POMS PRODUCTION AND OPERATIONS MANAGEMENT

PRODUCTION AND OPERATIONS MANAGEMENT POMS
Vol. 25, No. 11, November 2016, pp. 1919–1941
ISSN 1059-1478 | EISSN 1937-5956 | 16 | 2511 | 1919
DOI 10.1111/poms.12585

Supply Chain Structure Incentives for Corporate Social Responsibility: An Incomplete Contracting Analysis

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Downstream firms increasingly recognize the importance of integrating social and environmental concerns with their businesses. As a consequence, they urge to create incentives for their suppliers to invest in corporate social responsibility (CSR) activities. Contracts to provide these incentives are rarely observed in practice. If not totally absent, contracts may be *incomplete*, in that unforeseen contingencies or some CSR attributes that are difficult to measure may not be included in the contract. We show that incentives for CSR investments can also be provided through the supply chain structure, which consists of the distribution of ownership rights over the firms' assets of production, and involves horizontal and/or vertical alliances among supply chain members. Motivated by examples in agricultural contexts, this study adopts the property rights approach to study the impact of supply chain structures on the adoption of CSR activities. We show that the structure that best incentivizes CSR investments depends on the interaction between CSR vertical synergy, free-riding, and countervailing power. One of the main findings is that the alliance between suppliers is beneficial only if the revenues generated by a downstream investment are sufficiently high. In fact, only in this case, the suppliers can appropriate a sufficiently large stake of the revenues generated downstream, thanks to their countervailing power. When the upstream investment costs become high, however, the suppliers will invest in CSR only if the downstream distributor is vertically integrated. The resulting structure of a cooperative will best incentivize CSR investments only if the CSR vertical synergy between the two tiers of the supply chain is sufficiently high.

Key words: corporate social responsibility; supply chain structure; incomplete contracting; property rights; Shapley value
History: Received: October 2015; Accepted: May 2016 by Charles Corbett, after 2 revisions.

1. Introduction

Corporate social responsibility (CSR) refers to the obligations of the firm to a broad set of stakeholders that go beyond the firm shareholders. Business leaders and entrepreneurs embracing CSR activities are focused on optimizing the profits of the firm, while ensuring positive impacts (and/or reducing negative impacts) of the firm's business to the planet and the society at large (triple bottom line: *profits*, *planet*, and *people*).

Nowadays, downstream firms face increasing pressure from governments, competitors, and employees to distribute and sell goods that were produced in a sustainable and socially responsible way. Following this trend, the need for distributors and retailers to design proper incentives for their suppliers to invest in meaningful CSR programs has become an overriding concern. Contracts specifying payments contingent on business performance have always been the classical tool for firms to provide such incentives. However, contracts in the context of CSR are rarely observed in practice. If not absent, contracts may be *incomplete*, in that they may not foresee and thus specify all possible future contingencies or may concern attributes of the CSR programs that are difficult to be meaningfully measured. Incomplete contracts will not be enforceable in a court of law, and thus fail to provide the required incentives to invest in CSR. In this article, we argue that incentives to invest in CSR can be provided through an appropriate design of the supply chain.

The lack of enforceable contractual terms resulted in detrimental consequences for the business of egg farmers in the Netherlands. Solicited by their distributors, the Dutch farmers made costly investments in developing animal-friendly housing and sustainable production and processing technologies. As a consequence of these CSR investments, the variable cost for cage-free eggs increased for some farmers to 7.5 euro cents. The distributors, however, paid only 4.5 euro cents for each egg, even after the farmers' investments, while charging consumers a price of 17 cents (Van der Heijden 2013). As a result, some egg farmers stopped their CSR investments. It has been argued that, in the absence of contractual guarantees of appropriate payments for CSR investments, the egg farmers should form alliances to increase their bargaining power with their distributors, and so get higher payments for cage-free eggs (Van der Heijden 2013). On the other hand, the company FrieslandCampina, one of the world's five largest dairy companies, is recognized as a champion of CSR activities in the Netherlands (Van Riel and Ederer 2011). This dairy company is a cooperative, that is, it is owned by the farmers who have vertically integrated their processor/distributor, and originated from the merger of Friesland Foods and Campina in 2008. Since then, FrieslandCampina has embraced an extensive CSR program, with an increasing commitment to high quality, sustainability, and transparency standards throughout the entire chain, as represented by the company motto, "from grass to glass." It is recognized that the CSR activities of the company allow the farmers to charge a price premium for their dairy products, as "the investments that are being made by member dairy farmers give added value to milk and dairy and hence result into value creation in the market" (Van Ooijen 2012).

The two examples above show that the design of the supply chain is of pivotal importance for incentivizing CSR investments. The structure of a cooperative such as FrieslandCampina seems to favor CSR investments, whereas the fragmented structure of egg farmers in the Netherlands seems to limit them—only a horizontal alliance between the farmers might foster new CSR investments. To better understand the impact of supply chain design on the CSR investments, in a context where contracts cannot be enforced, we adopt the property rights (PR) approach by Grossman and Hart (1986) and Hart and Moore (1990). We consider a supply chain with two suppliers and one distributor, where each supply chain member uses an asset of production (e.g., production line, distribution equipments, inventory, cattle, poultry) on which he can undertake a costly CSR investment. According to the PR approach, having *ownership rights* on the firm asset means being entitled to use the asset and receive payments from that use. A *supply chain structure* is defined as an alliance among the supply chain members, where ownership rights over the assets are assigned. For instance, the cooperative FrieslandCampina has the structure of a horizontal alliance between the farmers who have integrated their processor/distributor. The farmers have ownership rights over the assets of FrieslandCampina, whereas the processor/distributor does not have such rights. This article studies the impact of the supply chain structure on CSR investments.

Given the motivational examples for this research, it is relevant to consider the three following supply chain structures: market exchange with no alliance among the parties, horizontal alliance between suppliers, and cooperative. Each member of the supply chain can produce extra revenues by undertaking costly CSR investments. In fact, CSR investments have a positive externality on the supply chain revenues by either attracting more consumers to purchase the distributor's product (i.e., market expansion) or increasing the consumers' willingness to pay for the product (i.e., price premium). If a CSR investment is taken both upstream and downstream, the extra revenues are even higher than the sum of those generated only upstream and only downstream by the same investments, as there is a market segment which appreciates that the whole supply chain is committed to embracing CSR activities (Grimmer and Bingham 2013). We refer to this positive externality on the consumers as *CSR vertical synergy* between the suppliers and the distributor.

The horizontal alliance between the suppliers can create two different effects: *free-riding*, and *countervailing power*. Both effects occur when the suppliers pool their assets and share their revenues. By free-riding, one supplier may decide not to invest and take advantage of the other supplier's investment. This opportunistic behavior by one of the suppliers discourages CSR investments upstream the supply chain. Countervailing power is the increase of bargaining power that the suppliers attain against their distributor by pooling their assets. Thanks to the countervailing power, the suppliers can appropriate a larger stake of the revenues generated by the distributor. In the previous example of Dutch poultry, countervailing power may be important for the egg farmers to negotiate better prices for cage-free eggs.

Our model is based on the PR view of the firm, which focuses on how different alliances and distributions of ownership rights affect investment incentives of the contracting parties. In this view, exemplified by Williamson (1979), Grossman and Hart (1986), and Hart and Moore (1990), complete contracts are impossible due to (i) the costs of specifying all the relevant contingencies, (ii) the difficulties of negotiating the responsibilities of all parties in all contingencies, and (iii) the costs of monitoring the contract. Without complete contracts, companies cannot provide effective incentives for CSR investments. Classical payment schemes such as piece-rate pay, payment by commission, gain-sharing, profit-sharing, and bonus plans cannot be enforced (Bolton and Dewatripont 2005). A possible mechanism could be that suppliers and distributor share the CSR investments costs upfront, but this practice does not find empirical support: most often, cost-sharing agreements or other mechanisms are not used in the context of CSR (Norman and MacDonald 2004). The *incomplete* contracting setting seems appropriate then for the study of incentives for CSR investments.

With incomplete contracts, the parties acknowledge that by investing their bargaining *position* will weaken as they will become vulnerable to opportunistic behavior in future renegotiations, and as a consequence be deprived of the revenue share originally agreed upon (i.e., as in the Dutch poultry example). Through the formation of alliances and the assignment of ownership rights, the supply chain structure distributes bargaining *power* among the parties and may offer sufficient guarantees to recoup the investments costs.

We study both horizontal alliances, to reflect the case of Dutch egg farmers, and vertical alliances, to reflect the case of FrieslandCampina. A horizontal alliance between the suppliers may not always be beneficial. If the investment cost is high, the distributor will not invest in CSR, and thus will not generate extra revenues. As a consequence, a horizontal alliance would not benefit from countervailing power to appropriate a share of the distributors' revenues, and would be rather plagued by the inefficiencies of free-riding. A horizontal alliance becomes valuable, instead, when the distributor's CSR investment cost is sufficiently low, as the suppliers can earn a share of the distributor's extra revenues in this case, thanks to their countervailing power. In a cooperative, the suppliers have not only formed a horizontal alliance, but also vertically integrated the distributor. As such, when the investment costs of the suppliers become high, the cooperative is the only structure that can still provide incentives to the suppliers to invest. However, the cooperative will be the optimal supply chain structure only if the CSR vertical synergy is sufficiently high, as the distributor has no ownership rights over the assets, and thus his motivation to invest in CSR depends just on his role of enhancing the value of the suppliers' products. Previous work demonstrated that without ownership rights a cooperative would never emerge as a dominant structure, as the distributor would never invest in CSR (Hendrikse 2011). We show instead that the very fact that investments at both tiers of the supply chain add value to the suppliers' product provides a motivation to the distributor to invest, even without ownership rights on the distribution assets. In fact, the distributor in a cooperative receives a share of the supply chain revenues, as his CSR investment is crucial to enhance the value of the product and thus harvest additional revenues.

The remainder of this study is organized as follows. In section 2, we survey the related literature and position our work. In section 3, we describe the model and apply it to the three supply chain structures. Section 4 derives the equilibrium investments for each structure, whereas section 5 determines the equilibrium structure. In section 6, we discuss the limitations of our model and describe possible extensions that could motivate future research. Finally, section 7 formulates concluding comments.

2. Literature Review

Our study contributes to the streams of literature on *incentives* and *supply chain design* for CSR activities, and *incomplete contracts*. The supply chain literature has only recently addressed the problem of incentivizing CSR activities, focusing mainly on ways to induce suppliers to behave responsibly such as monitoring or inspection (Chen and Lee 2014, Cho et al. 2014, Kim 2014, Lewis et al. 2014). This stream of research does not study the impact of the supply chain structure on CSR activities. There are several ways to characterize a supply chain structure. Bagnoli and Watts (2003) model strategic CSR as arising from companies seeking a competitive advantage in their product markets; the provision of CSR is then affected by the structure of the market (consumers' willingness to pay for CSR) and the structure of competition. Mendoza and Clemen (2013) analyze the value of two supply chain structures (shared vs. separate suppliers) on firm incentives for responsibility. Guo et al. (2015) show that greater downstream competition, a more concentrated supplier base, and a less flexible supply chain all make a firm more likely to source responsibly. Finally, Karaer et al. (2015) investigate when a buyer can use competition or cost sharing to improve a supplier's environmental performance. We depart from the previous literature in two fundamental aspects. First, we consider CSR activities as observable but nonverifiable, which implies that any contract between the parties cannot be enforced in a court of law, and thus cannot represent the instrument to incentivize CSR activities. This aspect of our settings is crucial, as suppliers are required to invest in CSR *ex-ante* in order to create revenues, but such an investment may deteriorate their bargaining position against the distributor. Without a binding contract, the latter will opportunistically exploit the weak bargaining position of the suppliers, and eventually deprive them of adequate payments to recoup the costs of their investments. Second, our supply chain structure not only consists of horizontal and/or vertical alliances, but also of an assignment of ownership rights over the asset. Alliances and ownership rights determine the bargaining power of each member of the supply chain and allocate the revenues generated by the CSR investments.

Providing incentives through contracts is an important area of research in supply chain management (Crocker and Letizia 2014; Krishnan and Winter 2012). There are three branches of contract theory that can be distinguished (Bolton and Dewatripont 2005). The first assumes that all the parties have full information about the states of the world. The second relaxes this assumption of full information, and studies settings where an agent may have "private information" on some of these states and/or may take a "hidden action" that affects the value of these states. In both these branches, contracts are assumed to be *complete*, in the sense that they can specify all possible states of the world as long as they are observable. The underlying assumption for contract completeness is that writing contracts is costless. Finally, the third branch considers the case where the states of the world are observable but nonverifiable in a court. Contracts then are *incomplete*, and this may be due to the prohibitive costs of specifying all possible states of the world in a contract or to the difficulty in measuring some of the relevant variables. In this setting, it is no longer possible to provide investment incentives through contracts. These incentives depend rather on the institutional design of the supply chain. The most relevant works in the area of contracts incompleteness are those by Grossman and Hart (1986) and Hart and Moore (1990), which explore the role of ownership and residual rights of control of assets (i.e., the PR approach) in providing incentives. Institutional design issues are a prominent area of research in supply chain management (Grover and Malhotra 2003). As previously explained, an incomplete contracting setting seems appropriate for the study of incentives for CSR investments. As a consequence, we adopt the PR approach.

In the supply chain management literature, incomplete contracts have received scant attention, even though it is generally recognized that it would be practically impossible to specify all contingencies, decisions, rights, and obligations of the parties in a contract (Krishnan and Winter 2012). Some recent works have modeled long-term contracts, which are necessarily incomplete and thus result in the parties renegotiating the original contractual terms. Renegotiation may be motivated by uncertainty about demand at the time the contract is signed (Plambeck and Taylor 2007a), the need to make the contract more flexible for the buyer (Plambeck and Taylor 2007a, b), or product *nonspecifiability* during the product design phase (Iyer and Villas-Boas 2003). In our study, renegotiation is not explicitly modeled, but the final allocation of revenues is determined through the Shapley value (Hart and Moore 1990, Shapley 1953).

Previous research using the PR approach is mainly empirical. For instance, Novak and Eppinger (2001) focus on the connection between product complexity and vertical integration using empirical evidence from the auto industry. In fact, product development in the auto industry is a classical example of contractual incompleteness: after testing a component, the party that owns the assets at the production stage determines the changes that are to be made to the initial design. Other similar examples are provided by by Williams et al. (2002), Cox et al. (2007), and Boudreau (2010). In their note, Grover and Malhotra (2003) argue that there are many opportunities for adopting the PR approach to study problems of outsourcing, allocation of investments, supply chain coordination, and integration. To the best of our knowledge, our study is the first analytical attempt in the supply chain management literature to respond to this call. Finally, our work is close to the study by Hendrikse (2011), where the author analyzes five structures in which two heterogeneous suppliers can undertake a costly investment, whereas the distributor provides access to the market for the suppliers' products. Hendrikse (2011) finds that the party who has no ownership rights will never invest; thus, a cooperative will never emerge as an optimal structure. These settings, however, would not explain the increasing CSR investments by a cooperative such as FrieslandCampina. By modeling the vertical synergy between the two tiers of the supply chain, our study establishes that the distributor in a cooperative might be better off by investing in CSR, as his investment might create extra revenues for the whole company (for instance, it can justify price premiums for the dairy farmers' products). Further, we have explicitly modeled the strategic choice of the supply chain structure by each party, whereas the above article compares the supply chain structures in terms of efficiency, and determines which structure maximizes the overall supply chain profits. With this respect, our work has a better fit with the field of supply chain management, where, in absence of (coordinating) contracts, the parties make strategic choices with the objective of maximizing their own rather than the overall supply chain profits.

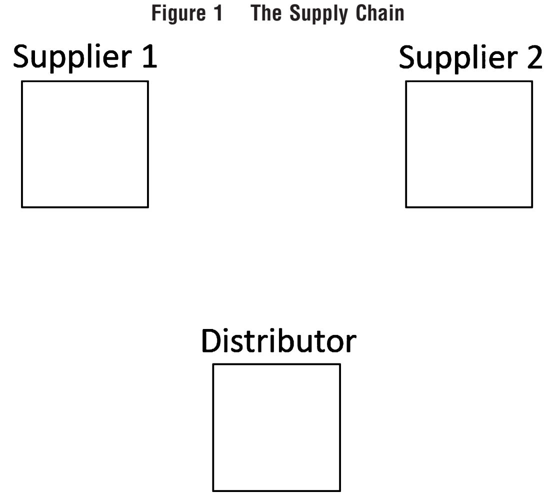
3. Model

We consider a two-tier supply chain with two upstream identical suppliers (players 1 and 2) and one downstream processor/distributor (player 3). A supply chain structure is characterized by a distribution of ownership rights and horizontal and/or vertical alliances between the upstream and downstream members of the supply chain. We consider three structures that capture practical alliance relationships within the chain and correspond to the motivating examples of Dutch poultry and FrieslandCampina.

The interaction between the supply chain structure and socially responsible operations is studied in a three stage game. In the first stage, the parties strategically choose the supply chain structure (i.e., supply chain structure game). For instance, the suppliers might decide to form a horizontal alliance, or they might decide to forward integrate the downstream distributor. In the second stage, each member of the supply chain decides whether to invest in CSR (i.e., investment decision game). In the third stage the parties engage in a multilateral bargaining process to allocate the revenues generated by the CSR investments (i.e., revenues allocation game). The second and third stages constitute a *biform* game (Brandenburger and Stuart 2007), as the parties *noncooperatively* decide about their CSR investments in the second stage, and then *cooperatively* allocate the generated revenues in the third stage. In the supply chain management literature, the biform game was first adopted by Anupindi et al. (2001) to model a distribution problem where independent retailers must order their inventory under demand uncertainty, and, after demand is realized, may earn additional profits by transhipping the leftover supplies to retailers with residual demands. The reader is referred to Nagarajan and Sošić (2008) for an extensive review of applications of biform games in a supply chain context. In our work, the supply chain structure game and the biform game are linked because the socially responsible investment choices of the chain parties are embedded within a supply chain structure.

To generate revenues, party i uses an asset of production, a_i (e.g., production plant, inventory, cattle), $i = 1, 2, 3$. Let x_1, x_2, and x_3 denote the CSR investment decisions of supplier 1, supplier 2, and the distributor, respectively; x_i can take on a value of either 0 or 1, where $x_i = 1(0)$ if and only if party i does (does not) invest. Through the CSR investment on a_i, party i generates extra revenues R_i, where we denote by A the extra revenues generated by the suppliers, that is, $R_i = A$ for $i = 1, 2$, and by B the extra revenues generated by the distributor, that is, $R_i = B$ for $i = 3$. The supply chain is represented in Figure 1.

Figure 1 The Supply Chain



When there are CSR investments at both the upstream and downstream stages of production, the value of the final product is increased. We model this added value through an exogenous parameter $s > 1$, which is referred to as the *CSR vertical synergy* within the supply chain. The total revenues of the supply chain when all parties invest in CSR is then given by $s(2A + B)$. To invest in CSR, party i incurs the cost k_i. As the two suppliers are identical, we assume $k_1 = k_2$ (from here on, k_1 will denote either k_1 or k_2). All players carry their cost of the investment entirely during the investment decision game, whereas they attain the associated revenues during the revenues allocation game.

In the context of a dairy product like milk, the two suppliers may represent farmers who decide to allow their cows graze in the meadow. Growing consumer interest in dairy products with organic and grass-fed labels may increase the market size and/or the willingness to pay for milk products, generating extra revenues equal to A per farmer. Paine (2009) reports several cases of grass-fed market development in the North of the United States. For instance, the farm Uplands Cheese in 2000 developed a new type of cheese to add value to their grass-fed milk. The farm increased the sales of its cheese from 6000 pounds in 2000 to 67,700 pounds in 2007, as consumers were increasingly attracted by both "the health aspects of the grass-fed cheese as well as animal welfare." Milk processors and distributors may also invest in sustainable operations; as a consequence their revenues may increase by B. The extra revenues B may derive from either an increase of the market size, due to consumers being attracted by the CSR initiatives of the distributors, or the reduction of the costs, due to a more efficient use of the resources by the distributors. For instance, in the 2012 sustainability report, the company Glanbia Foods documents its new ways to recycle water throughout their operations and reduce the amount of energy needed to cool their milk. The company reported an increase of revenues by 0.5 billion dollars in 2011, and estimated that this financial growth is substantially related to the company sustainability activities. Further, CSR investments at multiple tiers of the supply chain are shown to have an impact on the consumers' willingness to pay for the dairy product. Grimmer and Bingham (2013) report about segments of consumers that are more willing to purchase products from companies perceived to have a higher environmental performance at each stage of the product value chain. FrieslandCampina is an example of a cooperative where the farmers have actively developed grass-fed dairy products, while the milk processor/distributor has invested in green processing technologies. The 2012 CSR report of the cooperative documents an increase of the operating profits by 19.6% in 2012, due in part to an increase of the grass-fed milk price by almost 24% in the previous 3 years, and a more efficient use of energy, water and technology (Van Ooijen 2012).

Analytically, the parameters A and B can be illustrated through the following model of consumer demand. Assume consumers are heterogeneous in their willingness to pay v for the product, and are uniformly distributed over a bounded support with unit density, which we normalize to [0, 1]. A CSR investment in the product can have one of the two following effects or eventually both effects:

1. Market expansion,
2. Price differentiation.

In case 1, the CSR investment eventually affects the company reputation, without changing the product offered on the market. For instance, the suppliers and/or the distributor engage in some charity programs, and this strategy attracts more consumers to purchase the product. In particular, the CSR investment by the suppliers creates an effect of market expansion, so that the market size becomes $1 + a$, $a > 0$. Given the price p_A for the product, the demand is given by $1 - p_A$ *ex-ante* and by $(1 + a)(1 - p_A)$ *ex post* the CSR investment. The extra revenues A generated by each supplier are then given by: $2A = a(1 - p_A)$. If the CSR investment is undertaken by the distributor, and increases the market size to $1 + b, b > 0$, the extra revenues B generated by the distributor can be derived in a similar way.

In case 2, the CSR investment creates a different, socially responsible product, for which a portion of consumers has a higher willingness to pay δv, $\delta > 1$, than it has for the normal product. For instance, the Dutch egg farmers provide both cage-free and noncage-free eggs. Given the prices p_A and p_A^s for the normal and socially responsible product, respectively, the utility consumers extract from product purchase is $U_A = v - p_A$ for the standard product, and $U_A^s = \delta v - p_A^s$ for the socially responsible product. Consumers with willingness to pay $v^* = \frac{p_A^s - p_A}{\delta - 1}$ are indifferent among purchasing either product, whereas consumers with higher (lower) willingness to pay than v^* will buy the socially responsible (standard) product. The demand for the two products can be expressed as follows:

$$Q_A^s = \begin{cases} 1 - v^*, & p_A^s \geq \delta p_A \\ 1 - \frac{p_A^s}{\delta}, & \text{otherwise} \end{cases},$$

$$Q_A = \begin{cases} v^* - p_A, & p_A^s \geq \delta p_A \\ 0, & \text{otherwise} \end{cases}.$$

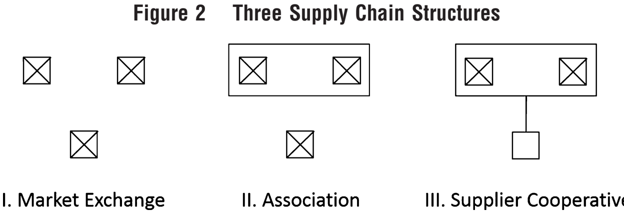
The extra revenues generated by the suppliers are then given by $2A = Q_A^s p_A^s + Q_A p_A - (1 - p_A)p_A$.

Consistent with the cases of the Dutch poultry farmers and the dairy company FrieslandCampina, we consider the three supply chain structures depicted in Figure 2. The structures are different along two dimensions: the distribution of *asset ownership* and the *alliance* among the chain members. In Figure 2, a cross in a box indicates that the corresponding party has ownership rights over the asset, which means that he has the power/authority to use the asset and to receive payments associated with that use. The Dutch poultry farmers are organized according to structure *I*, where each farmer owns his poultry and uses it to produce eggs and chicken meat. As discussed in the introduction, it is claimed that the farmers would increase their bargaining power against the distributor, such as retailer Albert Heijn, by forming a horizontal alliance, as represented in structure *II*. The dairy company FrieslandCampina evolved from an association of farmers that owned their processors to the full legal merger between Friesland Foods and Campina, which established the current supplier cooperative represented by structure *III*.

The alliance among the supply chain parties entails an agreement to jointly use the assets of production. It can be either horizontal or vertical, or both. Supply chain structure *I* represents market exchange, where each party is independent of the other parties in the supply chain. Thus, in structure *I* there is no alliance among the parties. In structure *II*, the two suppliers have formed a horizontal alliance, whereas supply chain structure *III* represents a cooperative, in which the suppliers have formed a horizontal alliance and have forward integrated the distributor. In structure *III*, the alliance is both horizontal and vertical.

We follow the approach by Hart and Moore (1990) to study the impact of a supply chain structure on the CSR investments by the parties, in an incomplete contracting setting. The first step is to determine the revenues created by each possible coalition of players, taking into account the investment decisions of the players, the allocation of asset ownership, and the alliance among the chain members. This is done by specifying the *characteristic function*, $v(C)$, for each coalition C. For instance, in structure *I* there are no alliances and each party is owner of the asset of production. Thus, the characteristic functions should be specified

Figure 2 Three Supply Chain Structures



for all types of coalitions among the members of the supply chain. The following assumption applies.

ASSUMPTION 1. *In structure I the characteristic functions are assigned the following values:*

(A1) $v(\{i\}) = x_i R_i$, *where* $R_i = A$ *for* $i = 1, 2$ *and* $R_3 = B$,

(A2) $v(\{i, j\}) = \{ v(\{i\}) + v(\{j\}),$ *if* $i + j \leq 3$ *or* $(i + j > 3$ *and* $x_i x_j = 0)$ $s[v(\{i\}) + v(\{j\})]$, *otherwise.*,

(A3) $v(\{1, 2, 3\}) = \left\{ s \sum_{i=1}^{3} v(\{i\}), \quad \text{if } x_j x_3 = 1, \right.$ $j = 1, 2 \sum_{i=1}^{3} v(\{i\})$*otherwise.*

(A1) states that player i will receive payments from the use of the asset as long as he invests in CSR. (A2) defines the revenues generated by a coalition of 2 players, taking into account that investments both upstream and downstream generate the CSR vertical synergy effect. Finally, (A3) specifies the total supply chain revenues, where again the vertical synergy may materialize.

Assuming all players have invested in CSR, i.e., $(x_1, x_2, x_3) = (1, 1, 1)$, the characteristic function values for all the coalitions in structure *I* are reported in Table 1. The characteristic functions for the cases where one or more parties do not invest can be computed in a similar way. For instance, for the case $(x_1, x_2, x_3) = (1, 0, 1)$, i.e., when supplier 2 is not investing in CSR, we have: $v(\{1\}) = v(\{1, 2\}) = A$, $v(\{2\}) = 0$, $v(\{3\}) = v(\{2, 3\}) = B$, and $v(\{1, 3\}) = v(\{1, 2, 3\}) = s(A + B)$.

The second step is to allocate the extra revenues generated by the CSR investments. The underlying assumption here is that the parties allocate the extra revenues from trade following a multilateral bargaining process. This process must have the following characteristics:

1. The allocation of revenues is unique;
2. The revenues are fully allocated among players;
3. The player that did not contribute to revenues receives an allocation of zero;
4. Identical players receive identical allocations.

All the properties above are jointly satisfied by the Shapley value. For this reason, it is adopted by Hart and Moore (1990) as the solution concept of the multilateral bargaining process. In the operations management literature, the Shapley value has been mainly used in the context of profit allocation (Kemahlioğlu-Ziya and Bartholdi 2011, Sošic 2006), cost allocation (Hartman and Dror 2005), contract renegotiation (Kemahlioğlu-Ziya 2015, Plambeck and Taylor 2007b), and price coordination (Yin 2010).

In our setting, the Shapley value is the outcome of the revenues allocation game. By definition, the Shapley value assigns each player i his marginal contribution, $(v(C \cup \{i\}) - v(C))$, to the subset of players C preceding i, when the ordering is randomly drawn from a uniform distribution. As explained in Cachon and Netessine (2004), if N is the set of players engaged in a cooperative game, there are $|C|!(|N| - |C| - 1)!$ ways to order players so that all the players in S are picked ahead of player i. If the orderings are equally likely, there is a probability of $|C|!(|N| - |C| - 1)!/|N|!$ that when player i is picked, he will already find a subset of $|C|$ players. The Shapley value for player i then is given by $\pi_i = \sum_{C \subseteq N \setminus i} \frac{|C|!(|N| - |C| - 1)!}{|N|!} (v(C \cup \{i\}) - v(C))$, and represents the expected marginal contribution of adding player i to the subset C of players.

As an example, we show how to compute the Shapley value of supplier 1, denoted by S_1, for the investment decision (1, 1, 1) in structure *I*. There are six possible orderings of the three players: {1, 2, 3}, {1, 3, 2}, {2, 1, 3}, {2, 3, 1}, {3, 1, 2}, and {3, 2, 1}. The marginal contributions of supplier 1 to the predecessors in each of these orderings is, respectively: $v(\{1\}) = A$, $v(\{1\}) = A$, $v(\{1, 2\}) - v(\{2\}) = A$, $v(\{1, 2, 3\}) - v(\{2, 3\}) = sA$, $v(\{1, 3\}) - v(\{3\}) = s(A + B) - B$, and $v(\{1, 2, 3\}) - v(\{2, 3\}) = sA$. The Shapley value for supplier 1 is the average of these contributions, which yields $S_1 = \frac{A(s+1)}{2} + \frac{B(s-1)}{6}$. Following a similar procedure, one can determine the Shapley values, S_i, $i = 1, 2, 3$, for all the investment decisions of the parties within structure *I*, as reported in Table 2.

For structures *II* and *III* we shall compute the characteristic functions and the Shapley values in two steps: the first, considering the upstream coalition of the two suppliers, {1, 2}, and the downstream coalition of the distributor, {3}; the second, focusing on the first coalition (i.e., {1, 2}) to determine how the two suppliers will split the total revenues generated upstream. The reason is that the two suppliers have formed a horizontal alliance, and so an allocation rule for the revenues of one single supplier and the distributor is problematic.

Table 1 Characteristic Function for Supply Chain Structure *I*, when All Players Invest in Corporate Social Responsibility

Characteristic function	$v(\{1\})$	$v(\{2\})$	$v(\{3\})$	$v(\{1, 2\})$	$v(\{1, 3\})$	$v(\{2, 3\})$	$v(\{1, 2, 3\})$
Value	A	A	B	$2A$	$s(A + B)$	$s(A + B)$	$s(2A + B)$

Consider structure *II*. Assuming $(x_1, x_2, x_3) = (1, 1, 1)$, in the first step we evaluate the characteristic functions for the two coalitions as follows: $v(\{1, 2\}) = 2A$, $v(\{3\}) = B$, and $v(\{1, 2\}, \{3\}) = s(2A + B)$. The possible orderings of the two coalitions are $\{\{1, 2\}, \{3\}\}$ and $\{\{3\}, \{1, 2\}\}$, to which coalition $\{1, 2\}$ contributes $v(\{1, 2\})$ and $v(\{1, 2\}, \{3\}) - v(\{3\})$, respectively, whereas coalition $\{3\}$ contributes $v(\{1, 2\}, \{3\}) - v(\{1, 2\})$ and $v(\{3\})$, respectively. The Shapley values then are given by $S_{\{1,2\}} = A(s+1) + \frac{B(s-1)}{2}$, and $S_{\{3\}} = A(s-1) + \frac{B(s+1)}{2}$. In the second step, we determine how the two suppliers will split the revenues generated by their coalition $\{1, 2\}$. The characteristic functions for the coalition of the two suppliers are given by: $v(\{1\}) = v(\{2\}) = A$, and $v(\{1, 2\}) = 2A$, and the associated Shapley values are equal to $S_{\{1\}} = S_{\{2\}} = 1/2$. This means that the two suppliers will split the upstream revenues in equal parts. Finally, the Shapley values for the three players can be computed as $S_1 = S_{\{1\}} S_{\{1,2\}} = \frac{A(s+1)}{2} + \frac{B(s-1)}{4}$, $S_2 = S_{\{2\}} S_{\{1,2\}} = \frac{A(s+1)}{2} + \frac{B(s-1)}{4}$, and $S_3 = S_{\{3\}} = A(s-1) + \frac{B(s+1)}{2}$. This procedure can be iterated for all the other combinations of investments, (x_1, x_2, x_3), resulting in the Shapley values reported in Table 3.

For structure *III*, it should be considered that the two suppliers are the owners of both the assets of production and those of distribution. Therefore, the two suppliers receive the revenues generated by the distributor. However, the distributor is needed to achieve the CSR vertical synergy in the supply chain. To formalize this scenario, we shall make the following assumption.

ASSUMPTION 2. *In structure III the characteristic functions are assigned the following values:*

(A4) $v(\{1,2\}) = \sum_{i=1}^{3} x_i R_i$, *where* $R_i = A$ *for* $i = 1, 2$ *and* $R_3 = B$,

(A5) $v(\{3\}) = 0$,

(A6) $v(\{1, 2\}, \{3\}) = \{ v(\{1, 2\}) + v(\{3\})$, *if* $(x_1 + x_2)x_3 = 0) s[v(\{1, 2\}) + v(\{3\})]$, *otherwise.*

(A4) and (A5) establish that the revenues generated by the distributor's investment are assigned to the coalition of the two suppliers. (A6) means that the distributor even without PR on the asset maintains his role of enhancing the total surplus by the factor s. Notice that if the distributor does not invest in CSR, the suppliers will harvest only the revenues generated by their own CSR investments, that is, $v(\{1, 2\}) = 2A$ if $x_3 = 0$. This means that there are no outside options for the suppliers to distribute their products through another distributor. More generally, in our model there are neither additional distributors for the suppliers nor additional suppliers for the distributor.

For the investment decision (1, 1, 1), we first determine the characteristic functions for the upstream and downstream coalitions as $v(\{1, 2\}) = 2A + B$, $v(\{3\}) = 0$, and $v(\{1, 2\}, \{3\}) = s(2A + B)$. Then, we focus on the coalition of the two suppliers and find that v

Table 2 Shapley Values of the Supply Chain Members for the Investment Decisions (x_1, x_2, x_3) in Structure *I*

(x_1, x_2, x_3)	S_1	S_2	S_3
(1, 1, 1)	$\frac{A(s+1)}{2} + \frac{B(s-1)}{6}$	$\frac{A(s+1)}{2} + \frac{B(s-1)}{6}$	$A(s-1) + \frac{B(2s+1)}{3}$
(1, 1, 0)	A	A	0
(1, 0, 1)	$\frac{A(s+1)}{2} + \frac{B(s-1)}{2}$	0	$\frac{A(s-1)}{2} + \frac{B(s+1)}{2}$
(0, 1, 1)	0	$\frac{A(s+1)}{2} + \frac{B(s-1)}{2}$	$\frac{A(s-1)}{2} + \frac{B(s+1)}{2}$
(1, 0, 0)	A	0	0
(0, 1, 0)	0	A	0
(0, 0, 1)	0	0	B

Table 3 Shapley Values of the Supply Chain Members for the Investment Decisions (x_1, x_2, x_3) in Structure *II*

(x_1, x_2, x_3)	S_1	S_2	S_3
(1, 1, 1)	$\frac{A(s+1)}{2} + \frac{B(s-1)}{4}$	$\frac{A(s+1)}{2} + \frac{B(s-1)}{4}$	$A(s-1) + \frac{B(s+1)}{2}$
(1, 1, 0)	A	A	0
(1, 0, 1)	$\frac{A(s+1)}{2} + \frac{B(s-1)}{2}$	0	$\frac{A(s-1)}{2} + \frac{B(s+1)}{2}$
(0, 1, 1)	0	$\frac{A(s+1)}{2} + \frac{B(s-1)}{2}$	$\frac{A(s-1)}{2} + \frac{B(s+1)}{2}$
(1, 0, 0)	A	0	0
(0, 1, 0)	0	A	0
(0, 0, 1)	0	0	B

$(\{1\}) = A$, $v(\{2\}) = A$, and $v(\{1, 2\}) = 2A + B$. Following a similar procedure as per structure *II*, the Shapley values for all the investment decisions of the parties in structure *III* are reported in Table 4.

The CSR investments undertaken, the distribution of ownership rights along the supply chain, and the horizontal and vertical alliances among the parties generate the three following effects:

1. *CSR vertical synergy*: This materializes when at least one supplier and the distributor decide to invest in CSR. In this case, independently of assets ownership, the total surplus will be augmented by the factor $s > 1$. For instance, the lack of asset ownership by the distributor in structure *III* does not prevent him from investing, as his investment is essential to generate the CSR vertical synergy. This gives the distributor bargaining power, and thus a positive Shapley value, as long as at least one of the two suppliers invests in CSR. If instead none of the suppliers invests, then the revenues generated by an eventual investment by the distributor will be assigned to the two suppliers, resulting in a zero Shapley value for the distributor (i.e., $S_3 = 0$ for $(x_1, x_2, x_3) = (0, 0, 1)$ in Table 4).
2. *Free riding*: This is the effect of one party realizing positive revenues even without investing in CSR. For instance, in structure *III*, supplier 1 attains revenues $\frac{B(s+1)}{4}$ for the investment decision (0, 1, 1) (see Table 4), i.e., the revenues of supplier 1 in structure *III* are positive even without him investing.
3. *Countervailing power*: This is the effect of the two suppliers offsetting the bargaining power of the processor/distributor by forming an association. For instance, in structure *I* suppliers 1 and 2 appropriate just one-sixth of the revenues generated by the distributor (i.e., $\frac{B(s-1)}{6}$), whereas they appropriate one-fourth of them by forming the association in structure *II* (i.e., $\frac{B(s-1)}{4}$). These different shares reflect the bargaining power of the two suppliers, which is larger in *II* than in *I*. The same effect can be captured by comparing the Shapley values of the distributor in structures *I* and *II*, where we notice that $B(2s + 1)/3 > B(s - 1)/2$, that is, the distributor retains a lower share of his revenues and thus loses bargaining power if the suppliers have formed an association.

We assume that the investments are taken in sequence by supplier 1, supplier 2, and the distributor. As a consequence, the investment decision game is a three stage game, where each party decides non-cooperatively about her investment decision. Investments may not be profitable as the investing party i has to incur the cost k_i. In case of negative profits, the party will not invest in CSR, and so she will not contribute to the revenues that will be cooperatively allocated during the revenue allocation game. Depending on the CSR investment decisions of all members of the supply chain, the revenues allocated to each party are given by the corresponding Shapley values. The biform game can be conveniently represented in extensive form, as shown in Figure 3 for supply chain structure *I*. In Appendix B we show that our results are robust to two other cases of investment sequences, that is, suppliers investing simultaneously, and distributor investing before the suppliers.

4. Equilibrium Investments

In this section, we focus on the biform game, assuming the supply chain structure has been already selected in the first stage. For each structure, we derive the Subgame Perfect Equilibrium (SPE), which results in equilibrium investment decisions and the associated allocation of payoffs to each party. The SPE can be conveniently represented in the investment costs plane, k_1k_3. Four areas corresponding to four different SPEs can be distinguished. If k_1 and k_3 are both high, none of the parties will invest, whereas if they are both low all of them will invest in CSR. In the other two cases, where the upstream and downstream investment costs are one low and the other high, the

Table 4 Shapley Values of the Supply Chain Members for the Investment Decisions $(\mathbf{x}_1, \mathbf{x}_2, \mathbf{x}_3)$ in Structure *III*

(x_1, x_2, x_3)	S_1	S_2	S_3
(1, 1, 1)	$\frac{A(s+1)}{2} + \frac{B(s+1)}{4}$	$\frac{A(s+1)}{2} + \frac{B(s+1)}{4}$	$A(s-1) + \frac{B(s-1)}{2}$
(1, 1, 0)	A	A	0
(1, 0, 1)	$\frac{A(s+1)}{2} + \frac{B(s+1)}{4}$	$\frac{B(s+1)}{4}$	$\frac{A(s-1)}{2} + \frac{B(s-1)}{2}$
(0, 1, 1)	$\frac{B(s+1)}{4}$	$\frac{A(s+1)}{2} + \frac{B(s+1)}{4}$	$\frac{A(s-1)}{2} + \frac{B(s-1)}{2}$
(1, 0, 0)	A	0	0
(0, 1, 0)	0	A	0
(0, 0, 1)	$\frac{B}{2}$	$\frac{B}{2}$	0

CSR investment will be undertaken only where the investment cost is low. The SPE for structure *I* is represented in Figure 4, where one can notice the four areas previously described: the two symmetric equilibria, (1, 1, 1) and (0, 0, 0), where either all or none of the parties, respectively, invest, and the two asymmetric equilibria, (1, 1, 0) and (0, 0, 1), where the investment is undertaken either upstream or downstream, respectively. There is, however, an additional asymmetric equilibrium, (1, 0, 1), where the CSR investment is undertaken upstream only by supplier 1. The reason for this outcome is that the benefits of the CSR vertical synergy are higher for one supplier when he is the only one to invest upstream. With both suppliers investing, in fact, the competition between the two suppliers would decrease their payoffs. As a matter of fact, $S_1 = \frac{A(s+1)}{2} + \frac{B(s-1)}{6}$ for the investment vector (1, 1, 1), whereas $S_1 = \frac{A(s+1)+B(s-1)}{2}$ for (1, 0, 1). Thus, supplier 1 is better off when he is the only investing party upstream. As k_1 becomes sufficiently large to prevent both suppliers from investing, supplier 1 exploits his advantage as the first mover and invests in CSR. Supplier 2 then prefers not investing and realizing a zero payoff above investing and realizing a negative payoff for both him and supplier 1.

Regarding structure *II*, recall that the suppliers have formed an association, which creates countervailing power against the downstream distributor. Hence, structure *II* should provide the suppliers with higher and the distributor with lower incentives to invest in CSR than structure *I*. The following proposition formalizes this result.

Proposition 1. *The SPE investments for structure I and II are presented in Figure 4, where the threshold values of the cost* k_1 *are given by* $\alpha_I = \frac{A(s+1)}{2} + \frac{B(s-1)}{6}$ *and* $\alpha_{II} = \frac{A(s+1)}{2} + \frac{B(s-1)}{4}$*, whereas those of the cost* k_3 *are given by* $\gamma_I = A(s-1) + \frac{B(2s+1)}{3}$ *and* $\gamma_{II} = A(s-1) + \frac{B(s+1)}{2}$.

The difference in the threshold values of the costs suggests that the equilibrium (1, 1, 1) can be sustained in structure *II* for higher values of the cost k_1 (i.e., $\alpha_{II} > \alpha_I$) but for lower values of the cost k_3 (i.e., $\gamma_I > \gamma_{II}$) than in structure *I*. This means that the suppliers have a stronger incentive to invest in structure *II* than in *I*, whereas the opposite is true for the

Figure 4 Subgame Perfect Equilibrium Investments for Structures *I* and *II*. The values of α_S and γ_S are given in Proposition 4 for $S = \{I, II\}$

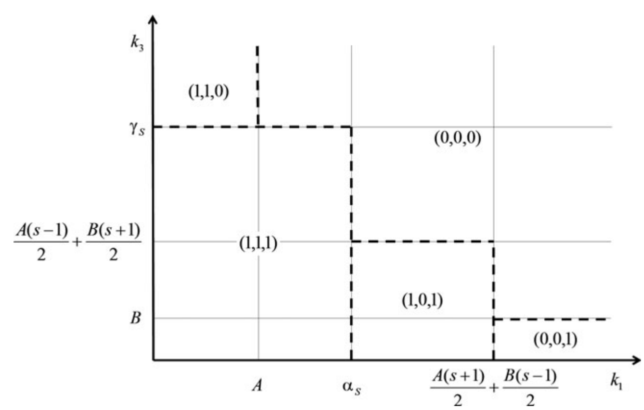
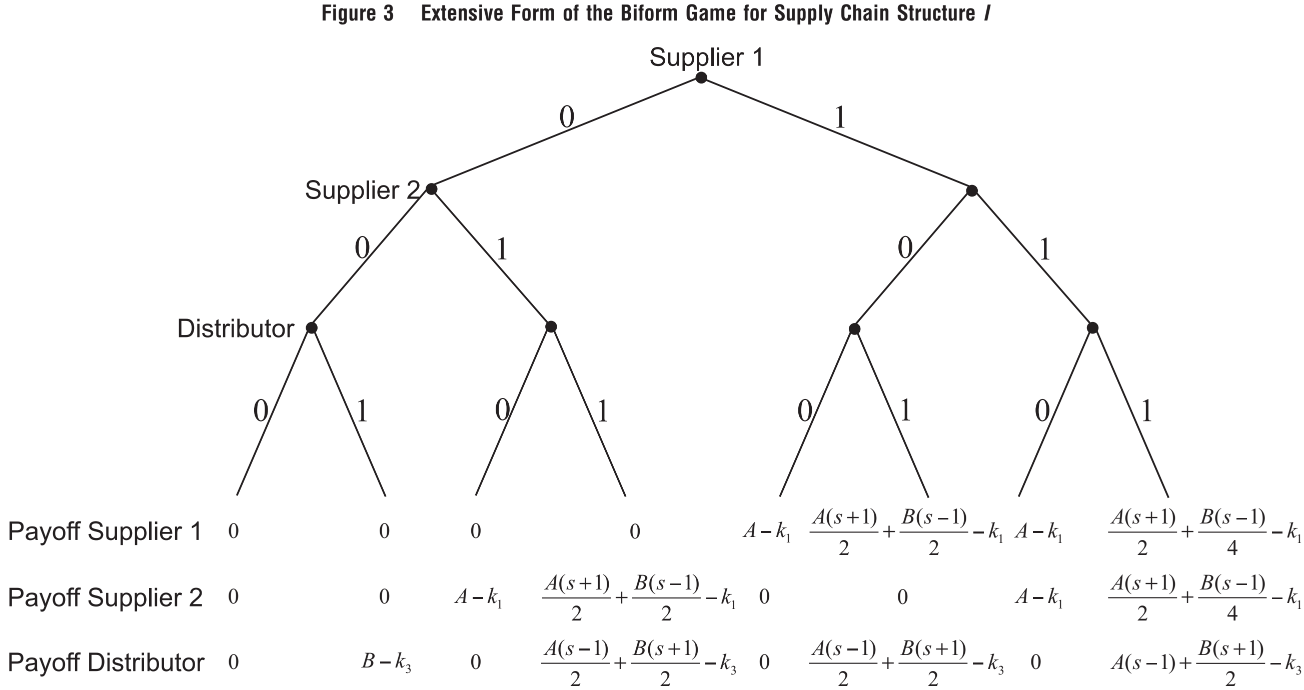


Figure 3 Extensive Form of the Biform Game for Supply Chain Structure *I*



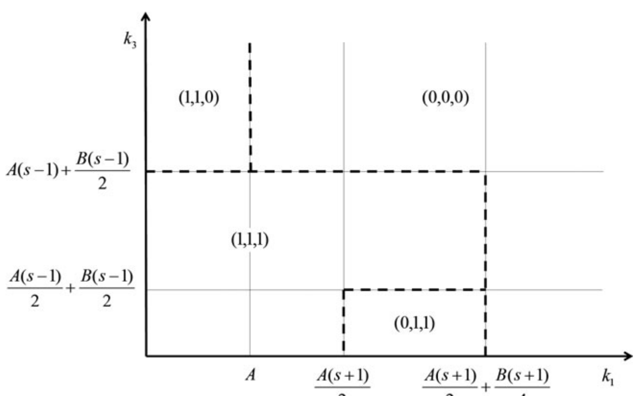
distributor. This result is driven by the countervailing power that the suppliers create through the alliance in *II*. The distributor is hurt by this increased power upstream, and so there are ranges of values for k_3 such that the distributor will invest in *I* but not in *II*.

Regarding structure *III*, one would expect that the equilibrium investment decisions be in line with the overall pattern that a party invests (does not invest) when the cost of the investment is sufficiently low (high). However, this is not always the case. The SPEs of the investment decision game for structure *III* are stated in the following proposition.

PROPOSITION 2. *The equilibrium investment decisions in structure III are presented in Figure* 5.

There are two SPE in structure *III* that are somewhat unexpected. The first is the investment decision (0, 0, 0) for $k_1 > \frac{A(s+1)}{2} + \frac{B(s+1)}{4}$, where the distributor decides not to invest in CSR, no matter how low his investment cost k_3 is. This outcome is due to the distributor's lack of asset ownership and the need for the investment by at least one supplier to realize the CSR vertical synergy. For k_1 sufficiently high, none of the suppliers opts for investing. In structure *III*, the only incentive to invest for the distributor is to realize the CSR synergy effect between the two tiers of the supply chain. However, with no supplier investing, this synergy cannot be realized, and so the distributor loses any incentive to invest in CSR. The second unexpected SPE is the asymmetric equilibrium (0, 1, 1) for $k_1 \in [\frac{A(s+1)}{2}, \frac{A(s+1)}{2} + \frac{B(s+1)}{4}]$ and $k_3 \leq \frac{A(s-1)}{2} + \frac{B(s-1)}{2}$, where the CSR investment is taken upstream by just the second supplier. The rationale for this asymmetry is that the distributor invests only when at least one of the suppliers invests, because he is essential for the realization of the CSR vertical synergy. Both suppliers investing is not an equilibrium because, if $k_1 > \frac{A(s+1)}{2}$, for either supplier the payoff of not investing (i.e., $\frac{B(s+1)}{4}$) will be greater than the one of investing (i.e., $\frac{A(s+1)}{2} + \frac{B(s+1)}{4}$). Having the advantage of the first mover, supplier 1 opts then for free-riding, and this decision will necessarily lead supplier 2 to invest together with the distributor to have a positive payoff.

Figure 5 Subgame Perfect Equilibrium Investments for Structure *III*



From the SPE of structures *II* and *III* one can notice that the incentives for the suppliers to invest in CSR are higher in the latter than the former structure. In fact, the suppliers in *III* benefit not only from the countervaliling power against the distributor, but also from the ownership of the asset at the downstream stage of production. The distributor instead has lower incentives to invest in CSR as he shifts from *II* to *III*, because in the latter structure he is deprived of the ownership of the asset of production and sees his role limited to the sheer realization of the CSR vertical synergy.

5. Supply Chain Structure Choice

We now turn to the first stage of the game, where the supply chain members decide which of the three structures to form. Clearly, each party prefers the supply chain structure that yields the highest profits for its firm. The outcome of this stage then is not obvious, as there might be no unanimous agreement on the preferred structure. We shall proceed in two steps. First, we identify for each player the ranking of the three supply chain structures for all possible parameter values. Second, we determine the equilibrium structure through the approach of *blocking* in coalition formation, when preferences differ (Ray and Vohra 2015).

Given the SPE derived in section 4, we can compare the profits attained in the three structures by each supply chain member. There are several general patterns on the preferences of the parties for the supply chain structures. A first general pattern is that the suppliers tend to lose interest toward a horizontal alliance as k_1 becomes low and k_3 becomes high. In fact, for k_3 high the distributor is not incentivized to invest in CSR; thus, an alliance between suppliers would not benefit from the countervailing power and would be rather plagued by the inefficiency of free-riding. For low values of k_1 and high values of k_3 then, the market exchange structure in *I* is favoured, as the lack of a horizontal alliance between the two suppliers maximizes the chances that the distributor will invest in CSR. The alliance between the suppliers becomes valuable, instead, as k_3 decreases and k_1 increases. In this case, the distributor has stronger incentive to invest than before, and so the suppliers are motivated to take a share of his revenues. As a consequence, for intermediate values of k_3 and k_1, structure *II* is the structure preferred by all parties. The following proposition describes this pattern.

PROPOSITION 3. *Structure I (II) is the preferred structure by all parties for* $(k_3, k_1) \in \Gamma_1(\Gamma_2)$, *where* $\Gamma_1 = \left\{(k_1, k_3):\ A(s-1) + \frac{B(s+1)}{2} \le k_3 \le A(s-1) + \frac{B(2s+1)}{3} \wedge k_1 \le \frac{A(s+1)}{2} + \frac{B(s-1)}{6}\right\}$ *and* $\Gamma_2 = \left\{(k_1, k_3):\ A(s-1) + \frac{B(s-1)}{2} \le k_3 \le A(s-1) + \frac{B(s+1)}{2} \wedge \frac{A(s+1)}{2} + \frac{B(s-1)}{6} \le k_1 \le \frac{A(s+1)}{2} + \frac{B(s-1)}{4}\right\}$.

The alliance between the suppliers in structure *III* is different than the one in structure *II*, as it deprives the distributor of ownership rights and gives him the exclusive role of realizing synergy in CSR. A second general pattern in the preferences of the parties among the structures, then, is that structure *III* will be the preferred structure by all parties when the following three conditions are satisfied: (i) k_1 is sufficiently high, as the suppliers have in structure *III* the highest incentives to invest in CSR, due to both their alliance and the ownership rights on the distributor's asset, (ii) k_3 is sufficiently low, to allow the distributor to invest in CSR, and (iii) s is sufficiently high, to strengthen the distributor's incentive to invest. The next proposition specifies the area in the plane k_1k_3 where the parties will unanimously agree to form structure *III*.

PROPOSITION 4. *Structure III is the preferred structure by all parties for either of the following conditions:*

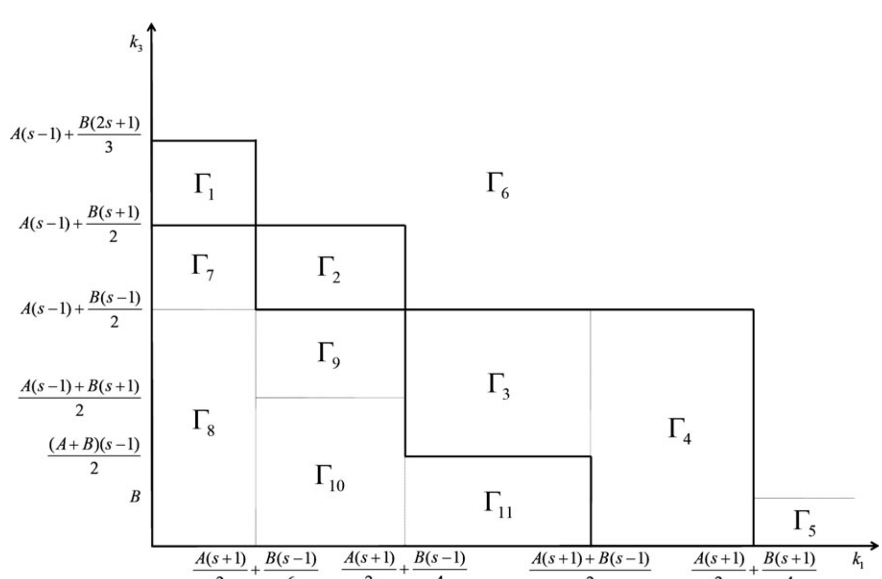
1. $\frac{A+3B}{A+B} \le s \le \frac{A+2B}{A}$ and $(k_3, k_1) \in \Gamma_3$,
2. $s \ge \frac{A+2B}{A}$ and $(k_3, k_1) \in \Gamma_3 \cup \Gamma_4$,

where $\Gamma_3 \equiv \{(k_3, k_1):\ \frac{(A+B)(s-1)}{2} \le k_3 \le A(s-1) + \frac{B(s-1)}{2} \wedge \frac{A(s+1)}{2} + \frac{B(s-1)}{4} \le k_1 \le \frac{A(s+1)+B(s-1)}{2}\}$ *and* $\Gamma_4 \equiv \{(k_3, k_1):\ k_3 \le A(s-1) + \frac{B(s-1)}{2}) \wedge \frac{A(s+1)+B(s-1)}{2} \le k_1 \le \frac{A(s+1)}{2} + \frac{B(s+1)}{4}\}$.

Proposition 4 highlights another important pattern in the preferences of the parties among the structures to form. That is, structure *III* is the preferred structure only for a sufficiently high vertical synergy parameter s. In other words, the distributor allows the suppliers to forward integrate with him only if his contribution to enhancing the value of the CSR investments is sufficiently high. The case of FrieslandCampina reflects the importance of the CSR synergy between the company and its suppliers. In fact, as reported by its CSR report, the increasing commitment of the company to high quality, sustainability, and transparency is recognized as positively affecting the market value of the dairy products supplied by the farmers owning the company.

An illustration of the results in Propositions 3 and 4 is provided in Figure 6 for $s \ge \frac{A+2B}{A}$. The areas in the plane k_1k_3 in which the preferences of the parties converge to the same structure choice are Γ_1 for structure *I*, Γ_2 for *II*, and $\Gamma_3 \cup \Gamma_4$ for *III*. In all the other areas, except Γ_5 and Γ_6 where the parties are indifferent among structures, there is no agreement about which structure to choose. Table 5 shows the different rankings of structures by the suppliers and the distributor in the areas $\Gamma_1 - \Gamma_{11}$, where the notation $X \succ Y$ means that structure X is strictly preferred to structure Y whereas $X \sim Y$ denotes indifference between

Figure 6 Areas in the Plane k_1k_3 with Different Rankings of the Preferences of the Supply Chain Members among the Three Structures for $s \ge \frac{A+2B}{A}$. The supply chain members unanimously prefer structure *I* in Γ_1, structure *II* in Γ_2, and structure *III* in $\Gamma_3 \cup \Gamma_4$



the two structures. For instance, from Table 5 we see that in the area Γ_8 the two suppliers have preferences $III \succ II \succ I$, whereas for a higher value of k_3, in Γ_7, they have preferences $II \succ I \succ III$. These different preferences occur because the suppliers want the distributor to invest, and as k_3 increases, the distributor has more incentive to invest in *II* than in *III*. The latter structure, in fact, deprives the distributor of his ownership rights, and so decreases his incentive to invest in CSR. In the same two areas, Γ_7 and Γ_8, the distributor has preferences $I \succ II \succ III$. As a matter of fact, it is better for the distributor that no countervailing power is formed upstream, when the suppliers invest in CSR. Structure *I* then is the structure preferred by the distributor. Similar reasoning can be applied to all the other areas of Figure 6. Notice that there are three other cases of preferences rankings, depending on ranges of values of *s*. The complete analysis is reported in Appendix A.

Whenever the parties have no unanimous agreement about the structure to form, we adopt the blocking approach in coalition formation to derive the equilibrium structure. To formally characterize this approach, recall that a supply chain structure is characterized by an allocation of asset ownership and an alliance structure. A *refinement* of an alliance structure occurs when at least one party has left the alliance. For instance, structure *I*, where the suppliers have no horizontal alliance, is a refinement of structure *II*, where they do have a horizontal alliance. Let π_{ij} represent the equilibrium payoff of player *i* in the alliance structure *j*. Given the vector of investment decisions, $\boldsymbol{x}_j^*$, the Shapley value, S_{ij}, and the investment decision of player *i* in the alliance structure *j*, x_{ij}, we have $\pi_{ij} = S_{ij}(\boldsymbol{x}_{ij}^*) - x_{ij}k_i$. An alliance is blocked according to the following definition.

Definition 1. *Let the alliance structure A' be a refinement of the alliance structure A. A' is defined to block A if $\exists$ a coalition $J \subset A' : \exists i \in J : \pi_{iA'} > \pi_{iA}$.*

Table 5 Preferences of the Supply Chain Members for Each Area in the Plane k_1k_3 for s $\geq \frac{A+2B}{A}$

Area in k_1k_3	Preferences supplier 1	Preferences supplier 2	Preferences distributor
Γ_1	$I \succ II \sim III$	$I \succ II \sim III$	$I \succ II \sim III$
Γ_2	$II \succ I \sim III$	$II \succ I \sim III$	$II \succ I \sim III$
Γ_3	$III \succ I \sim II$	$III \succ I \sim II$	$III \succ I \sim II$
Γ_4	$III \succ I \sim II$	$III \succ I \sim II$	$III \succ I \sim II$
Γ_5	$I \sim II \sim III$	$I \sim II \sim III$	$I \sim II \succ III$
Γ_6	$I \sim II \sim III$	$I \sim II \sim III$	$I \sim II \sim III$
Γ_7	$II \succ I \succ III$	$II \succ I \succ III$	$I \succ II \succ III$
Γ_8	$III \succ II \succ I$	$III \succ II \succ I$	$I \succ II \succ III$
Γ_9	$III \succ II \succ I$	$III \succ II \succ I$	$II \succ III \succ I$
Γ_{10}	$III \succ I \succ II$	$III \succ II \succ I$	$II \succ III \succ I$
Γ_{11}	$III \succ I \sim II$	$III \succ I \sim II$	$I \sim II \succ III$

According to definition 1, an alliance structure is blocked when at least one member of its refinement is strictly more profitable in the refinement than in the alliance structure. The approach of blocking is used to determine the equilibrium supply chain structure. Despite that we distinguish only three supply chain structures, this approach can be quite involved. In fact, there are six possible rankings of the supply chain structures for each player, and therefore $6 \times 6 \times 6 = 216$ possibilities for all the players. However, most of these possible rankings do not occur in equilibrium, due mainly to the two suppliers being identical. As reported in Tables 5 and A2, we have a total of 14 combinations of rankings for all possible parameter values.

By applying the blocking approach, we determine the equilibrium structure in all the cases where there is no unanimous agreement on the structure to form. Consider, for instance, the area Γ_7, where the two suppliers have preference $II \succ I \succ III$, whereas the distributor has preference $I \succ II \succ III$. The equilibrium structure in this case will be *II*, as both suppliers are better off by forming an alliance, whereas the distributor cannot block an alliance he would not be part of. Consider now the area Γ_{10}, where the supplier 1 has preference $III \succ I \succ II$, supplier 2 preference $III \succ II \succ I$, and the distributor $II \succ III \succ I$. In this case, the distributor will block the formation of the cooperative in *III* (as he prefers *II* to *III*), whereas supplier 1 will block the horizontal alliance in *II* (as he prefers *I* to *II*). In the end, the equilibrium structure in Γ_{10} will be *I*. With a similar reasoning, we can solve for all the cases where the parties have different preferences among the three structures. The equilibrium structure then is derived in the following result.

Proposition 5. *The unique equilibrium structure is:*

- *Structure I for either of the two conditions:*

  (1a) $k_1 \leq \frac{A(s+1)}{2} + \frac{B(s-1)}{6}$ *and* $A(s-1) + \frac{B(s+1)}{2} \leq k_3 \leq A(s-1) + \frac{B(2s+1)}{3}$,

  (2a) $\frac{A(s+1)}{2} + \frac{B(s-1)}{6} \leq k_1 \leq \frac{A(s+1)}{2} + \frac{B(s-1)}{4}$ *and* $k_3 \leq \frac{A(s-1)+B(s+1)}{2}$.

- *Structure II for either of the two conditions:*

  (1b) $k_1 \leq \frac{A(s+1)}{2} + \frac{B(s-1)}{6}$ *and* $k_3 \leq A(s-1) + \frac{B(s+1)}{2}$,

  (2b) $\frac{A(s+1)}{2} + \frac{B(s-1)}{6} \leq k_1 \leq \frac{A(s+1)}{2} + \frac{B(s-1)}{4}$ *and* $\frac{A(s-1)+B(s+1)}{2} \leq k_3 \leq A(s-1) + \frac{B(s+1)}{2}$.

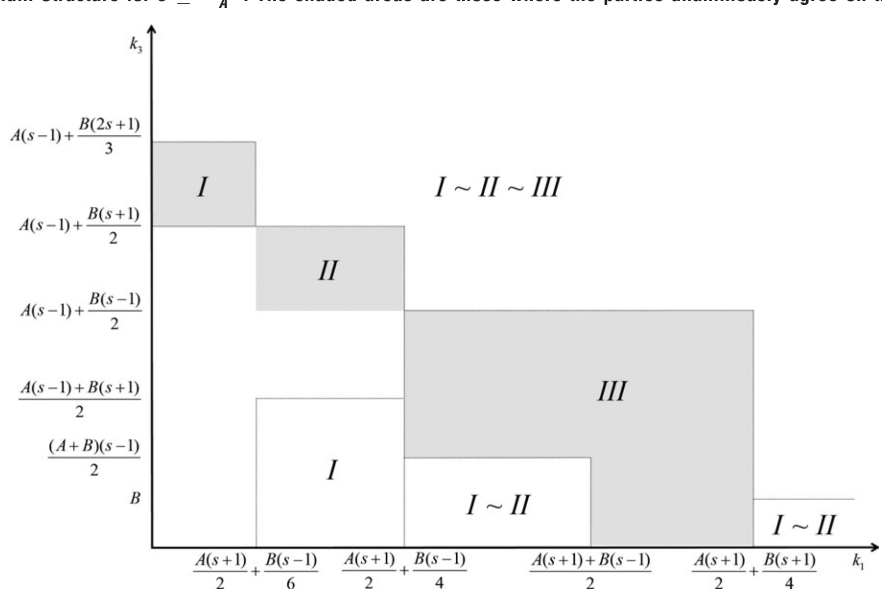
- *Structure III if and only if it is the preferred structured by all parties as per Proposition 4.*

An illustration of the results in Proposition 5 is provided in Figure 7, for the case $s \geq \frac{A+2B}{A}$. The shaded areas are those where there is unanimous agreement among the parties about the structure to form. Through the blocking approach, the equilibrium structure has been derived also for the areas where the parties do not have such an agreement. It is apparent that a horizontal alliance can be an important incentive for the suppliers to invest in CSR. The prerequisite is that the investment costs for both the suppliers and the distributor are sufficiently low. In fact, high costs would discourage CSR investments and a horizontal alliance upstream becomes profitable only if the ensuing countervailing power allows the suppliers to appropriate a sufficiently large share of the distributor's revenues. With the distributor not investing (i.e., $k_3 > A(s-1) + \frac{B(s+1)}{2}$), instead, a suppliers' alliance would not benefit from such countervailing power and be rather plagued by the inefficiencies of free-riding. The market exchange structure, in this case, provides the highest incentives to invest in CSR. It seems counterintuitive, however, that structure *I* may emerge again as the equilibrium structure when the cost k_3 is low (i.e., result (2a) of Proposition 5). As low k_3 motivates the distributor to invest in CSR, shouldn't the suppliers form an alliance also in this case? The rationale here is that for $k_1 > \frac{A(s+1)}{2} + \frac{B(s-1)}{6}$ it is no more convenient for the two suppliers to invest, thus the equilibrium (1, 0, 1) emerges in structure *I*. Supplier 1 has the advantage to be the only investing party upstream, and so he can attain higher revenues in structure *I* than through the alliance in *II*. Supplier 1 then blocks the formation of structure *II*.

Another counterintuitive result in Proposition 5 is related to structure *III*, which emerges as the equilibrium structure for $\frac{A(s+1)}{2} + \frac{B(s-1)}{4} \leq k_1 \leq \frac{A(s+1)+B(s-1)}{2}$, but only if k_3 is sufficiently high (i.e., $k_3 \geq \frac{(A+B)(s-1)}{2}$). Why do high investment costs lead the distributor to prefer being vertically integrated? The reason is that the distributor invests in any case for $k_3 \leq A(s-1) + \frac{B(s+1)}{2}$. However, as k_3 increases he prefers both suppliers investing, which is guaranteed only by structure *III*, than just one of them investing, as it would occur in structures *I* and *II*. In fact, with both suppliers investing, the distributor can benefit from a larger share of the overall supply chain revenues, thanks to the CSR vertical synergy between the upstream and downstream tiers of the supply chain. Notice that in the remaining areas in the plane k_1k_3, the supply chain members are indifferent between two or more structures. This result is due to the fact that either the two suppliers do not invest, so that $I \sim II$, or none of the parties invest, so that $I \sim II \sim III$.

Going back to the motivating examples for this research, our findings confirm that at equilibrium an alliance structure among the supply chain members can be an important incentive for investing in CSR, as long as both the suppliers and the distributor incur limited costs to invest in CSR. Applying this result to the case of fragmented poultry farmers in the Netherlands, the investments in building poultry friendly stables may be assumed as reasonably limited. Thus, the egg farmers should benefit from a horizontal alliance, as their increased bargaining power will allow them to obtain better deals from their distributors. Regarding

Figure 7 Equilibrium Structure for $s \geq \frac{A+2B}{A}$. The shaded areas are those where the parties unanimously agree on the structure to form



dairy farmers, the investments associated to the cattle welfare may be higher than those associated to the poultry welfare. As a consequence, dairy farmers could be better off by forward integrating their distributor. Indeed, forward integration of the distributor allows the suppliers to appropriate the extra revenues that are generated by his CSR investments. The cooperative is sustained, however, only when there is a high vertical synergy between the CSR activities of the distributor and those of the suppliers. FrieslandCampina is a remarkable example of vertical synergy between the company and its farmers who own it, as the company increasing commitment to high quality, sustainability, and transparency has allowed the farmers to increase their revenue by charging a price premium for their dairy products (Van Ooijen 2012).

6. Limitations and Future Research

The analysis above limited to considering one specific model of asset ownership and three specific supply chain structures. In this section, we propose how the analysis can be extended in considering alternative models of asset ownership and supply chain structure. We hope these additional models will spark future research in this area.

6.1. Joint Vertical Assets Ownership

The distributor in structure *III* has no ownership rights on his asset, thus the suppliers appropriate the extra revenues B generated by the distributor's CSR investment. This scenario reflects the case of FrieslandCampina, where the suppliers own the company, including the distributor's assets. In practice, however, there are also cases of joint ownership of the assets of distribution. For instance, the association Dairy Farmers of America has joint ventures and partnerships with several food and processing companies, such as the Chinese processor Inner Mongolia Yili, or the group Fonterra, one of the largest milk processors in the world (Yap 2014). This model of joint ownership of the distributor's assets implies that the extra revenues generated by the distributor's CSR investment will be split among the distributor and the suppliers. By denoting with α, $0 \le \alpha \le 1$, the share of the extra revenues B going to the suppliers, assumptions (A4) and (A5) will then change as follows:

(A4′) $v(\{1, 2\}) = \sum_{i=1}^{2} x_i R_i + \alpha B$,
(A5′) $v(\{3\}) = (1 - \alpha)B$.

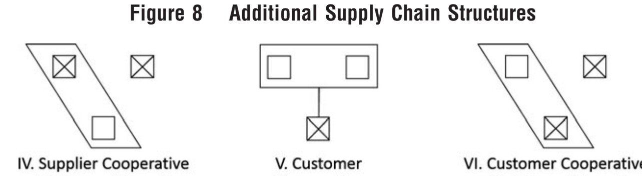
Notice that for $\alpha = 1$ we obtain the same structure *III* as previously considered, whereas for $\alpha = 0$, we obtain structure *II*. As α increases, the incentive to invest in CSR becomes higher for the suppliers but lower for the distributor, as the ownership of the distribution assets shifts from downstream to upstream the supply chain. We conjecture that the new cooperative with joint assets ownership will emerge as the preferred structure by all parties when the distributor's CSR investments cost is higher, and the CSR vertical synergy and the suppliers' investments costs are lower than the respective values for the cooperative previously analyzed. Joint ownership of the distributor's assets then provides stronger incentive to the distributor to invest, and it does so even when the market of consumers is not that sensitive to CSR investments taken at each stage of the supply chain. Put differently, with joint assets ownership the incentive for the distributor to invest may no longer depend on the CSR vertical synergy but just on the share of assets ownership.

6.2. Alternative Models of Cooperatives

Although this research has been motivated by the two examples of Dutch poultry farmers and dairy cooperative FrieslandCampina, other supply chain structures can be observed in practice. In particular, cooperatives can have different structures from the one of FrieslandCampina, depending on the presence of an *external supplier* and the type of integration (which can be either *forward* or *backward integration*). As a consequence, the structures depicted in Figure 8 are also relevant and may be considered in future research.

To illustrate, FrieslandCampina evolved from an association of farmers who were owning their processors/distributors (realizing structure *IV*), to the full merger between FrieslandFoods and Campina, which established the current cooperative with structure *III*. Recently, Starbucks Corporation signed a deal with the Chinese provincial government of Yunnan to set-up its coffee-bean farm (realizing structure *V*). However, the rapidly growing population of coffee drinkers in China required Starbucks to supply from external suppliers as well, as represented by structures *VI* (Burkitt 2010). Backward integration has also become the dominant model for livestock production. In fact, it is estimated that 90% of poultry, 69% of hogs, and 29% of cattle are contractually produced through vertical backward integration (Stokstad 2007).

Figure 8 Additional Supply Chain Structures



Intuitively, having an external supplier in the supplier cooperative, as in *IV*, has the advantage of eliminating free-riding, as the competition upstream creates incentives for CSR investments. However, the lack of a horizontal alliance prevents the formation of countervailing power as well, which eliminates incentives for CSR investments. The interaction between these two effects determines the dominance of each structure.

A full comparison of the six structures would be quite involved and is left for future research. However, we can make a few conjectures about the dominance of each structure. As k_1 increases, having an external supplier as in *VI* is a better option than the horizontal alliance in *II*, as long as k_3 is high. In fact, the distributor will not invest in CSR, thus countervailing power is useless, whereas the presence of an external supplier eliminates the inefficiency of free-riding that occurs instead in *II*. Also, for high values of k_1 the supplier cooperative dominates. As k_3 increases the likelihood that the distributor invests is reduced. Countervailing power then loses its shine, whereas it becomes more important to eliminate free-riding. As a consequence, structure *IV* will be the dominant structure for high values of k_1 and intermediate values of k_3.

7. Conclusions

In an agricultural context, farmers are often required by their distributors and resellers to make investments in CSR, in order to offer to the market of consumers a more sustainable and socially responsible product. Resellers and distributors, in turn, may expend resources to advertise the sustainability of their products, and also invest on their own in CSR, to further increase the revenues. In fact, the adoption of CSR activities may have an effect of market expansion, attracting more consumers to purchase the product, or an effect of price premium, allowing retailers to charge a higher price for the sustainable than for the normal product, or both effects.

Inducing suppliers to engage in CSR activities may be easier said than done, however. By undertaking costly investments, farmers deteriorate their bargaining position, and become vulnerable to the opportunistic behavior of their distributors. The Dutch egg farmers have experienced this situation, and eventually stopped their investments in CSR. A company like Starbucks had to deal with a similar issue. Committed to offering high-quality, ethically purchased and responsibly produced products, Starbucks required coffee farmers to take a number of CSR initiatives. Examples of these were waste management, water quality protection, water and energy conservation, biodiveristy preservation and agrochemical use reduction. The coffee company, however, could not easily obtain these investments from the farmers, as they lacked guarantees by Starbucks' suppliers that they would receive sufficient payments to recoup the investments costs. To solve this issue, Starbucks developed its "Coffee and Farmer Equity" practices, and imposed economic accountability and transparency to its suppliers: "The coffee suppliers must submit evidence of payments made throughout the coffee supply chain to demonstrate how much of the price that they are paid for green coffee goes to the farmers." (see Starbucks' website at http://www.starbucks.com/responsibility/sourcing/coffee). By requiring this transparency of the payments, the American coffee company augmented the bargaining power of the coffee farmers, and finally allowed them to undertake the desired CSR investments.

As markets are paying increasing attention to the social and environmental impacts of businesses, incentivizing CSR investments in a supply chain is a key issue. Formal contracts providing compensation contingent on financial performance are rarely observed in this context, and in most cases would not be viable, due to their incompleteness. As a consequence, alternative mechanisms to create the required incentives should be considered and designed. By applying the PR approach, we show that CSR investments may be solicited through a well designed structure of the supply chain, which consists of an assignment of ownership rights over the assets of production and a horizontal and/or vertical alliance among the chain parties. Our work shows that, in a context with no (enforceable) contracts, the structure of the supply chain is of pivotal importance for CSR investments.

We show that one way through which suppliers could increase their bargaining power against downstream firms, and thus have strong incentives to invest in CSR, is by forming a horizontal alliance. Such an alliance, in fact, generates countervailing power that allows the farmers to attain better prices for their sustainable or socially responsible products. We find, however, that a horizontal alliance is profitable only when the suppliers expect to appropriate a sufficiently large share of the distributor's revenues, which occurs when the distributor's CSR investment cost is sufficiently low. Otherwise, the alliance would not augment the suppliers' payoffs and would rather suffer from the inefficiencies of free-riding. In the example of the Dutch egg farmers, the distributors of cage-free eggs increased their revenues by advertising the adoption of CSR activities, and as a consequence they could charge a price of 17 cents to the consumers in the face of a standard price of 12.5 cents for normal eggs in the Netherlands. Because of their fragmented structure, the egg farmers experienced the opportunistic behavior of the distributors, who kept the large margins for themselves. In fact, even though the production costs of a cage-free egg for the farmer increased to 7.5 cents, as a consequence of the CSR investments, the price paid by the distributors was only 4.5 cents per egg. The unfortunate outcome was that the farmers completely lost their incentives to further invest.

When the CSR investments costs for the suppliers become too high, however, even a horizontal alliance upstream may not be sufficient to provide the required incentives. Farmers need to attain higher revenues to cover the increased investments costs, and a different supply chain structure is required. We show that by vertically integrating their distributor, the suppliers retrieve their motivation to invest in CSR, even for costly investments. The resulting structure of a cooperative provides the distributor with an incentive to invest in CSR as well, as long as the synergy between the investments upstream and downstream create sufficiently high extra revenues. The structure of a cooperative has produced remarkable CSR programs in the case of a company like FrieslandCampina. The synergy between the CSR activities of the upstream farmers and their downstream dairy company resulted in large market segments being willing to pay additional price premiums for the CSR dairy products.

There are many other models of asset ownership and alliances that could be relevant for future research. We have qualitatively illustrated the case of joint asset ownership between suppliers and the distributor, and other cooperative structures. A full analysis can precisely determine under which conditions each structure dominates. Also, our methodology can be applied in many other business contexts, where contracts are either absent or do not provide sufficient guarantees of payment. One example is provided by the context of emerging markets, which are often plagued by the lack of key institutions. Absent or unreliable sources of market information, uncertain regulatory environments, and inefficient judicial systems often characterize these markets, making contracts, once more, an inadequate instrument to generate incentives among supply chain members (Khanna and Palepu 2006). In these settings, executives might need to rethink the design of their supply chain, and form strategic alliances with other key players along the chain. Without formal contracts, the choice of an appropriate supply chain structure may be of vital importance to protect and promote their businesses. As such, we hope our work will contribute to open new avenues of research in supply chain contracting and design.

Appendix A.

Proof of Proposition 1. Given the extensive form of the biform game for structure *I* (see Figure 3), by backward induction there are three cases to be distinguished:

1. $k_3 \le \frac{A(s-1)}{2} + \frac{B(s+1)}{2}$,
2. $\frac{A(s-1)}{2} + \frac{B(s+1)}{2} < k_3 \le A(s+1) + \frac{B(2s+1)}{3}$,
3. $k_3 > A(s-1) + \frac{B(2s+1)}{3}$.

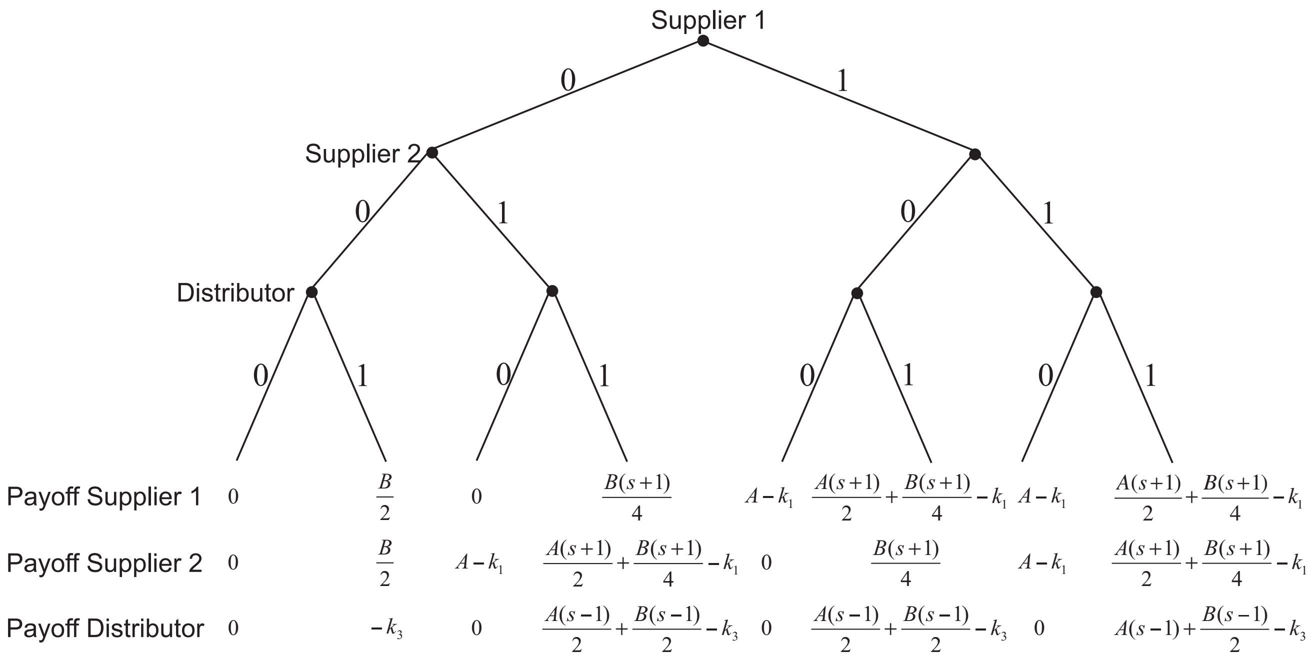
In case 1, the distributor always invests except when $k_3 > B$ and the two suppliers do not invest. Suppliers 1 and 2 will invest as long as $k_1 \le \frac{A(s+1)}{2} + \frac{B(s-1)}{6}$ and $k_1 \le \frac{A(s+1)}{2} + \frac{B(s-1)}{2}$, respectively. Thus, the two equilibria, (1, 1, 1) for $k_1 \le \frac{A(s+1)}{2} + \frac{B(s-1)}{6}$, and (1, 0, 1) for $\frac{A(s+1)}{2} + \frac{B(s-1)}{6} < k_1 \le \frac{A(s+1)}{2} + \frac{B(s-1)}{2}$ emerge. For $k_1 > \frac{A(s+1)}{2} + \frac{B(s-1)}{2}$, the two suppliers do not invest, which yields the equilibria (0, 0, 0) for $k_3 > B$, and (0, 0, 1) for $k_3 \le B$. In case 2, the distributor invests only if the two suppliers have already invested. This occurs for $k_1 \le \frac{A(s+1)}{2} + \frac{B(s-1)}{6}$, which yields the equilibrium (1, 1, 1). Otherwise, the equilibrium is (0, 0, 0). Finally, in case 3 the distributor never invests. The two suppliers then invest as long as $k_1 \le A$, which yields the equilibrium (1, 1, 0). Otherwise, the equilibrium is (0, 0, 0). For structure *II*, the derivation of the equlibria is identical to the one for structure *I*, the only difference being in the threshold values as described by Proposition 1. □

Proof of Proposition 2. Given the extensive form of the biform game for structure *III* in Figure A1, there are three cases to be distinguished:

1. $k_3 \le \frac{A(s-1)}{2} + \frac{B(s-1)}{2}$,
2. $\frac{A(s-1)}{2} + \frac{B(s-1)}{2} < k_3 \le A(s-1) + \frac{B(s-1)}{2}$,
3. $k_3 > A(s-1) + \frac{B(s-1)}{2}$.

In case 1, the distributor invests in CSR only if at least one of the two suppliers invests. In fact, from the extensive form of the game one may notice that if $x_1 = x_2 = 0$ then the distributor will choose $x_3 = 0$, as he would get the negative profit $-k_3$ otherwise. By backward induction, supplier 2 invests if $k_1 \le \frac{A(s+1)}{2} + \frac{B(s+1)}{4}$, whereas supplier 1 invests only if $k_1 \le \frac{A(s+1)}{2}$. Thus, the following three equilibria emerge: (1, 1, 1) for $k_1 \le \frac{A(s+1)}{2}$, (0, 1, 1) for $\frac{A(s+1)}{2} < k_1 \le \frac{A(s+1)}{2} + \frac{B(s+1)}{4}$, and (0, 0, 0) for $k_1 > \frac{A(s+1)}{2} + \frac{B(s+1)}{4}$. In case 2, the distributor invests only if both suppliers invest. Then, the

Figure A1 Extensive Form of Supply Chain Structure *III*



equilibrium (1, 1, 1) emerges for $\frac{A(s+1)}{2}+\frac{B(s+1)}{4}$, and (0, 0, 0) otherwise. Finally, in case 3, the distributor never invests. Then, both suppliers 1 and 2 invest only if $k_1 \leq A$, which yields the equilibrium (1, 1, 0). Otherwise, the equilibrium (0, 0, 0) is selected. □

PROOF OF PROPOSITIONS 3 AND 4. In Figures 4 and 5, we have derived the SPE for the three structures. Thus, we know the payoffs of all supply chain members at equilibrium. The threshold values for the costs k_1 and k_3 in the SPE of each structure are reported for convenience in Table A1.

Assuming $s < 3$, the threshold cost values for k_1 have the following order: $A < F1 < A1 < C1 < A2 < F2$. The threshold cost values for k_3 have different orders depending on the value of s:

1. $G1 < G2 < B < B1 < D2 < B2$, if $s \leq \frac{2A+3B}{2A+B}$,
2. $G1 < B < G2 < B1 < D2 < B2$, if $\frac{2A+3B}{2A+B} \leq s \leq \frac{A+3B}{A+B}$,
3. $B < G1 < G2 < B1 < D2 < B2$, if $\frac{A+3B}{A+B} \leq s \leq \frac{A+2B}{A}$,
4. $B < G1 < B1 < G2 < D2 < B2$, if $s \geq \frac{A+2B}{A}$.

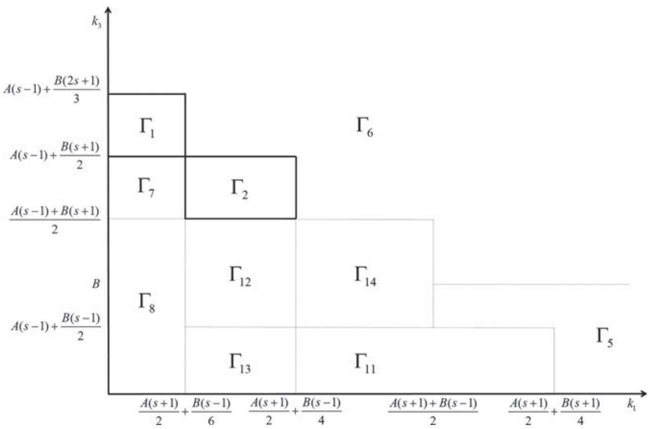
For each of the cases above it is possible to compare the three structures. For instance in case 4, i.e., for $s \geq \frac{A+2B}{A}$, consider the area $\Gamma_8^{(1)} = \{(k_1, k_2) : k_1 \leq A1, G1 \leq k_3 \leq G_2\} \cup \{(k_1, k_2) : k_1 \leq F1, k_3 \leq G_1\}$. From Figures 4 and 5 we know that in this area the equilibrium investment decision is (1, 1, 1) for all parties. Thus, the profits of player i in structure j, π_{ij}, are given by $\pi_{1I} = \pi_{2I} = \frac{A(s+1)}{2} + \frac{B(s-1)}{6} - k_1$;

Table A1 Threshold Values for the Costs k_1 and k_3 in the SPE of Each Supply Chain Structure

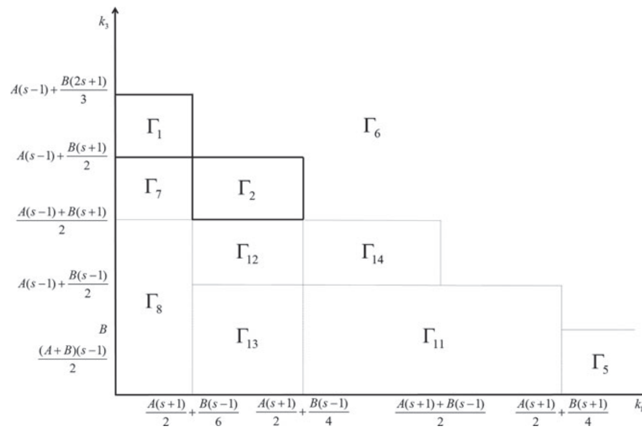
Structure	Threshold cost value for k_1	Threshold cost value for k_3
I	A	B
	$A1 = \frac{A(s+1)}{2} + \frac{B(s-1)}{6}$	$B1 = \frac{A(s-1) + B(s+1)}{2}$
	$A2 = \frac{A(s+1) + B(s-1)}{2}$	$B2 = A(s-1) + \frac{B(2s+1)}{3}$
II	A	B
	$C1 = \frac{A(s+1)}{2} + \frac{B(s-1)}{4}$	$B1$
	$A2$	$D2 = A(s-1) + \frac{B(s+1)}{2}$
III	A	$G1 = \frac{(A+B)(s-1)}{2}$
	$F1 = \frac{A(s+1)}{2}$	$G2 = \frac{(2A+B)(s-1)}{2}$
	$F2 = \frac{(2A+B)(s+1)}{4}$	

$\pi_{3I} = A(s-1) + \frac{B(2s+1)}{3} - k_3$; $\pi_{1II} = \pi_{2II} = \frac{A(s+1)}{2} + \frac{B(s-1)}{4} - k_1$; $\pi_{3II} = A(s-1) + \frac{B(s+1)}{2} - k_3$; $\pi_{1III} = \pi_{2III} = \frac{A(s+1)}{2} + \frac{B(s+1)}{4} - k_1$; $\pi_{3III} = A(s-1) + \frac{B(s-1)}{2} - k_3$. Consider now the area $\Gamma_8^{(2)} = \{(k_1, k_2) : F_1 \leq k_1 \leq A1, k_3 \leq G_1\}$, where the equilibrium investment decision is (1, 1, 1) for structures *I* and *II*, whereas it is (0, 1, 1) for structure *III*. The profits of the parties in structure *I* and *II* are the same as before, whereas those in structure *III* are given by $\pi_{1III} = \frac{B(s+1)}{4}$; $\pi_{2III} = \frac{(2A+B)(s+1)}{4}$; $\pi_{3III} = \frac{(A+B)(s-1)}{2}$. It is straightforward to verify that in both the areas $\Gamma_8^{(1)}$ and $\Gamma_8^{(2)}$ and for $s \leq \frac{2A+3B}{2A+B}$ it follows: $\pi_{1III} > \pi_{1II} > \pi_{1I}$, $\pi_{2III} > \pi_{2II} > \pi_{2I}$, and $\pi_{3I} > \pi_{3II} > \pi_{3III}$. This is the ranking of the preferences of the two suppliers and the distributor reported in Table 5 for the area $\Gamma_8 = \Gamma_8^{(1)} \cup \Gamma_8^{(2)}$. By applying a similar

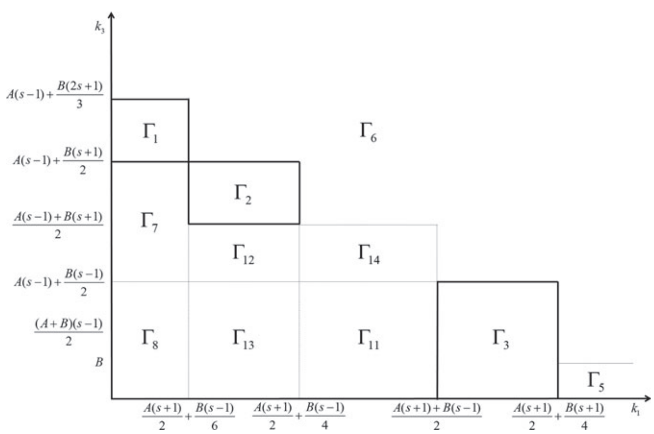
Figure A2 Areas in the Plane k_1k_3 with Different Rankings of the Preferences of the Supply Chain Members among the Three Structures for Different Ranges of Values of *s*. The supply chain members unanimously prefer structure *I* in Γ_1, structure *II* in Γ_2, and structure *III* in Γ_3



(a) $s \leq \frac{2A+3B}{2A+B}$



(b) $\frac{2A+3B}{2A+B} \leq s \leq \frac{A+3B}{A+B}$



(c) $\frac{A+3B}{A+B} \leq s \leq \frac{A+2B}{A}$

approach to all the other areas of the plane k_1k_3, where there are different investment decisions by the parties, one can obtain the analysis depicted in Figure 6 for the case $s \geq \frac{A+2B}{A+B}$. The analysis for the other three cases is reported in Figure A2a, b, and c. Table A2 reports the ranking of the preferences of the parties among the three structures in the areas Γ_{12}, Γ_{13}. and Γ_{14}, whereas the rankings in all the other areas are reported in Table 5.

Proof of Proposition 5. To derive the equilibrium structure we need to apply the blocking approach to all the the areas in Tables 5 and A2, i.e., the areas $\Gamma_1 - \Gamma_{14}$. The procedure is straightforward, as a potential member of an alliance can block the formation of *II* if he prefers *I* to *II* and can block *III* if he prefers either *I* or *II* to *III*. Table A3 reports the equilibrium structure.

Table A2 Preferences of the Supply Chain Members for the Areas Γ_{12}, Γ_{13}, and Γ_{14}

Area in k_3k_1	Preferences supplier 1	Preferences supplier 2	Preferences distributor
Γ_{12}	*I* ≻ *II* ≻ *III*	*II* ≻ *I* ∼ *III*	*II* ≻ *I* ≻ *III*
Γ_{13}	*III* ≻ *I* ≻ *II*	*III* ≻ *II* ≻ *I*	*II* ≻ *I* ≻ *III*
Γ_{14}	*I* ∼ *II* ≻ *III*	*I* ∼ *II* ≻ *III*	*I* ∼ *II* ∼ *III*

Table A3 Equilibrium Structure after Applying the Blocking Approach to the Preferences of the Supply Chain Members among the Structures

Area in k_1k_3	Equilibrium structure
Γ_1	*I*
Γ_2	*II*
Γ_3	*III*
Γ_4	*III*
Γ_5	*I* ∼ *II*
Γ_6	*I* ∼ *II* ∼ *III*
Γ_7	*II*
Γ_8	*II*
Γ_9	*II*
Γ_{10}	*I*
Γ_{11}	*I* ∼ *II*
Γ_{12}	*I*
Γ_{13}	*I*
Γ_{14}	*I* ∼ *II*

Appendix B. Sequence of Decisions

B.1. Suppliers Taking Simultaneous Investment Decisions

We start with structure *I*, where the extensive form of the game is the same as the one represented in Figure 3, but with an information set containing the two root nodes of supplier 2. The decision of the distributor to invest depends on the value of k_3. There are four cases that may occur:

1. $k_3 \leq B$,
2. $B < k_3 \leq \frac{A(s-1)}{2} + \frac{B(s+1)}{2}$,
3. $\frac{A(s-1)}{2} + \frac{B(s+1)}{2} < k_3 \leq A(s+1) + \frac{B(2s+1)}{3}$,
4. $k_3 > A(s-1) + \frac{B(2s+1)}{3}$.

For instance in case 1, no matter what the two suppliers do, the distributor will invest. In case 2, the distributor will always invest except when both the suppliers do not invest, whereas in case 3 he will invest only if both suppliers invest. Finally, in case 4 the distributor will never invest. Using the notation $X = \frac{A(s+1)}{2} + \frac{B(s-1)}{6}$ and $Y = \frac{A(s+1)}{2} + \frac{B(s-1)}{6}$, Figure B1 represents the simultaneous game in normal-form for each case.

It is straightforward to derive the equilibrium investment decision, (x_1, x_2, x_3). In case 1, the equilibrium is given by (1, 1, 1), if $k_1 \leq X$. There are three possible equilibra for $X < k_1 \leq Y$: (1, 0, 1), (0, 1, 1), and a mixed strategy equilibrium. Finally, if $k_1 > Y$, the equilibrium is (0, 0, 1). Case 2 yields the same equilibria as case 1 except (0, 0, 0) for $k_1 > Y$. In case 3, the equilibrium is (1, 1, 1) if $k_1 \leq A$. For $A < k_1 \leq X$ the following three equilibria may occur: (1, 0, 1), (0, 1, 1), and a mixed strategy equilibrium. Finally, in case 4, the equilibrium is (1, 1, 0) if $k_1 \leq A$ and (0, 0, 0) otherwise. The equilibria of structure 1 can be conveniently represented in the plane k_3k_1 as shown in Figure B2. Notice that the investment decision game in structure 1 for simultaneous moves of the suppliers has multiple equilibria, but one of them always corresponds to the equilibrium of the sequential game analyzed in the main text. The proof for the other two structures is completely similar to the one described above, and yields the same result that

Figure B2 Subgame Perfect Equilibrium for Structures ***I*** when Suppliers Take Simultaneous Investment Decisions. The equilibrium α can be (0, 0, 0),(1, 1, 1) or a mixed strategy equilibrium, whereas the equilibrium β can be (1, 0, 1), (0, 1, 1) or a mixed strategy equilibrium

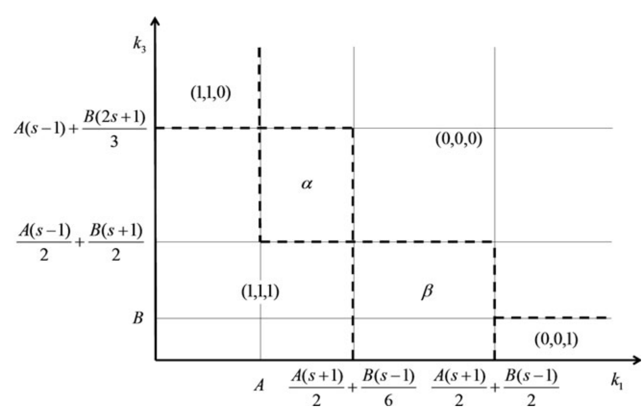


Figure B1 Bi-Matrices of the Simultaneous Game between the Suppliers for Each Case of Distributor's Investment Decision. The payoffs of supplier 1 and 2 are reported in order in brackets, where $X = \frac{A(s+1)}{2} + \frac{B(s-1)}{6}$ and $Y = \frac{A(s+1)}{2} + \frac{B(s-1)}{6}$. (a) $k_3 \leq B$; (b) $B < k_3 \leq \frac{A(s-1)}{2} + \frac{B(s+1)}{2}$; (c) $\frac{A(s-1)}{2} + \frac{B(s+1)}{2} < k_3 \leq A(s-1) + \frac{B(2s+1)}{3}$; (d) $k_3 > A(s-1) + \frac{B(2s+1)}{3}$

	$x_2 = 0$	$x_2 = 1$
$x_1 = 1$	$(0,0)$	$(0, A-k_1)$
$x_1 = 0$	$(A-k_1, 0)$	$(A-k_1, A-k_1)$

(a) $k_3 \leq B$

	$x_2 = 0$	$x_2 = 1$
$x_1 = 1$	$(0,0)$	$(0, A-k_1)$
$x_1 = 0$	$(A-k_1, 0)$	$(X-k_1, X-k_1)$

(b) $B < k_3 \leq \frac{A(s-1)}{2} + \frac{B(s+1)}{2}$

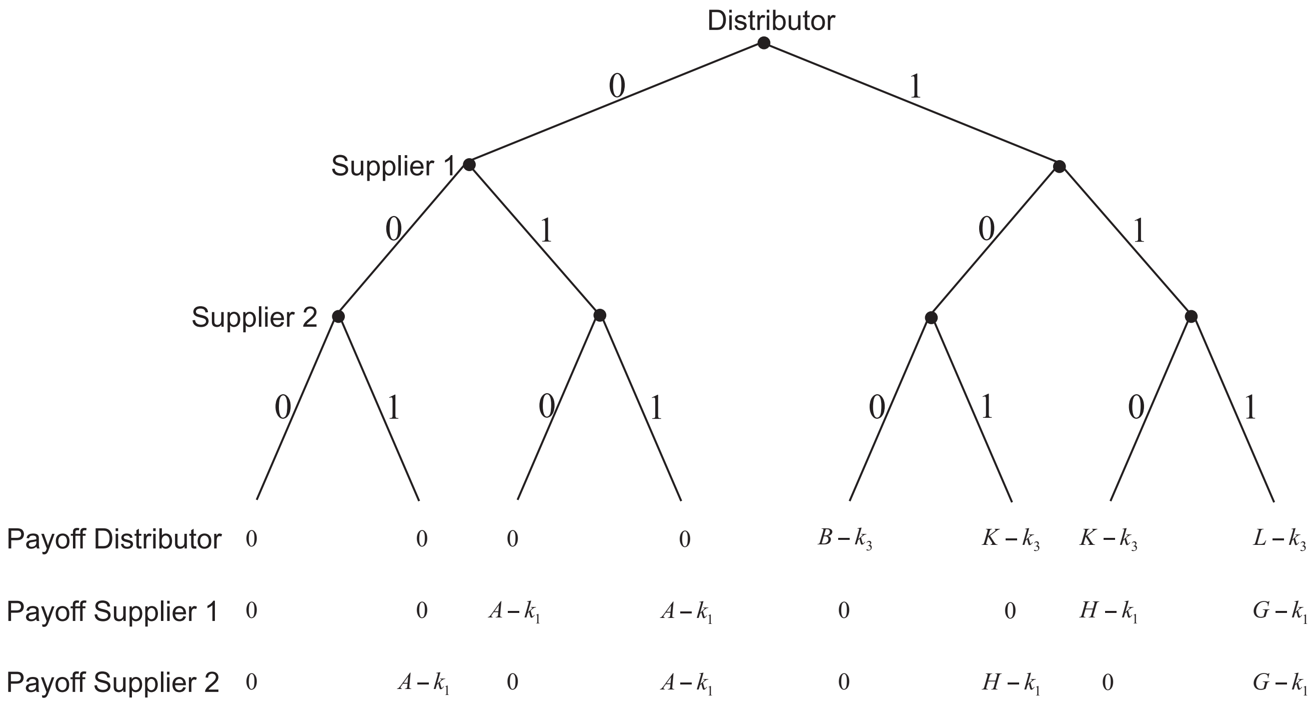
	$x_2 = 0$	$x_2 = 1$
$x_1 = 1$	$(0,0)$	$(0, Y-k_1)$
$x_1 = 0$	$(Y-k_1, 0)$	$(X-k_1, X-k_1)$

(c) $\frac{A(s-1)}{2} + \frac{B(s+1)}{2} < k_3 \leq A(s-1) + \frac{B(2s+1)}{3}$

	$x_2 = 0$	$x_2 = 1$
$x_1 = 1$	$(0,0)$	$(0, A-k_1)$
$x_1 = 0$	$(A-k_1, 0)$	$(A-k_1, A-k_1)$

(d) $k_3 > A(s-1) + \frac{B(2s+1)}{3}$

Figure B3 Extensive Form of Structure *I* when the Distributor Invests First. We use the notation $G = \frac{A(s+1)}{2} + \frac{B(s-1)}{6}$, $H = \frac{A(s+1)}{2} + \frac{B(s-1)}{2}$, $K = \frac{A(s-1)}{2} + \frac{B(s+1)}{2}$, and $L = A(s-1) + \frac{B(2s+1)}{3}$



one of the equilibria of the simultaneous game provides one equilibrium corresponding to the equilibrium of the sequential game analyzed in the main text of the study.

B.2. Distributor Investing First

We consider the case where in sequence the distributor, then supplier 1 and 2 invest in CSR. The extensive form of the game for structure *I* is represented in Figure B3, where we have used the notation $G = \frac{A(s+1)}{2} + \frac{B(s-1)}{6}$, $H = \frac{A(s+1)}{2} + \frac{B(s-1)}{2}$, $K = \frac{A(s-1)}{2} + \frac{B(s+1)}{2}$, and $L = A(s-1) + \frac{B(2s+1)}{3}$.

There are four cases to be distinguished:

1. $k_1 > H$,
2. $G < k_1 \leq H$,
3. $A < k_1 \leq G$,
4. $k_1 \leq A$.

In case 1, neither supplier 1 nor supplier 2 invest in CSR. The distributor invests if $k_3 \leq B$. yielding the equilibrium $(x_1, x_2, x_3) = (0, 0, 1)$, and does not invest otherwise, yielding the equilibrium (0, 0, 0). In case 2, supplier 2 invests only if the distributor does and supplier 1 does not invest in CSR. If $k_3 \leq K$ the distributor invests and the equilibrium (1, 1, 0) is selected; otherwise, (0, 0, 0). In case 3, supplier 2 invests if the distributor invests, which occurs if $k_3 \leq L$. Then, for $k_3 \leq L$, the equilibrium (1, 1, 1) is selected; otherwise (0, 0, 0). Finally, in case 4, supplier 2 always invests in CSR. Supplier 1 always invests as well, whereas the distributor invests only if $k_3 \leq L$. The equilibria then are (1, 1, 0) for $k_3 > L$ and (1, 1, 1) for $k_3 \leq L$.

Regarding structure *II*, the analysis is the same as for structure *I*, the only difference being in the values of the parameters *G* and *L*. Specifically, for structure *II* we have $G = \frac{A(s+1)}{2} + \frac{B(s-1)}{4}$ and $L = A(s-1) + \frac{B(s+1)}{2}$.

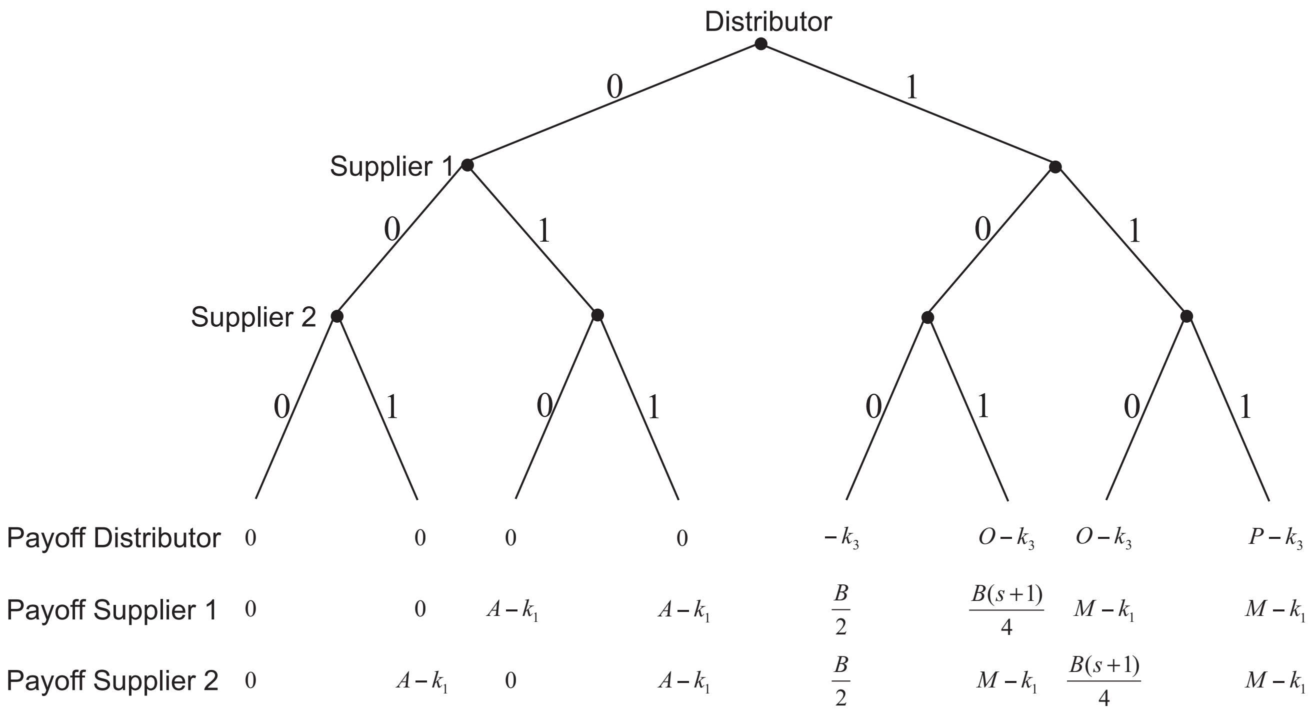
Finally, regarding structure *III* the extensive form of the game is represented in Figure B4, where we have used the notation $M = \frac{A(s+1)}{2} + \frac{B(s+1)}{4}$, $O = \frac{A(s-1)}{2} + \frac{B(s-1)}{2}$, and $P = A(s-1) + \frac{B(s-1)}{2}$.

We distinguish the following four cases:

1. $k_1 > M - \frac{B}{2} = \frac{A(s+1)}{2} + \frac{B(s-1)}{4}$,
2. $M - \frac{B(s+1)}{4} < k_1 \leq M - \frac{B}{2} \Leftrightarrow \frac{A(s+1)}{2} < k_1 \leq \frac{A(s+1)}{2} + \frac{B(s-1)}{4}$,
3. $A < k_1 \leq \frac{A(s+1)}{2}$,
4. $k_1 \leq A$.

In case 1, neither supplier 1 nor supplier 2 invest in CSR. The distributor then is better off not investing as well, as he would incur the loss $-k_3$ by investing in CSR. The corresponding equilibrium is given by $(x_1, x_2, x_3) = (0, 0, 0)$. In case 2, supplier 2 invests only if the distributor does and supplier 1 does not invest in CSR. If $k_3 \leq O$ the distributor invests and the equilibrium (0, 1, 1) is selected; otherwise,

Figure B4 **Extensive Form of Structure *III* when the Distributor Invests First. We use the notation $M = \frac{A(s+1)}{2} + \frac{B(s+1)}{4}$, $O = \frac{A(s-1)}{2} + \frac{B(s-1)}{2}$, and $P = A(s-1) + \frac{B(s-1)}{2}$**



(0, 0, 0). In case 3, supplier 2 invests if the distributor invests, which occurs if $k_3 \le P$. Then, for $k_3 \le P$, the equilibrium (1, 1, 1) is selected; otherwise (0, 0, 0). Finally, in case 4, supplier 2 always invests in CSR. Supplier 1 always invests as well, whereas the distributor invests only if $k_3 \le P$. The equilibria then are (1, 1, 0) for $k_3 > P$ and (1, 1, 1) for $k_3 \le P$. In summary, we may observe that the equilibria for structures *I* and *II* remain exactly the same when the distributor invests first. However, for $\frac{A(s+1)}{2} < k_1 \le \frac{A(s+1)}{2} + \frac{B(s+1)}{4}$ the equilibria in structure *III* are different when the distributor invests first.

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