Coordination mechanisms and sustainability performance of agri-food chains: insights from the Ecuadorian blackberry supply chain

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1. Introduction

Agri-food supply chains are challenged by pollution, resource depletion, and social conflicts. This has resulted in a growing body of research focusing on supply chain sustainability (Romero-Granja & Wollni, 2018; Zeidan et al., 2020) and its determinants (Centobelli et al., 2021). Experts agree that transforming agri-food supply chains into sustainable systems requires a coordinated approach along the chain (Raimondo et al., 2021). Coordination aims at improving joint performance by aligning individual actors' strategies (Li et al., 2021) and a lack of coordination complicates the achievement of shared objectives (Dries & Swinnen, 2007). Chain coordination is therefore acknowledged as a prerequisite for promoting sustainability-oriented performance in supply chains.

Supply chain actors coordinate interdependencies in time and space by adopting formal (e.g., contracts and certification), relational (e.g., social networks), or mixed mechanisms (Chaddad et al., 2017; Mishra & Dey, 2018) to lower transaction costs. Formal coordination in a hierarchical setting may take the form of supervision, scheduling, pre-planning, or standardization (Arshinder et al., 2008; Liu et al., 2013). This kind of coordination circumvents direct interaction among participants (Agrell et al., 2017), but may be prohibitively costly and is found to be effective mainly in settings with low levels of task interdependence (Xiao & Xu, 2013). Agri-food chains typically operate in dynamic environments prone to changes in climate and markets; therefore, hierarchical coordination may be less appropriate (Abebe et al., 2017; Uddin, 2017).

Relational coordination mechanisms are expected to improve the performance of a system, especially when there is high task interdependence (Prayetno & Ali, 2020), uncertainty (Dries et al., 2014), and time constraints (Hernández-Espallardo et al., 2010). Existing studies have investigated the nature of formal and relational coordination mechanisms primarily in the context of intra-organizational (i.e., within firms) performance (e.g., Camanzi et al., 2018; Alvarez et al., 2010). However, more empirical investigation is needed to understand how relationships between partners and transaction conditions can impact inter-organizational performance (Rungtusanatham et al., 2003). This paper will expand the knowledge on the role of formal and relational coordination and transaction features for performance across different supply chain stages.

Specifically, this paper will focus on two supply chain configurations, namely two- and three-stage supply chains in Ecuador's blackberry sector. This sector presents an interesting case for investigating the relationship between coordination and sustainability performance. First, the perishable nature of blackberries requires a high collection frequency (typically twice per week) to perform exchanges. Second, actors simultaneously use several mechanisms (e.g., informal and formal) to perform and coordinate supply activities. Third, in the 1980s, the government stabilized the blackberry price, and atomization of the local blackberry market occurred, which continues to hamper the sector development.

Using a chain perspective, the research applies the integrated sustainability assessment framework developed by Moreno-Miranda & Dries (2021). The framework includes qualitative and quantitative measures of relational and formal coordination mechanisms and transaction-related features, such as trust, exchange frequency, and formality. To this end, 406 farmers and 180 other chain actors (intermediaries, SMEs, large firms) were surveyed. The methods used to assess the role of coordination in supply chain sustainability are: confirmatory factor analysis to assess the appropriateness of the data to the relational and transactional constructs; hierarchical regression analysis to investigate the role of coordination in the economic, environmental, and social performance of different chain configurations; mediating analysis to test the sequential effect process from coordination mechanisms (relational, formal, and transactional) to sustainability performance.

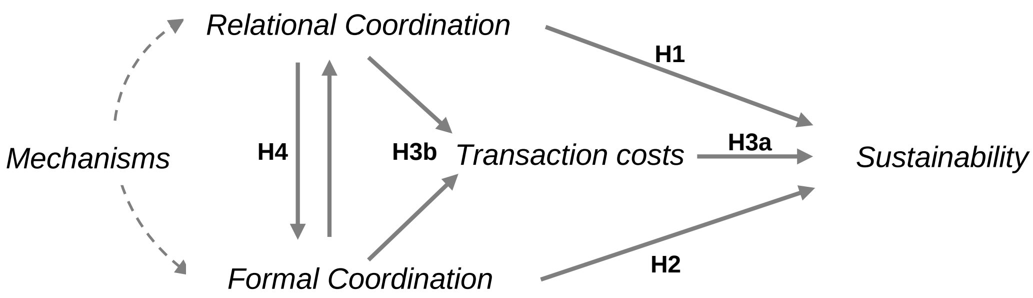
This paper contributes to current research on the sustainability performance of agri-food supply chains. The first contribution of the paper is the development of a model explaining how coordination mechanisms and transaction features relate to the economic, environmental, and social performance of agri-food chains. Existing research rarely considers the effect of coordination and transaction attributes on performance (Liang et al., 2018). This is consistent with Stranieri et al. (2019) who observe that the transaction cost economics and coordination literature often ignores implications for performance. The second contribution of the paper is to disentangle the concept of relational coordination in empirical research. The literature generally treats relational coordination as a single construct. Holcomb & Hitt (2007) recognize the multi-dimensionality of relational governance but do not empirically examine it as such. In this paper, we use confirmatory factor analysis to assess different aspects of relational coordination in the governance of supply chains. Finally, existing studies often examine the effects of formal and relational coordination separately (Poppo & Zenger, 2002). For instance, Liu et al. (2009) compared isolated effects of contract and relational governance and found that contracts are more effective in curbing opportunism while relational governance improves relationship performance. The third contribution of this paper is therefore to improve understanding of how coordination mechanisms interact and how this affects supply chain performance.

The remainder of the paper is structured as follows. Section 2 presents the theoretical foundations regarding supply chain coordination and multi-stage supply chain configurations. Section 3 introduces the benchmark model for a two- and three-stage supply chain configuration, while the research methodology is described in section 4. Section 5 presents the empirical results. Sections 6 and 7 contain the discussion and conclusions of the research, respectively. Finally, section 7 addresses the limitations of the study and presents future research avenues.

2. Theoretical foundations and proposed research model

Effective relationships are considered a key source for chain coordination and performance. Current frameworks for analyzing coordination in supply chains go back to early theories on relationship types (e.g., The nature of the firm by Coase, 1937) and new institutional economics (e.g., Transaction cost economics by Williamson, 1979). Apart from effective relationships, an organized and formal interaction can help cope with unexpected issues arising from a turbulent environment (Masten, 2000; Williamson, 2005; Zhang & Aramyan, 2009). Conceptually, as shown in Figure 1, this research proposes that relational and formal coordination mechanisms and transaction cost-related aspects are interrelated with supply chain sustainability performance. In addition, we expect that formal and relational coordination mechanisms act as complements in their effect on supply chain performance.

Figure 1. Conceptual model



Source: Authors' own representation

2.1 Relational coordination

Relational coordination is a mutually reinforcing process of communicating and interacting for effective task integration (Gittell et al., 2008). The concept of mutual adjustment (Argyris, 1957) is central to the concept of relational coordination. Exploratory research by Liu et al. (2009) and Lumineau & Henderson (2012) on sectors such as retailing and manufacturing has shown that relational coordination among chain actors helps to predict strategic outcomes and performance in terms of well-being, resilience, and satisfaction. This leads to hypothesis 1:

> Hypothesis 1. Relational coordination mechanisms used by supply chain actors to coordinate tasks are positively related to supply chain sustainability performance.

2.2 Formal coordination

Formal coordination is considered a means to assist in managing relationships (Huiskonen & Pirttilä, 2002; Mellewigt et al., 2007). Transaction cost economists (Ménard, 2004; Oxley, 1999; Williamson, 1981) claim that formal mechanisms (e.g., contracts) pursue the alignment of inter-organizational performance through adjusting payoff structures and incentives and increasing the transparency of relationships and monitoring. Outcomes from empirical studies are mixed. For example, Beck & Keiser (2003) observed that high levels of formality can be detrimental to inter-organizational performance because they may entail overregulated processes. Kurniawan et al. (2017) found that formalizing supply chain activities and decisions helps to achieve manufacturing goals in terms of costs, and quality. Tan (2002) showed that formal practices (rules and delegations) positively affect firm performance. This leads to hypothesis 2:

> Hypothesis 2. Formal coordination mechanisms used by supply chain actors to coordinate tasks have an ambiguous effect on supply chain sustainability performance.

2.3 Transaction costs

The transaction is the smallest exchange unit of a profit-seeking activity (Suematsu, 2014; Williamson, 1979). However, several studies (e.g., Escobal & Cavero, 2012; Liu et al., 2009) claim that transactions are not simply about increasing profit by reducing costs; they also imply understanding of the mechanisms that allow to accomplish a better performance than the average (Peterson, 2010; Tate et al., 2011; Wacker et al., 2016). For instance, Deng & Zhang (2019) found that more frequent transactions lead to higher transaction costs and a lower financial performance. Other studies (e.g., Ménard, 2011; Nyaga et al., 2013) suggest that better control over the transaction strengthens inter-organizational performance in efficiency terms. This leads to hypothesis 3a:

> Hypothesis 3a. Transaction costs incurred by supply chain actors when exchanging products are negatively related to supply chain sustainability performance.

Coordination pursues minimizing the cost of transactions within a network (Peterson et al., 2001) to enhance its performance. Transaction costs arise depending on the nature of the coordination mechanisms applied between partners. For instance, Hendrikse et al. (2014) connects formal mechanisms with higher transaction costs, and less inter-organizational interaction would lead to lower transaction costs and higher productivity (Ryall & Sampson, 2009). The literature on alliances instead suggests that coordination costs can be lowered when firms consider more than one business partner, even if this calls for more complex coordination (Artz & Brush, 2000). This motivates hypothesis 3b:

> Hypothesis 3b. Coordination mechanisms used by supply chain actors to coordinate tasks affect transaction costs, which influence supply chain sustainability performance.

2.4 Interaction between coordination mechanisms

The literature indicates several means, e.g., commitment, relational adaptation, or contracts, by which trading parties may coordinate their arrangements (Chang et al., 2015; Hadfield, 2005). In line with this, theoretical perspectives have emerged to explain the interplay between relational aspects and formality. In particular, several studies claim that trust and formality are substitutes (Annen, 2013; Atkin & Rinehart, 2006; Bloom & Hinrichs, 2011). Others defend their complementarity (Czernek et al., 2017; Méon & Sekkat, 2015) and say that a good relationship helps in overcoming rigidity in the contract by facilitating open communication and transparency (Bogetoft & Olesen, 2002; Woolthuis et al., 2016). This is consistent with Wacker et al. (2016) who observe that successful buyer-supplier relationships utilize various mechanisms to reduce supply chain performance ambiguity. This leads to hypothesis 4:

> Hypothesis 4. Formal and relational coordination mechanisms used by supply chain actors complement each other to influence supply chain sustainability performance.

3. Benchmark models of supply chain configurations

In this section, we describe two basic models of supply chain configuration. Figure 2a represents the first model, a three-stage configuration that includes a first linkage between a supplier (i) and an intermediary (j) and a second link connecting the intermediary with a buyer (k). The three-stage configuration, therefore, includes two transactions. Figure 2b shows the second model, a two-stage configuration that links a supplier (i) and a buyer (k). The two-stage configuration entails one transaction only. Straight-line and dash-line arrows denote the exchange/transaction of goods and coordination mechanisms, respectively. The supply chain optimality conditions are illustrated in the next sections, taking the three-stage configuration as a reference.

Figure 2a. Three-stage supply chain configuration.

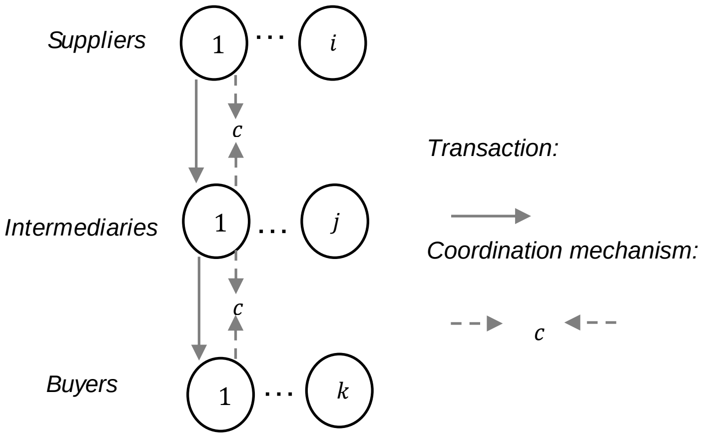


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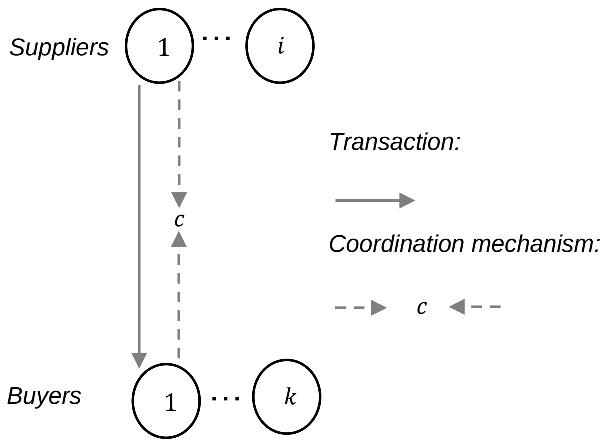
Figure 2b. Two-stage supply chain configuration.



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3.1 The supplier's optimality conditions

Let q_i denote the nonnegative production output of supplier i. Each supplier i faces a production cost function f that depends on the production output and which includes costs, that is:

$$f = f(q_i) \tag{1}$$

A supplier i makes an exchange with an intermediary j for a certain product amount denoted by q_{ij}. Each exchange of q_{ij} involves coordination and transaction costs denoted by c, given by:

$$c = c(q_{ij}) \tag{2}$$

A supplier may exchange products with multiple intermediaries, $j = 1, \dots, n$. The quantity produced by supplier i must satisfy the following conservation of flows equation:

$$q_i = \sum_{j=1}^{n} q_{ij} \tag{3}$$

If we let p_{1ij}^{*} denotes the product price a supplier i charges for the product to intermediary *j*, and note the conservation of flow equation (3), we can express the criterion of profit maximization for supplier i as follows:

$$\max\ p_{1ij}^{*} \sum_{j=1}^{n} q_{ij} - f(q_i) - \sum_{j=1}^{n} c(q_{ij}) \tag{4}$$

subject to $q_{ij} \geq 0$ for all *j*

3.2 The intermediary's optimality conditions

An intermediary j faces handling costs[1], denoted by the function g which depends on the purchased amount from suppliers. This can be written as:

$$g = \sum_{i=1}^{n} g(q_{ij}) \tag{5}$$

The intermediary j denotes product selling price to the buyer *k* at the storage place by p_{2jk}^{*}. The optimization problem of an intermediary j is given by:

$$max\ p_{2jk}^{*} \sum_{k=1}^{p} q_{jk} - \sum_{i=1}^{n} g(q_{ij}) \ - \sum_{j=1}^{o} p_{1ij}^{*}\ q_{ij} \tag{6}$$

$$subject\ to \sum_{k=1}^{p} q_{jk} \leq \sum_{i=1}^{n} q_{ij} \tag{7}$$

where $q_{ij} \geq 0$ and $q_{jk} \geq 0$ for all i and k. Constraint (7) expresses that intermediaries cannot sell more than what they hold in stock.

3.3 The buyer's optimality conditions

The buyer k considers h at the purchase decision, which is the set of coordination costs and depends on the purchased amount from the intermediary j:

$$h = \ h(q_{jk}) \tag{8}$$

[1] The costs associated with preparing inventory and order fulfilment.

The buyer also considers the price charged by the intermediary j for the product denoted by p^*_{2jk}. The product price at the buyer outlet is denoted by p^*_{3k}. The optimality condition for the buyer is:

$$p^*_{2jk} + h(q_{jk}) \begin{cases} \leq \; p^*_{3k} \quad if \; q_{jk} > 0 \\ > \; p^*_{3k} \quad if \; q_{jk} = 0 \end{cases} \tag{9}$$

Condition (9) states that buyers will only buy products from intermediaries if the price they can charge to their customers, p^*_{3k}, exceeds or is equal to the costs of transacting with intermediaries. Nagurney et al. (2002) apply similar conditions to develop the equilibrium conditions within a supply chain network with manufacturers, retailers and consumers.

4. Data and methodology

4.1 Context of the Ecuadorian blackberry supply chain

The Ecuadorian blackberry sector is characterized by a large number of small-scale producers. The Agricultural Research Institute in Ecuador (2016) reports at least 3800 ha of blackberry production, directly and indirectly involving 8000 peasant families. 65% of total production is located in Tungurahua, Chimborazo, Bolívar and Pichincha provinces. On average, the blackberry cultivation area per farm is 2500 m^2 (Ecuadorian Institute for Statistics, 2019), and most farms are equipped with irrigation systems subsidized by the government. Worldwide, at least 29,035 ha of blackberries are commercially cultivated. Mexico and Chile are the world leaders in production (Strik et al., 2008). The Ecuadorian Ministry of Agriculture (2021) reports that producer prices range between USD 1.30 and 1.40 / kg in a season of low production and from USD 0.80 to 0.90 / kg in high production periods.

Downstream in the supply chain, there is an important role for intermediaries. They dominate transactions from the highlands to the coastal region. Intermediaries buy the product from producers at the farmgate, or in distribution centers, after which intermediaries frequent local and regional markets to sell the products. According to the Ecuadorian Ministry of Agriculture (2021), the average cost of transporting the harvest is USD 0.10 / kg. Regulatory entities have reported that often the intermediary's margin is higher than the producer's margin. According to the Wholesale Market Administrator (EP-EMA, for its acronym in Spanish), the final consumer price in public marketplaces for fresh blackberries can range between USD 1.50 and 1.80 / kg in low production seasons and from USD 1.10 to 1.40 / kg in overproduction periods.

The blackberry processing industries are located in cities (e.g., Guayaquil, Cuenca, and Quito). Public-private and private firms lead this stage. The main manufactured products are frozen pulp, concentrate, nectar, and jelly. Local brands dominate the national market, and few of them export abroad. Official data shows that the industry annually transforms about 4520 tons of fresh blackberries, of which more than 75% is bought through intermediaries. The average price paid by the industry ranges from USD 0.70 to USD 1.00 / kg in times of overproduction and USD 1.20 to USD 1.50 / kg in times of low production. The strategic plans of the industry involve the training of intermediaries in quality and post-harvest issues and the storage of large volumes of frozen fruit in times of overproduction.

The modernization of the blackberry supply chain is the subject of much public and private interest. Novel marketing channels and supermarket chains play a crucial role. Ecuador has corporations whose supermarkets have national and international participation in Panama, Uruguay, and Argentina. The government has invested in projects that bring these corporations closer to small producers. The purpose has been to professionalize producers, minimize the role of intermediaries, and stabilize prices. The supermarket marketing channel is characterized by strict demands imposed on suppliers in terms of logistics and quality and there are penalties for non-compliance. Official data shows that the retail sector annually trades about 1230 tons of fresh blackberries, of which less than 30% is sourced directly from producers. The average price paid by the retailer to suppliers ranges from USD 2.8 to USD 3.2 per kg of high-quality blackberries. The consumer price at supermarkets ranges from 5.2 to 5.7 USD per kg.

4.2 Methodology for data collection

4.2.1 Variable measurement

The identification of indicators of coordination measures is based on the Integrated Sustainability Performance Assessment ISPA framework developed by Moreno-Miranda and Dries (2021) for agri-food supply chains. The ISPA framework resulted from a structured literature review and suggests a list of coordination indicators, categorized into vertical and horizontal mechanisms. Sector representatives and experts validated the indicators using criteria of relevance and operational feasibility. Indicators such as trust, fair treatment, and power-sharing, time frame and frequency of exchange and the formality in transactions of particular importance for chain actors.

Relational coordination mechanisms

Relational coordination is composed of a variety of concepts. *Trust* is widely discussed in the coordination literature, and is defined as "a willingness to rely on an exchange partner in whom one has confidence" (Vlaar et al., 2016). Wong and Sohal (2002) call trust a major determinant of relationships. *Fair treatment* and *power-sharing* are considered additional properties of chain actors' relationships. Fair treatment focuses on the quality of treatment that one gets from others (Sommerville et al., 2010), while power-sharing is the degree of influence applied by trade partners in negotiations (Humphries & McComie, 2010). Measurements of these properties capture the relative perception of the quality of the relationship between supply chain actors.

Formal coordination mechanism

Formal coordination concerns, for instance, written contracts and is measured as the *share of formal transactions*. Several studies (e.g., Marjit & Mandal, 2016; Luna & Wilson, 2015) have used this indicator to estimate the impact on agricultural system performance.

Transaction costs

Apart from relationship quality, organized interactions are needed to strengthen relationships and avoid the waste of effort. Several authors (e.g., Agarwal et al., 2007; Göbel et al., 2015) claim that wasted time due to waiting for tasks or rectifying errors prevent having healthy relationships between trading partners. The frequency and time frame of the exchange are indicators of a good trade relationship. The *time frame for negotiation* is defined as the perception regarding how long the negotiation takes without being considered a loss (Young-Ybarra & Wiersema, 1999). *Frequency in exchange* is the number of times a trade partner visits a location for trade purposes (Conrad et al., 2015). These indicators capture the invested *cost in the transaction process* of supply chain actors.

Sustainability performance

The measures for supply chain sustainability performance are based on Moreno-Miranda and Dries (2022), and include three sustainability performance indexes, namely, economic, environmental and social. The economic index includes costing, profitability, and price volatility aspects. The environmental index captures natural resource consumption and food losses. Work conditions, migration, and child labor indicators are used for the social index. We use bar charts for representing the distribution of sustainability performance scores by chain configuration. Appendix A lists the means and standard deviations for the sustainability performance variables included in the research.

4.2.2 Survey design

The described coordination variables were elicited from blackberry supply chain actors through a questionnaire. Appendix B shows details of the questions, which were translated to Spanish (respondents' native language) and checked by three experts to ensure full understanding. Questions about trust, fair treatment, power-sharing, and time frame of the exchange process were answered using a ten-point Likert scale, while frequency of exchange and formal transactions used times/week and shares, respectively. We pilot-tested the survey through exploratory interviews with ten representatives of agricultural associations, intermediaries, and food processors. The representatives completed the survey satisfactorily and suggested collecting data in two ways: in-situ interviews with producers, intermediaries, processing firms, and supermarket managers located near to the production places, and remote interviews – conducted online – with the processing firm and supermarket managers that are in more remote areas.

4.2.3 Data collection

We first applied the in-situ survey to producers. For this, dates were set together with the heads of producers and intermediaries organizations (e.g., associations and guilds) that coincided with member meetings. We ensured that each interview with a producer was conducted in a private space. On average, each interview took around 10 minutes. Twenty percent of the sessions were rescheduled due to a low attendance rate of participants. To ensure the chain perspective in data collection, we applied a downward spiral method. The producers provided the contacts of their clients (e.g., intermediaries) and information about the commercial exchange places. For example, an interview with a producer led to three wholesale intermediaries in the Tungurahua municipal market, and these, in turn, led to Facundo, a fruit processor in the coastal region. Next, we visited the intermediaries and applied the in-situ survey. In the case of a processor or supermarket, the survey invitation was sent via email. For remote interviews, we utilized a web-based survey. We used the survey tool QuestionPro. A single response for each organization was collected. This is consistent with the approach taken by other researchers in this area, e.g. (Wilhelm et al., 2016). Data collection took from mid-December 2019 to mid-February 2020.

4.2.4 Sampling

Data from different samples are combined in this research. A producer may be counted in different chain configurations because he/she may sell part of the harvest directly to processors and the rest through intermediaries. For the producers' sample, the population consists of all farms in the blackberry sector registered by the Ministry of Agriculture until December 2019. Registered farms are subjected to the authorities' requirements, such as the peasant health insurance and taxpayer registry. To be included in our sample, we randomly selected 406 candidate producers/farms from the convened meetings by organizations heads.

For the intermediaries' sample, the spiral method applied to the sample of producers allowed the identification of 68 intermediaries. Small and large intermediaries represented 58% and 42% of the sample, respectively. A small intermediary usually collects products on the farm and does not have a fixed location for the execution of transactions. Intermediaries that are considered "large" usually operate a warehouse in market places administered by public entities.

The processors and supermarkets samples were identified by the group of intermediaries. A total sample of 33 processors and 32 supermarkets was established. All of the companies are legally registered by the Ministry of Industries and the Internal Revenue Service. The processors sample includes SMEs (90%) and large companies (10%). The sample of supermarkets has 10% SMEs and 90% large corporations. Table 1 shows the sample distributions by supply chain configuration and actor.

Table 1. Distribution of supply chain configurations and actors in the study sample

	Chain configuration	**Frequency**	**%**
Three-stage	Producer → Small Intermediary → Retailer	93	22.9
	Producer → Small Intermediary → Processor	52	12.8
	Producer → Large Intermediary → Processor	177	43.6
Two-stage	Producer → Processor	50	12.3
	Producer → Retailer	34	8.4
	Chain actors	N° responses	%
	Producers	406	75.3
	Intermediaries	68	12.6
	Processors	33	6.2
	Retailers	32	5.9

Note. s.d. = standard deviation. The 'producer → large intermediary → retailer' configuration was not observed in the sample. The same producer may be counted in different chain configurations.

Source: Authors' survey

4.3 Methodology for analysis

4.3.1 Validity and reliability testing

Following the suggestions of Hair et al. (2009), we examine reliability and validity of the survey instrument. Cronbach's α coefficient (Cronbach, 1951), average variance extracted and composite reliability are generally used to test the consistency of a scale. We estimate these statistics using the 539 responses (406 of production and 133 of downstream actors) related to relational and formal coordination, and transaction cost aspects. Values equal to 0.70 or greater indicate good scale reliability (O'Leary-Kelly & Vokurka, 1998) and values between 0.50 - 0.70 tell that items can be valid measures of the underlying factors (DeVellis, 2012;

Spooren et al., 2007). Convergent validity is confirmed when strong loadings are found in the exploratory factor analysis.

Exploratory Factor Analysis

Exploratory factor analysis supports prior expectations from theoretical constructs (Henson and Roberts 2006). The method filters observed variables before applying structural equation modeling to the complete data set (Miyake et al., 2000). Exploratory factor analysis was used to examine the original survey items of relational coordination and transaction cost-related measures. Note that formal coordination was not included in the analysis because it comprises only one item. We use maximum likelihood as the factor extraction method, maximizing the variance accounted for in the observed variables by a smaller group of factors. As the next step, Promax rotation was used to explore variable relationships. The Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy was used to evaluate the correlations and partial correlations. Habibi et al. (2020) recommend a KMO value ≥ 0.5 to validate the KMO analysis. Bartlett's test of sphericity is also recommended to test the appropriateness of factor analysis (Bartlett, 1950). This tests the hypothesis that the correlation matrix is an identity matrix, and values $p < 0,001$ validate the analysis.

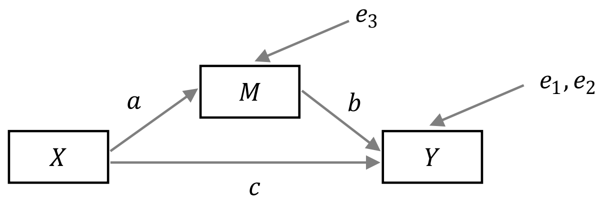
Confirmatory Factor Analysis

To confirm the result of the exploratory factor analysis, confirmatory factor analysis was carried out. Based on Wallace's approach (Wallace et al., 2004), the measurement model was constructed using SPSS AMOS 24 with the two latent variables (Relational Coordination and Transaction Costs). The analysis used maximum likelihood as the main estimation method (Browne, 1987). Maximum likelihood adjusts chi-square estimates for the presence of non-normality using the asymptotic covariance matrix provided; therefore, it generates more accurate test statistics under conditions of non-normality (Curran et al., 1996). The overall goodness of fit was measured using different measures (Bollen, 1989; Hair, 1998); namely, $\chi 2$/ degree of freedom ratio (CMIN/DF), Comparative Fit Index (CFI), the Incremental Fit Index (NFI), and root mean square error of approximation (RMSEA). The recommended values for CFI and NFI should be higher than 0.8 (Byrne, 2016). RMSEA values for good model fit should be less than or equal to 0.06 (Hu & Bentler, 1999).

4.3.2 Structural Equation Modeling

A structural equation model (SEM) of the hypothetical model shown in Fig. 1 is constructed to test the research hypotheses. SEM assesses the model predictive validity (Hoyle, 1995; Jadhav et al., 2018). In the model, the latent variables, Relational coordination and Transaction costs are indicated by the corresponding observed variables. Sustainability Performance is indicated by the composite sustainability indexes. Formal coordination is indicated by the single observed variable. Again a Maximum Likelihood approach was used as the main estimation method with the sample covariance matrix and the corresponding asymptotic covariance matrix employed. A mediating analysis assesses hypothesis H4. The mediator is defined as "the generative mechanism through which the independent variable influences the dependent variable" (Baron & Kenny, 1986). Figure 3 and equations 10 to 12 illustrate the general structure of the mediation analysis.

Figure 3. Mediation model



Source: Authors' own representation

$$Y = i_1 + cX + e_1 \quad (10)$$

$$Y = i_2 + cX + bM + e_2 \quad (11)$$

$$M = i_3 + aX + e_3 \quad (12)$$

The analysis starts first by testing the direct effect of X on Y (Eq.10). Then, variable M (mediator) is introduced in the correlational chain linking X and Y (Eq. 11). The system of equations is completed with Eq. 12 to test the effect of X on M. The intercepts are i_1,i_2 and i_3. The relationships are represented by a, b and c parameters, while e_1, e_2 and e_3 represent unexplained or error variability.

5. Characteristics of the supply chain actors

We received 539 usable questionnaires. 75.3 % and 24.7 % of responses represented producers and downstream partners, respectively. Three-stage chain partners represented the majority (77.3%) of the respondents. Table 2 shows means and standard deviations for a selected number of characteristics of the respondents by supply chain configuration. Descriptive statistics and correlations of the variables related to the measures of coordination are listed in Table 3.

Table 2. Frequency distribution of supply chain actors' characteristics

Variable	Unit	Two-stage		Three-stage		ANOVA
		Mean	s.d.	Mean	s.d.	F-values
Producers						
Farm income	USD	3511	1309	2704	1228	71.05***
Household size	number	3.72	1.41	3.86	1.20	4.47
Age	years	43.10	11.52	52.77	10.04	11.51**
Education	years	9.05	3.57	6.82	2.67	17.86**
Experience	years	15.44	4.96	18.33	3.55	6.12*
Yield	kg/m^2	0.69	0.38	0.53	0.29	20.03**
Selling price	USD/kg	1.71	0.12	1.55	0.31	35.08**
Intermediaries						
Business income	USD	-	-	3414	1097	-
Employees	number	-	-	7.81	3.39	-
Experience	years	-	-	10.20	5.01	-
Buying price	USD/kg	-	-	1.62	0.29	-
Selling price	USD/kg	-	-	2.06	0.44	-
Processors/Supermarkets						
Company age	years	23.23	9.10	10.77	5.82	24.07**

Employees	number	77.39	23.54	15.11	5.34	39.84***
Own capital	Share	55.76	4.98	75.73	8.93	14.03**
Loaned capital	Share	44.24	6.12	24.27	10.05	10.15*
Buying price	USD/kg	1.87	0.19	2.50	0.55	8.67
Value added	USD/kg	0.68	0.21	0.82	0.35	11.29

Note. s.d. = standard deviation. *, **, *** denote coefficient significant at 0.1, 0.05 and 0.001 level.

Source: Authors' survey

The vast majority of producers and intermediaries have been active in the blackberry supply chain for at least a decade. Firm sizes ranged from small to medium. The producer's selling price can range from USD 1.24 / kg to USD 1.86 / kg, and the intermediary margin in three-stage chains ranges from USD 0.44 to USD 1.17 / kg. In addition, the price of fresh blackberry to the final consumer can reach USD 2.55 / kg and USD 3.32 / kg in two- and three-stage chains, respectively.

Table 3. Descriptive statistics and correlation between variables on coordination (n=406)

			Two-stage		Three-stage		Trust	Fair treatment	Power - sharing	Time frame	Frequency exchange	Formal transactions
Variable	Code	Unit	Mean	s.d.	Mean	s.d.						
Trust perception	$Trust$	score [1-10]	5.64	1.75	4.94	1.73	1					
Fair treatment	$Fair$	score [1-10]	5.74	1.41	5.04	1.55	0,585**	1				
Power-sharing	$Power$	score [1-10]	5.06	1.31	5.52	1.87	0,546**	0,520**	1			
Time Frame	$Time$	score [1-10]	5.06	1.34	4.14	1.77	-0,289**	-0,266**	-0,426**	1		
Frequency exchange	$FrqExc$	times/week	1.87	0.76	2.23	1.01	-0,271**	-0,270**	-0,287**	0,375**	1	
Formal transactions	$Formal$	share	72.07	25.22	15.03	5.78	0,432**	0,333**	-0,006	-0,150**	-0,176**	1

Note. ** The correlation is significant at the level 0,01 two tail

Source: Authors' own representation

6. Results

6.1 Reliability and validity of coordination mechanisms

Table 4 shows that Cronbach's α and reliability values have acceptable scores above 0.70. Only the exchange frequency has an AVE value of 0.48, just below the common threshold of 0.50 recommended by other authors.

Table 4. Reliability and Exploratory Factor Analysis of original measures

				Factor loadings	
Factor and items	Cronbach's α	AVE	CR	Two-stage	Three-stage
Factor 1: Relational coordination					
Trust perception	0.811	0.571	0.796	0.620	0.816
Fair treatment	0.828	0.569	0.840	0.829	0.718
Power-sharing	0.938	0.730	0.915	0.575	0.835
Cumulative variance (%)				63.3	74.9
Eigenvalue				2.13	2.47
Factor 2: Transaction costs					
Time frame	0.784	0.509	0.763	0.585	0.706
Frequency exchange	0.773	0.480	0.742	0.518	0.623
Cumulative variance (%)				56.6	66.2
Eigenvalue				1.89	1.92
Factor 3 and item					
Formal transactions	0.702	0.536	0.778	-	-

Note. AVE: Average variance extracted; CR: composite reliability; KMO: The Kaiser-Meyer-Olkin measure of sampling adequacy. Estimation method: Maximum Likelihood. Sampling adequacy indices: $KMO = 0.637$ to two-stage and $KMO = 0.715$ to three-stage configurations.

Source: Authors' own representation

The Exploratory Factor Analysis of relational coordination and transaction costs is also presented in Table 4. Results show that trust, fair treatment, and power-sharing are captured in factor 1. Time frame and exchange frequency are represented by factor 2. Factor 1 items have relatively higher loadings than items of Factor 2. The cumulative variances of eigenvalues are above 56 % for each factor and each supply chain configuration. Table 5 presents the results of the confirmatory factor analysis, it confirms that relational coordination and transaction cost-related measures meet convergent validity conditions, so the instrument is deemed acceptable.

Table 5. Confirmatory factor analysis of relational and transaction costs measures

	Factor Loadings			
Construct and items	Relational coordination		Transaction costs	
	Two-stage	Three-stage	Two-stage	Three-stage
Trust perception	0.63***	0.82***		
Fair treatment	0.82***	0.72***		
Power-sharing	0.53**	0.83***		
Time frame			0.59**	0.71**
Frequency exchange			0.51**	0.62**

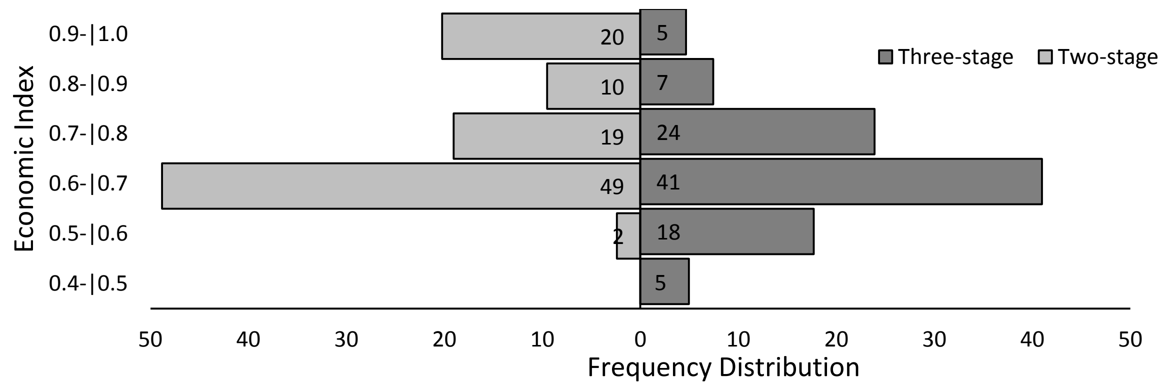
Note. Loadings are standardized; **, *** denote coefficient significant at 0.05 and 0.001 level. Goodness of fit indices: χ^2 0.21, $p > 0.05$, $RMSEA = 0.05$, $AIC = 43.38$, $CFI = 0.890$, $NFI = 0.853$ to two-stage. χ^2 0.35, $p > 0.05$, $RMSEA = 0.04$, $AIC = 57.53$, $CFI = 0.933$, $NFI = 0.914$ to the three-stage configurations.

Source: Authors' own representation

6.2 Economic, ecological and social performance

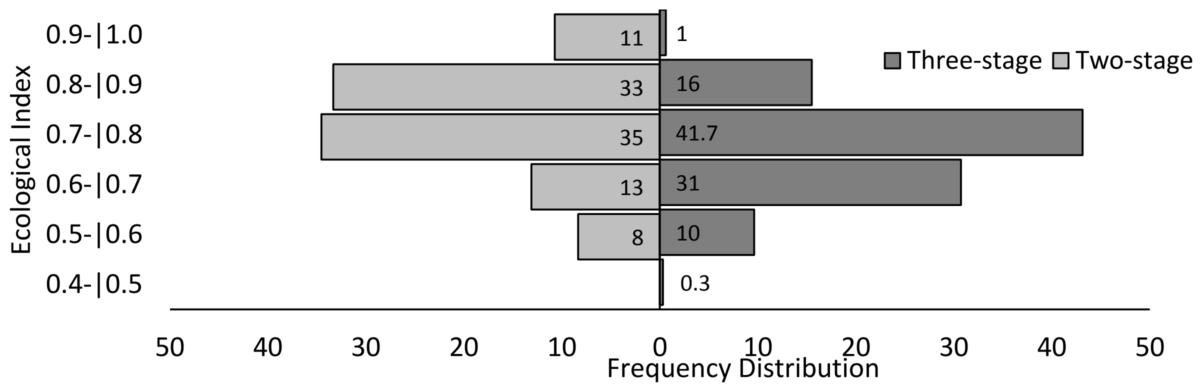
Figures 4a to 4c show the share of supply chains (n = 406) per configuration and distributed over intervals of the sustainability performance indexes. Bar charts represent the frequency distribution of each chain configuration. The results show more two-stage chains in economic and environmental score intervals close to one and more three-stage chains in social score intervals close to one. These different findings are described in more detail below.

Figure 4a. Percentage share of chains per interval of the economic performance index.



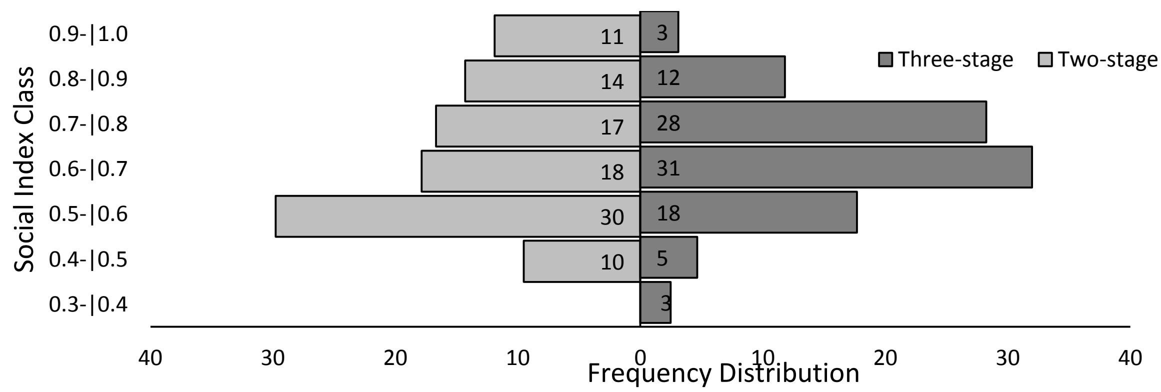
Source: Authors' own representation

Figure 4b. Percentage share of chains per interval of the ecological performance index.



Source: Authors' own representation

Figure 4c. Percentage share of chains per interval of the social performance index.

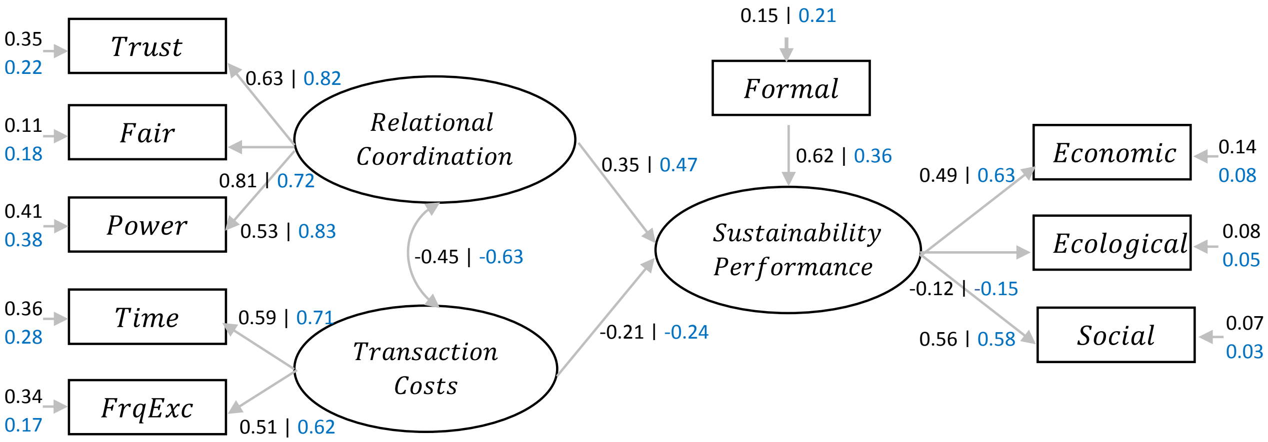


In the economic dimension, 49% and 41% of two-stage and three-stage chains scores are in the 0.6 - 0.7 interval, while at least 2% and 5% of two-stage and three-stage chains score below the cut-off point of 0.74 and 0.67, respectively. For the environmental index, two-stage chains are concentrated in the 0.7 – 0.8 and 0.8 – 0.9 intervals, a total of 68% of chains, and less than a quarter of the chains are below the cut-off point (0.78), while three-stage chains are concentrated in the 0.7 – 0.8 and at least 41% of chains are below the cut-off point (0.72). For the social index, the cut-off point in both configurations is 0.69; however, a larger share of two-stage chains is below the cut-off point (at least 40%). The two- and three-stage chains are highly concentrated in the 0.5 - 0.6 and 0.6 - 0.7 intervals, respectively.

6.3 Hypothesis testing

Before assessing the study hypotheses, the goodness of fit of the structural equation model has to be evaluated. Results show that all the indexes meet the acceptable fitness level in both chain configurations (indicated at the bottom of Figure 5). Figure 5 shows the path diagram of SEM for both chain configurations. The standard coefficients linking the variables investigated in two-stage and three-stage chains are in black and light blue and single-headed arrows imply one variable having a direct affect on another and the circular curved arrow represent covariance.

Figure 5 Path diagram of the fitted structural equation model for two- and three-stage chains



Note. Goodness of fit indices: $\chi^2 = 0.47$ p > 0.05 $RMSEA = 0.05$ $AIC = 81.47$ $CFI = 0.918$ $NFI = 0.929$ to two-stage chains and $\chi^2 = 0.19$ p > 0.05 $RMSEA = 0.06$ $AIC = 68.22$ $CFI = 0.924$ $NFI = 0.909$ to three-stage chains.
Source: Authors' own representation

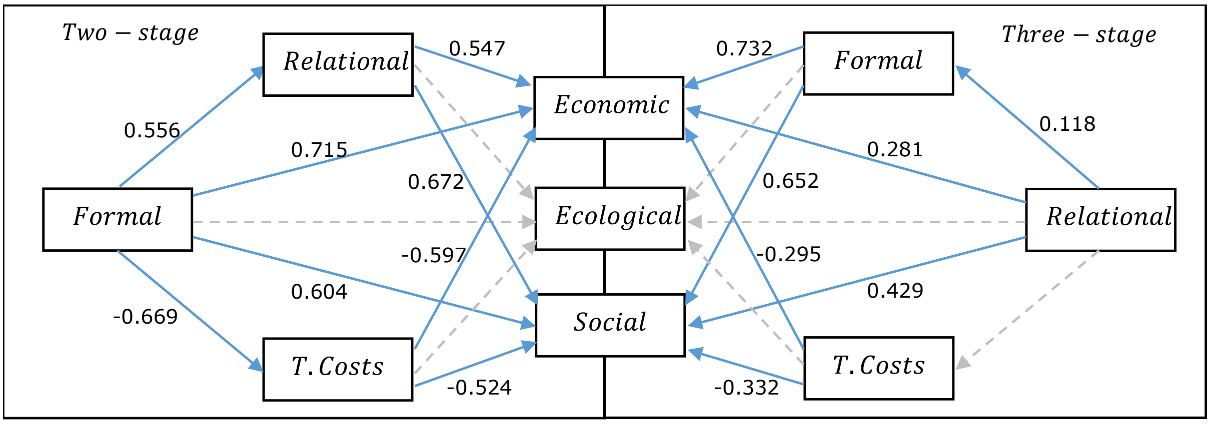
The coefficients between relational coordination and sustainability are positive and significant (p<0.001), 0.35 and 0.47 for the two- and three-stage chains, respectively. Hypothesis 1 is therefore supported. The path coefficients between formal coordination and sustainability are significant (p<0.001) with positive values of 0.62 for two-stage and 0.36 for three-stage chains, thus supporting hypothesis 2. The coefficients between transaction costs and sustainability performance were slightly significant (p<0.10), with negative values, -0.21 and -0.24 for two- and three-stage chains, thus supporting also hypothesis 3a.

The correlation coefficients between relational coordination and transactions costs are negative and slightly significant (p<0.10), -0.45 and -0.63 for two- and three-stage chains, respectively. We follow the approach of Ping (1995) to interpret this finding, which shows that poor relational coordination (i.e., the respondent has a poor relationship with its chain partners) may exacerbate transaction costs in the relationship.

6.4 The mediating effect of coordination mechanisms

Figure 6 shows the path diagram and table 6 presents the path coefficient estimates and model fit indices of the mediation analysis. Single-headed arrows in light blue indicate significant mediation effects, dotted line arrows indicate insignificant effects. Figure 6 indicates that relational coordination and transaction costs aspects within two-stage configurations partially mediate the relationship between formal coordination and social and economic performance but not the formal coordination and ecological performance relationship, thus hypothesis 3b and hypothesis 4 are partially supported. These effects can be explained by the relatively higher levels of formality in two-stage chains (see Table 3).

Figure 6. Path diagram of mediation effects for two- and three-stage chains



Note. Dotted lines mean that there is no mediation.
Source: Authors' own representation

Table 6. Path coefficient estimates and model fit indices.

Effect on sustainability dimension	Two-stage		Three-stage	
	Indirect	Med. Obs.	Indirect	Med. Obs.
Relational→Formal→Economic	0.016	Not significant	0.087**	Partial
Formal→Relational→Economic	0.304**	Partial	0.034	Not significant
Formal→Transactional→Economic	0.401***	Partial	-	Not found
Relational→Formal→Ecological	-0.031*	Undetermined	-0.008	Not significant
Formal→Relational→Ecological	0.021*	Undetermined	0.081*	Undetermined
Relational→Formal→Social	-0.091	Not significant	0.077**	Partial
Formal→Relational→Social	0.382***	Partial	0.036	Not significant
Formal→Transactional→Social	0.351***	Partial	-	Not found

Note. Med.Obs. is mediation observed. *** ** * the coefficient is significant at the level 0.01, 0.05, 0.10 two tail. Goodness of fit indices: $RMSEA = 0.04$ $AIC = 21.14$ $CFI = 0.897$ $NFI = 0.798$ to two-stage configuration; $RMSEA = 0.05, AIC = 52.84, CFI = 0.841,$ $NFI = 0.832$ to three-stage configuration.
Source: Authors' own representation

By contrast, transactions are highly informal in three-stage configurations, and formal coordination seems to mediate the effect of relational coordination on social and economic performance. In addition, no clear indirect effects on environmental performance were found in either chain configuration. The not significant indirect relationships are explained by strong correlations or direct relationships between the independent and dependent variables, as it is mentioned by Chen (2016). The lack of scope for mediation may also explain why previous studies did not identify other moderating and mediating elements.

7. Discussion

7.1 Effects of relational and formal coordination on sustainability performance

Our findings provide support for the hypotheses. The significant positive relationship identified for hypothesis H1 indicates that chain partners, both in two- and three-stage chain configurations, benefit from trust, fair treatment, and power-sharing in their business relations. This is a significant finding for the literature because, although Signori et al. (2015) and Kirchoff & Falasca 2022) studied the effects of some coordination variables on internal supply chain sustainability, the literature has not identified the effect of relational coordination mechanisms on sustainability performance considering a supply chain inter-organizational context. Nevertheless, a lack of trust or high levels of unfair and abusive practices curb chain partners' willingness to engage in potent relationships (Mahmud et al., 2021).

Another interesting finding is that, whilst relational coordination is an important contributor to supply chains' inter-organizational social and economic development, it does not directly benefit ecological performance. Therefore, the debate in the literature over which aspects directly affect inter-organizational supply chain sustainability performance remains open. On the other hand, a notable finding supported hypothesis H2 about the effect of formal coordination. This makes an essential contribution to the literature by determining that formality in exchanges improves supply chain sustainability performance, socially and economically, but does not directly enhance ecological performance. The knowledge could be extended here and elaborated more on the formal coordination construct and tested in future research designs.

7.2 Effects of transaction costs

Support was also found for hypothesis H3a; this contributes to the literature by determining that transaction costs have a significant effect on economic and social performance, but only in two-stage chains. The time frame of the exchange has the largest effect and is strongly associated with costly transactions, reflecting that actors perceive negotiations as time-consuming and laborious. The finding contrasts with previous studies (e.g., Xu & Beamon, 2006), which state that the more decentralized the supply chain (more actors), the more cumbersome, costly, and less optimal the transfer of the product. Transactions in a supply chain follow an iterative process, and as such, transaction costs tend to be less costly when parties coincide with an optimal allocation of the time per task. Therefore, we suggest that future research extends the transactions cost impact by examining categories such as information, decision, and enforcement.

7.3 Complementary effects of coordination mechanisms

Findings confirming H1, together with the result for H4 about the significant effect of formal coordination on relational coordination, indicate that relational coordination is a mediator (partially) between formal coordination and social and economic sustainability. Similarly, H3a was confirmed and together with the confirmed finding for H3b concerning the significant effect of formal coordination on transaction costs, indicates that transaction costs mediate (partially) the effect of formal coordination on social and economic sustainability. These are intuitive findings; however, the literature has not tested these relationships. This brings a valuable focus to the sustainable supply chain coordination literature, which does not differentiate the complementary effects of coordination mechanisms on sustainability performance. In addition, no mediation effects were found for environmental sustainability so it is important that future research designs further investigate these effects of coordination mechanisms.

Conclusion

The literature introduces the decision performance concept for the relationship between coordination mechanisms and agri-food supply chain performance. This study tested the role of formal and relational coordination and transaction features on sustainability performance across different supply chain stages. The formal and relational coordination mechanisms directly affected both social and economic sustainability performance in two-stage and three-stage supply chains. In two-stage chains, the relationships between formal coordination and social and economic performance were mediated by relational coordination and transaction costs. The three-stage chains differ; formal coordination and transaction costs mediate the relationships between relational coordination and social and economic performance.

The extant literature does not focus on the direct relationship between coordination mechanisms and sustainability performance of supply chains, e.g., Mariadoss, Chi, Tansuhaj, and Pomirleanu (2016) and Signori et al. (2015). In addition, it does not consider the different mediating effects of coordination mechanisms and transactions costs. Combining variables from the two construct groups (relational coordination and transactions costs) without considering their other effects is likely to affect the result of the relationships they are used to test.

Practical Implications

These findings indicate that relational, formal coordination mechanisms and trasaction costs are significant contributors to achieving supply chain sustainability. In order to improve supply chain environmental performance, managers will need to align their functional and strategic objectives with their supply chain environmental sustainability outcomes. Most importantly, however, this research indicates that a focus on relational and formal coordination and transaction costs will be the most effective approach for improving both supply chain social and economic sustainability performance. Naturally, relational and formal coordinations mechanisms will not be the only condition required to establish environmental sustainability; key resources and knowledge will also be required.

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