VILNIUS TECH
Vilnius Gediminas Technical University

Journal of Business Economics and Management
ISSN 1611-1699 / eISSN 2029-4433
2023 Volume 24 Issue 3: 422–448
https://doi.org/10.3846/jbem.2023.19266

THE SUSTAINABLE CYCLE BETWEEN LEAN PRODUCTION AND AUDITING PRACTICES AND ITS EFFICIENCY IN IMPROVING SUPPLIER RELATIONSHIPS AND GREEN SUPPLY CHAINS

Xiang HUANG[1], Ping-Kuo CHEN[2*], Guodao ZHANG[3]

[1]*Department of Business Administration, Shantou University, Shantou, China*
[2]*Institute of Scientific Research, Great Bay University, Dongguan, China*
[3]*Department of Digital Media Technology, Hangzhou Dianzi University, Hangzhou, China*

Received 07 December 2022; accepted 23 May 2023

Abstract. This study explores why a sustainable cycle is induced when manufacturers implement auditing in combination with lean production. Furthermore, it verifies whether this sustainable cycle enhances process integration and risk resilience, thereby allowing the manufacturer to build strong cooperation with suppliers, which further produces a positive effect on the green supply chain. Sociotechnical systems theory is our theoretical basis, and calculating Spearman's rank correlation coefficient and estimating PLS regressions are the main methods used. The results show that the implementation of auditing induces two driving forces: internal responsibility and the ability to respond to emergencies. These two forces drive suppliers to actively and positively cooperate with lean practices to ensure that the effect of those practices is strengthened. Moreover, stronger lean practices also produce two feedback forces – expanded tolerance for auditing and expanded acceptance of auditing interventions – that strengthen auditing practices. As a result, the mutually continuous strengthening of lean production and auditing practices is produced, which further becomes a sustainable cycle. This cycle can continue to enhance process integration and increase risk resilience, build strong cooperation with suppliers, and improve the green supply chain.

Keywords: sustainable cycle, supplier management, lean production, auditing practices, sociotechnical systems theory, green supply chain.

JEL Classification: M10.

Introduction

The development of the supply chain has complicated the internal/external operations of supply chain members and increased pollution emissions (Sarkis et al., 2019). With the increase in environmental consciousness, manufacturers carry the burden of the pollution emissions problem and recognize the importance of a green supply chain (GS). To improve the GS, cooperation among partners is critical, especially for a large amount of business related to

*Corresponding author. E-mail: *a1104100@ms23.hinet.net*

pollution in the manufacturer's and supplier's related operations (Zhang et al., 2017).

However, it is difficult to require an independent supplier to continue cooperation. These suppliers may engage in opportunistic behaviours (OBs) to gain individual profits and further cause cooperative instability. As a result, current theory encourages manufacturers to implement supplier selection and performance assessment (Suraraksa & Shin, 2019). However, these measures are only applicable in the case of multiple suppliers. In addition, performance assessment is a lagged indicator. When OBs are detected, cooperation is disrupted, and the risk of pollution emissions increases. Related empirical results have found that to build stronger cooperation with suppliers, manufacturers can try to enhance their process integration (PI) with suppliers and increase their risk resilience (RR) (Zhang et al., 2017; Gligor et al., 2019). Effective PI can deepen interdependence and improve the continuity of cooperation (Ralahallo et al., 2022); greater resilience can allow manufacturers to monitor, prevent, and control the OBs of suppliers, ensuring stable cooperation (Di Pasquale et al., 2020).

Today's manufacturers have found that lean practices (LPs) are a solution that can enhance PI and increase RR. Lean production (LP) is a technical organizational philosophy that focuses on the elimination of redundant activities (Alemsan et al., 2022). It can drive involvement, increase the connections among participants' production processes, allow participants to further review the supply chain process jointly, and finally, achieve high levels of production efficiency (Huo et al., 2019). LP can increase transparency, manufacturers can easily prevent, detect, and recover from any OBs to maintain stable cooperation with suppliers; this has the same effects as increasing RR (Alemsan et al., 2022). However, Chen et al. (2020) found that the involvement of participants may be weakened with long-term participation, which causes the PI level to decrease and reduces transparency, further affecting resilience. In addition, Birkie (2016) found that a trade-off exists between LP and resilience such that strengthening LPs reduces costs and waste, while also reducing the support available to resilience resources. Therefore, whether LPs can enhance PI and increase RR to further develop long-term effective cooperation with suppliers is still contentious.

For example, the Taiwan Semiconductor Manufacturing Company (TSMC) and Samsung Group have solved the above contentions through auditing mechanisms in combination with LPs. Auditing is a social system used in the internal operational environment (Kumar, 2016); it can be quantified based on related standards or requirements such as production processes (Popescu & Vasile, 2011) or supplier integration (Johng et al., 2020) and further adopted to detect any disruptive factor and alter it (Datta, 2017). Therefore, auditing seems to compensate for the trade-off between LPs and resilience. In addition, the benefits of auditing go beyond trade-offs through in-depth exploration. Auditing can induce driving forces (DFs) that encourage suppliers to cooperate with LPs actively and positively, thereby strengthening the effects of such practices. Conversely, strengthened LPs also induce some feedback forces (FFs) that strengthen the effects of auditing practices (APs). When LPs and APs are both strengthened, their effects produce greater efficiency in enhancing PI and increasing RR due to the strengthening of cooperation. Most importantly, these DFs and FFs even drive the LPs and APs to mutually and continuously strengthen each other, generating a sustainable cycle that seems to continuously enhance PI and increase RR. Finally, cooperation with suppliers becomes stronger, and greater improvements in the GS are achieved.

However, there is still a research gap. When the LPs combine with APs to produce DFs and FFs, which generates a sustainable cycle, how does this process generate benefits that in turn enhance PI, increase RR and further achieve the GS? Based on the above, the purpose of this study is to disclose the sustainable cycle between LPs and APs. We explore the following questions:

1) When LPs are combined with auditing, what DFs are induced to strengthen LPs? In turn, what FFs induced by strengthened LPs consolidate APs?
2) Do these forces induce a sustainable cycle between LPs and APs, enhance PI, increase the RR of suppliers, help further develop strong cooperation, and produce positive effects on the GS?

Our research adds to the literature on the intersection of LPs, auditing and the GS. Most importantly, using our research results, manufacturers can also think about how to develop related strategies to strengthen these forces, keep promoting the sustainable cycle between LPs and APs, and establish strong cooperation with suppliers to fully establish the GS. The study structure is as follows. In Section 1, we describe the theory base and literature review and develop our theoretical framework. In Section 2, we describe the methodology. Sections 3 and 4 describe the analysis results and further discuss them. Finally, we provide a conclusion.

1. Literature review and theoretical framework

1.1. Sociotechnical systems theory and its application to GS

Sociotechnical systems theory (STS) originated in the studies of the Tavistock Institute in the 1950s. The theory indicates that organizations are based on interactions between social subsystems and technical subsystems, which generates a sociotechnical system (SS); STS emphasizes that it is impossible for social or technical systems to be independent. The SS is characterized by both social and technical aspects that lead to goal-directed behaviour, and their interactions create conditions for either successful or unsuccessful system performance (Prodi et al., 2022). In terms of applying the theory, the core assumption of STS is that the joint optimization of the social and technical aspects is required for successful system performance. In line with the research purpose, the core idea of STS can be applied to this study.

Research models that apply STS to the GS typically begin by identifying the impact of human factors on SS and defining performance indices for successful organizations; then, they test human factors and social/technical systems and explore the relationship between systems and performance. For example, Babüroğlu and Selsky (2021) used the interactions between organizational systems and work systems to establish an SS and further explored its positive effect on sustainable work systems, involving the pollution emission problem. Taysom and Crilly (2017) used the work system as the technical system and stakeholders' perspectives as the social system and further explored how the interactions produced a positive effect on resilience, developing an effective SS with multiple stakeholders demands and a work system.

1.2. Efficiency of PI and RR in establishing cooperative supplier relationships and improving the GS

The aim of the GS is to minimize the environmental impacts of a product throughout its entire life cycle, such as through green design and harmful material reduction (Chen et al., 2021). Supply chain partners' cooperation plays a critical role in realizing the GS (Yang et al., 2022). Specifically, continuous and stable cooperation with suppliers ensures that every supplier maintains a strong intention to cooperate with the requirements of the GS (Paksoy et al., 2019). Empirical tests have found that PI with suppliers has a positive effect on the continuity of cooperation and that increasing RR promotes stable cooperation with suppliers. PI with suppliers usually means supplier integration; it involves strategic collaboration between a focal firm and its suppliers in managing cross-firm business processes (Wang & Zhao, 2022). According to Wang and Zhao (2022), greater PI with suppliers can raise awareness of cooperation, which produces a positive effect on the continuity of supplier cooperation and even leads to sustainable cooperation. Resilience is defined as the capability of a firm to be alert to, adapt to, and quickly respond to changes brought about by supply chain disruption and concerns risk prevention and control. Current studies such as Gao et al. (2020) have argued that if resilience can be enhanced in the process of establishing supplier cooperation, then the risk of breaking the cooperation between manufacturers and suppliers can be reduced, further positive effects that promote stable cooperation with suppliers can be produced, and the environmental sustainability of the supply chain can even be promoted (Shi et al., 2018). Drawing on the above, we develop the following two hypotheses and further verify them in this study:

H1a: Enhancing PI has a positive effect on the improvement of the GS.

H1b: Increasing RR has a positive effect on the improvement of the GS.

1.3. Driving forces

The first DF follows from the core idea behind STS and reviews of related cases; it is the formation of an internal responsibility drive (RD), which matches the task of STS. Specifically, to build a successful lean environment, these firms implement auditing mechanisms. They develop lean operational standards and measure suppliers that meet these standards (Qin & Chen, 2022). However, the company will first dispatch auditors to the supplier's factory to guide them and help them improve their business according to the standards. Through this guidance, auditors can better understand the suppliers' situation and attribute responsibility. This means that when problems appear, manufacturers immediately know the source of the problem and attribution of responsibility (Chen et al., 2022). As a result, the OBs of suppliers can be detected to help the manufacturer adjust or even reduce its level of cooperation with suppliers.

To reduce the loss of business profits, suppliers will actively and positively cooperate with LPs based on the established standards. LPs can improve and even strengthen the PI level between manufacturers and suppliers; such a system promotes interdependence and increases transparency (Hassani et al., 2020). The combination of the attribution of responsibility and transparency helps manufacturers find, control, and recover from OBs more quickly and bet-

ter control related suppliers. When transparency is enhanced, resilience will be significantly strengthened (Al Balushi, 2021). Therefore, although existing studies such as Birkie (2016) have indicated that the trade-off between LPs and resilience exists, LPs can promote PI and further enhance process transparency; thus, transparency is a critical factor in strengthening resilience. Therefore, the trade-off between LPs and resilience may not exist, even though LPs may enhance resilience. Based on the above, the RD appears to be a strong DF that can strengthen LPs, and it may have a positive effect on PI and RR. Although existing studies lack proof of the relationships between the RD, the enhancement of PI, and increases in RR, related studies such as Liu et al. (2020) have indicated that increasing the degree of internal responsibility has a positive effect on supply chain integration. Bai and Satir (2022) argued that responsibility can drive an increase in RR.

The ability to respond to emergencies (ES) is the second DFs, and it matches the technology ability of STS. The ES means that suppliers who immediately and positively respond to emergencies can even control unexpected damage before it is caused. Under LPs, the related operations of participants are intricately linked and share interests or risk. If the supplier appears to be a problem due to OBs, such operations must affect the related operations of other suppliers or participants, further causing the disruption of LP and common profit losses. This is expected to drive suppliers to actively develop a greater ES to reduce the disruptions due to unexpected OBs. However, an increase in the ES requires high levels of transparency. To promote transparency, suppliers can maintain their active and positive cooperation with LPs, which also strengthens the effects of LPs on PI.

As above, a high level of PI can strengthen not only transparency but also RR. Zhang et al. (2016) indicated that increasing and maintaining the ES certainly produces a positive effect on organizational practices and integration. According to Chen et al. (2022), an intention to be highly involved drives suppliers to actively cooperate with LPs, and the PI level between manufacturers and suppliers is strengthened. In addition, the ES is one of the capabilities of RR; thus, it can strengthen LPs and further enhance RR (Ivanov et al., 2019).

Based on the above, the RD and the ES seem to be two DFs. Therefore, three hypotheses are developed as follows:

H2a: The implementation of auditing induces the RD, which can strengthen the positive effects of LPs on PI and RR.

H2b: The implementation of auditing induces suppliers to increase their ES, which can promote the effects of LPs and enhance PI and RR.

H2c: If the implementation of auditing has a positive effect on the relationships among DFs, PI, and RR, then auditing has a mediating effect.

1.4. Feedback forces

Regarding feedback forces, the first is tolerance expanding to auditing (TE), which seems to be a people-based factor of STS, and the second is an expanded acceptability of auditing interventions (AI), which is similar to the structure formulation of STS. Specifically, auditing is binding because it requires sending auditors to direct and evaluate suppliers (Cao et al., 2022). The evaluation approach is to adopt related management standards and give

evaluation scores by quantifying calculations, such as tolerance scores (Smith & Alvarez, 2020) and auditing intention scores (Chen et al., 2022). Suppliers are unlikely to fully accept this approach. However, when DFs encourage suppliers to actively and positively cooperate with LPs, the cooperative level between manufacturers and suppliers increases significantly, and a structure of shared interests and risk is generated. Suppliers increase their intentions to cooperate with APs, their tolerance for auditing expands, and AI further expands (Qin & Chen, 2022). High TE means an increase in the desire to apply auditing pressure (Hutt, 1994), which expands the influence of auditing. Therefore, increased tolerance encourages the supplier to continue cooperating with LPs; thus, increasing TE can be seen as strengthening APs. Because the operational standards used in auditing are meant to guide participants towards cooperation with PI and establish closer integration to create a lean environment, TE is expected to strengthen the above relationship. Therefore, TE can also greatly enhance PI. Through closer PI, RR is also increased. Expanding the acceptability of appraisals such as TE has a positive effect on PI. In addition, McKinnon (2014) argued that when participants expand their tolerance for risk auditing, it has a positive effect on RR.

In addition, accepting constraints due to auditing also increases the AI. This means that manufacturers can expand the degree to which auditors intervene, and suppliers may also reduce their resistance to auditing interventions and fully abide by the auditor's guidance. Because auditing interventions increase the influence of APs and enhance the DFs, it is beneficial to strengthen APs and further promote the DFs that strengthen LPs. Because auditing initially has a positive effect on resilience (Karuppiah et al., 2022), strengthening APs is certainly effective at increasing RR. In addition, a high level of AI also promotes stronger interdependence; therefore, the PI level between manufacturers and suppliers seems to be enhanced. Therefore, the relationships among AI, PI, and RR seem likely to exist. It is possible to find support for the above phenomena. Related research, such as the work of Kerekes and Szegedi (2012), has argued that auditing can drive suppliers to actively and positively cooperate with manufacturers. Paksoy et al. (2019) indicated that the cooperation level of suppliers increases through LPs.

Based on the above, strengthening LPs induces two FFs that strengthen audit practices. Therefore, three hypotheses are developed as follows:

H3a: When LPs are strengthened, tolerance for auditing expands, further promoting the effects of APs and enhancing PI and RR.

H3b: When LPs are strengthened, suppliers become more accepting of auditing interventions, which can increase the effects of APs and enhance PI and RR.

H3c: If strengthening LPs has a positive effect on the relationships among the two FFs of PI and RR, then the strengthening of LPs has a mediating effect.

1.5. Theoretical framework

In line with the research purpose and the hypotheses, this study develops the theoretical model shown in Figure 1. As shown in Figure 1, this study additionally tests the path relationships among the forces driving LPs, the FFs affecting APs, the enhancement of PI, the increase in RR, and the improvement of the GS.

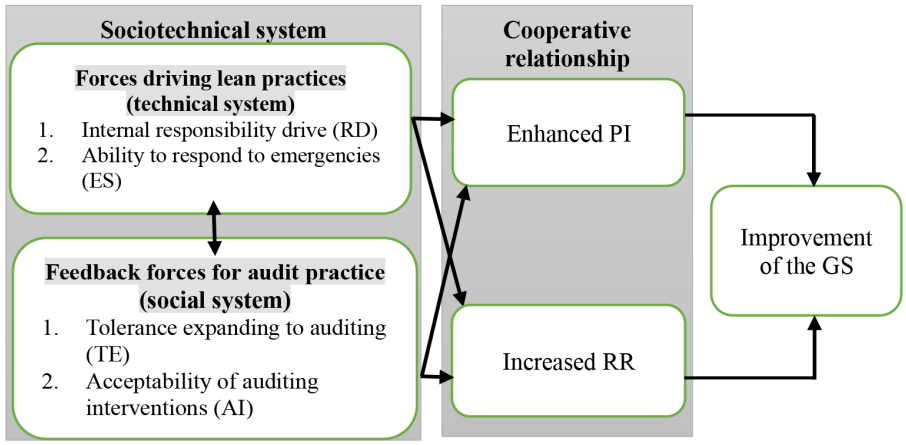

Figure 1. Theoretical framework

2. Materials and methods

2.1. Questionnaire, operationalization and variables of the constructs, data collection, and sample profile

To test the research hypotheses, this study utilized survey-based empirical data obtained from Chinese manufacturers. Based on the hypotheses proposed, the questionnaire included seven constructs, including the DFs of the RD and the ES, the FFs of the TE and the AI, the enhancement of PI, increases in RR, and the improvement of the GS. We attempted to operationalize each construct and its related variables by using related research. These variables became the construct items in the questionnaire, as shown in Table 1. To measure these variables, this study developed a five-point Likert scale for the questionnaire. The questionnaire is shown in the Appendix. In addition, we also give questions for each construct and guide respondents to know how to understand and response for each indicator of the questionnaire.

Table 1. Questionnaire content, operationalization, and variables for each construct and the cited source

Constructs	Variables	Operationalization	Cited source
Internal responsibility drive (RD)	RD1. Enhancement of purchasing process RD2. Every supplier has a stable purchasing source based on lean operations requirements RD3. Every supplier can improve its replenishment of product based on lean operations requirements RD4. Every supplier can improve production process based on lean operations requirements	Internal responsibility drive means the supplier actively and positively cooperates with lean practices because auditing leads to the attribution of responsibility and suppliers also worry about losing business profits due to bearing responsibility for disrupting lean practices. This construct measures whether internal responsibility is produced when auditing is implemented in combination with lean practices.	Handfield and Lawson (2007); van Weele and van Tubergen (2017)

Continued Table 1

Constructs	Variables	Operationalization	Cited source
Ability to respond to emergencies (ES)	ES1. Enhanced forecasting of the damage incurred when other participants engage in opportunistic behaviour	The ability to respond to emergencies means that the supplier can respond immediately and even control damage or prevent opportunistic behaviour by other participants before it occurs. This construct measures whether the supplier's ability to respond to emergencies increases when auditing is implemented in combination with lean practices.	Scholten et al. (2014); Tieman (2017)
	ES2. Supplier can immediately assess possible damage levels and respond early when other participants exhibit unusual behaviour		
	ES3. Supplier can immediately identify possible sources of damage and respond early when other participants exhibit unusual behaviour		
	ES4. Supplier can immediately adjust production operations to reduce negative effects when other participants exhibit unusual behaviour		
Tolerance expanding to auditing (TE)	TE1. Reduced resistance to auditing practices	This construct measures whether the supplier expands his or her tolerance for auditing, deeply accepts auditing, and abides by the audit results.	Dey et al. (2015); Dawande and Qi (2021)
	TE2. Increased auditing intentions		
	TE3. Positive perceptions of auditing		
Acceptability of auditing interventions (AI)	AI1. Supplier usually accepts all comments from auditor to improve related operations and meet lean practice standards	This construct measures the supplier's level of acceptance of auditing interventions and of guidance regarding how to cooperate with lean practice operational standards.	Pedersen and Andersen (2006); Long and Young (2016); Delgado (2021)
	AI2. Supplier is willing to share his or her real situation with auditor		
	AI3. Supplier is willing to continuously improve according to auditing assessment results		
Enhancement of process integration (PI)	PI1. Integration of purchasing processes	This construct measures which operations can be effectively and significantly integrated between manufacturers and suppliers when lean practices and auditing practices are strengthened.	Jørgensen and Emmitt (2009); So and Sun (2010)
	PI2. Integration of manufacturing information		
	PI3. Integration of design/ production modules between manufacturers and suppliers		
Increased risk resilience (RR)	RR1. Enhanced process monitoring capability	Resilience can be defined as the ability of a system to prevent and recover from disruptions with negative effects and unpredictable risky events and return to a better situation. This construct measures the increase in resilience when lean and auditing practices are strengthened.	Scholten et al. (2014); Chowdhury and Quaddus (2016); Tieman (2017)
	RR2. Possess the capability to detect unusual behaviour in the precrisis stage		
	RR3. Enhanced ability to respond early to any possible accidents		

End of Table 1

Constructs	Variables	Operationalization	Cited source
Improvement of the green supply chain (GS)	GS1. Cross-functional cooperation with suppliers for environmental improvements	This construct measures which operations in the green supply chain are strongly emphasized when cooperation between suppliers and manufacturers is continuous and stable.	Vachon and Klassen (2008); Feng et al. (2018)
	GS2. Joint decision-making with suppliers to reduce the overall environmental impact of products		
	GS3. A mutual understanding with suppliers of the responsibilities regarding environmental performance		

Then, we collected the related empirical data through the questionnaire. This study focused on the top 5 industrial provinces in China to collect related empirical data, including Guangdong, Jiangsu, Shandong, Zhejiang, and Henan. Manufacturers from these 5 provinces usually serve as industrial leaders in China; therefore, related data from these 5 provinces are considered representative. Then, we selected the top 200 manufacturers in every province and asked them via mail to help the investigation. We received positive responses from 283 manufacturers. We sent the questionnaire and other related information to these 283 manufacturing companies, and we received 212 valid responses; this provided us with a response rate of 74.91%. Based on the profiles of the companies in the sample, we investigated three characteristics: enterprise size, product type, and length of time implementing LPs and APs. The characteristics of the respondents in terms of aggregated results are shown in Table 2.

Table 2. Sample profiles

Characteristics	Profiles
Enterprise size (number of employees)	Up to 100 = 4.25% Between 101 and 300 = 28.77% Between 301 and 500 = 30.19% Between 501 and 1000 = 24.53% Above 1000 = 12.26%
Type of product	Manufacture of Smart Grid and Intelligent Electrical Apparatus = 23.58% Manufacture of fabricated metal products, except machinery and equipment = 21.23% Manufacture of computer, electronic and optical products = 14.62% Manufacture of electrical equipment = 3.30% Manufacture of motor vehicles, trailers and semitrailers = 5.66% Manufacture of other components = 22.17% Others = 8.96%
Age of implementation of lean and audit practices	Under 1 year = 6.13% 1 year to 3 years = 37.26% 3 years to 5 years = 28.30% 5 years to 7 years = 14.15% Over 7 years = 14.15%

2.2. Methods

In this study, Spearman's correlation analysis and partial least squares (PLS) were the main methods used; we adopted these two methods to test the hypotheses. Specifically, Spearman's correlation analysis was adopted to analyse the correlations among the constructs. Analysing the correlation results can be a way to evaluate the "copula" among constructs (Wen & Liu, 2009; Bonanomi et al., 2015); it can become an important base with which to measure hypotheses. Regarding the PLS analysis, bootstrapping was used to test the statistical significance of the hypothesized relationships. The bootstrapping procedure generates 5000 subsamples of randomly selected observations with replacement. This analytical process allows us to obtain the path coefficients for each randomly selected subsample. In addition, it also calculates the t value for every coefficient. With the path coefficient and the t value, we can evaluate the research hypotheses. We used SmartPLS 3.3 as the analysis tool.

Before testing the hypotheses, the validity and reliability of the constructs and multicollinearity should be tested. In this study, factor loadings, composite reliability (CR), and average variance extracted (AVE) were the main indices used. The factor loadings usually need to exceed 0.4; however, when Nemcic et al. (2005) explored the validation of questionnaires, they found that the validity of the constructs can be accepted if the factor loadings are higher than 0.3. Regarding the requirements for the CR and the AVE, the CR and the AVE should exceed 0.7 and 0.5, respectively (Hair et al., 2016). However, if the AVE is lower than 0.5 but greater than 0.36 and the CR is above 0.6, the situation is also acceptable and satisfies the index requirements (Fornell & Larcker, 1981). Regarding multicollinearity, which is the occurrence of high intercorrelations among independent variables, its existence will affect the theoretical framework test result; thus, we should ensure that multicollinearity does not exist (Perez-Melo & Kibria, 2020). To test the multicollinearity, we calculated the tolerance value. In this study, we used the variance inflation factor (VIF) as a tolerance value to measure multicollinearity. Regarding the VIF, if the VIF value is lower than 5, there is no issue of multicollinearity (Elrehail et al., 2021). Finally, we needed to measure the model's goodness of fit when finishing the hypothesis verification. The standardized root-mean-square residual (SRMR) was used as the main index. Regarding the SRMR requirements, according to Kline (2015), the model is considered acceptable if the SRMR is less than 0.1.

3. Test results

3.1. Construct measures and multicollinearity

We first tested the validity and reliability of the constructs. As shown in Table 3, most of the factor loadings exceeded 0.4; only GS3 has a loading less than 0.4 but higher than 0.3. However, according to Nemcic et al. (2005), this is still acceptable. Therefore, the factor loadings exceeded their required values. Regarding the CR and the AVE, the CR values for six constructs exceeded 0.7, and only the CR for the TE was less than 0.7. Regarding the AVE, we found that the AVE values for the AI were higher than 0.5, those for the other constructs were less than 0.5 but higher than 0.36, and their CR was higher than 0.6. The above values are considered below the normal requirements; however, as noted by Fornell and Larcker, they may still be accepted.

Table 3. Assessment of construct measures: composite reliability and convergent validity

Constructs	Variables	Factoring loading	CR	AVE
Internal responsibility drive (RD)	RD1	.655	.748	.428
	RD2	.584		
	RD3	.699		
	RD4	.672		
Ability to respond to emergencies (ES)	ES1	.727	.733	.412
	ES2	.670		
	ES3	.655		
	ES4	.492		
Expensed tolerance for auditing (TE)	TE1	.468	.692	.438
	TE2	.778		
	TE3	.699		
Acceptability of auditing interventions (AI)	AI1	.835	.784	.549
	AI2	.690		
	AI3	.689		
Enhancement of process integration (PI)	PI1	.709	.722	.466
	PI2	.611		
	PI3	.721		
Increased risk resilience (RR)	RR1	.746	.727	.473
	RR2	.588		
	RR3	.720		
Improvement of the green supply chain (GS)	GS1	.831	.731	.499
	GS2	.815		
	GS3	.377		

Regarding multicollinearity, the test results are shown in Table 4. According to Table 4, the VIF values were found to be lower than 5. Therefore, we can ensure that multicollinearity does not exist among independent variables.

Table 4. Test results of VIF

	(RD)	(ES)	(TE)	(AI)	(PI)	(RR)	(GS)
(RD)		1.421	1.548	1.603	1.494	1.524	1.591
(ES)	1.619		1.706	1.870	1.820	1.784	1.815
(TE)	1.559	1.485		1.579	1.594	1.607	1.493
(AI)	1.660	1.621	1.536		1.578	1.515	1.577
(PI)	1.298	1.291	1.289	1.287		1.308	1.312
(RR)	1.689	1.617	1.655	1.605	1.699		1.625
(GS)	1.380	1.364	1.295	1.328	1.375	1.316	

3.2. Estimation of the research hypotheses

Next, we calculated Spearman's rho; all the test results are shown in Table 5. According to the test results, strong and significant correlations among constructs existed. Therefore, we initially concluded that the hypotheses may be supported.

Table 5. Test results of Spearman's rho

	Mean	SD	(RD)	(ES)	(TE)	(AI)	(PI)	(RR)
(RD)	3.934	.559						
(ES)	4.019	.501	.538***					
(TE)	4.017	.540	.414***	.491***				
(AI)	4.156	.591	.438***	.436***	.443***			
(PI)	3.956	.558	.409***	.426***	.353***	.311***		
(RR)	4.201	.488	.482***	.463***	.377***	.522***	.269***	
(GS)	3.865	.687	.412***	.395***	.436***	.440***	.265***	.485***

Note: *** p value < 0.01.

In line with the logic behind the research purpose and the theoretical model, the PLS analysis was divided into two parts. The first part verified whether the two DFs have positive effects on PI and RR when auditing is implemented. Based on the above discussions, TE and AI seem to act as mediators. Therefore, we tested two mediating effects models to verify whether these two DFs strengthen LPs, enhance PI and increase RR through the influence of auditing. The test results are shown in Tables 6 and 7; we used the p value to judge whether these path relationships were supported. Although traditionally, the p value should not exceed 0.05, through mathematical and statistical calculations and related experience, Altman and Bland (1995) indicated that the p value can be accepted when less than 0.1. As seen in Tables 6 and 7, we found that all hypothesized relationships were supported, and the model fit requirements were satisfied. Based on Tables 6 and 7, Figures 2 and 3 show the numerical conclusion of the theoretical framework.

Table 6. Test results for the RD

Hypotheses	Path coefficient	t value	Results
RD -> Enhancement of PI	.188	2.533**	Supported
RD -> Increased RR	.279	3.291***	Supported
RD -> TE	.361	6.425***	Supported
RD -> AI	.412	5.570***	Supported
TE -> Enhancement of PI	.257	3.363***	Supported
TE -> Increased RR	.175	2.460**	Supported
AI -> Enhancement of PI	.167	1.815*	Supported
AI -> Increased RR	.334	3.303***	Supported

End of Table 6

Hypotheses	Path coefficient	t value	Results
Enhancement of PI -> Improvement of the GS	.117	1.779***	Supported
Increased RR -> Improvement of the GS	.427	7.149***	Supported
Variance explained in the endogenous variables			
TE	R^2 = .130		
AI	R^2 = .170		
Enhancement of PI	R^2 = .229		
Increase in RR	R^2 = .384		
Improvement of the GS	R^2 = .223		
Model fit			
SRMR	.094		

Note: ***p < .01, **p < .05, *p < .1.

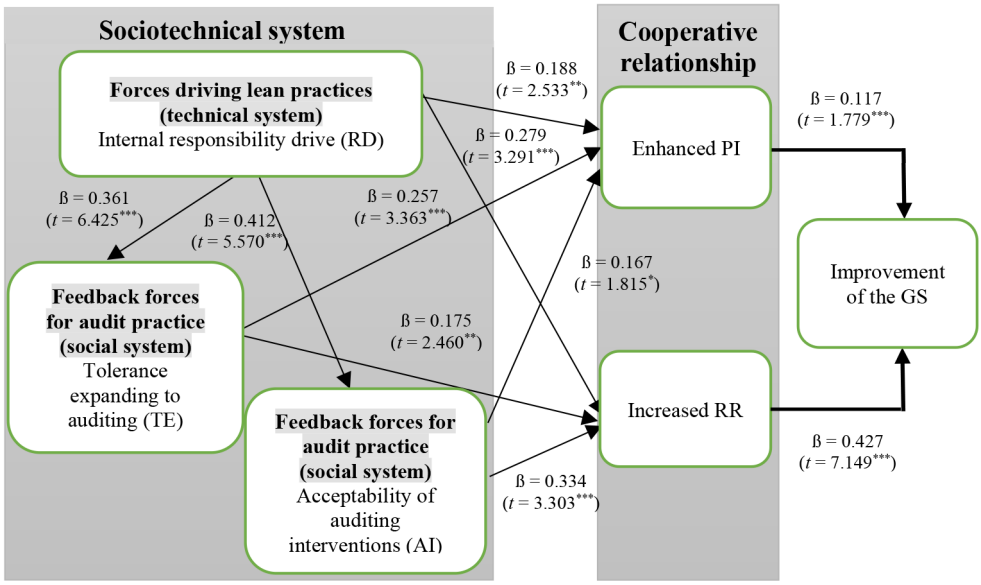

Figure 2. Numerical conclusion of the theoretical framework for Table 6

Table 7. Test results for the ES

Hypotheses	Path coefficient	t value	Results
ES -> Enhancement of PI	.239	2.917***	Supported
ES -> Increased RR	.273	3.128***	Supported
ES-> TE	.551	11.652***	Supported
ES -> AI	.422	6.174***	Supported
TE -> Enhancement of PI	.193	2.310**	Supported

End of Table 7

Hypotheses	Path coefficient	t value	Results
TE -> Increased RR	.125	1.807*	Supported
AI -> Enhancement of PI	.173	1.970**	Supported
AI -> Increased RR	.354	3.452***	Supported
Enhancement of PI -> Improvement of the GS	.120	1.840***	Supported
Increased RR -> Improvement of the GS	.420	6.916***	Supported
Variance explained in the endogenous variables			
TE	R^2 = .303		
AI	R^2 = .178		
Enhancement of PI	R^2 = .240		
Increased RR	R^2 = .374		
Improvement of the GS	R^2 = .218		
Model fit			
SRMR	.096		

Note: ***p < .01, **p < .05, *p < .1.

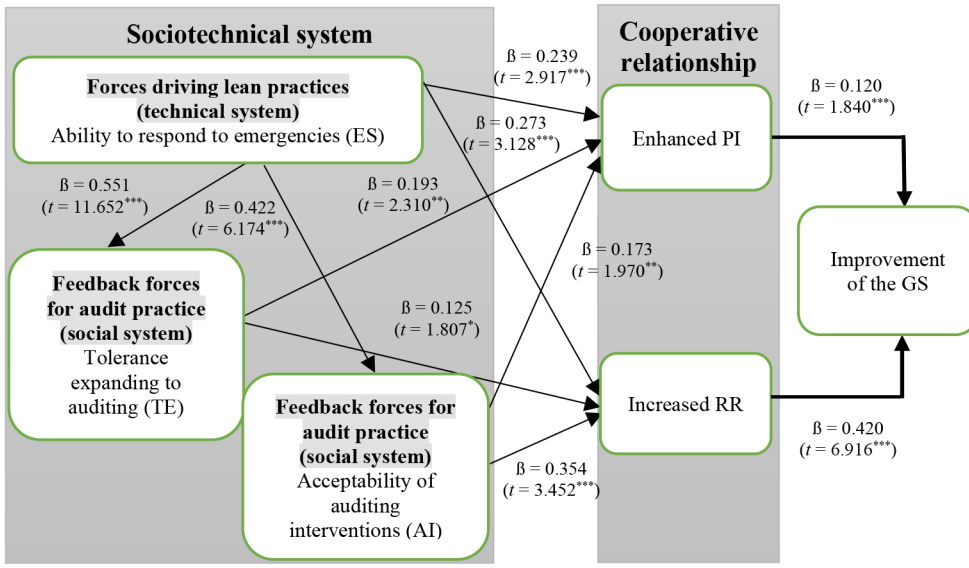

Figure 3. Numerical conclusion of the theoretical framework for Table 7

The above tests, in combination with Spearman's rho test, provided the following research results. First, the results of Spearman's rho test showed high correlations among the RD, ES, TE, AI, PI, RR, and the improvement of the GS. We found that the correlation coefficients for TE and the AI with the RD were 0.414 (p < 0.01) and 0.438 (p < 0.01), respectively; therefore, we can infer that the implementation of auditing induces the RD. The correlation coefficient between the RD and the ES was 0.538 (p < 0.01), which is significantly higher than the other

correlation coefficients. Therefore, as stated in the literature review, the RD increases the level of interdependence between manufacturers and suppliers, driving suppliers to increase their intention to cooperate with LPs. The RD can establish close PI; this is evident because the correlation coefficient between the RD and PI was 0.409 ($p < 0.01$). We can see that the correlation coefficient between PI and RR was found to be 0.269 and significant ($p < 0.01$); therefore, close PI increases transparency and further increases RR. Improvements in PI depend on the RD and further increase RR. The correlation coefficient between the RD and RR was 0.482 ($p < 0.01$); therefore, the RD has positive effect on RR.

Second, according to Tables 6 and 7, TE and AI certainly mediate the relationships among the DFs, PI, and RR. DFs should have a greater ability to encourage suppliers to actively and positively cooperate with LPs, and effective practices enhance PI and increase RR. As seen in Tables 6 and 7, our test results showed that the path relationships among the RD, ES, auditing tolerance, and auditing interventions are supported; the path relationships among auditing tolerance, auditing interventions, PI, and RR are supported; and the path relationships among RD, ES, PI, and RR are also supported. These results, in combination with the results of Spearman's rho test, prove that the implementation of auditing induces the RD and ES. These two DFs encourage suppliers to actively and positively cooperate with LPs, further enhance PI, and increase RR. In addition, the above analytical results prove that auditing has a mediating effect. The above results support H2a, H2b, and H2c.

Next, when LPs are strengthened through the DFs, FFs that strengthen APs are produced. This logic agrees with the results of Spearman's rho. The correlation coefficients between the RD and the two FFs are 0.414 ($p < 0.01$) and 0.438 ($p < 0.01$), and the correlation coefficients between the ES and the two FFs are 0.491 ($p < 0.01$) and 0.436 ($p < 0.01$). In addition, the correlation coefficients for PI with the TE and the AI are 0.426 ($p < 0.01$) and 0.353 ($p < 0.01$), respectively; the correlation coefficients for RR with the TE and the AI are 0.463 ($p < 0.01$) and 0.377 ($p < 0.01$), respectively. The above results support the relationships among the strengthening of LPs, FFs, PI, and RR. This means that the FFs promote APs, and the APs further increase the DFs, which maintains the strength of the LPs, further generating interaction efficiencies. When this occurs, the FFs strengthen the APs and lead those practices to enhance PI and increase RR.

To prove the above inferences, we treated strengthened LPs as a mediator; the two DFs must have mediating effects to promote the relationships among APs, the enhancement of PI, and RR. Based on this, we also tested two mediation models, as shown in Tables 8 and 9. We also show the numerical conclusion of the theoretical framework for Tables 8 and 9 in Figures 4 and 5. Tables 8 and 9 show that the SRMR values all satisfied the model fit requirement. In addition, we found that all path relationships were supported. By using Spearman's rho and the results of the PLS analysis, we can prove that when LPs are strengthened, the supplier expands his or her tolerance for auditing and even accepts auditing interventions. This strengthens APs, further producing positive effects that enhance PI and increase RR. The above results support H3a and H3b. In addition, the two DFs clearly have mediating effects because these two forces strengthen LPs. Therefore, the strengthening of LPs is a mediator that influences FFs, PI, and RR. Therefore, H3c is supported.

Table 8. Test results for the TE

Hypotheses	Path coefficient	t value	Results
TE -> RD	.359	6.314***	Supported
TE -> ES	.549	11.656***	Supported
TE -> Enhancement of PI	.226	2.734***	Supported
TE -> Increased RR	.199	2.620***	Supported
RD -> Enhancement of PI	.158	2.183**	Supported
RD -> Increased RR	.284	3.358***	Supported
ES -> Enhancement of PI	.214	2.543**	Supported
ES -> Increased RR	.235	2.857***	Supported
Enhancement of PI -> Improvement of the GS	.120	1.849***	Supported
Increased RR -> Improvement of the GS	.420	7.032***	Supported
Variance explained in the endogenous variables			
RD	R^2 = .129		
ES	R^2 = .302		
Enhancement of PI	R^2 = .236		
Increased RR	R^2 = .337		
Improvement of the GS	R^2 = .219		
Model fit			
SRMR	.095		

Note: ***p < .01, **p < .05, *p < .1.

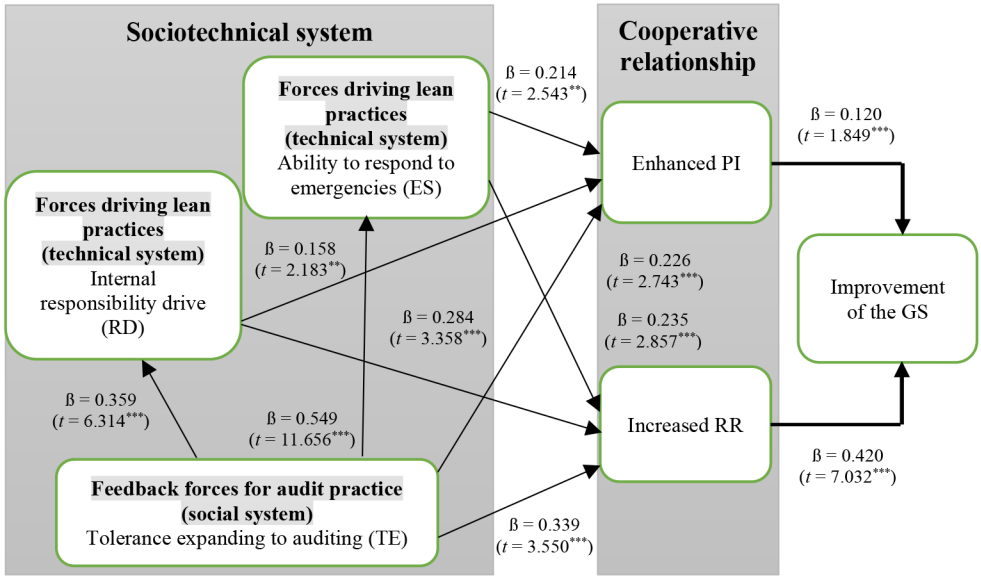

Figure 4. Numerical conclusion of the theoretical framework for Table 8

Table 9. Test results for the AI

Hypotheses		t value	Results
AI -> RD		5.592***	Supported
AI -> ES		6.203***	Supported
AI -> Enhancement of PI		2.003**	Supported
AI -> Increased RR		3.550***	Supported
RD -> Enhancement of PI		1.649*	Supported
RD-> Increased RR		2.660***	Supported
ES -> Enhancement of PI		3.490***	Supported
ES -> Increased RR		2.698***	Supported
Enhancement of PI -> Improvement of the GS		1.788***	Supported
Increased RR -> Improvement of the GS		7.016***	Supported
Variance explained in the endogenous variables			
RD	R^2 = .170		
ES	R^2 = .176		
Enhancement of PI	R^2 = .227		
Increased RR	R^2 = .396		
Improvement of the GS	R^2 = .222		
Model fit			
SRMR	.092		

Note: ***p < .01, **p < .05, *p < .1.

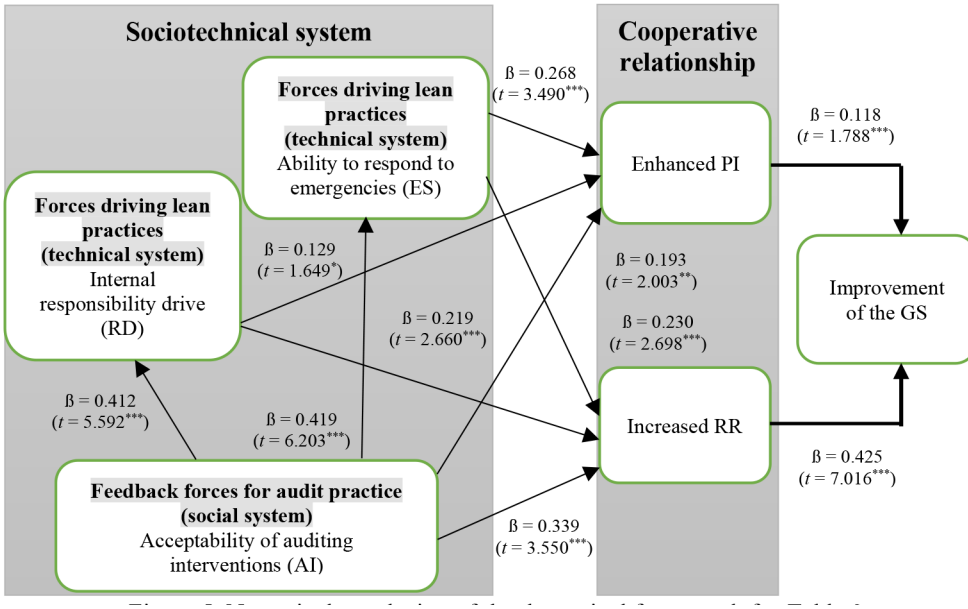

Figure 5. Numerical conclusion of the theoretical framework for Table 9

Finally, the Spearman's rho results showed that the correlation coefficients for PI and RR with the improvement of the GS were 0.265 ($p < 0.01$) and 0.485 ($p < 0.01$), respectively. In addition, the test results shown in Tables 6, 7, 8, and 9 support the hypothesized relationships among PI, RR, and the improvement of the GS. This means that enhancing PI and increasing RR greatly improves the GS. The above results support H1a and H1b. Based on the above, 8 research hypotheses test results are integrated, as shown in Table 10.

Table 10. Test results for 8 research hypotheses

Hypotheses	Test results
H1a: Enhancing PI has a positive effect on the improvement of the GS.	Supported
H1b: Increasing RR has a positive effect on the improvement of the GS.	Supported
H2a: The implementation of auditing induces RD, which can strengthen the positive effects of LPs on PI and RR.	Supported
H2b: The implementation of auditing induces suppliers to increase their ES, which can promote the effects of LPs and enhance PI and RR.	Supported
H2c: If the implementation of auditing has a positive effect on the relationships among the DFs, PI, and RR, then auditing has a mediating effect.	Supported
H3a: When LPs are strengthened, the tolerance for auditing expands, further promoting the effects of APs and enhancing PI and RR.	Supported
H3b: When LPs are strengthened, suppliers become more accepting of auditing interventions, which can increase the effects of APs and enhance PI and RR.	Supported
H3c: If strengthening LPs has a positive effect on the relationships among the two FFs, PI, and RR, then the strengthening of LPs has a mediating effect.	Supported

Based on the mediating effects, direct and indirect path relationships, and the results of Spearman's rho, we can conclude that the interaction efficiencies among these four forces can induce the generation of a sustainable cycle between LPs and APs. Because strengthening LPs and APs can enhance PI and increase RR, we have proven that this sustainable cycle can continue to enhance PI and increase RR and continue to further improve GS. According to the above test results, we discuss the details in the next section.

4. Discussion

This section further discusses the analysis results. Although auditing can make up for a lack of LPs, auditing imposes constraints and is an intervention; therefore, many suppliers usually resist auditing, and auditing may even create conflicts. In addition, it is difficult to persuade suppliers to accept auditing. Therefore, many manufacturers never consider implementing auditing to strengthen their LPs. However, with the changes in the industrial structure and in social awareness of the environment, auditing has gradually become more common. As the industrial structure has gradually transformed into a vertical supply chain, fewer large manufacturers are undertaking leadership roles in the supply chain. These manufacturers

place the majority of resource orders, and they even have authority over the share of profit suppliers receive. If partners, including suppliers, do not cooperate with the requirements of manufacturer auditing to improve LP, manufacturers can adjust or even reduce the share of orders made to the supplier, and suppliers lose the related profits. However, such coercive behaviour could cause suppliers to engage in OBs. Therefore, manufacturers usually have difficulty improving their continuous and stable cooperation with suppliers and further improving the GS.

However, with the increase in environmental awareness, manufacturers do not need to use coercive behaviour to enforce supplier cooperation with LPs. Because people have begun to feel the burden of the problem of industrial pollution emissions, if a manufacturer's supply chain emits large amounts of pollution, related social movements may resist the use of products from that manufacturer's supply chain and purchase substitute products from other manufacturers' supply chains. This is what happened to Volkswagen in Germany; when news broke of a problem with high pollution emissions from a diesel engine, Volkswagen's sales decreased significantly. Because of this, manufacturers today routinely roll out comprehensive pollution improvement or GS development strategies. However, these manufacturers also understand that it is difficult to control every partner's intention to participate. Therefore, pollution emission responsibilities are assigned through the auditing process, and auditing reports are opened. When a problem with pollution emissions occurs, people know who the main culprit is who has caused the pollution emissions to increase, and social pressure forces manufacturers to search for new suppliers to replace the polluting supplier. As a result, the existence of auditing drives suppliers to actively and positively cooperate with LPs to avoid bearing that responsibility. Effectively strengthening LPs through internal responsibility establishes close PI (Liu et al., 2020), increases transparency, and promotes RR. In addition, the chain of responsibility drives every supplier to improve its ES to prevent and change any OBs from other suppliers to avoid being implicated and becoming a joint offender in pollution emissions. Our findings confirm and match those of Carvalho et al. (2011), which state that lean practices can strengthen PI and achieve synergy with resilience by enhancing information transparency (a key factor for ES).

However, when these two DFs strengthen LPs, why do they also produce FFs that strengthen APs? As stated above, auditing imposes constraints and is an intervention. Specifically, the supplier does not accept the constraints and intervention, which results in large improvement costs. However, if the opening auditing report summarizes that the noncooperation of some supplier may increase pollution emissions, that supplier will face social pressure and may possibly lose orders. Therefore, when suppliers actively and positively cooperate with LPs, auditing tolerance also expands, and the acceptability of intervention increases. When this occurs, auditors from manufacturers can even be stationed in suppliers' factories for extended periods. For example, not only TSMC and Samsung but also even the Japanese companies of Panasonic and Sony have assigned auditors to be stationed with cooperative suppliers. Therefore, the feedback forces certainly strengthen APs. When APs are strengthened, the influence of auditing expands, and the DFs continue to increase. When LPs are strengthened by these DFs, FFs are produced that expand the supplier's auditing tolerance and acceptance of interventions. Therefore, the above situation certainly produces interaction

efficiencies, further producing a sustainable cycle between LPs and APs. This cycle causes APs and LPs to be mutually reinforcing, which continuously enhances PI, increases RR, maintains long-term cooperation with suppliers, and successfully improves GS.

Based on the above, the sustainable cycle produced by the combination of LPs and APs based on DFs (technical subsystem) and FFs (social subsystem) makes up a sociotechnical system for better performance. This system causes APs and LPs to be mutually reinforcing, which continuously enhances PI, increases RR, maintains long-term cooperation with suppliers, and successfully improves the GS. Our findings are in line with Chen (2023), who believes that good partnership cooperation through LPs can improve supply chain resilience and further realize environmental performance. However, few studies have combined PI, RR and GS with lean and audit practices. Thus, our research delves into the relationship between these factors and expands the existing research scope.

Finally, regarding the trade-off between lean and resilience, our research results provide a different opinion. By combining lean practices with auditing practices, a synergistic relationship between lean practices and resilience is promoted rather than seen as a trade-off. Lean practices are also considered by many scholars to be drivers of resilience (Ruiz-Benitez et al., 2017, 2018; Purvis et al., 2016), and a company with a higher level of lean practices will have a higher level of resilience (Birkie, 2016). However, few studies have considered the role of audit report disclosure in the context of the GS to explore lean and resilience. However, the role of auditing for LPs is not to be underestimated in the context of the GS. Chen et al. (2022) suggested that a combination of lean and auditing practices can improve the resilience of sustainable supplier management. Our results also confirm this relationship. Therefore, the sociotechnical system formed by auditing and lean practices ensures the long-term implementation of LPs while strengthening the tie between lean practices and resilience.

Conclusions

When implementing auditing practices and combining them with LPs, two DFs, namely, RD and ES, are induced. These forces can guide suppliers to actively and positively cooperate with LPs, strengthening the effects of the LPs. The strengthening of LPs also induces two FFs, namely, the TE and the acceptance of auditing interventions. These two forces can strengthen the effects of APs. In addition, our test results prove that these DFs and FFs can certainly produce interaction efficiencies. These efficiencies cause LPs and APs to be mutually continuously strengthening, further generating a sustainable cycle that continuously enhances PI and increases RR. When the sustainable cycle is formulated, strong cooperation with suppliers is established, and a greater cooperative environment is further built to improve the GS.

The research results of this study provide some valuable implications. Regarding the academic implications, as an introductory statement, the existing studies almost exclusively focus on the role of LPs in PI with suppliers and increasing RR; they less frequently discuss the deeply interconnected relationships among LPs, APs, PI, and RR in the context of the GS. In addition, there is a lack of related research results that discuss the efficiency in the combination of LPs and APs. We explain the reasons why audits can keep suppliers engaged in LPs. In addition, we reveal that LPs and APs can generate a sustainable cycle and mutu-

ally continuously strengthen each other, building strong cooperation and making it easier to improve the GS. Therefore, our research results fill this gap in the existing research. In terms of practical implications, our research results provide valuable suggestions for manufacturers. This study discusses which forces drive suppliers to actively and positively cooperate with LPs when implemented in combination with auditing. In addition, we also identify which FFs are produced that further promote APs when LPs are strengthened. Therefore, manufacturers can use these four forces as measurement indices and develop related strategies to ensure that the interaction efficiencies among the four forces become stronger, further strengthening the sustainable cycle that enhances cooperation with suppliers and ultimately builds a better environment for improving and establishing the GS. Therefore, in addition to the research results, our study specifically indicates how to build a stronger environment for improving the GS.

Although our research provides many valuable contributions, it has a few limitations. First, this study adopted an empirical analysis method to answer our research question. We interviewed related cases, reviewed related studies, and carefully integrated the results of our review to develop hypotheses and build a theoretical model. Then, the related literature was cited to support the research hypotheses, which were analysed and verified. However, our test results still need to be verified with additional observations to prove that this phenomenon exists widely. In addition, this study used the core idea behind STS to identify DFs and FFs. This approach may have limited the scope of exploration and caused us to ignore other forces that promote and strengthen LPs and APs. Based on the above limitations, future research could try to perform a longitudinal study to verify our research results. In addition, researchers may find and identify another possible force through a related theory to more deeply understand how to create more powerful sustainable cycles between LPs and APs.

References

Al Balushi, M. (2021). How internal transparency impacts organizational resilience. *International Journal of Quality & Reliability Management*, 38(5), 1246–1263. https://doi.org/10.1108/IJQRM-04-2020-0108

Alemsan, N., Tortorella, G., Rodriguez, C. M. T., Jamkhaneh, H. B., & Lima, R. M. (2022). Lean and resilience in the healthcare supply chain – a scoping review. *International Journal of Lean Six Sigma*, *13*(5), 1058–1078. https://doi.org/10.1108/IJLSS-07-2021-0129

Altman, D. G., & Bland, J. M. (1995). Statistics notes: Absence of evidence is not evidence of absence. *BMJ*, *311*(7003), 485. https://doi.org/10.1136/bmj.311.7003.485

Babüroğlu, O. N., & Selsky, J. W. (2021). Toward reconfiguring sociotechnical systems design: Digitally infused work systems and the "Platform-STS". In *Research in organizational change and development*. Emerald Publishing Limited. https://doi.org/10.1108/S0897-301620210000029004

Bai, C., & Satir, A. (2022). A critical content-analysis of sustainable supplier development literature and future research directions. *Journal of Cleaner Production*, *365*, 132443. https://doi.org/10.1016/j.jclepro.2022.132443

Birkie, S. E. (2016). Operational resilience and lean: In search of synergies and trade-offs. *Journal of Manufacturing Technology Management*, *27*(2), 185–207. https://doi.org/10.1108/JMTM-07-2015-0054

Bonanomi, A., Cantaluppi, G., Nai Ruscone, M., & Osmetti, S. A. (2015). A new estimator of Zumbo's Ordinal Alpha: A copula approach. *Quality & Quantity*, *49*, 941–953. https://doi.org/10.1007/s11135-014-0114-8

Cao, Y., Umberger, G., Shelton, A., & Butts, T. (2022). Development of a supplier scorecard for a medical device company to formalize its supplier monitoring and re-evaluation process toward ISO13485: 2016. *Journal of Pharmaceutical Innovation*, *17*, 1295–1304. https://doi.org/10.1007/s12247-021-09604-y

Carvalho, H., Duarte, S., & Machado, V. C. (2011). Lean, agile, resilient and green: Divergencies and synergies. *International Journal of Lean Six Sigma*, *2*(2), 151–179. https://doi.org/10.1108/20401461111135037

Chen, M. H., Wei, H., Wei, M., Huang, H., & Su, C. H. J. (2021). Modeling a green supply chain in the hotel industry: An evolutionary game theory approach. *International Journal of Hospitality Management*, *92*, 102716. https://doi.org/10.1016/j.ijhm.2020.102716

Chen, P. K. (2023). Efficiency of lean practices and blockchain combinations for green supplier integration improvements in sustainable development. *Sustainable Development*, *31*(1), 555–571. https://doi.org/10.1002/sd.2409

Chen, P. K., He, Q. R., & Huang, X. (2022). Enhancing the resilience of sustainable supplier management through combination with lean and audit. In *Recent advances and new perspectives in the Industry 4.0 Era*. IntechOpen. https://doi.org/10.5772/intechopen.102465

Chen, P. K., Lujan-Blanco, I., Fortuny-Santos, J., & Ruiz-de-Arbulo-López, P. (2020). Lean manufacturing and environmental sustainability: The effects of employee involvement, stakeholder pressure and ISO 14001. *Sustainability*, *12*(18), 7258. https://doi.org/10.3390/su12187258

Chowdhury, M. M. H., & Quaddus, M. (2016). Supply chain readiness, response and recovery for resilience. *Supply Chain Management: An International Journal*, *21*(6), 709–731. https://doi.org/10.1108/SCM-12-2015-0463

Datta, P. (2017). Supply network resilience: A systematic literature review and future research. *The International Journal of Logistics Management*, *28*(4), 1387–1424. https://doi.org/10.1108/IJLM-03-2016-0064

Dawande, M., & Qi, A. (2021). Auditing, inspections, and testing for social responsibility in supply networks. In *Responsible business operations* (pp. 243–259). Springer, Cham. https://doi.org/10.1007/978-3-030-51957-5_12

Delgado, I. T. (2021). CSR and Stakeholders' engagement: A relational perspective–suppliers' social responsibility: Auditing vs. engagement in a relational capital reference. In *Knowledge management for corporate social responsibility* (pp. 207–229). IGI Global. https://doi.org/10.4018/978-1-7998-4833-2.ch011

Dey, P. K., Bhattacharya, A., Ho, W., & Clegg, B. (2015). Strategic supplier performance evaluation: A case-based action research of a UK manufacturing organisation. *International Journal of Production Economics*, *166*, 192–214. https://doi.org/10.1016/j.ijpe.2014.09.021

Di Pasquale, V., Nenni, M. E., & Riemma, S. (2020). Order allocation in purchasing management: A review of state-of-the-art studies from a supply chain perspective. *International Journal of Production Research*, *58*(15), 4741–4766. https://doi.org/10.1080/00207543.2020.1751338

Elrehail, H., Rehman, S. U., Chaudhry, N. I., & Alzghoul, A. (2021). Nexus among cyberloafing behavior, job demands and job resources: A mediated-moderated model. *Education and Information Technologies*, *26*, 4731–4749. https://doi.org/10.1007/s10639-021-10496-1

Feng, M., Yu, W., Wang, X., Wong, C. Y., Xu, M., & Xiao, Z. (2018). Green supply chain management and financial performance: The mediating roles of operational and environmental performance. *Business Strategy and the Environment*, *27*(7), 811–824. https://doi.org/10.1002/bse.2033

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

Gao, Q., Guo, S., Liu, X., Manogaran, G., Chilamkurti, N., & Kadry, S. (2020). Simulation analysis of supply chain risk management system based on IoT information platform. *Enterprise Information Systems*, *14*(9–10), 1354–1378. https://doi.org/10.1080/17517575.2019.1644671

Gligor, D., Gligor, N., Holcomb, M., & Bozkurt, S. (2019). Distinguishing between the concepts of supply chain agility and resilience. *The International Journal of Logistics Management*, *30*(2), 467–487. https://doi.org/10.1108/IJLM-10-2017-0259

Hair Jr, J. F., Hult, G. T. M., Ringle, C., & Sarstedt, M. (2016). *A primer on partial least squares structural equation modeling (PLS-SEM)*. Sage Publications.

Handfield, R. B., & Lawson, B. (2007). Integrating suppliers into new product development. *Research-Technology Management*, *50*(5), 44–51. https://doi.org/10.1080/08956308.2007.11657461

Hassani, Y., Ceaușu, I., & Iordache, A. (2020). Lean and Agile model implementation for managing the supply chain. *Proceedings of the International Conference on Business Excellence*, *14*(1), 847–858. https://doi.org/10.2478/picbe-2020-0081

Huo, B., Gu, M., & Wang, Z. (2019). Green or lean? A supply chain approach to sustainable performance. *Journal of cleaner production*, *216*, 152–166. https://doi.org/10.1016/j.jclepro.2019.01.141

Hutt, E. (1994). Fault tolerant auditing. *Computer Audit Update*, *1994*, 31–45. https://doi.org/10.1016/0960-2593(94)90003-5

Ivanov, D., Tsipoulanidis, A., & Schönberger, J. (2019). Supply chain risk management and resilience. In *Global supply chain and operations management* (pp. 455–479). Springer, Cham. https://doi.org/10.1007/978-3-319-94313-8_15

Johng, H., Kim, D., Park, G., Hong, J. E., Hill, T., & Chung, L. (2020, March). Enhancing business processes with trustworthiness using blockchain: A goal-oriented approach. In *Proceedings of the 35th Annual ACM Symposium on Applied Computing* (pp. 61–68). https://doi.org/10.1145/3341105.3374022

Jørgensen, B., & Emmitt, S. (2009). Investigating the integration of design and construction from a "lean" perspective. *Construction Innovation*, *9*(2), 225–240. https://doi.org/10.1108/14714170910950849

Karuppiah, K., Sankaranarayanan, B., & Ali, S. M. (2022). Evaluation of suppliers in the tannery industry based on emergy accounting analysis: Implications for resource conservation in emerging economies. *International Journal of Sustainable Engineering*, *15*(1), 1–14. https://doi.org/10.1080/19397038.2021.1982066

Kerekes, K. N., & Szegedi, K. (2012). Challenges of responsible supply chain management. *Theory, Methodology, Practice*, *8*(2), 68.

Kline, R. B. (2015). *Principles and practice of structural equation modeling*. Guilford Publications.

Kumar, A. (2016). A quick scan audit of the 'socio-technical' system in a leather accessories manufacturing SME. *International Journal of Indian Culture and Business Management*, *12*(3), 386–406. https://doi.org/10.1504/IJICBM.2016.075543

Liu, X., Qian, C., & Wang, S. (2020). When do 3PLs initiate low-carbon supply chain integration?. *International Journal of Operations & Production Management*, *40*(9), 1367–1395. https://doi.org/10.1108/IJOPM-12-2019-0809

Long, T. B., & Young, W. (2016). An exploration of intervention options to enhance the management of supply chain greenhouse gas emissions in the UK. *Journal of Cleaner Production*, *112*, 1834–1848. https://doi.org/10.1016/j.jclepro.2015.02.074

McKinnon, A. (2014). *Building supply chain resilience: A review of challenges and strategies* (International Transport Forum Discussion Papers, No. 2014/06). OECD Publishing, Paris. https://doi.org/10.1787/5jrw2z6nnxlq-en

Nemcic, N., Novak, S., Maric, L., Novosel, I., Kronja, O., Hren, D., Marusic, A., & Marusic, M. (2005). Development and validation of questionnaire measuring attitudes towards sexual health among university students. *Croatian Medical Journal*, *46*(1), 52–57.

Paksoy, T., Çalik, A., Yildizbaşi, A., & Huber, S. (2019). Risk management in lean & green supply chain: A novel fuzzy linguistic risk assessment approach. In *Lean and Green Supply Chain Management* (pp. 75–100). Springer, Cham. https://doi.org/10.1007/978-3-319-97511-5_3

Pedersen, E. R., & Andersen, M. (2006). Safeguarding corporate social responsibility (CSR) in global supply chains: how codes of conduct are managed in buyer-supplier relationships. *Journal of Public Affairs: An International Journal*, *6*(3–4), 228–240. https://doi.org/10.1002/pa.232

Perez-Melo, S., & Kibria, B. G. (2020). On some test statistics for testing the regression coefficients in presence of multicollinearity: A simulation study. *Stats*, *3*(1), 40–55. https://doi.org/10.3390/stats3010005

Popescu, M., & Vasile, E. (2011). Internal auditing value added concept. *Internal Auditing & Risk Management*, *VI*(1), 22.

Prodi, E., Tassinari, M., Ferrannini, A., & Rubini, L. (2022). Industry 4.0 policy from a sociotechnical perspective: The case of German competence centres. *Technological Forecasting and Social Change*, *175*, 121341. https://doi.org/10.1016/j.techfore.2021.121341

Purvis, L., Spall, S., Naim, M., & Spiegler, V. (2016). Developing a resilient supply chain strategy during 'boom' and 'bust'. *Production Planning & Control*, *27*(7–8), 579–590. https://doi.org/10.1080/09537287.2016.1165306

Qin, Z., & Chen, P. K. (2022). Enhancing the resilience of sustainable supplier management through the combination of win-win lean practices and auditing mechanisms – An analysis from the resource-based view. *Frontiers in Environmental Science*, *10*, 1541. https://doi.org/10.3389/fenvs.2022.962008

Ralahallo, F. N., Tetelepta, E. G., & Sijabat, A. (2022). Supply chain management performance of the furniture industry in ambon during the Covid-19 pandemic. *Budapest International Research and Critics Institute (BIRCI-Journal): Humanities and Social Sciences*, *5*(2), 9159–9170.

Ruiz-Benitez, R., López, C., & Real, J. C. (2017). Environmental benefits of lean, green and resilient supply chain management: The case of the aerospace sector. *Journal of Cleaner Production*, *167*, 850–862. https://doi.org/10.1016/j.jclepro.2017.07.201

Ruiz-Benítez, R., López, C., & Real, J. C. (2018). The lean and resilient management of the supply chain and its impact on performance. *International Journal of Production Economics*, *203*, 190–202. https://doi.org/10.1016/j.ijpe.2018.06.009

Sarkis, J., Gonzalez, E. D. S., & Koh, S. L. (2019). Effective multi-tier supply chain management for sustainability. *International Journal of Production Economics*, *217*, 1–10. https://doi.org/10.1016/j.ijpe.2019.09.014

Scholten, K., Scott, P. S., & Fynes, B. (2014). Mitigation processes–antecedents for building supply chain resilience. *Supply Chain Management: An International Journal*, *19*(2), 211–228. https://doi.org/10.1108/SCM-06-2013-0191

Shi, Q., Zhu, J., & Li, Q. (2018). Cooperative evolutionary game and applications in construction supplier tendency. *Complexity*, *2018*, 8401813. https://doi.org/10.1155/2018/8401813

Smith, J. B., & Alvarez, R. (2020). *Beyond compliance design of a quality system: Tools and templates for integrating auditing perspectives*. Quality Press.

So, S., & Sun, H. (2010). Supplier integration strategy for lean manufacturing adoption in electronic-enabled supply chains. *Supply Chain Management: An International Journal*, *15*(6), 474–487. https://doi.org/10.1108/13598541011080455

Suraraksa, J., & Shin, K. S. (2019). Comparative analysis of factors for supplier selection and monitoring: The case of the automotive industry in Thailand. *Sustainability*, *11*(4), 981. https://doi.org/10.3390/su11040981

Taysom, E., & Crilly, N. (2017). Resilience in sociotechnical systems: The perspectives of multiple stakeholders. *She Ji: The Journal of Design, Economics, and Innovation*, *3*(3), 165–182. https://doi.org/10.1016/j.sheji.2017.10.011

Tieman, M. (2017). Halal risk management: Combining robustness and resilience. *Journal of Islamic Marketing*, *8*(3), 461–475. https://doi.org/10.1108/JIMA-06-2015-0041

Vachon, S., & Klassen, R. D. (2008). Environmental management and manufacturing performance: The role of collaboration in the supply chain. *International Journal of Production Economics*, *111*(2), 299–315. https://doi.org/10.1016/j.ijpe.2006.11.030

van Weele, A., & van Tubergen, K. (2017). Responsible purchasing: moving from compliance to value creation in supplier relationships. In *Sustainable Supply Chains* (pp. 257–278). Springer, Cham. https://doi.org/10.1007/978-3-319-29791-0_11

Wang, J., & Zhao, C. (2022). Reducing carbon footprint in a resilient supply chain: Examining the critical influencing factors of process integration. *International Journal of Production Research*. https://doi.org/10.1080/00207543.2022.2063088

Wen, F., & Liu, Z. (2009). A copula-based correlation measure and its application in chinese stock market. *International Journal of Information Technology & Decision Making*, *8*(04), 787–801. https://doi.org/10.1142/S0219622009003612

Yang, F., Kong, J., Liu, T., & Ang, S. (2022). Cooperation and coordination in green supply chain with R&D uncertainty. *Journal of the Operational Research Society*, *73*(3), 481–496. https://doi.org/10.1080/01605682.2020.1848359

Zhang, M., Pawar, K. S., & Bhardwaj, S. (2017). Improving supply chain social responsibility through supplier development. *Production Planning & Control*, *28*(6–8), 500–511. https://doi.org/10.1080/09537287.2017.1309717

Zhang, Y., Zou, D., Zheng, J., Fang, X., & Luo, H. (2016). Formation mechanism of quick emergency response capability for urban rail transit: Inter-organizational collaboration perspective. *Advances in Mechanical Engineering*, *8*(6), 1687814016647881. https://doi.org/10.1177/1687814016647881

APPENDIX

Questionnaire

Constructs	Variables	Strongly disagree	Dis-agree	Neither agree nor disagree	Agree	Strongly agree
Q1. Can the company measure its internal responsibility drive through the following situations?						
Internal responsibility drive (RD)	RD1. Enhancement of purchasing process	☐	☐	☐	☐	☐
	RD2. Every supplier has a stable purchasing source based on lean operations requirements	☐	☐	☐	☐	☐
	RD3. Every supplier can improve its replenishment of products based on lean operations requirements	☐	☐	☐	☐	☐
	RD4. Every supplier can improve its production process based on lean operations requirements	☐	☐	☐	☐	☐
Q2. Can the company measure its ability to respond to emergencies through the following situations?						
Ability to respond to emergencies (ES)	ES1. Enhanced forecasting of the damage incurred when other participants engage in opportunistic behaviour	☐	☐	☐	☐	☐
	ES2. Supplier can immediately assess possible damage levels and respond early when other participants exhibit unusual behaviour	☐	☐	☐	☐	☐
	ES3. Supplier can immediately identify possible sources of damage and respond early when other participants exhibit unusual behaviour	☐	☐	☐	☐	☐
	ES4. Supplier can immediately adjust production operations to reduce negative effects when other participants exhibit unusual behaviour	☐	☐	☐	☐	☐
Q3. Can the company measure whether suppliers or other participants will increase their auditing intention through the following situations?						
Tolerance expanding to auditing (TE)	TE1. Reduced resistance to auditing practices	☐	☐	☐	☐	☐
	TE2. Increased auditing intentions	☐	☐	☐	☐	☐
	TE3. Positive perceptions of auditing	☐	☐	☐	☐	☐

Constructs	Variables	Strongly disagree	Dis-agree	Neither agree nor disagree	Agree	Strongly agree
Q4. Can the company measure whether suppliers or participants will accept auditing interventions through the following situations?						
Acceptability of auditing interventions (AI)	AI1. Supplier usually accepts all comments from auditor to improve related operations and meet lean practice standards	☐	☐	☐	☐	☐
	AI2. Supplier is willing to share his or her real situation with auditor	☐	☐	☐	☐	☐
	AI3. Supplier is willing to continuously improve according to auditing assessment results	☐	☐	☐	☐	☐
Q5. Can the company measure whether the process between manufacturers and suppliers or participants has effectively improved through the following situations?						
Enhancement of process integration (PI)	PI1. Integration of purchasing processes	☐	☐	☐	☐	☐
	PI2. Integration of manufacturing information	☐	☐	☐	☐	☐
	PI3. Integration of design/ production modules between manufacturers and suppliers	☐	☐	☐	☐	☐
Q6. Can the company measure whether the risk resilience has significantly increased through the following situations?						
Increased risk resilience (RR)	RR1. Enhanced process monitoring capability	☐	☐	☐	☐	☐
	RR2. Possess the capability to detect unusual behaviour in the precrisis stage	☐	☐	☐	☐	☐
	RR3. Enhanced ability to respond early to any possible accidents	☐	☐	☐	☐	☐
Q7. Can the company measure the green supply chain improvement situation through the following situations?						
Improvement of the green supply chain (GS)	GS1. Cross-functional cooperation with suppliers for environmental improvements	☐	☐	☐	☐	☐
	GS2. Joint decision-making with suppliers to reduce the overall environmental impact of products	☐	☐	☐	☐	☐
	GS3. A mutual understanding with suppliers of the responsibilities regarding environmental performance	☐	☐	☐	☐	☐