental contamination, and diminish their carbon footprint, thus making a valuable contribution towards achieving Sustainable Development Goals. This discovery highlights the critical role of reverse logistics for SMEs in their endeavors to advance sustainable development goals. It not only contributes to the reduction of operating expenses but also enhances the corporate social responsibility image. Reverse logistics will persist as a vital strategy for SMEs to accomplish effective resource management and safeguard the environment as the worldwide demand for sustainability has steadily increased. In this context, reverse logistics offers support and advantageous prospects for companies to differentiate themselves in a fiercely competitive market.

Our findings suggest that the strategic integration of reverse logistics into SME operations is essential for achieving sustainability objectives and gaining a competitive advantage. This perspective aligns with the Quadruple Helix model, which highlights the value of collaborative innovation in driving sustainable practices. The ongoing demand for sustainability presents SMEs with opportunities to leverage reverse logistics for enhanced environmental and economic outcomes.

While this research contributes significantly to understanding the symbiotic relationship between reverse logistics, green logistics, and sustainable development in SME management, it is essential to acknowledge its limitations. The study's cross-sectional design and limited sample size constrain the depth of our insights. To further elucidate the dynamics and causal mechanisms underlying these relationships, future research should consider employing longitudinal research designs and expanding the scope of the sample. Additionally, broadening the research sample would enhance the generalizability and applicability of the findings. By addressing these limitations, future studies can offer more comprehensive insights into the strategic integration of reverse logistics, green logistics, and sustainable development practices in SME management.

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Appendix

Table A1. Industry descriptions.

Industries	**Descriptions**
Retail industry	The retail industry, encompassing both online retailers and physical stores, may encounter various reverse logistics requirements such as the management of product returns, exchanges, and recycling of out-of-season merchandise.
Electronic manufacturing industry	The electronic manufacturing industry comprises various segments, namely electronic consumer goods, home appliances, and related spheres. Within this industry, reverse logistics encompasses activities such as product return, repair, recycling, as well as remanufacturing.
Automotive manufacturing industry	Automobile manufacturers, auto parts suppliers, etc. all need to deal with reverse logistics processes such as returns, waste parts recycling, and remanufacturing.
Fast-moving consumer goods industry	The fast-moving consumer goods industry encompasses a wide range of products, including food, beverages, personal care items, and household products, among others. The reverse logistics process can encompass various activities such as the return of expired products and the recycling of packaging materials, among others.
Healthcare industry	The healthcare industry encompasses various sectors including medical equipment manufacturers, pharmaceutical companies, and other related entities. The present study investigates the diverse requirements of reverse logistics, encompassing facets such as the reprocessing of return items, the management of expired products, and the recycling of medical waste.
Textile and clothing industry	The textile and clothing industry, encompassing clothing manufacturers, retailers, among others, may require management of reverse logistics operations, pertaining to activities such as product returns, sample recycling, and old clothing recycling.
Aerospace industry	The aerospace industry encompasses various entities, such as airlines and aviation parts suppliers, among others. Organizations may be required to address reverse logistics requirements encompassing the handling of returned components and disposal of discarded equipment.
Packaging industry	The packaging industry encompasses manufacturers and suppliers of packaging materials, as well as reverse logistics operations that entail the retrieval and recycling of packaging materials.