Journal of Global Information Management
Volume 32 • Issue 1

Developing Measurement of Collaboration Between the Supplier and Client Firms:

A Study on Networked Firms in the Natural Forest Products Industry

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ABSTRACT

This study recommends a suitable model for evaluating supply chain collaboration in the natural forest products industry. We follow a two-step analysis: The first-order measurement model is leveraged to assess collaboration level, and the second-order confirmatory factor analysis develops the collaboration level by using four indicators representing customer and supplier firms as well as two specific indicators for each of them. Four items are common practices for both sides: joint sales forecasting, exchange of basic information, joint planning, and joint delivery improvement. Two practices are highly oriented toward customers: resource sharing of logistics assets and exchange of performance evaluation. Business-to-business practices engaged mostly with suppliers include the implementation of replenishment systems and joint new product development. Collaboration measurement between suppliers and client firms contributes to effectively manage the relationship between the supplier and client firms and can improve the competitiveness of participating firms in the network.

KEYWORDS

Collaboration Level, Forest Products Industry, Structural Equation Model, Supply Chain

1. INTRODUCTION

Studies on supply chain management and inter-firm collaboration are emerging as a preferred research field across Operation management, Corporate sustainability, and Strategic management, among others. In the case of the supply chain, there is an opportunity to develop new models integrating new technologies such as Information technology (IT) to support collaborative practices in the natural resource industry supply chain that usually is slow to adopt advanced technology (Choudhry & O'Kelly, 2018; Al-Azad et al., 2022) and different from other industrial sectors (Lezoche, Hernandez, Díaz, Panetto, & Kacprzyk, 2020). Similarly, there is an opportunity to improve supply chain management in natural resource sectors by streamlining production value chains and inter-firm collaborations

DOI: 10.4018/JGIM.342838
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among the participant firms. The supply chain management of the forest products industry differs from other manufacturing industries and has several specific characteristics necessary to fulfill the needs of its end consumers for better efficiency and higher productivity. For example. There are several different types of activities involved in the forest industry, such as harvest planning, harvest organization and control, operations, transport, and logistics as well as timber sales (Müller et al., 2019) along with different types of organizations such as forest enterprises, timber enterprises as well as independent contractors with competing, complementing and independent activities (Müller et al, 2019). Despite the increased interest in this research area, the measurement of supply chain collaboration (SCC) in the forest industry remains scattered in multiple disciplines (Injazz and Paulraj, 2004; Rota et al., 2016; Sanders and Premus, 2005), and few studies have been undertaken using data from the natural forest industry. Most of the supply chain measurement models have been developed for the manufacturing supply chains. Due to the differences between the manufacturing supply chain and natural forest industry supply chains, a measurement model of the supply chain collaboration level specifically for the natural forest industry is needed to address effectively the collaboration level and types of collaboration. Moreover, the natural forest industry plays an important role in the socio-economic development of many countries, including Canada. This study fills this gap by developing a supply chain collaboration index in the natural forest industry. In an era of global value chain and dispersion of activities, competition is no longer among firms or products but rather depends largely on the capability to coordinate dispersed activities along the supply chain. Thus, collaboration among the various stakeholders in the forest supply chain becomes indispensable for the overall competitiveness of the value chain (Aschemann-Witzel et al., 2017; Mohiuddin and Su, 2014; Ramanathan, and Gunasekaran, 2014; Soundararajan, and Brown, 2016) and sustainability of participating firms (Schaltegger and Burritt, 2014). Supply chain collaboration among the value chain stakeholders can reduce transaction costs and risks and give access to resources and competencies from the collaborating firms, thereby creating a sustainable competitive advantage. Collaboration allows participating firms to combine their resources, knowledge, and capabilities to speed up their new product and process development, increase market share, and focus on core competencies to improve their specialization further. Collaboration contributes to inter-organizational dynamics by strengthening knowledge absorption capacity, structuring solutions, and motivating activity around a commonly defined goal (Van Hoof, and Thiell, 2014). However, SCC in the forest value chain is relatively low compared with the manufacturing industry. The forest supply chain is very often considered discrete and disconnected entities performing businesses based on short-term transactions with distorted information from tier-one suppliers or clients (Feng & Audy, 2020). Such circumstances necessitate in-depth study of SCC in the forest industry and its constituents to capitalize on the benefits that SCC brings to participating firms. However, few firms have truly captured the benefits emanating from the SCC despite its great potential (Min et al., 2005), and more research is needed to explore this vital issue (Goffin et al., 2006). Although many studies have been undertaken on SCC (Allred et al., 2011; Cao et al., 2011; Fawcett et al., 2011; Lambert et al., 2004; Morali and Searcy, 2013; Nyaga et al., 2010) in the manufacturing or service industry, more in-depth study is needed to understand the characteristics and natures of SCC in the natural forest products industry. Despite the existence of several well-known studies, few have addressed the exact ***nature and attributes*** of SCC (Cao and Zhang, 2011) in the forest industry. This study seeks to fill this gap by providing a reliable and valid measurement model of ***collaboration intensity*** and its ***determinants*** for the natural resource industries like the forest product industry. In fact, research on SCC is scattered among multiple research paradigms. Research in marketing and management focuses on such factors as commitment (Handfield and Bechtel, 2002); studies in operation research concentrate on such factors as information sharing and inventory systems (Srinivasan and Swink, 2015; Garcia, Grabot, & Paché, 2023); and information systems research focuses on information technology (IT) capabilities (Chi, Huang, & George, 2020). Fragmentation of research in multiple research streams has inhibited a thorough understanding of phenomena (Barringer and Harrison, 2000) and has limited our ability to explain and evaluate the ***level of collaborative*** efforts (Saeed et al., 2005) in the natural forest products industry.

This study aims to analyze B2B processes and collaboration factors for multiple levels of the forest products supply chain, which contains sawmills (timber, the first transformation in the forest industry), paper and carton manufacturers, furniture producers, fabricators, and other value-added and building-material makers. Thus, this study is not just limited to the relationship between retailer and supplier, as illustrated in Simatupang and Sridharan (2005). Furthermore, as Champ Vereecke and Muylle (2006) suggested, this study involves a methodical analysis for both ends—supplier and client. Therefore, the collaboration ideas discussed in this study are not, in essence, a hypothesis describing the complexity of business relationships; instead, ***the ideas help to develop better organizational ties***. To achieve this objective, organizations must move toward improved collaborative integration with their supply chain partners in possible areas for mutual benefit. Using the same guidelines, the collaboration design prototype can be extended to the overall industrial sector to baseline B2B processes in the forest products industry.

The prime objective of this study is to present a measurement of collaboration level and its underlying factors among forest industry products' supply chains. Historically, researchers have rarely attempted to evaluate the collaboration level from the perspective of the customer or supplier (Hojat et al., 1999). The first objective of this study is to explore the possibilities of collaboration in the natural forest industry and any other possible gaps. In addition, this study suggests contributing to the ***factors*** underlying ***better*** collaboration and its possible variations/ mediating factors within the industry, depending on its size, volume, staff, and other legitimate factors. The third objective is to assess the contribution of the IT stream while integrating suggested collaborative practices. In the past few decades, a lot of research has been undertaken related to IT implementation, benefits, observations, obstacles, and projects in the North American forest industry (Dupuy and Vlosky, 2000; Jabeur et al., 2013; Vlosky, 2001). However, not much research has been undertaken to analyze the full impact of IT on collaborative processes. This study draws three key research questions from the literature review.

- Can a collaboration level and all the underlying factors be assessed in the forest supply chain?
- Does this collaboration level really vary across the supply chain categories?
- Do IT, age of company, size, internationalization, and position on the value chain contribute to enhancing the collaboration level?

This study is an innovative investigation in several respects. First, to the best of our knowledge, this is among the few SCC studies in the forest products industry that integrates firms across the value chain of first-degree and second-degree suppliers and clients. Second, this study considers SCC as an organizational construct that allows an organization to develop collaborative relationships with other partners in the supply chain. This helps firms in the supply chain to embody multiple identities as suppliers or clients, depending on the companies used for comparison. Whereas previous research has focused on collaborative advantage (Cao and Zhang, 2011) or competitive advantage and operational performance (Balfaqih et al., 2016; Lavie, 2006), the current study presents the extent or level of collaboration in the forest products industry.

The remainder of the paper is organized as follows: Section 2 provides a literature review of SCC practices and their measurement methodology. Section 3 identifies the research questions addressed in this study. Section 4 describes the questionnaire and data collection process. Section 5 presents the data analysis procedures and Section 6 demonstrates the overall result covering 12 reliable and valid collaboration level indicators. Conclusions and implications for researchers and practitioners are summarized in the final section.

2. LITERATURE REVIEW

Research on SCC has been undertaken from multiple angles and perspectives. Supply chain integration, collaborative advantage, and impact on operational performance are some of the topics addressed in this research stream. Simatupang and Sridharan (2002) describe SCC as two or more value chain members working *collaboratively in order to create a competitive advantage by sharing information, making decisions together, and sharing benefits that result from higher profitability of satisfying end users' needs than acting alone.* The basic premise of SCC is the coordination among the partnering organizations, such as virtual enterprises, global manufacturing companies, and logistics firms (Akyuz and Erkan, 2010). This literature review first introduces an overview of various classification schemes of SCC. Next, the literature on evaluating SCC levels is considered, leading to a review of SCC determinants in the natural forest products industry.

2.1 Supply Chain Collaboration: From Zero-Sum to Win-Win Strategy

Historically, supply chain organizations depend on each other for products and services, and their interactions are recorded as transactions. In this process, organizations compete with the objective of improving their services and dominating the market segment. The company positions itself as either a buyer of goods and services or a seller of value-added goods. In this type of collaborative growth, the profit earned by one company is perceived as an improvement opportunity by the competing company. Because of the wider acceptance of modern supply chain practices (e.g., Vendor Managed Inventory (VMI), Collaborative Planning Forecasting and Replenishment (CPFR), and early supplier involvement, there has been extensive research on the topic, and many authors have explained the development model for business-to-business (B2B) relationships as expanding from being transactional to collaborative (Kumar, Chau, Negash, & Tang, 2022). The relationship model is formulated using a three-level scale starting from shorter-term transactional exchange patterns and leading to longer-term relationships that involve many dimensions of collaborative practice, like collaborative product design, development, and joint investment, access to expertise, and improving market share (Lapide, 2002; Mohiuddin and Su, 2013a). Short-term collaboration refers to the collaboration among supply chain partners aimed at satisfying the needs of both usual and unusual demand for products and services. Mid-term collaboration refers to sharing responsibilities to synchronize product design and logistics capability to cope with growing demand for broader market offerings. Long-term collaboration refers to creating superior service capabilities by setting joint priorities and sharing capabilities (Simatupang and Sridharan, 2002). Guerrero & Hansen (2018) defined a collaborative supply chain as cooperation among independent but related firms in sharing resources and capabilities to meet their customers' most extraordinary needs. However, in the forest product industry, companies often operate independently based on the data from the immediate customers, which are also dependent on information provided by their downstream customers, or they depend on historical data (Feng and Audy, 2020). This type of dependency creates "Bullwhip effect" and entities in the supply chain take their decisions based on distorted information.

During the development of the B2B relationship model, the key assumption is that B2B relationships originate because of the transactional arrangement between organizations and can contribute to establishing collaboration at all levels. This kind of mutual-benefit model could help to classify various schemes for B2B relationships and provide qualitative insights into the scales of SCC levels. Similarly, Fu et al. (2023), Li, Yang, & Chen (2023) and Poulin et al. (1994) proposed a wide-ranging classification of inter-organizational relationships, starting from the traditional supplier-client relationship to the joint-venture set-up kinds of partnership. The authors identified three generic relationship classes: supply, outsourcing, and co-production.

Many collaboration schemes have been proposed in the literature. However, these classification schemes, rather than identifying classes of practices, mainly have concentrated on the way in which companies have introduced collaboration within their own set-up. For instance,

Table 1. Patterns of collaboration (adapted from Frayret (2002))

Type	Principle	Examples of practice
Outsourced local decision-making	Increase the level of responsibility of suppliers	Vendor-managed inventory, supplier quality program, early supplier involvement (component design)
Improved local decision-making	Enhance and align local decision-making	Information sharing, shared POS data, joint capacity management, joint inventory management
Decision objective alignment	Joint objective planning and objective alignment	Collaborative forecasting, collaborative promotion planning, early supplier involvement, category management
Pooled resource and capacity sharing	Resource pooling and sharing, and joint investment	Shared pallets, joint trailer, 3PL (mediated resource sharing), joint facility and R&D investment, shared prototyping facility
Process and IS integration	Business process and information system integration	JIT supplier (ex.: Toyota), CPFR standards adoption, B2B marketplace, E-business standards compliant
Supply chain process reengineering	Internal business process redesign and alignment	Joint cycle time reduction, supply chain event management, suppliers training and evaluation, process postponement, performance metrics

Simatupang and Sridharan (2002) identified six distinct means of collaboration—formulating smarter joint objectives to address better demand variability, decision rules as an input to refine the response coordination to market signals, adequate performance measurement to equalize partners' efforts, setting up precise decision domains to improve the supply chain decision-making process, information exchange for improved decision making, and leveraging a suitable incentive system to elevate the supply chain decision model. Likewise, Frayret (2002) identified six types of generic collaboration patterns (see Table 1).

These collaboration patterns include outsourcing decision rights, managing supply chain decisions, and defining common goals. This indirectly helps facilitate the supply chain decision-making process, resource sharing, use of a transaction-based integration set-up and related technologies, and a joint effort from participating companies reconstructing supply chain processing.

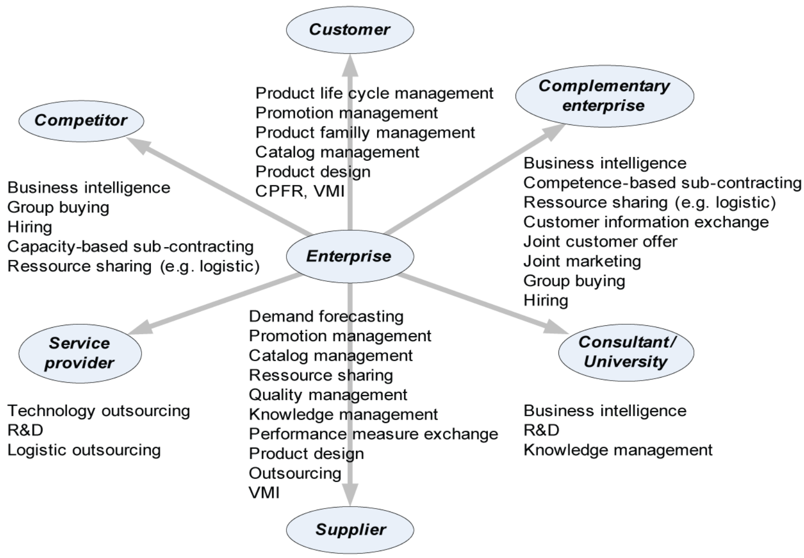
Many collaboration opportunities exist in the forest supply chain that few researchers are able to categorize. For example, Lapide (2002) identified three collaboration opportunity areas: manufacturers with suppliers, manufacturers with distribution channel members, and manufacturers with logistics service providers. Frayret et al. (2003) offered an activity-based fusion for a wider range of opportunities by evaluating collaborative practices consisting of such processes as research and development (R&D), procurement, production, marketing, distribution, and sales. Alternatively, these opportunities can be grouped as per the partner (Figure 1).

2.2 Measures of Supply Chain Collaboration Level

Researchers have adopted different approaches to determining collaboration levels among supply chain partners. The primary approach is based on the evolution models of B2B interactions. This approach provides an authentic qualitative assessment of the relationship's collaboration level using the closest associated class of the collaboration level.

Many other researchers have analyzed the impact of a specific B2B collaborative practice on the supply chain engagement model (Akyuz, and Erkan, 2010; Manders, Caniëls, and Ghijsen, 2017; Ramanathan and Gunasekaran, 2014). These researchers have proposed empirical methods for assessing the extent of collaboration or levels. The researchers leverage a five-point scale framework to gauge the adoption level of a set of specific collaboration practices. For example, Chang et al. (2022) and Stank et al. (2001) devised an evaluation process considering internal and external collaborative practices. Similarly, Gunasekaran et al. (2001) and Vereecke and Muylle (2006) used a process that

Figure 1. Collaboration Opportunities (adapted from Frayret et al. 2003)



considered key relationships between key suppliers and customers. In their seminal work on supply chain performance measurement, Akyuz and Erkan (2010), Beamon (1999), and Maestrini et al. (2017) proposed developing partnership, collaboration, agility, flexibility, information productivity, and business excellence metrics for inclusion in future research on a supply chain framework and adoption of a performance measurement system (PMS). Ramanathan et al. (2011) proposed a framework to study the performance of companies in the supply chain in the initial and advanced stages of collaboration.

In addition, Simatupang and Sridharan (2005) proposed a similar detail-oriented approach to calculate a quantitative collaboration index using a three-dimensional framework. This procedure utilized the following inputs for quantitative analysis: information sharing, decision synchronization, and incentive alignment. These parameters contained many items that were explicitly developed for retailer–supplier collaborative practices. The assessment of the adoption level for each practice (leveraging five-point scales) contributed to the measurement of the volume of information distribution, decision harmonization, incentive orientation procedures, and, most importantly, the collaboration index. Finally, Cao et al. (2010) conceptualized SCC as seven interconnecting components: information sharing, goal congruence, decision synchronization, incentive alignment, resource sharing, collaborative communication, and joint knowledge creation. The authors found a strong and positive relationship between a firm's level of SCC and its performance. Non-financial performance measures are more likely to be part of the collaborative PMS, as it is difficult to establish agreement on and design financial measures (Papakiriakopoulos and Pramatari, 2010), which are short-term in nature (Mohiuddin and Su, 2013b).

2.3 Supply Chain Collaboration in the Natural Forest Industry: A Multi-Dimensional Construct?

Much research has been undertaken in the literature to date to identify, record, and study the collaboration components. For example, a robust research stream dependent on actor characteristics and collaboration types is represented by, among others, Hussain & Malik (2020), Scott (1991), and Duong and Chong (2020). These authors commonly assumed that the operationalized feature includes a specific background, relevant constituents, emotional and logical bias, and learning pattern. Larger firms are able to collaborate more effectively than smaller firms are, particularly in the R&D domain. Kleinknecht and Van Reijnen (1992) have explored the impacts of type of partners and agreements.

Heide and John (1992) analyzed a different scenario in which strong buyers in a setting of smaller suppliers face the risk of opportunistic behavior that can impact the anticipated collaboration. The authors also found that norms are significant in managing hindrances. In yet another scenario, Berthon et al. (2003) investigated the interactions of strong suppliers with numerous small buyers. In contrast to Heide and John's findings, Berthon et al. (2003) observed that interpersonal norms have no profound effect because governance mechanisms are shielded against the possibility of opportunistic behavior in the case of transaction-specific assets. However, the power dependence theory was confirmed with buyer size directly impacting buyer behavior.

Achrol (1997) categorized network collaborators by such factors as density, multiplicity, reciprocity of ties, and shared values. Farrell and Klemperer (2004) researched network density, stressing "*instrumental intimacy*," in which organizations complement each other through the joint influence of new product design and application of the necessary business strategies. Trust and commitment have been identified as the most important collaboration attributes. When a supplier gets involved in new product development, the interactions can be rated at multiple levels. For example, maximum collaboration occurs when resources are shared between both organizations, working together on the design, development, and product testing and innovating with new ideas (Handfield and Nichols, 1999; Wasti and Risky, 1997). Brody et al. (2006) studied collaborative ecosystem management and found significant benefits for the collaborating parties, as the reciprocal relationships and trust developed through collaboration and decreased regulations resulting from stakeholders working together on common resources.

Ritter et al. (2002) analyzed four main factors that significantly impact a company's network capabilities: resource availability, the network-specific aspect of managing human resources, streamlining internal communications within an organization, and corporate culture candidness. Similarly, Morten and Nohria (2004) identified four potential barriers to effective collaboration between units: rigid mindset, incapability to search and discover expertise, lack of helpfulness, and poor teamwork.

2.4 Role of IT in Collaboration

Through its various functions and infrastructure types, IT helps recognize and bridge the gaps between multiple information systems, making a firm more ready to collaborate at diverse levels of information systems (Al-Omoush, de Lucas, & del Val, 2023; Liu, Chiu, Chu, & Zheng, 2022; Kamdjoug et al., 2023). IT can help firms in the forest supply chain establish true connectivity, coordination, and transparent relationships and have full visibility into the needs and the status of others (Schrauf & Berttram, 2016). Clark et al. (2001) recommended a seven-step design starting from independence and extending to virtual integration along with analyzing common technology-specific interactions between organizations. The seven-step design for interconnecting organizations—physical data portability, technology-enabled document exchange, sending and receiving electronic data, maintaining all new captured information and data distribution, better policies and combined operations, joint performance optimization practices for improving relationships, and virtual channel incorporation. IT competency can enhance strategic collaboration among the supply chain partners by improving effective communication among the top management for formulating strategic plans, allows the firm to process and assess information for more effective joint planning and decision making, and facilitates better and faster coordination between firms in the supply chain to project future demand (Kim, and Lee, 2010; Lewis and Talalayevsky, 1997;). Therefore, IT competency is vital for enhancing system collaboration and strategic collaboration (Chi, Huang, & George, 2020). In the seven-step design, IT is expected to improve collaboration arrangements but only in specific scenarios. However, Lee et al. (2003) and Yang et al. (2023) found that many supply chain members, both suppliers, and buyers, are not interested in cooperating or sharing data with each other, fearing that their negotiating position will be weakened *despite implementing B2B networks.* The authors explained that the best returns are possible only in the case of proactive information sharing. Because many organizations have a shared IT, infrastructure, and business operations model, there is an implicit expectation that they operate more cohesively and have an improved trust model. In this journey, the business processes might have to be modified or re-formulated for better realignment, cost benefits, and performance optimization purposes (Aysolmaz, Joshi, & Stubhan, 2023). The improved IT processes should help improve the collaboration level. Given that the supply chains in the natural resource industry do not function the way they work in the more established industries, such as manufacturing, there is room for exploring the SCC level and determining factors in the natural resources industry.

3. RESEARCH DESIGN AND METHODOLOGY

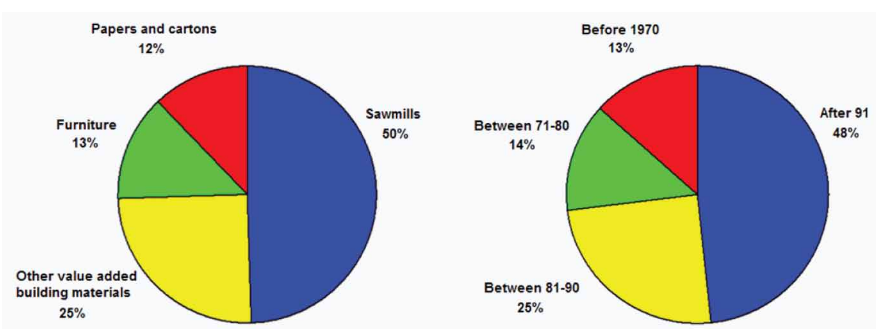
3.1 Questionnaire Development and Data Collection

To meet our objectives, this study completed a survey of forest product companies in Canada. Our questionnaire was created using the research questions, objectives, and existing literature related to assessing the collaboration level and related factors, as outlined in the previous sections. The questionnaire was confirmed by a range of experienced forest industry professionals in Canada. Company professionals, mainly managers, were asked to independently evaluate their collaboration practices from both customer and supplier perspectives. The literature review has helped us to develop the final instrument in the Appendix. This final instrument was shared with 695 forest products companies in Canada. In this process, this study received valuable responses from the top executives of 312 companies. As per our quantitative analysis, the 44.9% response rate was much higher than the commonly accepted standard of 15–35% for such surveys. To further strengthen the reliability of the 312 received valid responses, this study collected supplementary data from public and professional databases, including the Canadian Ministry of Industry, *Institut de la Statistique Québec,* and *I-CRIQ* database.

3.2 Profile of Respondents

The forest products supply chain includes sawmills, pulp and paper mills, furniture manufacturers, and other value-added building materials, which include door and window manufacturers. Distributions of respondents by industry are as follows: 12% from paper and cartons, 13% from furniture, 50% from sawmills, and 25% from other value-added building materials. In terms of firm age, 13% of firms were founded before 1970, 14% between 1971 and 1980, 24% from 1981 to 1990, and 48% after 1991. Details on the respondents can be found from Figure 2.

Figure 2. Profile of Respondents (sector and year of establishment)



3.3 Non-Response Bias Test

The non-response bias test methods use a very interesting way to compare the distribution of respondents' and non-respondents characteristics depending on whether they are known to each other. Similarly, other independent surveys can provide valuable insight and an alternative comparison base for selected characteristics. In this study, for statistical test purposes, the data from the *I-CRIQ* database were used to compare respondents (n = 145) and non-respondents (n = 139) in the sawmill category, which is the largest group in our survey. A two-sample t-test was conducted for valid homogeneous samples and showed no statistically significant response bias between the respondents and non-respondents with a specified number of employees and year of establishment as input parameters.

4. DATA ANALYSIS

4.1 Indexes of Collaboration

This study assesses each respondent's collaboration level using the questionnaire in the Appendix. The B2B practices pursued by both suppliers and customers were used as input to evaluate collaboration levels. As an alternative to using a five-point scale, respondents were asked to precisely confirm "yes" or "no" for what type of collaboration they had initiated and maintained with their suppliers and customers. The computed scores of "yes" responses demonstrated an evolutionary collaborative path with customers and suppliers. This approach to gathering quick responses requiring only short answers is similar to that proposed by Link and Bauer (1987), who used a dummy variable with the value 1 if the firm cooperates and 0 otherwise. For better qualitative analysis and to strengthen the sturdiness of the construct further, each "yes" response was assigned a value on a scale ranging from 0 to 4, referring to the executive position. The scale itself is created collating each of the responses from the B2B practices assuming that higher collaboration leads to fewer "yes" responses owing to the pragmatic mindset of the senior executives. In other words, this simplified approach assumes that collaborative processes are the most advanced B2B practices. Thus, in a traditional industry like forest products, there is minimum probability for these processes to have been adopted by the majority, except for advanced companies.

4.2 Measurement Model

To answer the first research question accurately, this study formulated an intuitive two-stage measurement model--exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). EFA explores the possible underlying factor structure of a set of observed variables without imposing a preconceived structure on the outcome (Child, 1990). By performing EFA, the underlying factor structure is identified. CFA is a statistical technique used to verify the factor structure of a set of observed variables. CFA allows the researcher to test the hypothesis whether a relationship between observed variables and their underlying latent constructs exists.

The test hypothesis results helped answer the second and third research questions. As *a priori* theoretical model was unavailable, this study followed Schumacker and Lomax's (2004) recommendation and executed an analysis model using EFA and CFA.

4.3 Confirmatory Factor Analysis

CFA tests whether a relationship exists between the observed variables and their underlying latent construct(s). As per Byrne's (1994) recommendations, CFA was selected. To reduce the probability of any measurement favoritism while evaluating the data fit for the model, Browne and Cudeck (1993) and Hu and Bentler (1999) recommended many fit statistics in the structural equation model (SEM). This study utilized the most common indexes in the literature to measure the accuracy of our model for the 312 survey companies. i) The ratio of chi-square to the degree of freedom (χ^2/df) has an acceptable range between 2 and 3 (Carmines and McIver, 1981). A few conservative schools have considered a chi-square/df ratio of less than 2.00 to have an insignificant P-value (e.g. P>0.05) (Byrne, 1994). Chau (1997), Hair et al., (1995), and Hartwick and Barki (1994) recommended an upper limit of 3.0. ii) The root-mean-square residual compares the predicted variances and covariances in the model with the data-driven results to spot discrepancies between the two, assuming zero represents a perfect fit. iii) The root mean square error of approximation (RMSEA) should have a value less than 0.06. Schumacker and Lomax (2004) recommended 0.05 or less for the RMSEA to provide a good data fit. iv) The standardized root mean square residual (SRMR) should have a value close to 0.08 or better (Hu and Bentler, 1999). v) The comparative fit index (CFI) should have a value close to 0.95 or better (Hu and Bentler, 1999). vi) The goodness-of-fit index (GFI) should range from zero (no fit) to one (perfect fit).

4.4 Exploratory Factor Analysis

This study applied the following listed constraints to our EFA: the Kaiser–Meyer–Olkin measure of sampling adequacy should be greater than 0.80, communalities extraction should be greater than 0.50, variance explained should be greater than 0.50, factor loading should be greater than 0.50, double loading should be greater than 0.50, and there should be single loading for parsimony. Varimax rotation with Kaiser normalization is applied with eigenvalues greater than 1. This study calculated a correlation matrix to identify possible multicollinearity. The internal reliability of our constructs was measured using a Cronbach's alpha coefficient greater than 0.70.

5. RESULTS AND DISCUSSIONS

5.1 Exploratory Factor Analysis

As illustrated in Table 2, EFA was performed using SPSS 11.00, which resulted in three distinct factors. Customer and supplier items were loaded disjointedly, except for the joint investments on both sides, which were loaded in different dimensions. A reliability analysis was directed for all three factors. As shown in Table 3, removed items included the exchange of performance evaluation for low extraction. Furthermore, new product development in partnership, sharing resources, and implementing replenishment systems were curbed for loading on the two distinct factors. Removed items are generally considered the most advanced forms of collaborative practices, reflecting a rather poor level of collaboration in the forest products industry. Table 2 lists the Cronbach's alfa coefficient to validate our instrument's strength further. As summarized in Table 4, no multicollinearity was detected in the correlation matrix because all coefficients are less than 0.85 with a minimum of 0.10. The outcome is a coefficient of 0.81 for the supplier side and 0.80 for the buyer/client-side items. These rates are generally greater than the commonly accepted level of 60% for exploratory studies (Flynn et al., 1990). Therefore, joint investments on the supplier and client sides were dropped owing to poor reliability (0.54). Table 2 presents the exploratory factor analysis.

Table 3 presents the deleted items.

Table 4 presents the Multicollinearity Analysis results.

Prior to performing a CFA leveraging the retained items; a univariate distribution normality test was performed. In a CFA with maximum probability as an estimation method, the acceptable skewness and kurtosis levels for a normal distribution are set bigger than 2 and 7 (West et al., 1995). Skewness and kurtosis coefficients for the items in this study met the recommended limits.

5.2 Confirmatory Factor Analysis

Although a univariate distribution method meets the estimation criteria by the maximum likelihood approach, this study used diagonally weighted least squares (DWLS), as recommended by Flora and

Table 2. Exploratory Factor Analysis

Kaiser-Meyer-Olkin Sampling Adequacy	0,86	1.1.1	1.1.2
Rotated Component Matrix.	**Factor 1**	**Factor 2**	**Factor 3**
z37e Joint planning	**0.74**	0.14	0.16
z37g Joint delivery improvement	**0.73**	0.16	0.11
z37b Exchange of basic information	**0.72**	0.23	-0.12
z37f Exchange performance evaluation	**0.67**	0.06	0.30
z37c Resources sharing of logistic assets	**0.66**	0.12	0.20
z37a Joint sales forecasting	**0.63**	0.24	-0.07
z35b Exchange of basic information	0.09	**0.78**	-0.03
z35a Joint sales forecasting	0.14	**0.71**	-0.06
z35e Joint planning	0.14	**0.70**	0.15
z35h Joint new products development	0.07	**0.68**	0.11
z35g Joint delivery improvement	0.26	**0.62**	0.06
z35d Replenishment systems	0.31	**0.58**	0.17
z35i Joint investment	0.05	0.20	**0.79**
z37i Joint investment	0.20	0.00	**0.77**
Alfa Cronbach's Coefficient calculated on items in bold	0.81	0.80	0.54

Table 3. Deleted items

Deleted items	Level of deletion	Reason
z35f Exchange performance evaluation	1st iteration	extraction<0.5
z37h Joint new products development	2nd iteration	double load.>0.5
z35c Resources sharing of logistic assets	2nd iteration	double load.>0.5
z37d Replenishment systems	2nd iteration	double load.>0.5
z37j Vendor Managed Inventory	3rd iteration	extraction<0.5
z35i Joint investment	reliability analysis	Cr. alfa <0.7
z37i Joint investment	reliability analysis	Cr. alfa <0.7

Curran (2004) and Jöreskog and Sörbom (1996). In this scenario, a stable parameter estimator is required for the smaller samples.

This study began with first-order confirmatory models for each of the supplier side and the customer side. Using LISREL 8.71, the two models were then aggregated as a combination measurement model with covariance between both sides. The combined measurement model is depicted in Figure 3.

Subsequently, second-order CFA was executed to assess the relative contribution of each side as per the collaboration level. The results of second-order CFA are shown in Figure 4.

After thoroughly checking for residuals and modification indexes using a step-by-step modification procedure, beginning with residual matrixes and followed by modification indexes, all the final models were retained before deleting any non-significant parameter. The final model fit indexes (displayed

Table 4. Multicollinearity Analysis

Inter-items Correlation Matrix	z35 a	z35 b	z35 d	z35 e	z35 g	z35 h	z35 i	z37 a	z37 b	Z37 c	z37 e	z37 g	z37 i	z37 f
Collaboration with customers														
z35a Joint sales forecasting	1.00													
z35b Exchange of basic information	0.51	1.00												
z35d Replenishment systems	0.37	0.41	1.00											
z35e Joint planning	0.41	0.43	0.42	1.00										
z35g Joint delivery improvement	0.35	0.40	0.34	0.43	1.00									
z35h Joint new products development	0.33	0.43	0.37	0.37	0.40	1.00								
z35i Joint investment	0.11	0.14	0.19	0.22	0.18	0.18	1.00							
Collaboration with suppliers														
z37a Joint sales forecasting	0.32	0.18	0.30	0.25	0.22	0.19	0.12	1.00						
z37b Exchange of basic information	0.26	0.30	0.21	0.25	0.23	0.23	0.10	0.52	1.00					
z37c Resources sharing of logistic assets	0.16	0.20	0.36	0.22	0.25	0.10	0.18	0.30	0.41	1.00				
z37e Joint planning	0.16	0.16	0.31	0.24	0.33	0.21	0.19	0.41	0.46	0.39	1.00			
z37g Joint delivery improvement	0.15	0.20	0.34	0.19	0.38	0.21	0.15	0.35	0.44	0.42	0.55	1.00		
z37i Joint investment	0.07	0.05	0.15	0.11	0.06	0.11	0.37	0.15	0.13	0.22	0.24	0.20	1.00	
z37f Exchange performance evaluation	0.17	0.13	0.30	0.20	0.22	0.13	0.22	0.31	0.36	0.47	0.46	0.10	0.27	1.00

in Table 5) are greater than the generally accepted standards, thereby confirming that our proposed model fits the sample data perfectly.

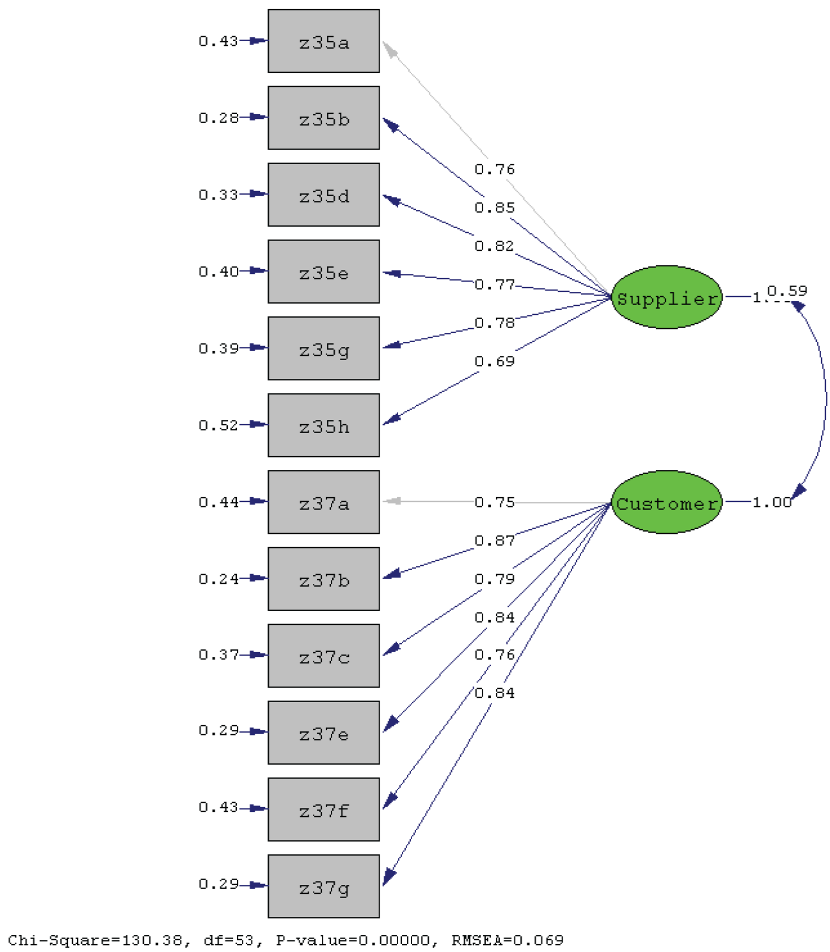
5.3 Testing the Model Validity

In order to validate the model, SEMs often depend on content, convergent, discriminant criteria, and nomological validities. In this study, content and face validity encircling wording and phrasing was met at the preliminary stage of the questionnaire. An external validity valuation can be performed using four diverse methods: result simulation to meet a real-world situation, model testing using a new sample, random splitting of the original sample into two and testing using the same model, and finally, bootstrapping the test results while assessing the parameter estimate variations (Byrne, 1994; Schumacker and Lomax, 2004).

First, convergent validity can be achieved when the factor loadings are larger than 0.50 (Kline, 1998). This common loading rule is fully met, as all the items in the final models have values greater than 0.50. A second criterion for assessing the convergent validity is by assessing the variance extracted by every factor whose recommended threshold is 0.50.

Second, to evaluate discriminant validity, correlations between the factors underlying the set of indicators were calculated to confirm that the constructs are empirically different from each other. The limits are mostly set in the range of 0.10 and 0.85 (Kline, 1998) for a promising discriminant validity. Our results confirmed that none of the correlation coefficients exceeds the

Figure 3. First Order CFA

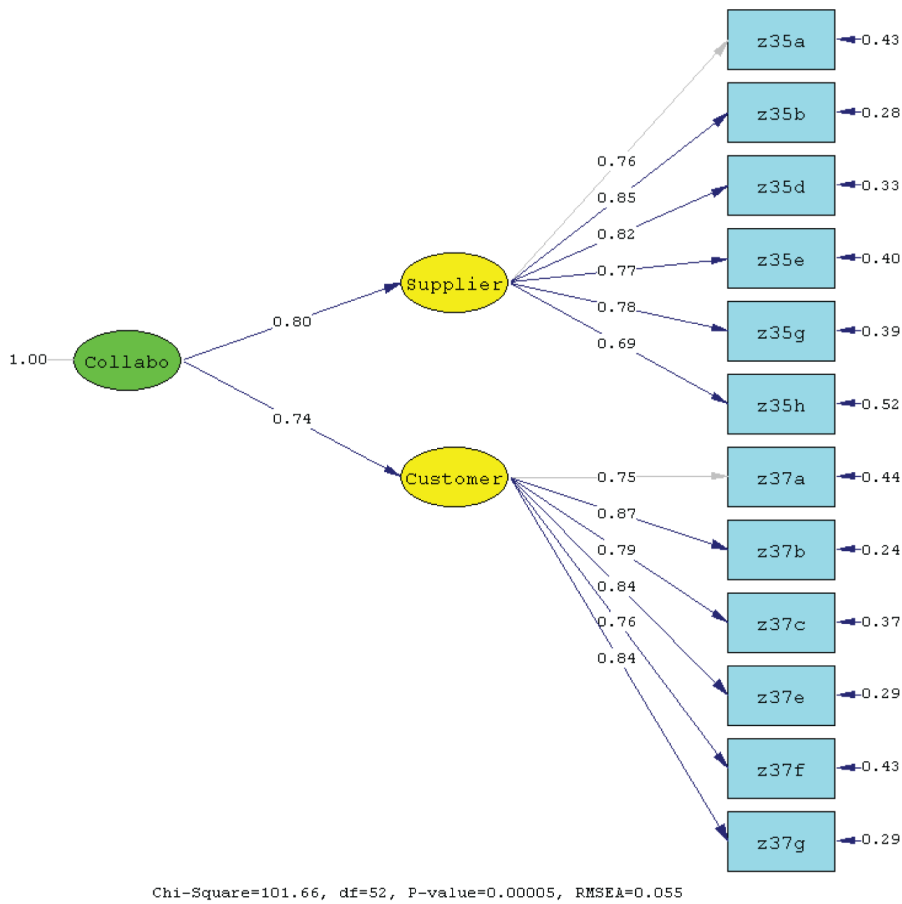


recommended limits. Furthermore, each item loads stronger on its associated factor compared to any other factor.

Third, to assess the criterion validity of the two constructs in the second-order factor analysis model, this study estimated a regression model between these constructs as independent variables. The overall supply chain collaboration in the forest industry was assumed to be a dependent variable. In addition, both the constructs were found to be significant and to exert a positive influence on the overall collaboration concept, like a dependent variable. Fourth, the nomological validity could not be evaluated with no historical study data. It can usually be identified if an instrument were to behave as it should compared to the empirical literature.

To replicate the results for external validity, the two-factor model was split into two random samples using SPSS. A first-order CFA using LISREL 8.71 and DWLS as the estimating method was executed on the two randomly split samples (n1= 156, n2= 156). The results reported in Table 6 show similar goodness-of-fit indexes in all three samples. Compared to the first-order CFA model, these fits show no statistically significant difference for the three samples. Our finding shows the SCC constructs have been properly measured.

Figure 4. Second-Order CFA



5.4 Supply Chain Collaboration in the Forest Industry as a Multi-Item Construct

According to the results presented in subsections 5.1 to 5.3, supply chain collaboration in the forest products industry can be explained using four items shared by clients and suppliers and two specific items. The four shared practices are joint sales forecasting, exchange of basic information, joint planning, and joint delivery improvement. The two practices that are highly customer-oriented are resource sharing of logistics assets and exchange of performance evaluation. Moreover, B2B practices involved mostly suppliers, including the implementation of replenishment systems and new product development as a joint effort.

Table 5. Measurement Models Fit Indices

	Chi2	df	Chi2/df	P-value	RMSEA	CFI	SRMR	GFI
1st order CFA	130.38	53	2.45	0.00000	0.069			
2nd order CFA	101.66	53	1.92	0.00005	0.055			
Desirable level			2 - 3		0.060	0.95	0.08	0 - 1

Table 6. External Validity

Fit indice	Sample 1 model N=156	Sample 2 model N=156	1st order CFA model N=312
Chi-square	**76.26** (*P =0.020*)	**98.73** (*P= 0.00014*)	**130.382** (*P = 0.000*)
Df	53	53	53
NFI	0.97	0.96	0.975
CFI	0.99	0.98	0.985
GFI	0.99	0.98	0.986
RMSEA	0.053	0.075	0.0685

5.5 Testing Invariant Structure

Our third research question is linked to validating the model across groups in a sampled population. For this hypothesis test, this study undertook an invariant structure analysis across the groups of forest companies, using a comparison of correlation matrixes according to the following criteria: exporting firms in comparison to the rest, young companies formed since 1991 to older companies formed before 1991, respective position in the supply chain, having a website or not, IT-enabled interactions or not, and number of employees as a proxy of size. All the correlation matrixes were evaluated as equal, and thus, the null hypothesis cannot be rejected. At a *p-value* of *0.05*, there is no statistically significant difference, as reported in Table 7. This confirms there is a lot of similarity in the low collaboration intensity across the forest products industry. In other words, the IT function does not seem to have an impact on the collaboration level of the forest products industry.

We have thus demonstrated our three research questions. We have assessed the SCC with four common items and two specific items for customers and suppliers. Though some of these items can be also part of SCC constructs in the manufacturing industry, our study focused on forest supply chain collaboration only. It shows that the SCC level does not really vary across the supply chain categories, i.e., different groups of firms involved in the natural forest industry.

6. CONCLUSION, LIMITATIONS, AND FUTURE RESEARCH

Forest industry plays an important role in national economy and sustainable development. With so many ongoing economic changes and cost pressures, collaborative practices in the supply chain network are continually growing internally and externally. The key drivers include IT, industrial sectoral culture, size of companies, and location. However, based on our best understanding from the surveys conducted, there has never been an evaluation of the collaboration level and underlying

Table 7. Invariant Structure Analysis

	Chi-Square	p-value
Having a website (n=196) versus no website(n=116)	85.123	0.272
Interacting via IT(n=168) versus non interacting (n=144)	75.606	0.556
Export (n=172) versus non export (n=140)	69.062	0.755
Number of employees: 141 large companies versus 171 small ones	77.953	0.480
Domain of activity: 145 sawmills versus 167 other companies	78.238	0.471

factors in the forest industry. This study developed a mechanism to fill this gap and initiate the debate on collaboration construct measurements. Therefore, this study's primary ***theoretical contribution*** is developing the measurement model of collaborative practices in the supply chain from forest product industry. Practices were categorized as common to customers and suppliers or as specific to either of these sides.

This study remained focused on relationships and impacts within the forest products industry. The overall results show that the primary economic sector, such as forest industry and/or natural resource industry is relatively less prone to collaboration than manufacturing industries. An apparently strong industrial culture (i.e., traditional business practices without many changes over time) does not favor collaboration or, eventually, knowledge or resource sharing. In addition, the invariant structure tests across different grouping criteria resulted in no statistically significant differences.

From the perspective of ***practical implications***, managers can find the assessment guidelines related to current collaborative practices using the classification of collaboration indicators discussed in this paper. Potential vendors of IT products or services and public institutions identify a few key areas that need products and services to improve the current collaborative processes in the industry. In addition, hardware and software companies should leverage the results to enter the least explored e-supply chain management market in the forest products industry. Despite the relatively low level of collaboration and the use of advanced technology, policymakers and managers should think of structural changes in the forest industry and the use of advanced technology such as Industry 4.0 for truly connected, coordinated, and transparent forest supply chain collaboration for higher productivity and innovations.

Some limitations of this study are evident. First, the quality of the survey could be improved by increasing the number of respondents and possibly could be extended to cover the entire organizational hierarchy. Data should be aggregated as per employees' personal traits. The demographic data can include age, training, prior experience, and position held within the organization. In addition, future research should explore the type of collaboration tools used for improved integration, cost savings, and process automation. Although IT has a very negligible impact on collaboration levels, the adoption rate and extent of enhancing collaboration practices might have been influenced by external factors, including public and private institutions. Inspecting engagement with these external organizations could help forecast the successful implementation of any home innovation, as Granovetter (1985) stated. Hence, extending future research to this collaboration level with additional actors would certainly lead to more credible explanations to explain why the forest products industry is lagging in both IT and collaboration practices.

Furthermore, future research should focus and extrapolate on the role played by the history of forest industry firms and determine the degree of correlation with lower collaboration levels previously mentioned. Barney (1991) highlighted acquiring experience and accumulation over time. Past capabilities of varying routines could be a key indicator for how to adapt to upcoming technological changes and adoption of new innovations.

Similarly, another interesting subject for future research would be to compare the pre-adoption status with the post-adoption results, thereby evaluating IT impacts on collaborative practices. Such longitudinal research could uncover how successful IT tools are implemented in various companies with varying magnitudes to boost collaboration levels. The agenda for future research could include the following issues: i) standardization of collaboration practices within the industry and harmonization of channels to formulate an all-purpose collaboration framework; ii) improved internal communication and integration between departments of the organization under study, as mentioned by Kim (2001) and Stank et al. (2001); iii) commitment, trust, culture, and social embedding of knowledge; and iv) technology stack and security policies to enhance collaborative practices.

Finally, a potential source of conflicting findings in quantitative research is dependency on highly circumstantial studies, which creates non-generalizable output. Using our confirmed hypotheses under different integration arrangements would further enhance their validity and create more value.

COMPLIANCE WITH ETHICAL STANDARDS

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.
Informed consent: Informed consent was obtained from all individual participants included in the study.

FUNDING

The APC has been paid from the following research grants: i) The Social Science Key Program of Tianjin (TJYJ18-018), and, ii) Determination of Commercial Potential and Research on Commercial Development Model of Beijing-Tianjin-Hebei Urban Rail Transit Station (TJYJ18-08).

ACKNOWLEDGMENT

We are grateful to the FORAC (Laval University, Quebec, Canada) where Author Dr. Egide Karuranga had access to the dataset during his work at that organization.

PROCESS DATES

Received: July 18, 2021, Revision: February 7, 2024, Accepted: March 18, 2024

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APPENDIX: SURVEY QUESTIONS

Respondents were asked to answer "yes" if they had implemented these practices, and "no" if not.

Table 8. Survey questions

Clients	Suppliers
Joint sales forecasting (q35a), Exchange of basic information (q35b), Resource sharing of logistics assets (q35c), Replenishment system (q35d), Joint planning (35e), Exchange performance evaluation (q35f), Joint delivery improvement (q35g), Joint new products development (q35h), Joint investment (q35i)	Joint sales forecasting (q37A), Exchange of basic information (q37B), Resources sharing of logistics assets (q37c), Replenishment system (q37d), Joint planning (37e), Exchange performance evaluation (q37f), Joint delivery improvement (q37g), Joint new products development (q37h), Joint investment (q37i), Vendor managed inventory (q37j)

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