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Implementation of Collaborative Activities for Sustainable Supply Chain Innovation: An Analysis of the Firm Size Effect

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Abstract: This study examines the effects of collaborative and implementation activities on environmental performance for sustainable supply chain management. Specifically, the proposed research investigates the moderating effect of firm size on the effect relationships. The structural equation modeling with AMOS 23.0 was employed to test hypotheses. The results confirm the positive effects of collaborative activities on environmental performance and the positive relationship between collaborative activities and green certification programs in both small and medium enterprises (SMEs) and large-sized firms. Contrary to general belief, firm size did not moderate the relationship between autonomous collaborative activities and green activities. However, other relationships were supported in the research model, thus firm size partially moderates the relationships of collaborative activities with implementation activities and environmental performance. The study demonstrates that implementation activities play a key role in improving collaborative activities with suppliers and vendors for sustainable supply chain innovation. Additionally, it contributes to the practice of sustainable supply chain innovation as well as to efficiency through collaborative activities in the supply chain process.

Keywords: sustainable supply chain innovation; collaborative activities; implementation activities; environmental performance; firm size

1. Introduction

Industry 4.0 and digitization present many opportunities to organizations. However, they also bring challenges because of the increased dynamicity and complexity of supply chain management (SCM). In addition, severe weather and climate change have received significant attention as they bring difficulties to coordination and response issues with suppliers and customers in SCM [1]. Given the increased uncertainty and risk, these phenomena force firms to invest on technical resources toward disaster prevention so as to enhance organizational resilience, visibility, agility, tightness, simplification, on-demand data, and prevention in the supply chain (SC) [1–5]. In addition, with the fluid global market demand, many organizations strive to reduce risk and cost, including environmental issues in their global/regional SC [1–4,6,7]. Environmental issues are critical in developing sustainable SCM with suppliers [8,9], managing economic, social, and environmental responsibility [1,10], enhancing SCM innovation [3], fostering dynamic capabilities of SCM [2], and improving sustainable performance [1]. Thus, companies should develop innovative solutions to meet customer needs with agile responses to dynamic changes in the environment.

For an innovative and sustainable supply chain, collaborative activities among partner firms within the SC are important. For example, Walmart asked all of its associated carriers and transportation companies that supply and deliver their products to reduce environmental pollution and terminated

contracts with those who failed to meet the target [11]. Thus, collaborative activities for the successful implementation among companies in the SC play a major role in sustainable SC innovation.

The expected benefit of collaborative and implementation activities is improved organizational performance. To introduce successful sustainable SC innovation, we suggest two fundamental requirements: (1) Collaborative activities that are autonomous and espousal among partner organizations in the SC; and (2) Implementation activities that are espousal and yet compulsory among partner firms. To derive collaborative activities, it is necessary to develop a trust relationship among partner organizations that is voluntary and enforceable at the same time. Collaborative activities should be completely autonomous. Implementation activities, on the other hand, can be espousal but compulsory simultaneously, such as participation in green certification programs (e.g., ISO 14001 certification) and green practices (e.g., reducing pollution and greening of products and processes). Accordingly, for the shared goal of sustainable SC innovation, all partner organizations should actively participate in both collaborative and implementation activities [12]. To encourage participation, it is necessary to first clarify how autonomous collaborative activities and compulsory implementation activities would affect firms within the SC. In other words, the sequential interrelationship of collaborative and implementation activities for organizational performance should be analyzed for sustainable SC innovation based on empirical data. This analysis of interrelationship would provide valuable basic information for establishing trust among related SC companies.

As a result of this research, organizational outcomes of collaborative activities in SCM would provide valuable strategic information. Yet, there is a paucity of empirical research on the collaborative activities for sustainable SC innovation as well as on environmental performance. Thus, this research focuses on operational strategies for effective collaborative activities within the SC. This study attempts to provide answers to the following two basic research questions: (1) Does a company's collaborative activities in the SC impact the implementation of sustainable SC innovation? (2) Do the implementation activities for sustainable SC innovation have an impact on environmental performances? Considering the expected results of the research based on previous research and studies, this study will contribute to the theory and practice through examining the proposed research model with developed hypotheses on sustainable SC innovation. The results of this study will be practically applied in sustainable SC innovation to enhance environmental performance.

The rest of the paper is structured as follows. Section 2 proposes a research model with developed hypotheses based on relevant literature reviews on SCM; Section 3 presents research methodology; Section 4 reports the results of analysis; and Section 5 provides the study with the conclusions and limitations of the study, including future research opportunities.

2. Literature Review and Hypotheses Development

2.1. Sustainable Supply Chain Management

The supply chain is a dynamic system that undergoes constant change in terms of demand, supply, trade, and market conditions because it is inherently exposed to risks and uncertainties [1,13]. The cause of the volatility (uncertainty) of the SC can be explained based on previous studies as follows (e.g., [1–4,14–17]): (1) Demand variability due to customers' urgency changes, customer/market forecasting, and demand shaping; (2) Supply chain information inaccuracy (e.g., production capacity, inventory information, availability of raw materials) and supply variability due to disruptions in development/production/purchase; and (3) Simplifying and rapid sharing of volatility due to the pursuit of efficiency in each sector, such as sales, development, production, and purchasing, and lack of integration of unprocessed information. In particular, the speed and scale of change in terms of distance, diversity, and cycle would compound operational uncertainty. Therefore, continuous monitoring of delivery period, transit times, production yield, and component availability should be maintained, including environmental conditions. However, with the increased uncertainty and vulnerability due to the geographical scope of the global supply chain, there is a need to secure the robustness of SC

operations through a buffer stock or multi-procurement strategies, including collaborative activities with SC partners.

The objective of SCM is to maximize the value of the SC as a whole, that is, SC profitability. The value generated within SC can be assessed as the difference between the value of the final finished product provided to the customer and the efforts required to meet customer needs. Since value creation can be accomplished in collaboration with partners within the SC, collaborative activities for sustainable SC innovation can be a strategy to optimize value creation. As the overall customer experience is becoming more important, beyond the level of providing goods/services, the scope of customers as extended internal members, partner organizations, and society at large, it is important to implement effective collaborative activities to ensure sustainability.

Sustainability is assumed to have a positive influence on environment conditions through energy-efficient operations, greenhouse gas emission reduction, green management, and corporate social responsibility (CSR). Sustainability in SCM has been introduced for tackling environmental issues, maintaining sustainable business, and implementing SC innovation [1–4,7,16,18–20]. Shrivastava ([21], p. 955) defined sustainability as “the potential for reducing long-term risk associated with resource depletion, fluctuations in energy costs, product liabilities, and pollution and waste management.” Góncz et al. ([22], p. 4) defined sustainability as “equal weightings for economic stability, ecological compatibility, and social equilibrium.” Carter and Rogers [18] emphasized attainment of organizational goals of economic, social, and environmental responsibility to define sustainability and expanded their research to develop sustainable SCM. Sustainable supply chain management (SSCM) is covered by the flow of material and information, cooperation with partners and stakeholders, and meeting requirements of customers and stakeholders within SC [20]. Ahi and Searcy ([23], p. 339) defined SSCM based on previous studies related to green supply chain management (GSCM) and characteristics of business sustainability as “The creation of coordinated supply chains through the voluntary integration of economic, social, and environmental considerations with key inter-organizational business systems designed to efficiently and effectively manage the material, information, and capital flows associated with the procurement, production, and distribution of products or services”.

Although sustainability is difficult to define in terms of SCM because of the latter’s complex global nature, most definitions encompass environmental, social, and economic issues, and highlight the importance of innovation in the SC [3,7,16,24]. To develop sustainable SC innovation, firms attempt to lower the risk level in the uncertain environment, including sustainable collaboration with in-out partners, suppliers, and customers.

In SCM, advanced technologies have important roles in linking suppliers and vendors within internal and external SCs [6,16]. In particular, environmentally friendly technologies can contribute to cost and risk reduction [25], developing a sustainable process system [15,16], and better communication with suppliers and customers [13]. Such technologies can lead innovation for the sustainable SC based on environmental strategies, such as reduction of pollution and gas emission, expanded environmental policies, and optimization of inputs (e.g., resources, raw materials, capitals, and energies) [6,16,26].

Lee and Lim ([27], p. 21) defined innovation as “actual application of any idea or approach in fundamentally different ways to create new or greater value for the organization and other stakeholders”. In SCM, innovation is not only focused on technology or ideas, but it also strives to prevent negative impacts on the environment [6,13]. A set of collaborative activities is laid out to improve communication, promote energy efficiency, and mitigate the effects of environmental issues through the synergy of partners [28]. Innovation in SCM is crucial for creating new solutions and close relationships with subcontractors, including continuous quality improvement; quick responses to suppliers, vendors, and customers; and development of technology-based processes and procedures [1,14]. Artsiomchyk and Zhiviskaya [14] proposed SC innovation linked with information technology and logistic procedures for improving operational efficiency.

Although innovation in the SC helps generate operational strategies, it is derived by collaborative activities among suppliers, vendors, and governments to prevent environmental issues. Thus,

sustainable SC innovation can address environmental issues through SC activities. In this study, sustainable SC innovation is defined as operational management approaches to achieve better results of sustainable development by responding to environmental regulations and issues through implementation of innovative solutions within the SC.

In this study, the scope of research for sustainable SC innovation focuses on the environment within the SC through collaborative and implementation activities and their results in the form of performance. This is primarily because collaboration among related SC partners is important for sustainability in SCM. Therefore, this study examines how collaborative activities (e.g., autonomous collaborative and adoption activities) and actual implementation activities (e.g., green certification programs and green activities) impact environmental performance, depending on firm size.

2.2. Conceptual Framework and Hypotheses

2.2.1. Collaborative and Implementation Activities

Firms often develop SC partnerships within SCs in order to deal with internal and external environmental changes for SSCM [1,29,30]. The collaborative efforts with partners and suppliers can be beneficial in attaining world-class SC competence. However, in the external environment, it may not be possible to cover all risk possibilities in spite of the partnerships. Thus, most firms strive to develop good relationships with partners through promotional and collaborative activities to manage and sustain the internal and external environment with agility.

Previous studies suggested the scope of SC collaboration activities with internal and external partners for efficient SCM. This includes the willingness of the top management of organizations to encourage participation of employees [31], promoting human capacity or skill development [32,33], encouraging cooperation and collaboration with partners and vendors [1,34–36], and developing sustainable SCM strategies [31,37,38]. These studies suggest that firms can develop collaborative relationships and implement strategies with partners to build a sustainable SC model that can help create competitive advantage over conventional SCs. In general, collaboration within SCM enables the formation of a partnership with suppliers and vendors within the internal and external SC [16].

Lambert and Knemeyer [35] identified two types of partnerships, one is a limited cooperative and integrated relationship with multiple parts in the SC, and the other is a cooperative relationship with a partner company. On the contrary, Lee and Schniederjans [16] proposed three categories of partnerships, namely a limited cooperative, an integrated cooperative, and a mutual cooperative relationship. Matopoulos et al. [39] emphasized the importance of collaboration among SC partners to enhance operational efficiency. According to Villena et al. [40], cooperation achieved by building trust among firms leads to a positive influence in the formation of strong relationships. Lee and Schniederjans [16] suggested that sustainable SCM is achieved through collaboration among subcontractors within the SC. Therefore, increased collaborative activities should improve operational efficiency among partner firms [40,41]. As revealed in earlier studies, a sustainable SC might be developed through more collaborative activities.

The implementation of voluntary collaborative activities enables firms to co-create competitive advantage [13]. Furthermore, participation of vendors and suppliers to achieve shared goals and outcomes can promote commitment of partner firms toward sustainable SC innovation. For example, voluntary collaborative activities within the SC on environmental issues may include: (1) reinforcement of information sharing according to environmental norms or behaviors; (2) monitoring and regulation of the existing processes and systems to reduce waste and emission; (3) active participation in environmental regulation to maintain sustainability within SC; and (4) evaluation and promotion of measures among subcontractors with respect to achievement of environmental goals. On the other hand, actual implementation of collaborative and mandatory activities within the SC on environmental issues may require: (1) obtaining and/or implementing green vendor certification programs (e.g.,

ISO 14001 certification) to certify quality and operations; (2) adopting other similar green vendor certification programs; and (3) making aligned green activities with partner firms.

If the incumbent firm is a well-known organization for environmental conservation and commitment toward sustainability issues within the SC, then the firm's brand value can be maximized through its contribution toward environment projects and recognition of the brand reputation by customers [42,43]. Vendors who have collaborative relationships with organizations that are well-known for their commitment toward environmental issues are more likely to have environmental activities in their SC system. This indicates that collaborative activities can be implemented through vendors, suppliers, and subcontractors to provide a milestone for the partner firms on performance improvement. In turn, SC firms secure competitive advantage through implementing sustainable SC innovation activities [17]. It is evident that collaborative activities impact the performance of all SC partner firms. Additionally, collaborative and promotional activities with vendors and stakeholders lead to improvement in business activities and removal of environmental obstacles to SSCM.

Thus, collaboration activities that involve vendors can drive implementation of sustainable SC strategies where information and risk sharing with suppliers, vendors, manufacturers, and consumers improve responsiveness and agility to environmental changes, including improvement in organizational performance. Therefore, the following hypotheses are suggested.

Hypothesis 1 (H1). *Autonomous collaborative activities will positively influence implementation of green certification programs.*

Hypothesis 2 (H2). *Autonomous collaborative activities will positively influence implementation of green activities.*

Hypothesis 3 (H3). *Adoption activities will positively influence implementation of green certification programs.*

Hypothesis 4 (H4). *Adoption activities will positively influence implementation of green activities.*

2.2.2. Implementation Activities and Environmental Performance

As SCM is a complex network of activities, SC firms need to deal with operational strategies with their partners to achieve better long-term relationships and performance [1]. SC activities include reverse logistics that involves recycling and/or disposal of products as environment-friendly activities for sustainable development [6]. A number of firms have implemented green initiatives in SCM for sustainable development activities, such as reduction in pollutant discharge, and production, storage, packaging, transportation, distribution, and consumption of recyclable products [44]. In addition to this, a set of collaborative activities with subcontractors for promoting a synergy among SC partners to improve environmental performance through eliminating waste and implementing environment-friendly activities has been set up. These activities are performed through collaborative initiatives in association with other related SC firms and governments, instead of just within the company [45]. Therefore, collaborative activities can positively influence the widely accepted elements, such as green vendor certification programs and suppliers' green practices.

Sustainable SC innovation can be driven through the optimization of processes that reduce waste, the production of emissions, and the adoption of collaborative activities within the SC to manage the increasing concerns related to the environment such as green actions. It is also necessary for the lead SC firm to provide environmental criteria (e.g., certification; roles of savings in water and energy; environment-friendly packaging and distribution; and reverse logistics) to suppliers and vendors. These activities can be implemented by mandatory roles within the SC to ensure that the shared goals are achieved through collaborative activities of all associated vendors. Thus, improvement of environmental performance can be expected from the voluntary adoption of collaborative activities by all firms within the SC [46].

To attain sustainable SC innovation, it is imperative that SC firms do not act alone, but rather collaborate and work in harmony to ensure environmental protection and the search for opportunities to improve SC processes, build environment-friendly corporate ecosystems, and improve organizational performance and brand value [16]. In general, companies tend to ignore environmental protection activities that are not profitable in the short term. Thus, it is important for governments to develop regulations that compel firms to safeguard environmental protection activities. The parent firm should request that green vendor certification programs are obtained or implemented to make sure that similar green vendor certification programs are adapted by SC partners, and investment in suppliers' green activities is made. Such activities represent environmental protection commitment for achieving common goals, e.g., environmental performance, brand reputation, and competitive advantage through adoption of collaborative activities in the SC. Sustainable SC innovation provides value to SC partner firms, stakeholders, and the community by building a sustainable ecosystem. Some of the reasons for performing collaborative practices in sustainable SC innovation include improvement of cost competitiveness, flexibility, delivery, regulatory compliance, and image enhancement through green activities. Thus, the actual implementation of SC innovation activities with vendors can improve environmental performance. Therefore, the following hypotheses are proposed.

Hypothesis 5 (H5). *Implementation of green certification programs will positively influence environmental performance.*

Hypothesis 6 (H6). *Implementation of green activities will positively influence environmental performance.*

The impact of firm size depends on the various factors of the enterprises (e.g., number of suppliers and distribution centers). Small and medium-sized enterprises (SMEs) usually use low-tech information technology applications while large firms use high-tech applications [13,47]. Thus, firm size (large vs. small or medium) has an impact on SCM activities or processes [5].

The examination of firm size by tier may shed additional insight about the relationships between suppliers and vendors. Previous studies on SCM have rarely examined the moderating effect of firm size. Large-sized firms invest more on resource efficiency, recycling, developing eco-friendly products and services, and adopting systems that prevent environmental damage than SMEs [5,48]. Consequently, characteristics such as firm size seem to have a moderating effect on SCM. Thus, the following hypothesis is proposed:

Hypothesis 7 (H7). *Firm size will moderate the relationships between collaborative activities, implementation activities, and environmental performance for sustainable SC innovation.*

We examined in this study the effects of collaborative activities on environmental performance through implementation activities in sustainable SC innovation depending on firm size. As with previous studies, we assumed that collaborative activities are a prerequisite for sustainable SC innovation, and that implementation activities improve environmental performance in an SC, including the moderating effects of firm size. The proposed research model is shown in Figure 1.

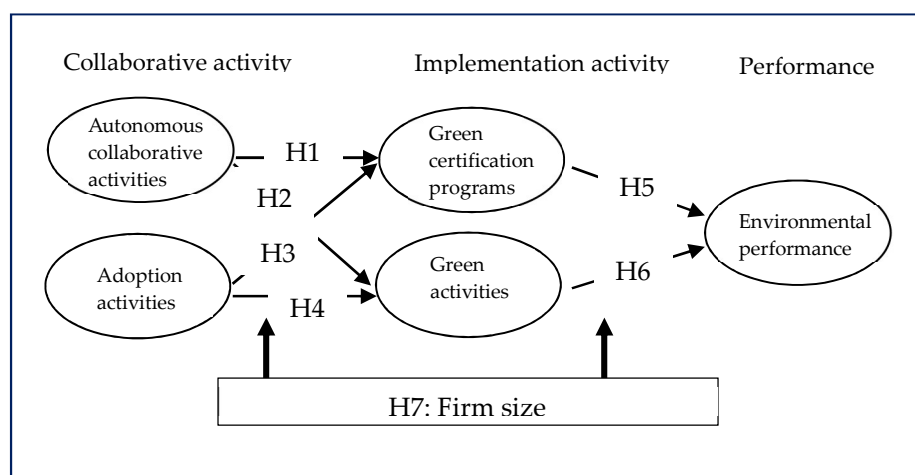


Figure 1. The proposed research model.

3. Methodology

3.1. Data Collection

Data was collected from supplier firms by means of visits and/or online contacts with the staff and/or manager of related SC firms from 20 August to 30 November 2018 in South Korea. Supplier firms voluntarily participated in this study. The questionnaire items were developed through the double translation protocol approach [49]. The measurement items for autonomous collaborative activities, adoption activities, green certification programs and green activities, and environmental performance in sustainable SC innovation are shown in Table 1 based on Global Manufacturing Research Group (GMRG) 5.0 survey questionnaire [50] and Lee [1].

Out of 700 questionnaires that were distributed to manufacturing supplier firms in South Korea, 227 (32.4%) responses were returned. As incomplete questionnaires were discarded, the final useable sample consisted of 218 (31.1%) valid questionnaires.

Table 1. Measurement items.

Variables	Measurement Items	References
Autonomous collaborative activities	ACA1: systematically control the environmental impact ACA 2: implement a systematic approach for setting environmental targets ACA 3: implement a systematic approach for achieving environmental targets ACA 4: implement a systematic approach for demonstrating environmental targets	GMRG 5.0 survey questionnaire [50]; Lee [1]
Adoption activities	AAE1: a systematic approach to reduce cost AAE 2: a systematic approach to demonstrate delivery speed AAE 3: a systematic approach to set regulatory compliance	
Green certification programs	GCP1: use green vendor certification programs to certify GCP 2: implement green vendor certification programs with suppliers GCP 3: adopt similar green vendor certification programs	
Green activities	GCA1: with partners for reducing pollution activities GCA 2: with partners for perceived favorable activities by their customers GCA 3: with partners for products' and processes' green activities	
Environmental performance	ENP1: reduced energy use in our facilities ENP2: reduced water use in our facilities ENP3: reduced waste at our facilities ENP4: reduced emissions at our facilities	

As shown Table 2, the characteristics of the sample firms and respondents are summarized. The majority of business units are manufacturers of parts of machines and machinery (61.2%). Of the respondents, 98.2% were male, with working experiences ranging from less than 10 years (54.6%) to more than 20 years (11.0%) in the current organization.

Table 2. Characteristics of firms and respondents.

Characteristics of Firms		Frequency	Percent
Years since establishment	Less than 10 years	75	33.0
	More than 10 years–less than 20 years	80	35.2
	More than 20 years–less than 30 years	49	21.6
	More than 30 years	23	10.1
Number of employees	Less than 300	145	63.9
	More than 300	82	36.1
Number of partners	Less than 50	143	63.0
	More than 50–less than 100	20	8.8
	More than 100	60	26.4
	Missing	4	1.8
Business unit	Electronic and other electrical equipment	14	6.2
	Manufacture of motor vehicles	17	7.5
	Petroleum refining and related industries	28	12.3
	Metal industry	29	12.8
	Manufacture of parts of machines and machinery	139	61.2
Characteristics of Respondents		Frequency	Percent
Gender	Male	223	98.2
	Female	4	1.8
Position	Team Leader	97	42.7
	Manager	50	22.0
	Director/Supervisor	18	7.9
	Executive	62	27.3
Working years	Less than 10	124	54.6
	More than 10–less than 20	78	34.4
	More than 20	25	11.0
Total		227	100.0

3.2. Variables

The questionnaire utilized the five-point Likert scales to measure the variables. To analyze the collected data, the SPSS 23.0 and the AMOS 23.0 programs were used. Structural equation modeling (SEM) was used considering the tools necessary to test the developed hypotheses.

Reliability of these constructs was tested based on Cronbach's α -value (Table 3). All of the coefficients of reliability measures for the constructs exceed the threshold value of 0.7 for exploratory constructs in basic research [51]. In the reliability test, Cronbach's α -value for autonomous collaborative activities was the highest (0.926), while it was the lowest (0.855) for green activities. Thus, all of the study constructs have Cronbach's α -value larger than 0.8, which reveals high reliability $p < 0.05$.

Validity refers to the accuracy of a measure. Principal component analysis (PCA) is used to identify the most meaningful basis and to express similarities and differences of the data, and confirmatory factor analysis (CFA) is a way of testing how well the measured variables represent the constructs based on Brown's [52] recommendation. As the Eigen values and percent of variance explained for each construct of the study are shown in Table 3, the cumulative percentage of explained variance was 80.294 for the constructs. The loading values of each factor of the study ranged from 0.752 to 0.898 as shown in Table 3.

For the convergent and discriminant validity test [52], the measurement model was used for autonomous collaborative activities, adoption activities, green certification programs, green activities, and environmental performance. The standardized factor loadings, t -values, and p -values for measurement variables, and results of CFAs are presented in Table 3. In the measurement model, the values of standardized loading of all variables reported by the study were greater than 0.7 and significant at the 0.001 level.

Table 3. Results of PCA and CFA.

Constructs	Variables	PCA		CFA				Cronbach's Alphas
		Eigen Value	Percent of Variance Explained	Factor Loading	Standardized Loading	t-Value	p-Value	
Autonomous collaborative activities	ACA1	4.807	28.276	0.881	0.845	15.747	0.000	0.926
	ACA2			0.890	0.908	17.683	0.000	
	ACA3			0.880	0.891	17.172	0.000	
	ACA4			0.846	0.839	-	-	
Adoption activities	AAE1	1.048	6.162	0.752	0.751	13.269	0.000	0.876
	AAE2			0.896	0.887	16.292	0.000	
	AAE3			0.877	0.886	-	-	
Green certification programs	GCP1	1.276	7.505	0.832	0.839	13.651	0.000	0.879
	GCP2			0.851	0.905	14.521	0.000	
	GCP3			0.808	0.791	-	-	
Green activities	GCA1	2.217	13.044	0.847	0.797	11.989	0.000	0.855
	GCA2			0.898	0.882	12.542	0.000	
	GCA3			0.859	0.776	-	-	
Environmental performance	ENP1	4.226	24.857	0.853	0.834	13.993	0.000	0.894
	ENP2			0.841	0.789	13.029	0.000	
	ENP3			0.862	0.862	14.560	0.000	
	ENP4			0.827	0.810	-	-	

Table 4 is summarized the results of fit indices of the measurement model. Based on the recommended values, the values of GFI, CFI, RMR SRMR, RMSEA, and χ^2 were satisfactory. This model, thus, showed good acceptance measures for a majority of fit indices.

Table 4. Results of fit indices for CFA.

Model	χ^2	d.f	$\chi^2/\text{d.f}$	GFI	CFI	RMR	SRMR	RMSEA
Measurement model	163.052	109	1.496	0.924	0.978	0.034	0.045	0.047
Recommended values			≤ 3.0	≥ 0.9	≥ 0.9	≤ 0.08	≤ 0.08	≤ 0.08

GFI: goodness of fit index, CFI: comparative fit index, RMR: root mean square residual, SRMR: standardized root mean square residual, RMSEA: root mean square error of approximation.

The off-diagonal elements are correlations between latent variables, while the square roots of average variance extracted (AVE) of latent variables are shown in Table 5. For adequate discriminant validity, the square root of AVE of any latent variable should be greater than the correlation between this particular latent variable and other latent variables [53]. A value of AVE above 0.7 and an acceptable value of CR above 0.7 would be considered very good [54]. As the values of AVE and CR of autonomous collaborative activities, adoption activities, green certification programs, green activities, and environmental performance were all greater than 0.7 and 0.9, respectively, the convergent validity met the threshold. The statistics shown in Table 5, therefore, satisfied this requirement, lending evidence to discriminant and construct validity.

Table 5. Correlation matrix and average variance extracted.

Constructs	Autonomous Collaborative Activities	Adoption Activities	Green Certification Programs	Green Activities	Environmental Performance
Autonomous collaborative activities	0.920				
Adoption activities	0.096	0.930			
Green certification programs	0.604	0.035	0.899		
Green activities	0.160	0.022	0.383	0.866	
Environmental performance	0.042	0.576	0.055	0.011	0.905
CR	0.957	0.950	0.927	0.900	0.947
AVE	0.847	0.865	0.809	0.750	0.819

CR (critical ratio) = $\sum (\text{factor loading}^2) / \sum (\text{factor loading}^2) + \sum (\text{error})$; AVE = $\sum (\text{factor loading}^2) / \sum (\text{factor loading}^2 + \sum (\text{error}))$; Bold value was the square root of AVE.

4. Results and Discussion

This section presents the results of hypotheses tests, including the standardized coefficient of each path in the research model. Compared to the recommended values for the goodness of fit tests, the proposed model had the values of GFI (0.891), CFI (0.948), RMR (0.039), SRMR (0.054), and RMSEA (0.070), which had good fit, and $\chi^2/\text{d.f}$ (2.115) and p -value (0.000) were satisfactory, but the value of GFI (0.891) was slightly inferior.

The results of significance tests for paths of the research model are shown in Table 6. For the H1 and the H2, the standardized path coefficients between autonomous collaborative activities and green certification programs and green activities were 0.304 and 0.222, respectively, and significant at the 0.05 level. Thus, H1 and H2 were supported. The results of this research imply that firms provide collaborative and implementation activity to improve environmental performance in sustainable SCM for their supplier, vendors, and subcontractors to promote synergy effects such as eliminating waste, saving resources, and reducing pollution. Thus, collaborative/cooperative activities with stakeholders can be seen as a preliminary task in developing a sustainable ecosystem [1].

Table 6. Results of significance test for paths of the model.

	Path	Path Coefficient	S.E.	t-Value	p-Value	Hypothesis Test
Autonomous collaborative activities	→ Green certification programs	0.304	0.079	2.957	0.003 **	Supported H1
Autonomous collaborative activities	→ Green activities	0.222	0.076	2.122	0.034 *	Supported H2
Adoption activities	→ Green certification programs	0.241	0.071	2.380	0.017 *	Supported H3
Adoption activities	→ Green activities	0.237	0.069	2.276	0.023 *	Supported H4
Green certification programs	→ Environmental performance	0.212	0.099	2.686	0.007 **	Supported H5
Green activities	→ Environmental performance	0.950	0.125	9.136	0.000 ***	Supported H6

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

For H3 and H4, the standardized path coefficients between adoption activities and green certification programs and green activities were 0.241 and 0.237, respectively, and also statistically significant at the 0.05 level, supporting both. An organization strives to achieve business goals through effective strategies such as voluntary participation activities and adoption activities of employees with subcontractors. To control the adoption activities in SCM, organizations should develop sustainable activities with suppliers through cooperation/collaboration—for example, systematic and integrated green vendor certification programs to implement environmental goals in SCM.

For H5 and H6, the standardized path coefficients between environmental performance and green certification programs and green activities were 0.212 and 0.950, respectively, and statistically significant at the 0.01 level, supporting H5 and H6. Green certification programs and green activities for

improving environmental performance can help implementation of SC activities, which can be adapted in SCM processes with internal and external activities of supplier, vendors, and subcontractors.

Moderating Effects of Firm Size between Groups

We utilized structural equation modeling (SEM) techniques in AMOS Version 23.0 to compare groups to discover whether firm size may moderate the relationships between the constructs under study. The test for moderating effects (H7) was conducted using two groups: more than 300 and less than 300 employees. To examine the moderating effect of firm size (large vs. SMEs), we conducted covariance matrices to perform a measurement equivalence test through examination of combinations of constrained and unconstrained models for determining any differences in the constructs [55].

Table 7 shows the results of the CFAs model comparing the two groups. First, the test of loose cross validation (model 1) presented an χ^2 of 329.808 (d.f = 206), a CFI of 0.860, an RMR of 0.046, and an RMSEA of 0.047. To determine whether the measurement model is equivalent for the two groups, the second model (model 2) was estimated. The factor loadings (λ) were constrained across the two groups to evaluate this model 2. The χ^2 difference between models 1 and 2 was significant ($\Delta\chi^2 = 16.251$, d.f = 212, CFI = 0.855, RMR = 0.050, RMSEA = 0.047). This result suggests that the measurement scale is assumed to be equivalent for the two groups [55]. However, model 3, for the factor correlations (Φ) and factor loadings (λ), is non-significant from model 2 ($\Delta\chi^2 = 23.382$, d.f = 231, CFI = 0.852, RMR = 0.064, RMSEA = 0.045). This result implies that the factor correlations and the factor loadings are equally constrained [55]. In addition, model 4 estimated the error variances (θ) to be equal across the two groups. Model 4 is significantly different from model 1 ($\Delta\chi^2 = 38.026$, d.f = 218, CFI = 0.852, RMR = 0.066, RMSEA = 0.043) as shown in Table 7. The measurement items between the two groups assumed the steps outlined in Table 7 to effectively determine the path coefficients between the two groups. The measurement items for each construct of this study suggest a good acceptance value of convergent and construct validity as shown in Table 7.

Table 7. Results of CFAs Model Comparison.

Model	χ^2	d.f	p-Value	CFI	RMR	RMSEA	$\Delta\chi^2$ /d.f	Δ^2 Sig. Diff.
Unconstrained (model 1)	329.808	206	0	0.86	0.046	0.047		
λ Constrained (model 2)	346.059	212	0	0.855	0.05	0.047	16.251/6	Yes
Φ, λ Constrained (model 3)	353.19	231	0	0.852	0.064	0.045	23.382/25	No
Φ, λ, θ Constrained (model 4)	367.834	218	0	0.852	0.066	0.043	38.026/12	Yes

Table 8 shows the moderating effects of firm size groups in the proposed model. The results can be interpreted using path loadings at $p < 0.05$ meaning that SMEs and large sized firms can improve environmental performance through green activities in SCM ($\beta = 0.855$ of SMEs and $\beta = 0.991$ of large sized firms at $p < 0.01$), but not for autonomous collaborative activities and green activities for both groups ($\beta = 0.250$ of SMEs and $\beta = 0.181$ of large sized firms).

For the SMEs group, the results of moderating effects were significant at $p < 0.05$ for two paths in Table 8: adoption activities and green certification programs ($\beta = 0.299$, $p < 0.05$) and adoption activities and green activities ($\beta = 0.346$, $p < 0.05$), but not for green certification programs and environmental performance ($\beta = 0.109$). In the large sized firm group, the moderating effects were significant at $p < 0.05$ for green certification programs and environmental performance ($\beta = 0.132$, $p < 0.05$), but not for adoption activities and green certification programs ($\beta = 0.229$) and green activities ($\beta = 0.172$).

As shown in Table 8, SMEs have more flexibility in collaborative and implementation activities through autonomous and adoption activities for successful sustainable SC innovation. The results of the moderating effects of this study also show a similar result with previous studies (e.g., [5]). In addition, SMEs should be able to improve environmental performance through the adoption activities in SCM. The results of this research imply that SMEs are more efficient through their mandatory

activities with suppliers to improve environmental performance while large sized companies consider autonomous activities with suppliers.

Table 8. Results of path coefficients between groups.

Path			SMEs		Large	
			Path Coefficient	p-Value	Path Coefficient	p-Value
Autonomous collaborative activities	→	Green certification programs	0.342	0.026 *	0.321	0.017 *
Autonomous collaborative activities	→	Green activities	0.250	0.121	0.181	0.175
Adoption activities	→	Green certification programs	0.299	0.048 *	0.229	0.082
Adoption activities	→	Green activities	0.346	0.036 *	0.172	0.192
Green certification programs	→	Environmental performance	0.109	0.205	0.132	0.019 *
Green activities	→	Environmental performance	0.855	0.000 **	0.991	0.000 **

* $p < 0.05$, ** $p < 0.001$.

5. Conclusions

The results of this study offer related SC firms new insights on ways to improve SCM processes by tackling environmental issues to maintain competitive advantage. The hypotheses test showed positive effects of the autonomous collaborative activities on green certification programs (H1) and green activities (H2), and of adoption activities on green certification programs (H3) and green activities (H4). The study also found positive relationships between environmental performance and green certification programs (H5) and green activities (H6). The moderating effects for autonomous collaborative activities and green certification programs (H1) and green activities and environmental performance (H6) were significant at $p < 0.05$ for SMEs and large-sized firms; however, autonomous collaborative activities and green activities (H2) were not significant at $p < 0.05$ for both groups.

The above results suggest potential SSCM areas that need improvement in an operational SC process. As the results of this study indicate, green activities affect environmental performance in both groups. In addition, the study showed that green activities of implementation play a key role in increasing operational efficiency, thus enhancing organizational performance through suppliers. Furthermore, this study showed a positive relationship between autonomous collaborative activities and green certification programs in both groups. However, these results also suggest that firm size may be a decisive factor in altering implementation activities while performing eco-friendly activities in sustainable SCM. We view in this study the implementation activity in the SC industry as an enabler that can be positively applied in the future when supported by the ongoing collaborative/cooperative activities strategy for a sustainable ecosystem.

This research has made contributions in the following ways: First, for sustainable SC innovation, environmental performance can be achieved through collaborative and implementation activities. Thus, for sustainable business, firms can increase their operational efficiency by performing activities simultaneously that are somewhat enforceable as well as autonomous. Second, although adopting activities with forcedness did have a positive effect on green certification programs and collaborative activities in SMEs, in large sized companies, it did not have significant effects. The reasons appear to be that most large sized companies strongly pursue environmentally friendly certification and activities to subcontractors because SC activities are conducted through sub-suppliers, but they may not actually implement green certification and activities. For example, Walmart requires a certain level of emission reduction from its suppliers. Third, there was not significance between autonomous collaborative activities and green activities among companies of similar size, which means that mutual autonomous activities among groups of different sizes are more important. Lastly, the results of the whole group analysis and large sized firms showed that the green certification programs affect environmental performance, but did not make a difference in SMEs. This result demonstrates that a small firm faces difficulties in certain business situations (capital, cost, system, etc.) compared to large sized companies due to the lack of manpower to acquire certification. Therefore, to create a sustainable environment,

large sized companies conduct strategic investment activities (e.g., training and know-how to acquire green certification, information technology usage, benchmarking materials) for SMEs. This can lead to a cost burden for large sized companies in the short term but provide a positive synergy for all companies within the SC in the long-term and create mutual trust among firms [13].

Thus, to ensure sustainable SC innovation, firms should continuously develop collaborative and implementation activities considering the suppliers' perspectives to promote voluntary participation in SCM activities, including free participation and suggesting possible activities. To establish effective collaborative and implementation activities with suppliers, firms should build trust-based relationships with their suppliers for improving agility and flexibility in the increased uncertainty and risk in SCM. In addition, related SC firms can invest in green certification programs, which lead employees and suppliers to participate in pollution reduction activities as well as products and process related green practices and implement activities that are favorably perceived by their customers.

Collaborative activities should be developed in SCM for autonomous participation suppliers, vendors, and subcontractors to induce a positive influence on green certification programs and/or green activities for improving environmental performance. These suggestions based on the study imply that well-developed collaborative and implementation activities play a key role in a sustainable ecosystem, which in turn affects environmental performance as well as organizational performance. Thus, sustainable SC innovation requires collaborative and implementation activities with related SC firms.

The results of the study have significant theoretical and practical implications for operational efficiency and effectiveness in SCM. There are different results from previous studies and the current research regarding the moderating effect of firm size on the relationship between autonomous collaborative activities and green activities. Our study found no moderating effect of firm size, which indirectly suggests that some compulsory regulations may be needed for green management rather than just autonomous activities. Therefore, companies should strive to achieve common goals by implementing visible and purpose-oriented programs (e.g., a range of green activities, number of activities per year, etc.) in their operations. We believe this result applies not only to the industries we studied but to general industries as well. The sustainability of firms depends on operational efficiency and effective response to dynamic environment trends through collaboration/cooperation with vendors and stakeholders in facing environmental obstacles [1,7]. For adapting dynamic environmental issues regarding uncertainty and risk so as to enhance operational efficiency, collaborative activities in sustainable SC innovation need to be considered. In addition, firms might apply different policies and strategies depending on vendor competencies to ensure resilience, visibility, and agility because the SC is a complex system that must deal with uncertainty and risk [1,5,13]. Consequently, the results of this study will offer valuable insights to SCM-related companies and potential firms that want to develop eco-friendly SC processes with suppliers/vendors for enhancing organizational competitiveness in the global market.

In spite of the contributions offered by this study, they suffer from some limitations. First, while South Korea is well-known as a manufacturing economy in the world, the data were collected from cross-industry Korean firms. As the firms that participated in this study have similar or SC processes with subcontractors, further analysis based on the type of industry may yield additional insights. Second, this study used measurement items of green certification programs. However, we measured them as perceived by respondents within SC activities. If we had selected certified companies with green programs (e.g., ISO 14001), the results would have provided valuable new information about successful activities for environmental performance. Third, future study might be needed to examine the moderating effects of firm size in greater depth and scale using autonomous collaborative activities and green activities. For developing effective strategies to achieve common sustainability goals, it is important to compare and analyze the effects of autonomous and compulsory activities among the related firms.

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