OWNERSHIP STRUCTURE IN AGRIFOOD CHAINS: THE MARKETING COOPERATIVE

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Globalization, technological developments, and consumer concerns press farmers and food producers to enhance product innovation and to seek more efficient production and distribution structures. These changes in agrifood markets shift the relative importance of the investments by different chain partners. It may therefore be necessary to change the allocation of ownership of essential assets to induce agents to make those investments that generate the chain optimum. This article analyzes the impact of ownership structure on investments in a three-tier supply chain from an incomplete contracting perspective. Circumstances are determined in which a marketing cooperative is the unique first-best ownership structure.

Key words: chain, incomplete contracting, marketing cooperative.

Globalization, consumer concerns, and increased competition press farmers and food producers to enhance product innovation and to seek more efficient production and distribution structures. In recent years, agriculture and the food industry have shown increasing collaboration on issues of product development, quality guarantee systems, and improved logistics (Downey; Royer and Rogers). Spot markets are being replaced by contract-production and systems of vertical coordination (Martinez and Reed). More coordination and collaboration may lead to improved efficiency in production and distribution channels and to more product and market innovations (Galizzi and Venturini). These vertical relationships can take many forms, like strategic alliances, long-term contracts, licensing, subcontracting, joint ventures, and franchising (Mahoney and Crank).

Marketing cooperatives are a special type of vertical integration, with farmers owning assets in another tier of the agrifood production and distribution system. Changes in the market for food products raise the question whether cooperatives are still efficient organizations for processing and marketing of agricultural products (Cook). Are cooperatives well suited to make the investments needed in R&D and marketing, given their particular characteristics of democratic decision making and raising equity capital among members?

Increasing vertical coordination of production, distribution, and marketing among firms in a supply chain may have an impact on the investment decisions of each firm individually. Investments by a firm in one tier of the chain must be coordinated with investments by firms in other tiers to obtain optimal chain performance. As there are complementarities among the activities of different chain participants, the investments are of a relationship-specific kind. In other words, vertical coordination may increase asset specificity. The central question of this article is how different ownership structures affect the investment incentives of firms participating in specific agrifood supply chains. In addressing this question, we apply incomplete contract theory as developed by Grossman and Hart, and Hart and Moore.

We seek to make two contributions to the economics of vertical coordination. Where incomplete contract models have mainly been developed on the basis of two agents engaged in a vertical or lateral relationship, in this article we develop a model with three agents. Moreover, the three-agent model is used to analyze the efficiency of ownership structures in the agrifood sector, particularly the farmer-owned marketing cooperative.

The rest of this section presents a stylized example for the agrifood industry to

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introduce the main themes. Consider three agents, a dairy farmer, a manager of a dairy company (the 'processor'), and a manager of a supermarket store (the 'retailer'). There are three assets: the farm, the dairy factory, and the store, owned by the farmer, processor, and retailer, respectively. Each agent has investment opportunities.

For example, the farmer invests in acquiring knowledge of how to produce organic milk. The investment is specific to the farm, as organic farming requires extensive knowledge of local soil and climatic conditions. This investment of the farmer will benefit from all three assets in the chain. Surplus is added by the assets at the processing stage of production, for instance, the processing is done in a separate processing line. Surplus is also added in the retailing stage of production, for instance, by putting it on an attractively located shelf. We will assume that the total chain surplus, which is generated by the investment of the farmer, is $(2+\alpha)t$. The contribution of the assets at the farming (processing, retailing) stage of production is $t(t, \alpha t)$. The investment is efficient when the costs are not more than $(2+\alpha)t$.

To secure a net benefit from the investment, the farmer may consider signing a contract with the processor and the retailer about the division of the surplus. However, a contract is often incomplete, for instance, because developments in demand for organic dairy products cannot be foreseen. The chain-specific nature of the farmer's investment means that his investment will yield a significantly lower return if the local processor and/or the local retailer renege on the contract. The farmer has become—for a certain part of his investment—dependent on the processor and retailer. An opportunistic contract party may take advantage of the dependency relationship, for instance, when market conditions change. Once the farmer has done his sunk investment, the processor or retailer may demand a larger part of the total chain surplus under the threat of discontinuing the contract altogether. Such opportunistic behavior is often possible as most contracts can hardly cover all relevant future contingencies. Particularly in situations of great uncertainty and market volatility, opportunities for contract reneging increase. This uncertainty about the future behavior of his contract partners may lead the farmer to decide on a lower level of investment. However, this is inefficient from a welfare perspective.

Another option for the dairy farmer is to take over the dairy company or to start his own processing company. Being the owner of the processing plant, the farmer has control over all activities of the dairy company. The manager of the dairy company is no longer also the owner; he is now an employee of the farmer. This way the farmer can prevent opportunistic behavior by the manager. Here, we have one of the classic reasons for a group of farmers to set up a farmer-owned processing and marketing cooperative (Schrader). Similarly, the farmer could take over the supermarket store if he expects or experiences opportunistic behavior from the manager of the supermarket. Due to scale economics this solution cannot easily be chosen, although there are small-scale examples of farmers selling their own specialty products. An example (at least in the Netherlands) are the cheese-farms, where milk production, processing milk into cheese, and the sale of cheese are all done on-farm.

The value of vertical coordination among farmer, processor, and retailer increases if not only the farmer does a chain-specific investment but the processor and the retailer as well. The processor may invest in knowledge of making cheese from organic milk. The processor's investment will generate a higher surplus if he receives the organic milk from the local farm and if his organic cheese is sold in the local store. For this reason, the processor's investment is also (at least partially) chain-specific. Finally, the retailer may also make an investment in setting up a store identity featuring organic dairy products. As the focus is on locally produced products, the investment is specific to the relationship with the farmer and the processor. The investment by the retailer is also chain-specific.

The investment by the processor (retailer) is also vulnerable to contract reneging by the other chain agents. The processor (retailer) also faces the risk that after having made his sunk investment, a larger than contracted for part of the surplus will be appropriated by the other agents. The processor (retailer) has various options for safeguarding his chain-specific investment. The option we pursue in this article is the shift of ownership of essential assets. Essential assets are those assets that an investing agent needs to have accessible to generate the maximum surplus. Thus, by acquiring essential assets in other stages of the production and distribution chain, the processor (retailer) can safeguard his chain-specific investment. Once he has control over those assets, he can fire the managers working with these assets if they threaten him with contract reneging.

As all three agents can make a chain-specific investment and all three can acquire assets in other stages of the chain to safeguard their investment, the question arises who should own which assets. It entails that the allocation of ownership over assets determines the distribution of the surplus $(2+\alpha)t$ of the investment of the farmer over the three parties. In this article, we develop a model for analyzing the relationship between ownership structure and efficient investment decisions. Before we introduce our model, we briefly introduce incomplete contract theory. The model is elaborated separately for two agents and for three agents. This is followed by formulating the comparative statics results, while the final section presents our conclusions.

Incomplete Contract Theory

Incomplete contract theory starts from the basic idea that it is often difficult to write enforceable comprehensive contracts. Real-world contracts are almost always incomplete in the sense that there are inevitably circumstances or contingencies left out of the contract, because they are unforeseen or simply because it is too expensive to enumerate them in sufficient detail. As contracts are incomplete, actions and payments must often be determined *ex post*, either unilaterally or through negotiation. Consequently, contracting agents should be concerned *ex ante* with the possibility of opportunistic behavior and the results of possible renegotiation. This is particularly problematic if *ex ante* transaction-specific investments must be made. These investments create the opportunity for *ex post* appropriation of quasi-surplus (surplus plus specific investment costs) by the noninvesting agent to the transaction. The anticipation of possible holdup may lead to under-investment in the economic relationship. Klein, Crawford, and Alchian and Williamson (1979, 1985) have suggested that vertical integration may resolve this problem.

Grossman and Hart have argued that vertical integration brings costs as well as benefits. To understand what changes when two firms merge, Grossman and Hart, and Hart and Moore have developed a property rights theory of the firm. A firm is identified as a collection of nonhuman assets under common ownership, where ownership means holding residual rights of control. Residual rights are all rights to an asset that are not expressly assigned to another agent (including the state). The allocation of residual rights of control influences the bargaining position of agents to a contract after they have made relationship-specific investments. In the absence of comprehensive contracts, property rights largely determine which *ex post* bargaining position will prevail. An agent owning assets that are essential for value creation in the relationship is in a position to reap at least some of the benefits from the relationship that were not explicitly allocated in the contract by threatening to withhold the assets otherwise. Thus, a shift of ownership affects the *ex ante* investment incentives of contracting agents.[1]

The standard model of incomplete contract theory consists of a three-stage noncooperative game. The first stage consists of the choice of ownership structure, where each ownership structure is associated with a specific distribution of bargaining power. The second stage holds the specific investment decision(s). At the third stage, the noninvestor has the choice whether to honor the contract or renegotiate it.

This game is solved by backward induction. Therefore, we start with the third stage. Two agents, for instance, a farmer and a food processor, sign a contract before investment by the farmer takes place. The contract specifies that each agent receives half of the surplus generated by the investment. The contract is incomplete because situations may arise for which the contract does not specify anything. If, for example, consumer demand turns out to be lower than expected, the processor may argue that the quasi-surplus instead of the surplus has to be divided in such situations. The specificity of his assets has weakened the farmer's *ex post* bargaining position to such an extent that he will accept these new

[1] The main Grossman/Hart/Moore conclusions on optimal asset ownership in a two-tier vertical relationship (i.e., buyer–seller relationship) are the following. (1) An agent with an important investment (in human capital) should have ownership rights over the asset for which the investment is required. (2) If investments by agent A become relatively more important than investments by agent B, then A should own more assets. (3) Highly complementary assets should be under common ownership. (4) Independent assets should be separately held. (5) Important assets should not be owned by a third agent.

contract terms. The subgame perfect equilibrium strategy in the third stage is therefore to renegotiate the *ex ante* contract.

The investment decision in the second stage of the game determines the bargaining positions in the third stage. The specificity of the investment places the investor in a weak bargaining position regarding the division of the surplus in the third stage. Therefore, the investor anticipates that the other agent may take advantage of the incompleteness by claiming a larger share of the *ex post* surplus than initially agreed upon. This fear of *ex post* opportunistic behavior results in underinvestment.

In the first stage of the game, the ownership structure is chosen. It is assumed in incomplete contracting theory that an ownership structure is efficiently chosen. Every ownership structure is associated with a particular distribution of bargaining power. For capturing bargaining power, we adopt the game theoretic solution concept Shapley value (Shapley), just like the seminal article by Hart and Moore.

The Model: Two Agents

There are two agents (1 and 2), two assets (A_1 and A_2), and two investment decisions (x_1 and x_2). For simplicity, x_i can only take the value 0 or 1. The investment is in human capital; that is, it is person-specific. The investment pays off in the future only if the agent has access to a particular asset; that is, the acquired skill is asset-specific. This implies that the investment does not generate surplus if the investing agent is denied access to the asset.

The model consists of three stages: an ownership structure stage, an investment stage, and a bargaining stage. We make the following assumptions about investment (x). Investments are made simultaneously and noncooperatively (i.e., each agent invests without taking into account the choice of the other agent). Investments are observable, but not verifiable. This means that no contract can be written about the precise investments, but that agents can observe each other's investments once they have been made. The observability implies that bargaining at T_1 takes place under symmetric information about the T_0 investments. No contracts are possible about cost sharing at T_0 or benefit sharing at T_1. As contracts at date T_0 are necessarily incomplete, the distribution of value at date T_1 depends on the bargaining power of the agents.

Table 1. Quasi-Surplus for Two Investment Decisions and Various Assets Involved

Assets Involved	Investment Decision	q
A_1	$x_1 = 1$	t
A_1A_2	$x_1 = 1$	$2t$
A_2	$x_2 = 1$	f
A_1A_2	$x_2 = 1$	$2f$

Notes: $x_i = 1$ means that agent i invests; q is quasi-surplus; $t =$ surplus generated by the investment of agent 1 at agent 1's stage of production; and $f =$ surplus generated by the investment of agent 2 at agent 2's stage of production.

We assume complementarities in asset use.[2] An investment by agent 1 generates a higher value if not only asset A_1, but also A_2 is used. Similarly, for an investment by agent 2: it generates a higher value if more assets are used. As the generation of maximum value depends on the use of assets belonging to another tier of the chain, the investments are chain-specific. Because chain-specificity refers to assets and not to agents, not always all agents are needed to generate the total chain value. The total chain value of an investment will be established by coalitions consisting of at least the investing agent and the agents owning assets. For example, if agent 1 is the investor and owns assets A_1 and A_2, then agent 2 is not needed for generating the maximum chain value of the investment of agent 1.

The value generated by a specific investment is the quasi-surplus (q), being the surplus plus that part of the investment that is sunk in the relationship. The actual value of q depends on who invests and which assets are used. We assume that agent 1 generates a quasi-surplus of t when A_1 is used and $2t$ when both assets are used. Similarly, we assume that agent 2 generates a quasi-surplus of f when A_2 is used and $2f$ when both assets are used. The quasi-surplus for various investment decisions and various assets used are shown in table 1. The full quasi-surplus of each investment is generated only when all assets are used.

[2] Complementarity among a group of activities means that if the levels of any subset of activities is increased, then the marginal return to increases in any or all of the remaining activities rises (Milgrom and Roberts). Notice that our model has complementarity in asset use, whereas Hart and Moore provide an example of complementarity in investment.

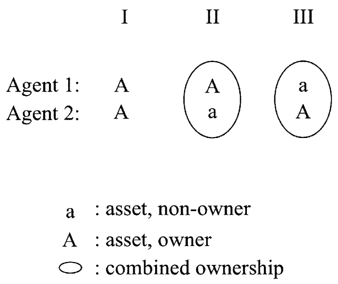

Figure 1. Three ownership structures

Various distributions of asset ownership are possible. We have distinguished three different ownership structures. Figure 1 shows the assets that each agent owns for each of the three ownership structures. Ownership structure I represents market exchange. Forward integration, where both A_1 and A_2 are owned by agent 1, is captured by ownership structure II. This ownership structure is associated with the agricultural marketing cooperative, where farmers own the processing or trading company at the second tier of the chain. Finally, ownership structure III represents backward integration.

The bargaining power of each agent in the supply chain under the various ownership structures is captured by its Shapley value.[3] The Shapley value is computed for each ownership structure and each investment by using the characteristic function. A characteristic function v assigns a number to every coalition S, given a particular ownership structure G and given an investment choice x and is denoted $v(S|G, x)$. This number is the total value generated by the agents in the coalition S without any help from the agents outside of S.[4] G gives the allocation of asset ownership.

Table 2. Shapley Values for Two Agents, Two Investment Decisions, and Three Ownership Structures

$X = (x_1, x_2)$	G	SV_1	SV_2
(1, 0)	I	$1.5t$	$0.5t$
(1, 0)	II	$2t$	0
(1, 0)	III	t	t
(0, 1)	I	$0.5f$	$1.5f$
(0, 1)	II	f	f
(0, 1)	III	0	$2f$

Notes: $x_i = 1$ means that agent i invests; $G =$ governance structure; and $SV_i =$ Shapley value of agent i.

The characteristic function and the computation of the Shapley values are provided in Appendix A. Table 2 presents the resulting Shapley values (SV) for each investment decision and all ownership structures. This entails six cases.

The Shapley value is a measure of power in the *ex post* bargaining process.[5] It specifies for each agent the size of the quasi-surplus that this agent will receive in the bargaining process. Therefore, the Shapley value determines the maximum costs of investment the agent is willing to make. If we denote the sunk cost (or specific) part of the investment as 'k,' then the (investment)

[3] The Shapley value is an allocation of payoffs to each player. The payoff of a player is based on the marginal contribution of a player to a surplus that is created jointly. Shapley recognized that the sequence in which the various players participate in a coalition has an effect on the value of the marginal contribution of each player. Then the question arises which sequence to consider? He resolved this issue by taking all possible sequences into account and to give them equal weight. The payoff assigned to a player is equal to the average marginal contribution he makes to each coalition to which he could belong, where all coalitions are regarded as equally likely. This way of determining and disentangling individual contributions to a joint project was an important reason for choosing the Shapley value in our model. An empirical reason for choosing the Shapley value is that the "performance of the Shapley value for prediction or analysis turns out rather well" (Dixit and Skeath, p. 572).

[4] We make the assumption that marginal contributions are distinguishable. This is in line with the seminal articles of Grossman and Hart (1986) and Hart and Moore (1990). It can be traced to the assumption that the investments are observable for the parties involved. This is used in the calculation of the Shapley value to distribute chain benefits in the different governance structures. The case of nondistinguishable marginal contributions can also be analyzed in our model. The motivation for nondistinguishable marginal contributions can be made by pointing to the nonverifiability of marginal contributions. The calculation of the Shapley value has to be done in a different way. It cannot be based anymore on marginal contributions, but it can be based on which parties are essential. Essential parties are the investor and the parties who own assets. This provides sufficient variability in the Shapley value to distinguish the various governance structures. The results are similar.

[5] In our model, we have assumed that a specific agent 1 is trading with a specific agent 2, and that each investment is specific to this trade relationship, in the sense that it generates a higher surplus in this particular relationship than in trade with a third agent. However, substitutability of agent 1 and agent 2 can be easily incorporated in the model, both for the noninvestor and the investor. Substitutability of a particular agent reduces its Shapley value in two ways when the agent is a noninvestor. First, an increasing number of substitutes for a particular agent reduces the Shapley value of all these substitutes jointly. The reason is that the probability increases that a particular order of the grand coalition has the feature that one of these noninvestors is earlier than the investor. The value added by a noninvestor in such an order is zero, whereas the value added by the investor and the noninvestor together is assigned to the investor. Second, one of the four axioms underlying the Shapley value requires that identical players have to have identical Shapley values. So, the decreasing share of the surplus going to the noninvestor has to be split equally between an increasing number of substitutes. If the agent is an investor, then it is obvious that its incentives to invest are diminished when identical rivals benefit from the positive externality of the investment. This is the classic public good problem.

participation constraint[6] for agent 1 under ownership structure I is

(1) $k_1 \leq 1.5t$.

Efficient Ownership Structures (with Two Agents)

An ownership structure is first-best efficient when it implements all and only surplus generating investments. To determine whether a particular combination of investments will yield the first-best, we use the participation constraints of the two agents, i.e., $k_1 \leq SV_1$, and $k_2 \leq SV_2$.

Table 2 implies a ranking regarding the suitability of the various ownership structures with respect to the specific investments.[7] The ranking of maximum possible investment outlays by agent 1 for the various ownership structures is:

(2) III < I < II.

Ownership structure II is always first-best efficient regarding the specific investment of agent 1. In other words, every surplus generating investment by agent 1 will be implemented under ownership structure II, regardless of the value of k_1. The reason is that all benefits of the investment accrue to agent 1.

The ranking of maximum possible outlays regarding the investment k_2 by agent 2 for the various ownership structures is:

(3) II < I < III.

Figure 2 shows which ownership structures are first-best efficient as a function of the sunk costs of each agent. The smaller the specific part of the investment, the more the ownership structures yield the first-best efficient outcome. If k_1 as well as k_2 have a low value, then the invariance and efficiency result of the Coase theorem holds.

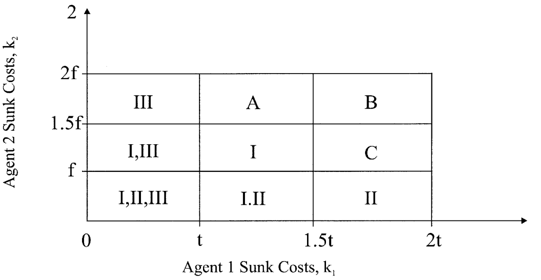

Figure 2. First-best efficient ownership structures

The choice of governance structure does not matter in these circumstances. However, the choice of ownership structure matters for efficiency when the value of at least one of the k_i's exceeds a certain level. With higher levels of investment, fewer ownership structures are efficient. For instance, if $f < k_2 \leq 1.5f$ and $t < k_1 \leq 1.5t$, then only I is first-best efficient. The general result is that a first-best ownership structure assigns more power to an agent when its sunk costs/quasi-surplus ratio increases, ceteris paribus.[8]

There is no first-best efficient combination of investments possible in the areas A, B, and C in figure 2. If investments of 1 and 2 fall in the area A, B, or C, then only second-best efficient ownership structures are possible. This means that only one of the two agents will invest. The second-best ownership structure choice in region A is III when $2f - k_2 \geq 2t - k_1$ and I or II, otherwise. Similarly, the second-best ownership structure choice in region C is II when $2t - k_1 \geq 2f - k_2$ and I or III, otherwise. Finally, the second-best ownership structure choice in region B is II when $2t - k_1 \geq 2f - k_2$ and III, otherwise. The general result is that the second-best ownership structure assigns more power to an agent when the surplus of its investment increases, ceteris paribus.

The Model: Three Agents

Now we will present the model for the three agents (1, 2, and 3), three assets (A_1, A_2, and A_3), and three investment decisions (x_1, x_2, and x_3). For simplicity, x_i can only take

[6] The participation constraint formulates the circumstances under which the investor invests. It is an inequality which states that the revenues of the investment for the investor are not smaller than the costs of investment (k). The revenues of the investment for the investor are equal to the Shapley value of the investor in our model.

[7] The ordinal ranking of the ownership structures can be interpreted as a 'reduced form' of an underlying model (Williamson, 1991). The reduced form is an early stage of the development of the theory of the firm (cf. Holmstrom and Roberts). The empirical importance of ordinal rankings is that they formulate some constraints with respect to the data. To be more specific, various changes in the choice of ownership structure as a function of the level of asset specificity are predicted not to happen. If they do occur in reality, the relevance of the model must be doubted.

[8] The choice of ownership structure is in our model driven by efficiency considerations only. However, considerations of equity may prevent that the first-best ownership structure will be chosen. A possible solution is to accompany the choice of ownership structure with a lump sum transfer scheme.

the value 0 or 1. The three agents represent a specific tier in this agrifood chain: agent 1 is a farmer, agent 2 is a manager in a processing firm (hereafter called a processor), and agent 3 is a manager in a retail firm (hereafter called the retailer). The assets are land, factory, and shop. The investments are in human capital (e.g., skills) and are asset-specific. For instance, the farmer invests in skills to improve the productivity of his fields, the processor invests in knowledge to increase the efficiency of processing in his factory, and the retailer invests in particular knowledge of the consumers that visit his shop. The asset-specificity of the investment implies that if the agent does not have access to the asset, the investment will not pay off.

Once again, we assume complementarities in asset use. The whole quasi-surplus of an investment will be generated when all assets in the chain are used. The notion of a chain entails that there is a difference between being in the middle or at the end of the chain. We capture this by assuming that the value generated by the investment will be higher if two adjacent assets are used than if two nonadjacent assets are used. In the three-tier agrifood chain, this means that the positive externalities of the investment of the farmer (agent 1) are higher for the processing company (agent 2) than for the retailer (agent 3). The quasi-surplus for various investment decisions and assets used is shown in table 3, where the difference between adjacent and nonadjacent assets is captured by $\alpha < 1$ and $\beta < 1$.

Figure 3 distinguishes ten ownership structures. It shows the assets that each agent owns for each ownership structure. For instance, ownership structure V entails that the assets A_2 and A_3 are owned by agent 3 and asset A_1 is owned by agent 1. Ownership structure II represents the cooperative, where farmers own the processing company at the second stage of the chain. In a marketing cooperative, agent 1 owns A_1 and A_2, while agent 3 owns A_3.

Table 3. Quasi-Surplus for Three Investment Decisions and Various Assets Involved

Assets Involved	Investment Decision	q
A_1	$x_1 = 1$	t
A_1 A_2	$x_1 = 1$	$2t$
A_1 A_3	$x_1 = 1$	$(1+\alpha)t$
A_1 A_2 A_3	$x_1 = 1$	$(2+\alpha)t$
A_2	$x_2 = 1$	f
A_1 A_2	$x_2 = 1$	$2f$
A_2 A_3	$x_2 = 1$	$2f$
A_1 A_2 A_3	$x_2 = 1$	$3f$
A_3	$x_3 = 1$	h
A_1 A_3	$x_3 = 1$	$(1+\beta)h$
A_2 A_3	$x_3 = 1$	$2h$
A_1 A_2 A_3	$x_3 = 1$	$(2+\beta)h$

Notes: q is quasi-surplus; $x_i = 1$ means that agent i invests; $t =$ surplus generated by the investment of agent 1 at agent 1's stage of production; $f =$ surplus generated by the investment of agent 2 at agent 2's stage of production; and, $h =$ surplus generated by the investment of agent 3 at agent 3's stage of production.

Also for the three agent supply chain, we can find the bargaining power of each agent by computing the Shapley values for each investment and each ownership structure (see Appendix A for an example). The Shapley value determines the appropriation rate; that is, it allocates the surplus which the investment of an investor generates between the parties.

Once we know the Shapley value, we know the maximum investment each agent is willing to do under each ownership structure. As we have assumed noncooperative investment decisions, each agent will base his investment only on its own Shapley value. The (investment) participation constraint for agent 1 under ownership structure I is

$$(4) \quad k_1 \leq (9+3\alpha)t/6 = (1.5+0.5\alpha)t.$$

Table 4 gives the maximum cost of investment for each investing agent under the ten different ownership structures. It follows immediately from table A-5 in appendix A.

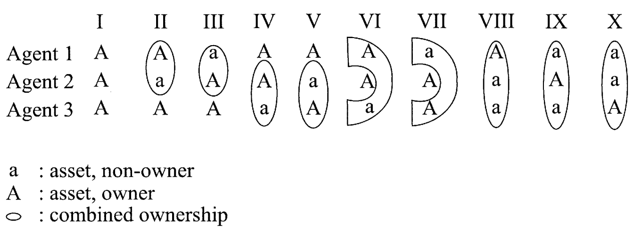

Figure 3. The ten possible ownership structure choices

Table 4. Maximum Investment Levels Under Various Ownership Structures

Ownership Structure	Max. Investment by Agent 1	Max. Investment by Agent 2	Max. Investment by Agent 3
I	$(1.5+0.5\alpha)t$	$2f$	$(1.5+0.5\beta)h$
II	$(2+0.5\alpha)t$	$4f/3$	$(1.5+0.5\beta)h$
III	$(1+\alpha/3)t$	$2.5f$	$(1.5+0.5\beta)h$
IV	$(1.5+0.5\alpha)t$	$2.5f$	$(1+\beta/3)h$
V	$(1.5+0.5\alpha)t$	$4f/3$	$(2+0.5\beta)h$
VI	$(1.5+\alpha)t$	$2f$	$(5/6+0.5\beta)h$
VII	$(5/6+0.5\alpha)t$	$2f$	$(1.5+\beta)h$
VIII	$(2+\alpha)t$	$1.5f$	$(1+0.5\beta)h$
IX	$(1+0.5\alpha)t$	$3f$	$(1+0.5\beta)h$
X	$(1+0.5\alpha)t$	$1.5f$	$(2+\beta)h$

Efficient Ownership Structures in a Three-Tier Chain

Just as for the two-agent model, in the three-agent agrifood chain, an ownership structure is first-best efficient when it implements all (and only) surplus generating investments. The participation constraints of the three agents determine whether a particular combination of investments will yield the first-best. The constraints are $k_1 \leq SV_1$, $k_2 \leq SV_2$, and $k_3 \leq SV_3$.

Table 4 implies a ranking with respect to the incentives that each ownership structure holds for various investment decisions. The ranking of ownership structures according to the maximum level of investment under each structure is:

(5) $$\text{VII} < \text{III} < \text{IX/X} < \text{I/IV/V} < \text{VI} < \text{II} < \text{VIII}.$$

Ownership structure VIII is always first-best efficient regarding the specific investment of agent 1. In other words, every surplus generating investment by agent 1 will be implemented under ownership structure VIII, because all benefits of the investment accrue to agent 1.

Because the positive externalities of investment are not fully taken into account when the investing agent makes its investment decision, underinvestment may result. For example, agent 1 will invest under ownership structure II when $k_1 \in [0, (2+0.5\alpha)t]$, but not when $k_1 \in ((2+0.5\alpha)t, \infty)$. Ownership structure II is inefficient for high levels of k_1, when $k_1 \in ((2+0.5\alpha)t, (2+\alpha)t)$, because agent 1 does not take the full positive externality of investment for agent 3 into account in its investment decision.

From the perspective of an investment by agent 1, ownership structure VI is less efficient than ownership structure II. Under II agent 1 owns the assets at tiers 1 and 2 (see figure 3) and under VI he owns assets at tiers 1 and 3, while his investment generates more value in tier 2 than in tier 3. Ownership structures I, IV, and V are identical and dominated by ownership structure VI because in I, IV, and V, agent 1 only owns the asset at the first tier of the chain. Ownership structures IX and X are identical with respect to investment incentives for agent 1: he is indispensable because he makes the investment, while the other agent (i.e., agent 2 in IX and agent 3 in X) is indispensable because he owns all assets. Ownership structure III is less efficient than IX and X because agent 1 has to negotiate with two other agents instead of only one. Finally, ownership structure VII is the least efficient with respect to the investment incentives for agent 1. It is even less efficient than ownership structure III because the combination of agents 1 and 2 in III generate more surplus than the combination of 1 and 3 in VII.

The ranking of ownership structure according to the maximum possible investment k_2 by agent 2 is:

(6) $$\text{II/V} < \text{VIII/X} < \text{I/VI/VII} < \text{III/IV} < \text{IX}.$$

Similarly, the ranking of ownership structures for the maximum possible investment k_3 by agent 3 is:

(7) $$\text{VI} < \text{IV} < \text{VIII/IX} < \text{I/II/III} < \text{VII} < \text{V} < \text{X}.$$

The explanation of these rankings is similar to that of agent 1.

These three rankings can be presented in a three-dimensional diagram with k_1, k_2, and k_3 on the axes. This diagram represents first-best efficient ownership structures. For reasons of simplicity it is sliced into six two-dimensional figures, with each figure representing a range of values of k_2. Figure 4 presents the first-best ownership structure for $k_2 \leq 1.33f$. Agent 2 will always invest when the specific level of investment is not above $1.33f$.

The next step is finding first-best efficient ownership structures for a higher investment by agent 2: $1.33f < k_2 \leq 1.5f$. Figure 5 presents this slice. Ownership structures II and V are no longer first-best efficient. Additional figures, shown in Appendix B, show that:

- if $1.5f < k_2 \leq 2f$, then VIII and X are no longer first-best efficient;
- if $2f < k_2 \leq 2.5f$, then I, VI, and VII are no longer first-best efficient;
- if $2.5f < k_2 \leq 3f$, then III and IV are no longer first-best efficient.

It follows from figures 4 and 5 (and the ones in Appendix B) that each possible ownership structure can be uniquely first-best efficient. The ordering of efficient ownership structures for each investing agent shows that a change in ownership structure increases the incentive to invest for one agent as well as decreases the incentive to invest for other agents. While a shift in ownership structure strengthens agent i's bargaining position, it weakens agent j's bargaining position.

An interesting case is ownership structure II: the farmer owns both the land and the factory, and the retailer owns the shop. This is the typical farmer-owned marketing cooperative (MC). If the three agents—the farmer, the manager/processor of the factory, and the retailer—all make chain-specific investments, it is the relative size of the investment that determines whether this particular ownership structure is efficient. Figures 4 and 5 show that ownership structure II is the unique first-best efficient structure if and only if $(1.5+0.5\alpha)t < k_1 \leq (2+0.5\alpha)t$, $0 < k_2 \leq 1.33f$, and $(1+0.5\beta)h < k_3 \leq (1.5+0.5\beta)h$. Here the farmer's specific investment is relatively large compared to the investments by the processor and the retailer (i.e., $k_1/q_1 > k_2/q_2$ and $k_1/q_1 > k_3/q_3$). If the farmer's investment is smaller, then also I and V are first-best effi-

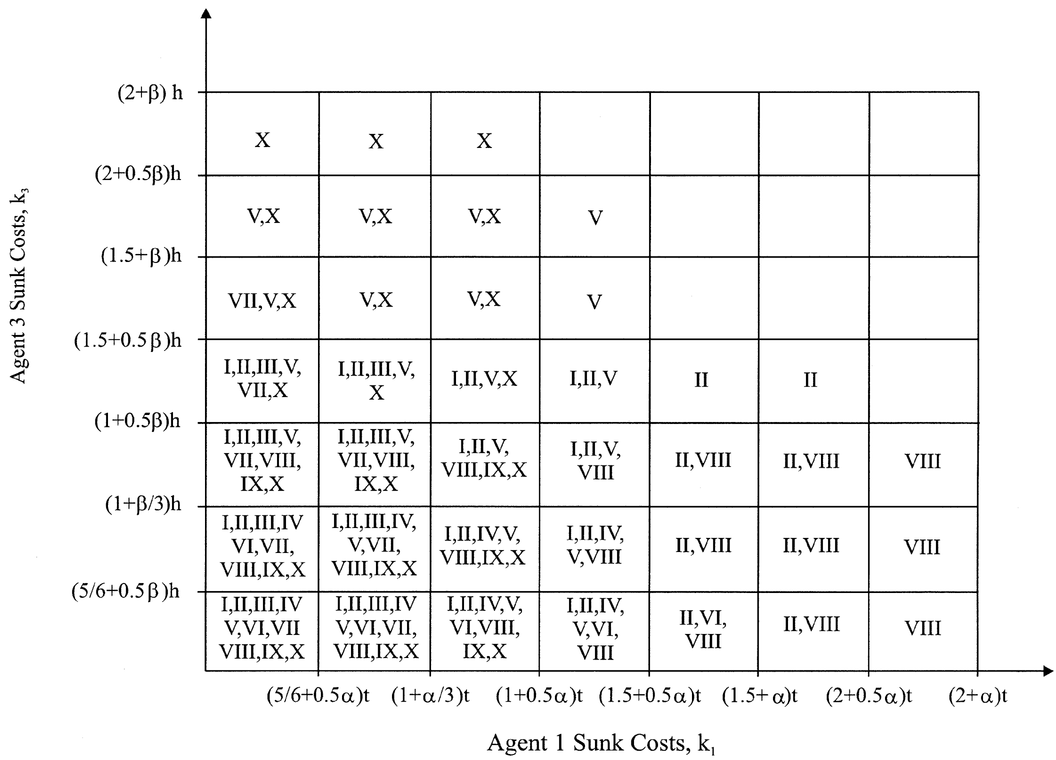

Figure 4. First-best efficient ownership structures when agent 2 always invests, i.e., $k_2 \leq 1.33f$

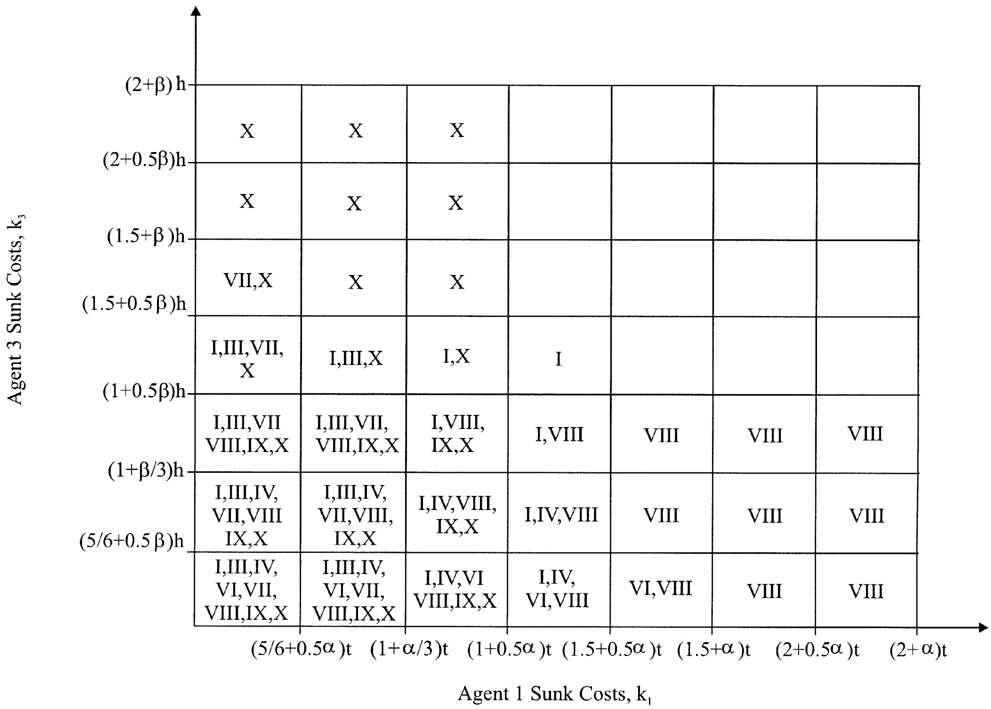

Figure 5. First-best efficient ownership structures when the costs of investment of agent 2 are $1.33f < k_2 \leq 1.5f$

cient. With ownership structure I each agent owns an asset, and with ownership structure V the processing plant and the shop are both owned by the retailer. If the investment by the retailer is smaller (if $k_3 \leq (1 + 0.5\beta)h$), then also VIII becomes first-best efficient. Ownership structure VIII means that the farmer owns all three assets. This situation of full chain integration will only yield the social optimum if the specific investments by the processor and the retailer are much smaller than the investment by the farmer.

Ownership structure II does not show up anymore in figure 5, indicating that an increase in k_2 will reduce the attractiveness of an MC in inducing investments by all agents in the chain. When the specific investment by agent 2 increases in proportion to the investments by agents 1 and 3, an MC is no longer the best solution to the various holdup problems. Because an MC is geared toward the interests of the farmer (agent 1), expressed by farmer-ownership of the processing firm, investments by agent 2 face the threat of holdup by the farmers. The conclusion is that if the manager of a farmer-owned processing firm needs relatively high chain-specific investments, for instance, in product innovation or marketing innovation, a shift from MC to another ownership structure may be necessary. For instance, if the manager owns the processing firm, he has a much stronger bargaining position and therefore a better incentive to invest.

Comparative Statics Results

A number of comparative statics results can be derived from this model. First, the set of efficient ownership structures shrinks when the specific costs of investment increases relative to the surplus it generates. When k/q increases, the ownership structure has to be more fine-tuned to prevent holdup problems. Another way of formulating this result is that an increase in the value of q, given the level of k, will increase the set of efficient ownership structures. The increase in the ratio surplus/quasi-surplus provides more leeway in the choice of ownership structure such that both agents feel secure that their investments will be recouped. In the cells in the upper right corners of figures 4 and 5, there is no first-best ownership structure; that is, there is no ownership structure that is able to obtain the first-best when k_1 as well as k_3 have a high value (in proportion to the level of q).[9]

Second, many agricultural markets are nowadays surplus instead of shortage markets. The response of more product differentiation and more vertical coordination entails a higher level of asset specificity, thus increasing k/q. Third, the globalization of markets entails more competition. This means that surplus decreases and k/q increases, making it more difficult to establish the first-best outcome.

Finally, what happens if the complementarities in the chain increase (i.e., if α or β increases)? A higher value of α means that the specific investment by agent 1 generates a higher quasi-surplus. This results in a shift to the right of the borderlines between the cells in figures 1 and 2. This implies that with given investment levels for agents 1, 2, and 3, more ownership structures are now first-best efficient (also showing that less integrated structures become efficient for agent 1). A similar argument is valid for the value of β. In general, we see that a higher quasi-surplus of a given investment makes more ownership structures efficient.

Conclusions

Vertical coordination in the agrifood sector often requires aligning activities of agents in more than two tiers of the production and distribution system. Particularly if specialty agricultural products are produced, processed, and marketed (like with identity preservation), vertical contracting is relationship-specific. If these activities require investments which can only be recouped with particular partners in the system, then dependencies exist. Such dependencies provide room for opportunistic behavior in the form of appropriation of a larger share of the surplus than contracted for. If a company participating in a specific agrifood chain has insufficient guarantee that he will be able to recoup his investment, inefficient investment decisions will result.

In this article, we have applied the incomplete contract model to the analysis of investment decisions by three agents in a three-tier agrifood supply chain. In fact, the agrifood supply chain consists of three agents and three assets: farmer + land, processor + factory, and retailer + store. Incomplete contract theory predicts that asset ownership has an effect on agents' incentives to invest. This effect is due to the impossibility to write comprehensive contingent contracts for relationship-specific investments and the resulting potential for opportunistic behavior and *ex post* renegotiation over the trade benefits. The risk of *ex post* contract reneging results in under-investment. Changing the allocation of asset ownership between the trading agents may solve the holdup problem.

Each agent in a three-tier agrifood supply chain can make investments yielding a higher surplus if the agent collaborates with agents in the other tiers of the chain. An important element in the incomplete contract model is the distinction between agents and assets. Each agent makes an investment in human capital, the investment will only yield surplus if the agent has access to a particular asset, and the investment will yield a higher surplus if the agent has also access to assets in other tiers of the chain. The latter characteristic makes the investment (at least partially) chain-specific. Whether agents are actually willing to make the chain-specific investments depends on the division of value in case of *ex post* renegotiation. The bargaining power in this renegotiation process is determined by the ownership of assets that are essential for the investment; that is, without access to these assets the investment will generate no or lower value.

Our model shows that optimal asset ownership is determined by the specific investment cost/quasi-surplus ratio for agent 1 in proportion to the specific investment cost/quasi-surplus ratio for agent 2 when first-best efficiency is attainable. If this ratio is higher for agent 1 than for agent 2, then agent 1 should own most of the assets that are used in generating the quasi-surplus. In other words, if the specific investment by agent 1 generates a smaller surplus (relative to the investment) than the specific investment by agent 2 does, then agent 1 should own more assets to obtain the efficient investment decisions. The second-best ownership structure choice assigns most power to the agent generating the highest surplus.

When the farmer's specific investment is high relative to the specific investment by the processor, farmer-ownership of the assets in the processing stage of the chain obtains

[9] Which ownership structures are second-best efficient depends on the relative size of the agents' investment decisions.

the first-best solution. This is the classic farmer-owned marketing cooperative. However, if the investment by the processor (or retailer) becomes relatively more important for total chain value than the investment by the farmer, the cooperative may no longer be an efficient ownership structure. The current trend toward restructuring of cooperatives, particularly toward finding solutions for the lack of equity capital, may be an indication of the inefficiency of farmer-control over assets in the processing and marketing stages of the agrifood chain.

The model of a three-tier chain has been illustrated with the example of the farmer, processor, and retailer. A three-agent supply chain for fresh produce consisting of a seed company, a vegetables grower, and a wholesaler can be analyzed in the same way. The same results will of course hold, but the marketing cooperative is in such a chain represented by ownership structure IV instead of ownership structure II.

If changes in technology or changes in agrifood markets shift the relative importance of the individual investments by different chain partners (that is, if retailer investment becomes more important than farmer investment), then it may be necessary to change the allocation of ownership of essential assets to induce agents to make those investments that generate the chain optimum. Thus, it may be necessary to change the ownership structure in agrifood chains to obtain that combination of investment decisions yielding the first-best ownership structure. The model we have presented may contribute to determine ownership structures that induce the generation of maximum value.

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Appendix A

Characteristic Functions and Shapley Values

Explanation for table A-1: $v(\phi)$ represents the value which is assigned to the empty coalition, which is always zero; $v(1)$ is a coalition with only agent 1 and generates only value if agent 1 has access to asset A_1 (i.e., under I and II); $v(2)$ is a coalition with only agent 2 and generates only value if agent 2 has access to asset A_2 (i.e., under I and III); $v(12)$ is a coalition of agents 1 and 2 and generates the full quasi-surplus of $2t$ or $2f$.

By using the characteristic function, we can compute the Shapley value for each agent under each ownership structure. For investing agent 1 (i.e., $x = (1, 0)$) under ownership I, the Shapley value is computed by adding his marginal contribution in each possible sequence of the grand coalition of agents 1 and 2, and dividing the total contributions by the number of coalitions (table A-2). In coalition (12), the marginal contribution of agent 1 is t, in coalition (21), the marginal contribution of agent 1 is $2t$. The sum $3t$ is divided by 2, giving a Shapley value of $1.5t$ for agent 1 under ownership structure I.

The computation of the Shapley value for three agents is done the same way. Suppose ownership I is chosen and agent 1 invests (i.e., $x = (1, 0, 0)$). The characteristic function $v(S|\ \text{I}, (1,0,0))$ is:

$$N = \{1, 2, 3\}$$
$$v(\phi \mid \text{I},(1, 0, 0)) = 0$$
$$v(1 \mid \text{I},(1, 0, 0)) = t$$
$$v(2 \mid \text{I}, (1, 0, 0)) = 0$$
$$v(3 \mid \text{I}, (1, 0, 0)) = 0$$
$$v(12 \mid \text{I}, (1, 0, 0)) = 2t$$
$$v(13 \mid \text{I}, (1, 0, 0)) = (1 + \alpha)t$$
$$v(23 \mid \text{I}, (1, 0, 0)) = 0$$
$$v(123 \mid \text{I}, (1, 0, 0)) = (2 + \alpha)t.$$

Table A-3 presents the computation of the Shapley values for ownership structure I and investment by agent 1. We illustrate the numbers in the table by elaborating on two possible orders in which the grand coalition of all players can be formed. Consider first the order 123. The marginal value added by player 1 is $v(1 \mid \text{I}, (1, 0, 0)) - v(\phi \mid \text{I}, (1, 0, 0)) = t - 0 = t$. The marginal value added by player 2 is $v(12 \mid \text{I}, (1, 0, 0)) - v(1 \mid \text{I}, (1, 0, 0)) = 2t - t = t$. The marginal value added by player 3 is $v(123 \mid \text{I}, (1, 0, 0)) - v(12 \mid \text{I}, (1, 0, 0)) = (2 + \alpha)t - 2t = \alpha t$. The marginal contribution of each player in order 312 is computed similarly. The marginal value added by player 3 is $v(3 \mid \text{I}, (1, 0, 0)) - v(\phi \mid \text{I}, (1, 0, 0)) = 0 - 0 = 0$. The marginal value added by player 1 is $v(13 \mid \text{I}, (1, 0, 0)) - v(3 \mid \text{I}, (1, 0, 0)) = (1 + \alpha)t - 0 = (1 + \alpha)t$. The marginal value added by player 2 is $v(123 \mid \text{I}, (1, 0, 0)) - v(13 \mid \text{I}, (1, 0, 0)) = (2 + \alpha)t - (1 + \alpha)t = t$.

In the three-agent model, there are ten possible ownership structures and three types of investments. Thirty different characteristic functions have therefore to be analyzed to determine the level of investment of each agent and the efficient choice of ownership structure. Table A-4 presents the characteristic functions. We will explain the numbers of rows seven (with ownership structure VI) and eight (with VII) of this table to illustrate its construction. Assume that agent 1 invests. Coalitions without agent 1 have value 0 because agent 1 has to invest and is therefore essential. This implies $v(2) = v(3) = v(23) = 0$. If all agents are in the coalition, then the whole surplus is of course created by this coalition: $v(123) = (2 + \alpha)t$.

Table A-1. Characteristic Functions for the Two-Tier Model

$X = (x_1, x_2)$	G	$v(\phi)$	$v(1)$	$v(2)$	$v(3)$
(1,0)	I	0	t	0	$2t$
(1,0)	II	0	$2t$	0	$2t$
(1,0)	III	0	0	0	$2t$
(0,1)	I	0	0	f	$2f$
(0,1)	II	0	0	0	$2f$
(0,1)	III	0	0	$2f$	$2f$

Notes: $x_i = 1$ means that agent i invests; $G =$ governance structure; and, $v(Z) =$ value of coalition Z.

Table A-2. Computation of Shapley Value for Investment by Agent 1 and Ownership Structure I

Order in Coalition S	Value Added by Agent 1	Value Added by Agent 2
(12)[a]	t	t
(21)	$2t$	0
Sum of marginal contributions	$3t$	t
Shapley value	$1.5t$	$0.5t$

[a] (xy) is the sequence in which agent x is first, and agent y is second.

Table A-3. Shapley Values for Ownership Structure I and Investment by Agent 1

Order in Coalition S	Value Added by Agent 1	Value Added by Agent 2	Value Added by Agent 3
(123)[a]	t	t	αt
(132)	t	t	αt
(213)	$2t$	0	αt
(231)	$(2+\alpha)t$	0	0
(312)	$(1+\alpha)t$	t	0
(321)	$(2+\alpha)t$	0	0
Sum of marginal contributions	$(9+3\alpha)t$	$3t$	$3\alpha t$
Shapley values	$(9+3\alpha)t/6$	$t/2$	$\alpha t/2$

[a] (xyz) is the sequence in which agent x is first, and agent y is second, and agent z is third.

Table A-4. Characteristic Functions for the Three-Tier Model

X	G	$v(1)$	$v(2)$	$v(3)$	$v(12)$	$v(13)$	$v(23)$	$v(123)$
(1,0,0)	I	t	0	0	$2t$	$(1+\alpha)t$	0	$(2+\alpha)t$
(1,0,0)	II	$2t$	0	0	$2t$	$(2+\alpha)t$	0	$(2+\alpha)t$
(1,0,0)	III	0	0	0	$2t$	0	0	$(2+\alpha)t$
(1,0,0)	IV	t	0	0	$(2+\alpha)t$	t	0	$(2+\alpha)t$
(1,0,0)	V	t	0	0	t	$(2+\alpha)t$	0	$(2+\alpha)t$
(1,0,0)	VI	$(1+\alpha)t$	0	0	$(2+\alpha)t$	$(1+\alpha)t$	0	$(2+\alpha)t$
(1,0,0)	VII	0	0	0	0	$(1+\alpha)t$	0	$(2+\alpha)t$
(1,0,0)	VIII	$(2+\alpha)t$	0	0	$(2+\alpha)t$	$(2+\alpha)t$	0	$(2+\alpha)t$
(1,0,0)	IX	0	0	0	$(2+\alpha)t$	0	0	$(2+\alpha)t$
(1,0,0)	X	0	0	0	0	$(2+\alpha)t$	0	$(2+\alpha)t$
(0,1,0)	I	0	f	0	$2f$	0	$2f$	$3f$
(0,1,0)	II	0	0	0	$2f$	0	0	$3f$
(0,1,0)	III	0	$2f$	0	$2f$	0	$3f$	$3f$
(0,1,0)	IV	0	$2f$	0	$3f$	0	$2f$	$3f$
(0,1,0)	V	0	0	0	0	0	$2f$	$3f$
(0,1,0)	VI	0	f	0	$3f$	0	f	$3f$
(0,1,0)	VII	0	f	0	f	0	$3f$	$3f$
(0,1,0)	VIII	0	0	0	$3f$	0	0	$3f$
(0,1,0)	IX	0	$3f$	0	$3f$	0	$3f$	$3f$
(0,1,0)	X	0	0	0	0	0	$3f$	$3f$
(0,0,1)	I	0	0	h	0	$(1+\beta)h$	$2h$	$(2+\beta)h$
(0,0,1)	II	0	0	h	0	$(2+\beta)h$	h	$(2+\beta)h$
(0,0,1)	III	0	0	h	0	h	$(2+\beta)h$	$(2+\beta)h$
(0,0,1)	IV	0	0	0	0	0	$2h$	$(2+\beta)h$
(0,0,1)	V	0	0	$2h$	0	$(2+\beta)h$	$2h$	$(2+\beta)h$
(0,0,1)	VI	0	0	0	0	$(1+\beta)h$	0	$(2+\beta)h$
(0,0,1)	VII	0	0	$(1+\beta)h$	0	$(1+\beta)h$	$(2+\beta)h$	$(2+\beta)h$
(0,0,1)	VIII	0	0	0	0	$(2+\beta)h$	0	$(2+\beta)h$
(0,0,1)	IX	0	0	0	0	0	$(2+\beta)h$	$(2+\beta)h$
(0,0,1)	X	0	0	$(2+\beta)h$	0	$(2+\beta)h$	$(2+\beta)h$	$(2+\beta)h$

Notes: $\mathbf{X} = (x_1, x_2, x_3)$ is the vector of investments; $G =$ governance structure; and $v(Z) =$ value of coalition Z.

Table A-5. Shapley Values for the Three-Tier Model

X	G	Shapley Value Agent 1	Shapley Value Agent 2	Shapley Value Agent 3
(1,0,0)	I	$(1.5+0.5\alpha)t$	$t/2$	$0.5\alpha t$
(1,0,0)	II	$(2+0.5\alpha)t$	0	$0.5\alpha t$
(1,0,0)	III	$(1+\alpha/3)t$	$(1+\alpha/3)t$	$\alpha t/3$
(1,0,0)	IV	$(1.5+0.5\alpha)t$	$(0.5+0.5\alpha)t$	0
(1,0,0)	V	$(1.5+0.5\alpha)t$	0	$(0.5+0.5\alpha)t$
(1,0,0)	VI	$(1.5+\alpha)t$	$t/2$	0
(1,0,0)	VII	$(5/6+0.5\alpha)t$	$t/3$	$(5/6+0.5\alpha)t$
(1,0,0)	VIII	$(2+\alpha)t$	0	0
(1,0,0)	IX	$(1+0.5\alpha)t$	$(1+0.5\alpha)t$	0
(1,0,0)	X	$(1+0.5\alpha)t$	0	$(1+0.5\alpha)t$
(0,1,0)	I	$f/2$	$2f$	$f/2$
(0,1,0)	II	$4f/3$	$4f/3$	$f/3$
(0,1,0)	III	0	$2.5f$	$f/2$
(0,1,0)	IV	$f/2$	$2.5f$	0
(0,1,0)	V	$f/3$	$4f/3$	$4f/3$
(0,1,0)	VI	f	$2f$	0
(0,1,0)	VII	0	$2f$	f
(0,1,0)	VIII	$1.5f$	$1.5f$	0
(0,1,0)	IX	0	$3f$	0

Table A-5. Continued

X	*G*	Shapley Value Agent 1	Shapley Value Agent 2	Shapley Value Agent 3
(0,1,0)	X	0	$1.5f$	$1.5f$
(0,0,1)	I	$0.5\beta h$	$0.5h$	$(1.5+0.5\beta)h$
(0,0,1)	II	$(0.5+0.5\beta)h$	0	$(1.5+0.5\beta)h$
(0,0,1)	III	0	$(0.5+0.5\beta)h$	$(1.5+0.5\beta)h$
(0,0,1)	IV	$\beta h/3$	$(1+\beta/3)h$	$(1+\beta/3)h$
(0,0,1)	V	$0.5\beta h$	0	$(2+0.5\beta)h$
(0,0,1)	VI	$(5/6+0.5\beta)h$	$h/3$	$(5/6+0.5\beta)h$
(0,0,1)	VII	0	$0.5h$	$(1.5+\beta)h$
(0,0,1)	VIII	$(1+0.5\beta)h$	0	$(1+0.5\beta)h$
(0,0,1)	IX	0	$(1+0.5\beta)h$	$(1+0.5\beta)h$
(0,0,1)	X	0	0	$(2+\beta)h$

Notes: $\mathbf{X} = (x_1, x_2, x_3)$ is the vector of investments; $G =$ governance structure; and $v(Z) =$ value of coalition Z.

Compare ownership structure VI with ownership structure VII. Agent 3 adds no value in ownership structure VI to a coalition of which agent 1 is already a member because agent 1 owns the assets at the third stage. This implies $v(1) = v(13)$ and $v(12) = v(123)$. The coalition of agent 1 adds a value of $(1+\alpha)t$ because he owns the assets at stages 1 and 3: $v(1) = (1+\alpha)t$. The coalition of the agents 1 and 2 generates the whole surplus because together they own all the assets: $v(12) = (2+\alpha)t$. The agents 1 and 3 are both essential in ownership structure VII because agent 1 invests and agent 3 owns the assets at stage 1. This implies $v(1) = 0$ and $v(12) = 0$. Agent 2 is essential for the agents 1 and 3 for generating the value with his asset: $v(13) = (1+\alpha)t$.

The Shapley value is used to determine the appropriation rate. It allocates the surplus which the investment of an investor generates between the three agents. Notice that for each particular case, the Shapley value specifies an appropriation rate for all the three agents and of course the maximum investment cost only for the investor. Table A-5 gives the Shapley values for three investment decisions, three agents, and ten ownership structures.

Appendix B

Efficient Ownership Structures

There are no first-best efficient ownership structures for $k_2 > 3f$ because the investment is larger than the quasi-surplus.

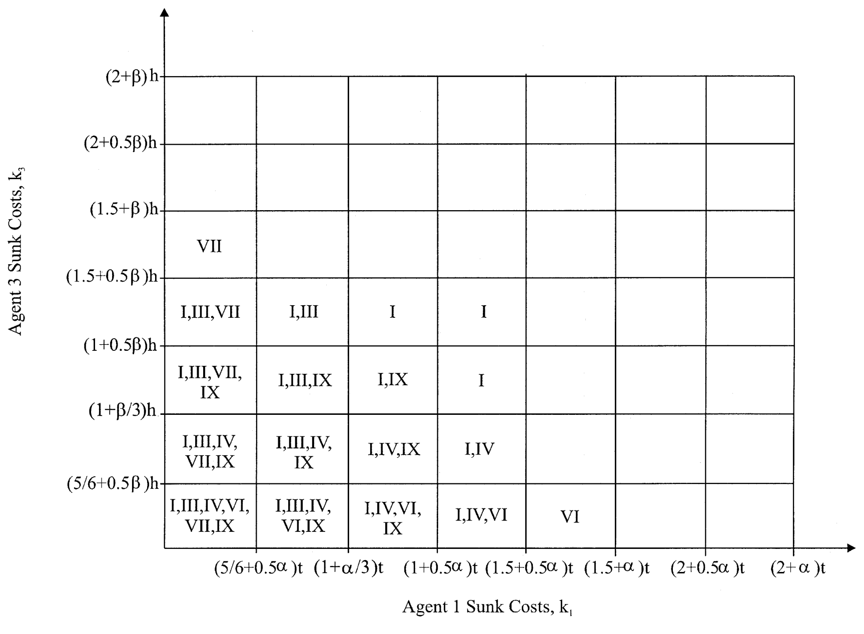

Figure B.1. First-best efficient ownership structures when the costs of investment of agent 2 are $1.5f < k_2 \leq 2f$

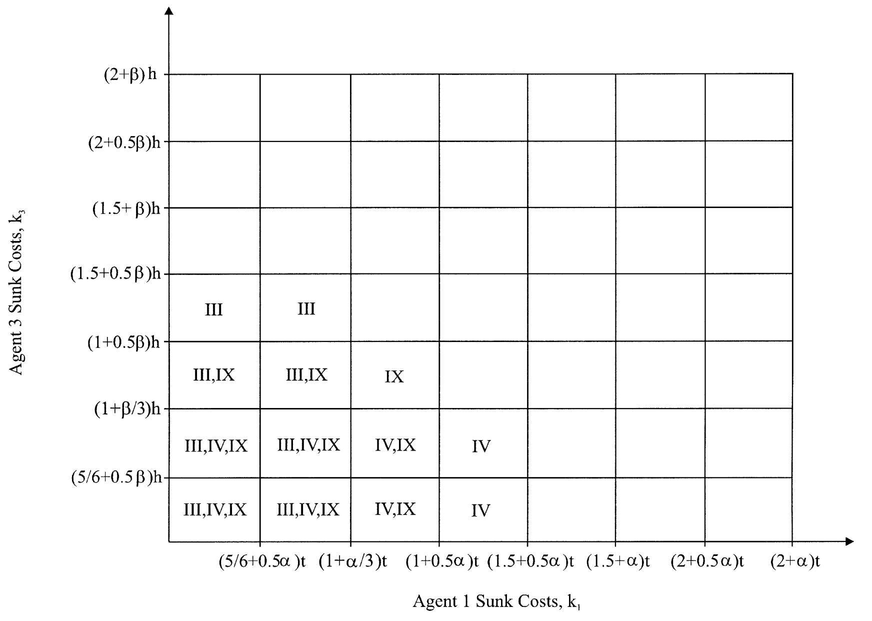

Figure B.2. First-best efficient ownership structures when the costs of investment of agent 2 are $2f < k_2 \leq 2.5f$

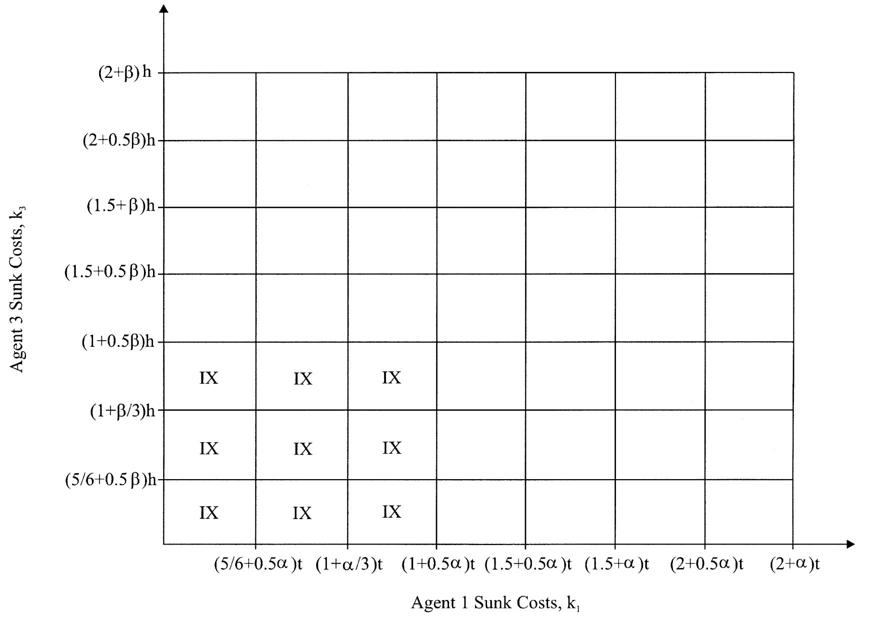

Figure B.3. First-best efficient ownership structures when the costs of investment of agent 2 are $2.5f < k_2 \leq 3f$