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How Negotiation Influences the Effective Adoption of the Revenue Sharing Contract: A Multi-Agent Systems Approach

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1. Introduction

Supply Chain Management (SCM) can be pursued by adopting a centralized or decentralized control. In the former case, a unique decision maker exists in the SC, who possesses any information on the whole SC that is relevant to make decision and the contractual power to have such decisions be implemented. The centralized control assures the system efficiency (channel coordination). In the case of decentralized control, different decision makers exist in the supply chain (SC), who pursue their own objectives, which can be conflicting and lead to system inefficiency. To cope with this problem, proper coordination mechanisms need to be adopted, which modify the incentives of the different decision makers, so as to induce them to maximize the SC total profit.

SC contracts are coordination mechanisms that utilize incentives to make SC actors' decisions coherent among each other. In particular, the incentives let the risk and the revenue (which arise from different sources of uncertainty and from channel coordination, respectively) be shared by all SC actors.

SC contracts allow two main objectives to be achieved: i) to increase the total SC profit so as to make it closer to the profit resulting from a centralized control (channel coordination) and ii) to share the risks among the SC partners (Tsay *et al.*, 1999)

A further important issue for the contract design concerns the so-called *win-win* condition: this occurs if under the contract every SC actor gains a profit higher than he/she would get without contract. Otherwise, the SC actor would not be prompted to adopt the contract.

Different models of SC contracts have been developed in the literature. They include the quantity flexibility contracts (Tsay, 1999), the backup agreements (Eppen & Iyer, 1997), the buy back or return policies (Emmons & Gilbert, 1998), the incentive mechanisms (Lee & Whang, 1999), the revenue sharing contracts (Cachon & Lariviere, 2000; Giannoccaro & Pontrandolfo, 2003), the allocation rules (Cachon & Lariviere, 1999), and the quantity discounts (Weng, 1995).

Most of these models address the problem of coordinating serial SCs made up of two stages. Moreover, the majority of them addresses channel coordination, whereas much less emphasis is given to the analysis of the conditions supporting the contract implementation. In fact, even if an effective contract exists, this does not imply that the SC agents will adopt

it. They need to reach an agreement on the values of the contract parameters, given that they influence their profit. As a result, every SC actor will tend to impose her own preferences that could not be accepted by the others.

We focuses on the implementation issues of SC contracts. In particular, we consider the revenue sharing contract. As pointed out by Cachon & Lariviere (2002), a few problems can limit the use of revenue sharing contracts, namely the amount of administration costs due to the contract implementation, and the retailer efforts on sales. In fact, once a contract is designed, its implementation is not always straightforward. Organizational problems, such as those related to the parties' relative contractual power as well as the need for sharing certain information among parties, may indeed lessen the potential benefits coming from adopting a contract. Therefore, adequate attention should be paid to (i) designing the contract so as to make it acceptable by the parties and (ii) analyzing the process by which the parties reach the agreement on the contract.

Our aim is to characterize the scenarios that are appropriate for the adoption of the revenue sharing (RS) contract. First we identify the main features characterizing the video-rental industry (such as the distribution of contractual power among the actors and the shape of the supply chains involving them) in which the RS contract is already effectively used, and compare such features with other industries not adopting the contract. Then, we develop a simulation analysis to define the scenarios in which the RS is more likely to be successfully implemented.

Simulation is carried out through an approach based on agent-based systems (Ferber, 1999; Durfee, 1998; Wooldridge, 2000). Such systems consist of a set of autonomous agents (each modeling a certain SC actor), which share their information and cooperate each other to achieve a global goal while optimizing their own objectives.

Recently, the agent-based systems have been used to address SCM issues. For example, Lin & Shaw (1998) propose a multi agent information system approach for the re-engineering of the order fulfilment process in a SC. Cantamessa (1997) reviews the seminal works on agent-based modelling applied to address manufacturing issues and proposes a generic agent-based simulator useful to build agent-based models in manufacturing domain. Similarly, but with more attention for SCM applications, Swaminathan et al. (1998) propose a multi-agent simulation-based framework for developing customized SCM models from a library of software components involving generic SCM processes and activities. Albino et al., (2006) develop an agent model to study cooperation and competition in the SCs of an industrial district.

The agent-based systems approach is chosen as it allows us to model the cooperative and competitive behaviors of the different SC actors (that independently make decision, coherently with a decentralized control) and the strategies they adopt to negotiate.

Each agent is provided by objectives, beliefs, and actions. They negotiate seeking to reach an agreement on the values of the contract parameters. At the end of negotiation, however, the SC agents could adopt or not the RS contract due to the beliefs influencing their behaviors. In this way the scenarios which favor the implementation of the RS contract can be identified.

The chapter is organized as follows. First, we introduce the RS contract and the main features of the industries in which it is used. Then, we design a RS contract for a two-stage SC that assures the channel coordination and satisfy the *win-win* condition. Successively, we

develop the agent-based system model of the negotiation process. Finally, the simulation analysis is carried out and the results are presented.

2. The revenue sharing contract

The RS contract is a coordination mechanism offered by the distributor to the retailer, which modifies the retailer's profit (as well as the distributor's) so as to incentive her to make decision coherent with the SC total optimization. A RS contract is described by two parameters (ω, Φ): the supplier charges the retailer the unit wholesale price ω, lower than the unit marginal cost c, in exchange for the percentage $(1-\Phi)$ of the retailer's revenue. The condition $\omega < c$ guarantees channel coordination, whereas Φ determines the distribution of total profits between supplier and retailer. In particular, Φ is the SC profit quota gained by the retailer (Cachon, 2004).

The RS contract is widespread mostly in the video-rental industry and has been adopted by companies such as Blockbuster Inc. and Holliwood Entertainment. The specific features of this industry that can be identified as favorable to the application of the RS contract are listed in Table 1.

Demand uncertainty (that can be stochastic and variable)
Single selling period
Single type of retailers
Goods supplied by unique supplier
Competition among retailers
Not satisfied inventory and demand are lost
Demand not influenced by sales promotions made by retailers
Easy control on retailer profits by the distributors

Table 1. Features of video-rental industry important for application of RS contract

Based on such features, we argue that a few other industries not yet adopting the RS contract are potential user of the RS contracts: CD, editing, newspaper, flowers.

2.1 The design of the revenue sharing contract for a two-stage supply chain

In this Section we present a revenue sharing (RS) contract and point out the way in which it can assures both *effectiveness* and *desirability*. The RS model is said to be *effective* (first objective) if it assures channel coordination, while it is said to be *desirable* (second objective), if all the chain partners increase their profits (with respect to the market setting) by adopting the contract. Notice that desirability is key if the bargaining power is symmetrically distributed among the chain partners, whereas it is less relevant if one or a few partners can make the others accept an uneven sharing of the (increase of the) total profit.

Consider a SC in which a distributor D provides a single product to a retailer R, who in turn serves the market demand. The demand is uncertain, with probability density function $f_d(d)$. The marginal unit costs of the retailer and distributor are c_1 and c_2, respectively. The distributor charges the retailer a wholesale unit price ω. The retailer sells the product at the unit price p (Figure 1).
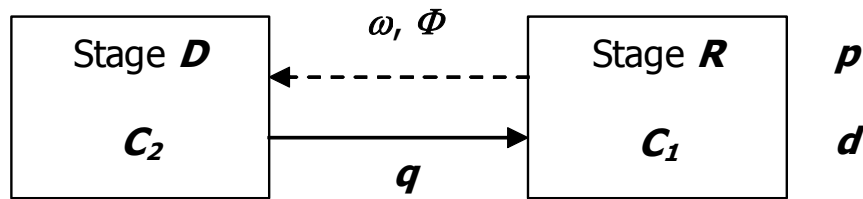
Figure 1. The two-stage SC model

The SC is characterized by a decentralized control, namely each SC actor makes decision by optimizing his own objective. In particular, the distributor D chooses the wholesale unit price ω, whereas the retailer decides the order quantity q, each of them trying to maximize his own profit. Both actors are risk neutral.

To achieve channel coordination (effectiveness), the two independent decision-makers should act coherently so as to maximize the SC total profit given by:

$$\Pi(q) = R(q) - q \cdot (c_1 + c_2) \tag{3.1}$$

being R(q) the expected retailer's revenue during the selling period.

Under the RS contract, the retailer's profit is given by:

$$\Pi_R(q) = \Phi \cdot R(q) - q \cdot (\omega + c_1) \tag{3.2}$$

Therefore, the retailer's optimal quantity q^o must satisfy:

$$\Phi \cdot R'(q^\circ) = \omega + c_1 \tag{3.3}$$

Hence, to achieve channel coordination, it is necessary that the optimal order quantity chosen by the retailer (q_h) corresponds to the order quantity that optimizes the SC total profit (q^c).

The latter satisfies:

$$R'(q^c) = c_2 + c_1 \tag{3.4}$$

By matching the (3.3) with the (3.4), it follows that, under the RS contract, the distributor will set a wholesale unit price such that:

$$\omega = \Phi \cdot (c_1 + c_2) - c_1 \tag{3.5}$$

Given that ω must be positive, it follows that:

$$\Phi > c_1 / (c_1 + c_2) = \Phi_{min,cc} \tag{3.6}$$

To assure desirability, the contract has to be designed so that every SC actor achieves a profit higher than he/she would do without contract. Otherwise, the SC actor would not be prompted to adopt the contract. We measure such a desirability for actor X by the expected value of the ratio Π_{Xc}/Π_{Xm} between his profits with and without (i.e. under a market-like setting) the contract. The higher the ratio (provided that it is not lower than 1), the more actor X is content with the adopted contract. To measure such a desirability index it should be known the unit price applied by every actor to his customer under a market-like setting (Giannoccaro & Pontrandolfo, 2004).

The values of Φ that assure desirability as stated above can be derived by letting all the expected value (E) of the ratio Π_{Xc}/Π_{Xm} be not lower than 1 for each $X \in \{R, D\}$.

The profits of retailer under the contract and the market-like setting are respectively:

$$\Pi_{Rc} = \Phi\,p\,\min\{q,d\}-(\omega+c_1)q \tag{3.7}$$

$$\Pi_{Rm} = p\,\min\{q,d\}-(\omega_m+c_1)q \tag{3.8}$$

where ω_m is the market price.

The profits of distributor under the contract and the market-like setting are respectively:

$$\Pi_{Dc} = (1-\Phi)p\,\min\{q,d\}+(\omega-c_2)q \tag{3.9}$$

$$\Pi_{Dm} = (\omega_m-c_2)q \tag{3.10}$$

By substituting equations (3.7) to (3.10) into the two *win-win* conditions ($\Pi_{Xc}/\Pi_{Xm}>1$) and being ω given by the (3.5), it follows:

$$\Phi > [p\cdot E(\min\{q_m,d\})-(\omega_m+c_1)q_m]/[p\cdot E(\min\{q^c,d\})-(c_1+c_2)q_c] = \Phi_{min,ww} \tag{3.11}$$

$$\Phi < 1-[(\omega_m-c_2)q_m)]/[(p\cdot E(\min\{q_c,d\})-(c_1+c_2)q_c] = \Phi_{max} \tag{3.12}$$

Therefore, any RS contract, which is both effective and desirable, has to simultaneously satisfy the inequalities (3.6), (3.11), and (3.12), which results in $\Phi \in \{\Phi_{min};\Phi_{max}\}$, being $\Phi_{min} = max\{\Phi_{min,cc}, \Phi_{min,ww}\}$.

Notice that Φ affects how the SC profit is shared between the retailer and distributor. This issue is directly related to the contract implementation process: in such a process the distribution of the contractual power play a key role in determining the actual Φ value. Therefore, we explicitly model contractual power in next Section.

3. The model of the negotiation process

In this Section we model the negotiation process between the distribution and the retailer, to analyze whether and how they reach an agreement on the Φ value.

We assume that the negotiation process is affected by two main variables, namely the relative contractual power of the SC actors and the collaboration among them.

The relative contractual power has been described in the literature in terms of abandon of the negotiation process by the actor: the most powerful actor will tend to devote lesser time to negotiate and will tend to more frequently threaten the abandon of the negotiation. In this way, the most powerful actor influences the negotiation process so as to reach a more advantageous agreement (Grant, 1999).

In particular, we use the following two variables to operationalize the contractual power of the SC actor: (1) the propensity to negotiate, and (2) the propensity to threaten the abandon of the negotiation. We assume that if the contractual power is high then the propensity to negotiate is low and the propensity to threaten the abandon of the negotiation is high.

The above variables model the competitive behavior of the parties. However, the latter can show a cooperative behavior as well. Relationships based on collaboration between buyers and suppliers characterize indeed the most recent trends in supply management. In this case the SC actors tend to become partners sharing costs and rewards (Lamming, 1993; Bensaou, 1999). Therefore, when the two actors are collaborative, they will behave so as to reach an agreement that satisfy both of them. We then consider the propensity to collaborate of the SC actors as a further variable of the model.

3.1 The Agent-based model of the negotiation process

Let us consider the SC described in Figure 1. The two SC actors are the agents of the model. The two agents intend to adopt the revenue sharing contract (ω, Φ) to achieve channel coordination. To do this and increase their profits, they need to reach an agreement on the value of $\Phi \in [\Phi_{min}; \Phi_{max}]$.

Therefore the retailer and the distributor negotiate the Φ value. We assume a discrete time negotiation process made up of K steps. Each step (k) of the negotiation process starts with a bid of the distributor that offers a given value of Φ ($\Phi_D(k)$), followed by the answer of the retailer. Notice that the first bid of the distributor is equal to Φ_{min}, whereas the most advantageous value of Φ for the retailer is Φ_{max}.

According to the most common agent architecture (Wooldridge, 2000), the agents are defined in terms of objectives, beliefs, and actions. In particular, the beliefs defines the agent mental model that drives its behaviour. Behavioural rules defining the agent behaviour are built using beliefs and actions, namely the values of the beliefs influence the action the agent undertakes.

The objective of each agent is to maximize his own profit.

Based on the above discussion, the beliefs of the agent are:

- Propensity to negotiate, namely the probability that the agent will negotiate at a given step (Pr_n);
- Propensity to threaten the abandon of the negotiation (Pr_t), namely the probability that the agent will threaten the abandon of the negotiation at a given step;
- Propensity to collaborate, namely the variation of Φ ($\Delta\Phi$) that the agent is willing to offer at the next step. Notice that this is positive for the distributor and negative for the retailer.

We assumed the first two beliefs as dynamic (i.e. they change according to the trends shown in Figure 2, with K =10). The last belief is assumed to be constant.
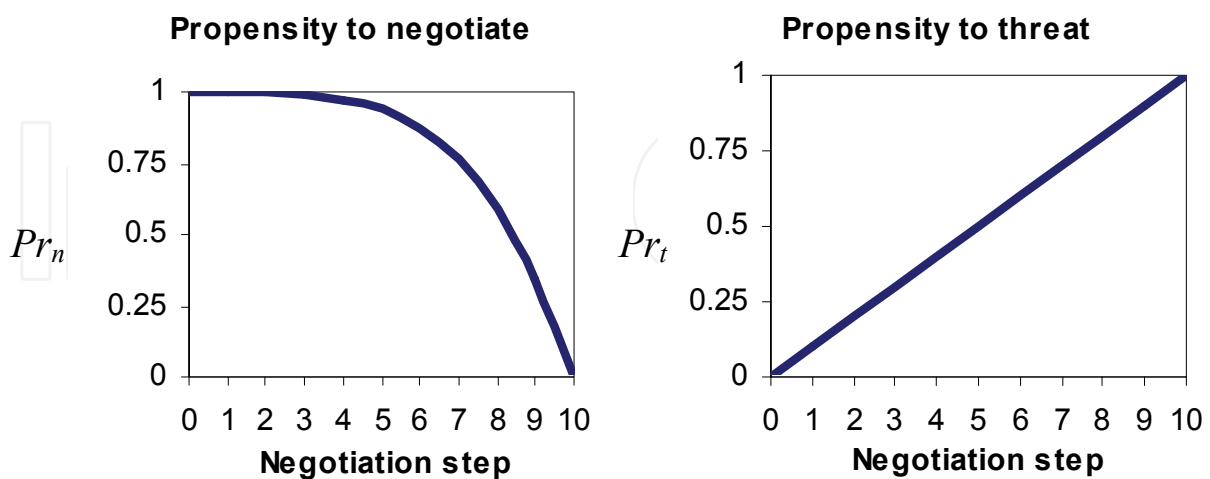

Figure 2. The agent dynamics beliefs.

At a given step of the negotiation, each agent is characterized by the values of propensity to negotiate and propensity to threaten the abandon of negotiation. These values represent the

probability that in step k the agent will negotiate ($Pr_n(k)$) and will threaten the abandon of the negotiation ($Pr_t(k)$), respectively.

All the beliefs influence the choice of the actions undertaken and the Φ value offered at each step by the agent.

The agent has **four** alternative **actions** to be chosen:

− "To accept the bid";
− "To not accept the bid and to make a new bid";
− "To exit the negotiation";
− "To threaten the abandon of the negotiation".

At each step a random number $x \in (0,1)$ is drawn lots. If x is lower than $Pr_n(k)$, the agent will accept the bid. On the contrary, if x is higher than $Pr_n(k)$, the agent will randomly choose between two actions, i.e. "to not accept the bid and to make a new bid" and "to exit the negotiation". In the first case, there is also the possibility to threaten the abandon of the negotiation. As before, a random number is drawn lots. Only if the latter is lower than $Pr_t(k)$, the agent will threaten the abandon of the negotiation. In this case, the other agent has only two alternative "to accept" or to "exit the negotiation". The choice between these two actions is random.

The value of Φ that is offered by the agent at each step depends on the propensity to collaborate. At a given step the agent will offer a value $\Phi(k) = \Phi(k-1) + \Delta\Phi$ (Figure 3).
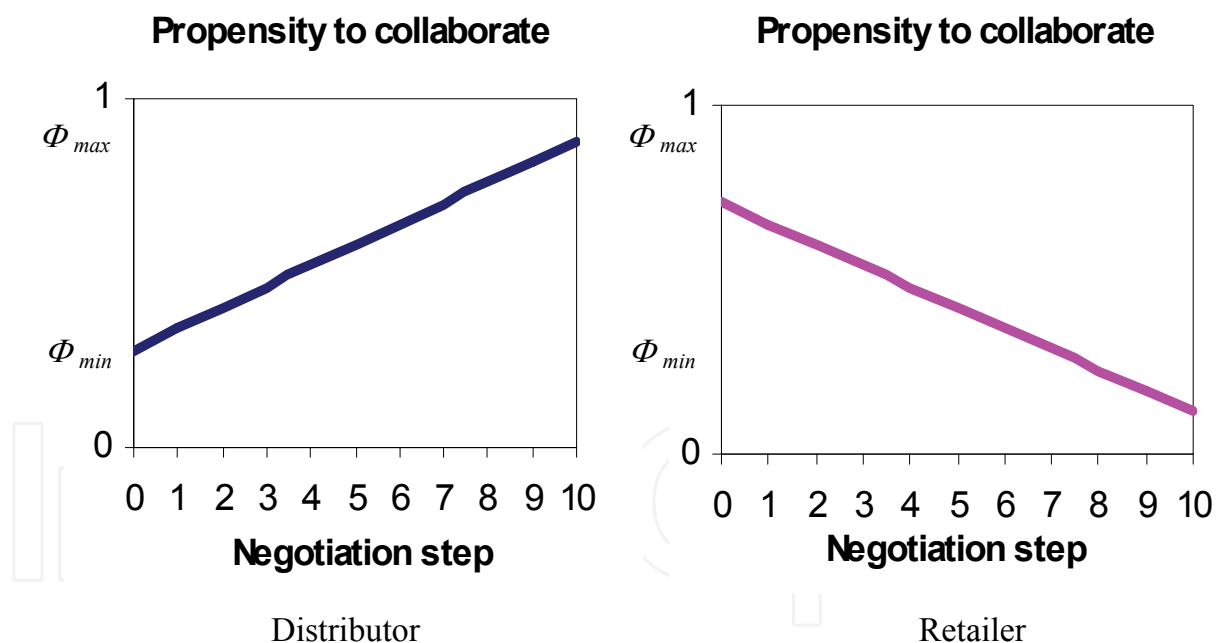

Figure 3. The choice of Φ during the negotiation

The negotiation process can end in two ways: 1) the agents reach an agreement on the value of Φ (*agreed* Φ), and 2) the agents do not reach an agreement.

Our aim is to analyze how the relative contractual power of SC actors and the collaboration among them influence the RS contract adoption, in terms of the actual use of the RS contract and the value of the agreed Φ.

4. Simulation analysis and results

We conducted a simulation analysis using the proposed model (the assumed cost and demand data are reported in Table 2). The simulation is developed by using MatLab.

SC Variables	c1	c2	ωm	P	D
Value	1	2	18	30	Normal distribution, mean = 100, std. dev. = 30

Table 2. Cost and demand data.

We simulated different scenarios characterized by diverse behaviors of the retailer and the distributor due to the values assumed by their beliefs, i.e. propensity to negotiate (Pr_n), propensity to threaten the abandon of the negotiation (Pr_t), and propensity to collaborate ($\Delta\Phi$). In particular, each variable can assume two values, namely *High* and *Low*. Figure 4 depicts the data assumed for the propensity to negotiate and the propensity to collaborate in both cases. $\Delta\Phi$ is assumed equal to 0.1 (*high*) and 0.05 (*low*).
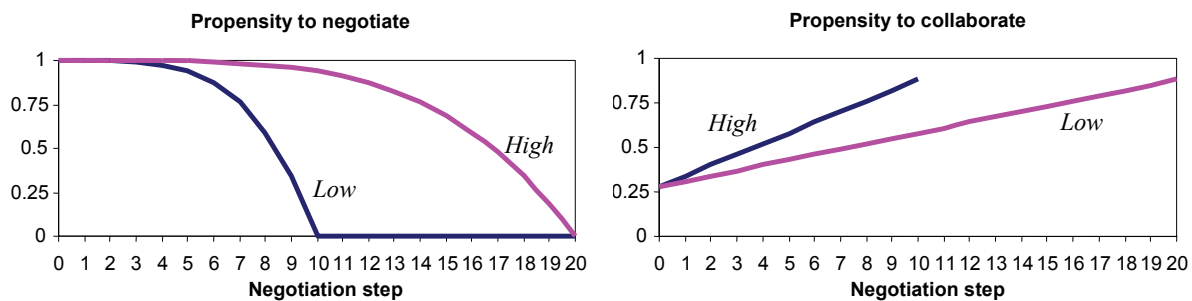

Figure 4. Data assumed for the agent beliefs

In each scenario we carried out 1000 runs and measured: the number of times that an agreement is reached on Φ (%RS is the relative frequency of agreement) and the average value of *agreed* Φ (AvΦ). Then, we computed the SC profit, which depends on both %RS and AvΦ: we assumed that the actors achieve the profits associated with the contract with probability %RS and the profits associated with the market setting with probability (1-%RS). The SC profits are then given by:

$$\Pi_{SC} = \Pi_R + \Pi_D$$

$$\Pi_{R(D)} = \%RS\Pi_{R(D)c} + (1- \%RS)\Pi_{R(D)c}$$

Results of the simulation analysis are shown in Table 3.

In Table 4, only the SC profit are reported. Notice that the worst SC profits are achieved when the contractual power is *low* for both SC agents (fourth column), no matter the propensity to collaborate. In such a case, none of the actors is able to impose his/her preference and the negotiation tends to end more frequently without an agreement. Only a *high* propensity to collaborate by the retailer can slightly improve the SC profit under this contractual power setting.

Relative contractual power		Propensity to collaborate		$Av\Phi$	$\%RS$	Π_{SC}	Π_R	Π_D
Distributor	Retailer	Distributor	Retailer					
High	High	Low	Low	0.366697	58.90%	2353.584	786.064	1567.52
High	High	High	Low	0.368474	66.00%	2384.233	813.5713	1570.662
High	High	Low	High	0.365149	66.30%	2385.529	809.0421	1576.486
High	High	High	High	0.36616	73.00%	2414.452	833.8039	1580.648
Low	High	Low	Low	0.359251	60.10%	2358.764	778.885	1579.879
Low	High	High	Low	0.360741	64.10%	2376.031	794.3732	1581.658
Low	High	Low	High	0.362365	59.40%	2355.742	781.2793	1574.463
Low	High	High	High	0.354521	69.60%	2399.774	801.5961	1598.178
High	Low	Low	Low	0.37171	61.10%	2363.081	801.4199	1561.661
High	Low	High	Low	0.37279	58.10%	2350.13	792.2589	1557.871
High	Low	Low	High	0.37223	58.80%	2353.152	793.9527	1559.199
High	Low	High	High	0.37048	67.90%	2392.436	823.6709	1568.765
Low	Low	Low	Low	0.37006	55.40%	2338.474	778.6829	1559.792
Low	Low	High	Low	0.37154	53.80%	2331.567	775.0321	1556.535
Low	Low	Low	High	0.36048	62.00%	2366.966	787.0223	1579.944
Low	Low	High	High	0.37016	58.10%	2350.13	788.3914	1561.739

Table 3. Results

Propensity to collaborate		Contractual Power								
		D	R	D	R	D	R	D	R	Average
D	R	H	H	H	L	L	H	L	L	
H	H	2414.45		2392.44		2399.77		2350.13		2389.20
H	L	2384.23		2350.13		2376.03		2331.57		2360.49
L	H	2353.58		2363.08		2358.76		2338.47		2365.35
L	L	2384.45		2364.70		2372.58		2346.78		2353.48
Average		2384.45		2364.70		2372.58		2346.78		

Table 4. SC profits

Also, the results are quite poor when the propensity to collaborate is *low* for both agents (fourth row), regardless the contractual power. In this case the agents are not able to reach an agreement on the value of Φ, given that they tend to modify their initial preference at a lower rate (low $\Delta\Phi$).

Leaving out these worst cases (last column and row), the best SC profits are achieved when both agents are highly propense to collaborate (first row). In fact, in this case the agreement is reached with a higher frequency, given that both the agents modify the Φ value with a higher pace (higher $\Delta\Phi$). Only when both agents have low contractual power (last column), a high propensity to collaborate of both is not enough to guarantee an adequate percentage of agreement: this could depends on the sensible reduction of those agreements wherein the negotiation ends because one of the parties forces the other to accept his bid. This seems to be confirmed by the good results achieved when both agents have *high* contractual power (first column): the high quota of "forced" agreements compensate the possible lower propensity to collaborate.

Notice that the best scenario, characterized by high contractual power and propensity to collaborate for both agents, is associated with the highest number of agreements (73%).

82In this case even though the value of the average Φ is not the highest (which would let think the retailer to miss his highest possible profit), the retailer gains the highest profit, due to a higher number of agreements. Furthermore, also the distributor achieves a good performance (i.e. the best third one of its results).

5. Conclusions

The revenue sharing contract is a coordination mechanism adopted by supply chains, wherein the decision making process is decentralized, to assure channel coordination. It has been mainly used in the video-rental industry by firms such as Blockbuster or Hollywood Planet. Despite the ease of this coordination mechanism, based on two parameters, the RS contract is not much widespread in other industries due to implementation problems. We have then analyzed this issue.

First, we have defined the features of the video rental industry which we believe critical with respect to the RS contract adoption. This has allowed other industries to be identified as potential users of the contract. Then, we have described the design of a RS contract for a two-stage SC that assures the channel coordination and allows the SC actors to increase their profits.

Successively, we have developed an agent-based system model of the negotiation process between the two SC actors which takes into account two further variables, which we believe to play a key role for the negotiation: the relative contractual power and the collaboration of the SC actors.

In the proposed model, the two agents (i.e. the SC actors) negotiate on the value of the contract parameter that influences the SC profit sharing between them. Based on the agent beliefs influencing their behaviors, the negotiation process can end in different ways: either the agents reach an agreement on the value of the parameter, or they can not reach such an agreement (which results in the SC not adopting the contract and operating under a market setting).

Finally, we have carried out a simulation analysis aimed at identifying the scenarios in which the RS is more likely to be adopted. In particular, we have measured how many times the negotiation ends with an agreement and the agreed value of the parameter.

The simulation has shown that high propensity to collaborate for both SC actors and high contractual power of al least one SC actor prove critical for the RS implementation. In this case only the collaboration of retailer can increase the SC profit. Further research will be devoted to extend the model to different SC topologies (e.g. SCs made up of one distributor and multiple retailers).

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Supply Chain

Edited by Vedran Kordic

Traditionally supply chain management has meant factories, assembly lines, warehouses, transportation vehicles, and time sheets. Modern supply chain management is a highly complex, multidimensional problem set with virtually endless number of variables for optimization. An Internet enabled supply chain may have just-in-time delivery, precise inventory visibility, and up-to-the-minute distribution-tracking capabilities. Technology advances have enabled supply chains to become strategic weapons that can help avoid disasters, lower costs, and make money. From internal enterprise processes to external business transactions with suppliers, transporters, channels and end-users marks the wide range of challenges researchers have to handle. The aim of this book is at revealing and illustrating this diversity in terms of scientific and theoretical fundamentals, prevailing concepts as well as current practical applications.

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