Profit allocation in supply chains on the basis of revenue-sharing rates

VIKTOR MOLNAR[1*], ZOLTAN MUSINSZKI[1], TAMAS FALUDI[1]
[1]Faculty of Economics
University of Miskolc
H-3515 Miskolc-Egyetemvaros
HUNGARY
[*]szvmv@uni-miskolc.hu

Abstract: Supply chain coordination with contract types is a wide area of cooperation of supply chain members. Although several approaches and models have been developed in the recent decades, supply chains rarely tend to take academic advice; more practice-oriented analyses and empirical research are needed in this topic. The topic is analyzed basically from theoretical point of view and most of the researchers do not consider the behavioral elements connected to contract types. In this paper an approach is introduced that keeps the conventional decentralized setting of wholesale price but shifts to a fairer setting with the use of the revenue-sharing contract type. This approach is demonstrated through a mathematical model that could help the decision-makers in describing and understanding the phenomenon. We consider the recommended model as an innovative one because in today's turbulent world a manager make decisions mainly on the basis of costs and profits and makes agreements by using their negotiation power and behavioral or other soft management elements are suppressed. Our analysis highlights that our model ensures fairer profit allocation among the supply chain members if their goals in cooperation can be moved to the direction of a long-term approach. The supply chain was modeled as a sequential one. It was also introduced in this paper that the topic is wider because of the legal regulations of transfer pricing between supply chain members.

Key-Words: Supply chain coordination, Revenue-sharing contract, Centralized setting, Decentralized setting, Transaction costs

1. Introduction

Both general and specific contract types play an important role in supply chain coordination of companies that recognize the importance of cooperation with their suppliers or customer companies. In industrial branches like the automotive industry the extended network of suppliers facilitates relatively healthy competition, so that original equipment manufacturers can focus on earning higher profits and not on long-lasting searches for suppliers. However, in both cases a shift in the direction of vertical integration always helps form more balanced cooperation. In the classic approach, members of a supply chain tend to operate in a decentralized manner (when supply chain members act like the organization units of an enterprise); due to the central decision-making, higher profit can be earned [1]. Of course, this type of integration is difficult to realize. There are many areas that influence the operation and success of this type of contract [2]. Academic researchers have analyzed supply chain coordination mechanisms from a game theory point of view [3, 4]. Arani et al. [5] investigated mixed-type contracts on the basis of the Nash equilibrium. Most of the publications introduce simple analytic models [6] or simulations [7]. Some researchers have begun to analyze the supply chain as a dynamic system, e.g. [8]. This collection highlights the fact that there is only a small rate of research results that are based on empirical studies or real-life data.

However there are several useful analytical models introduced and analyzed in existing works. They provide useful methods for decision-makers but the main problem is that these models are not systematically collected in one or more academic books. Concerning the differences among the existing models, a great amount of the models do not allow the grouping of them because there are several different models and approaches. One useful and wide-spread comparison of the models is the one that is demonstrated in Table 1 (type of coordination and form of results). Another problem in some existing papers is that they introduce mathematical models and neglect experiments or empirical data in the analyses. However simulation results, which are applied by many of them, are useful.

In this paper the profit of members of a sequential supply chain is calculated on the basis of production costs and constants that characterize the

market. The recommended method differs from the existing ones in its basic conception: it incorporates a conventional contract type (wholesale pricing in decentralized setting) and an up-to-date one (revenue-sharing type in centralized setting) in order to link the advantages of the latter (higher total profit of the members) and at the same time to keep the possibility of the sometimes unavoidable short term thinking of the former one.

Table 1. Some recent research in coordination with contract types

Type of coordination	Author(s) (year)	Results
Quantity discount	Zhao &Wei (2014) [9]	Comparative statistical analysis
Price discount	Heydari (2014) [10]	Numerical experiments
Real-option contract	Luo et al. (2015) [11]	Analytical results
Trade credit	Luo & Zhang (2012) [12]	Analytical results
Fixed ordering	Geunes et al. (2016) [13]	Analytical results
Quantity-flexibility	Li et al. (2015) [14]	Analytical results
Option contract	Cai, Zhong, Shang, Huang et al. (2017) [15]	Analytical results
Revenue-sharing	Krishnan & Winter (2010) [16]; Zhang et al. (2015) [17]; Dye & Yang (2016) [18]	Analytical results

The revenue-sharing contract has been analyzed widely in recent years [1, 17, 18, 19]. In this setting the total profit of the considered part of the supply chain (cooperating members) is always higher than that could be earned by the decentralized setting. When applying a revenue-sharing contract, the members divide the retailer's revenue among them and therefore their profits are also divided in the same proportion. This means that the rates of profit depend on the members' negotiation power. However, it is possible for the members to divide the rates of profit equally among each other.

2. Notations and basic settings

A new approach is introduced in the paper on the basis of the revenue-sharing type of coordination contract, which partly keeps one disadvantage of a decentralized setting (lower than the theoretically possible maximum profit) while ensuring some level of independence for the companies, and shifts to a centralized setting that ensures higher profit than in the decentralized setting. Although this setting is not perfect in terms of the profit maximization criteria, the division of profits can be fairer than in the pure revenue-sharing model from all members' points of view. To build up the model some basic equations are necessary; the notations used in the model are summarized in Table 2.

Table 2. Notations applied in the model

R	Retailer
CST	Customers
i	Index of members
SU_i	ith supplier
n	Number of suppliers
q	Quantity sold by the chain members
$P(q)$	Inverse demand function
x, y	Constants of the demand function
P	Market price charged by the retailer
$R(q)$	Retailer's revenue
w_i	Wholesale price of the ith supplier
c_R	Unit production cost of the retailer
c_i	Unit production cost of the ith supplier
c	Sum of unit production costs
α_R	Retailer's rate of revenue
α_i	ith supplier's rate of retailer's revenue
Π_R	Retailer's profit
Π_i	ith supplier's profit
Π	Total profit of the supply chain

The supply chain is modeled as a sequential chain of member companies. It has to be noted that coordination is not guaranteed if there is more than one retailer in the supply chain [20], and the calculations differ from those introduced here if more than one supplier or customer is connected to one member. The structure of the model is shown in Fig.1. If a supply chain is managed centrally (vertical integration), i.e. one decision maker decides about profit optimization, the profit maximum can be derived as indicated in Eqs. (1-3).

$$\Pi^* = qP + q\sum_{i=1}^{n} w_i - qc_R - q\sum_{i=1}^{n} c_s - q\sum_{i=1}^{n} w_i = \\ = q(P - c), \quad (1)$$

where π^* is the profit of the whole supply chain in centralized setting.

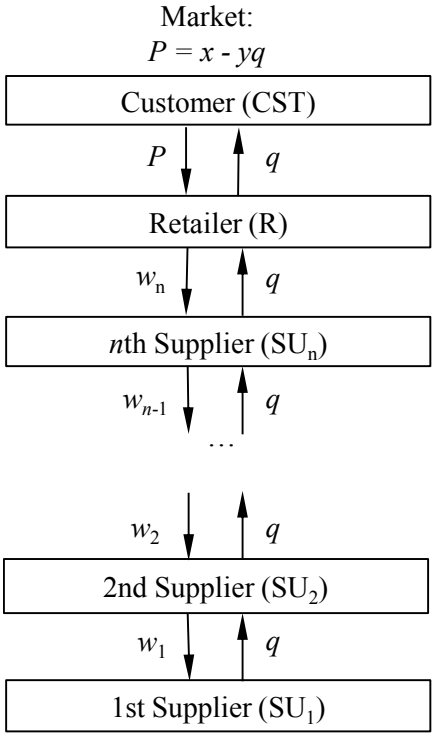

Figure 1. Structure of the supply chain model

Maximum profit belongs to the q^* of which value is determined by partial derivation (Eq. (2)).

$$\frac{\partial \pi^*}{\partial q^*} = x - 2yq - c = 0 \rightarrow q^* = \frac{x-c}{2y} \quad (2)$$

After substituting q^* in Eq. (1):

$$\Pi^* = \frac{(x-c)^2}{4y} \quad (3)$$

If the supply chain members manage their profits individually, the basis of profit maximization is the wholesale price w (decentralized setting). It can be shown that the sold quantity depends on the number of suppliers (n) of the supply chain given by Eq. (4).

$$q^* = \frac{(x-c)^2}{2^{n+1}y} \quad (4)$$

In this setting the profits of the suppliers and the retailer can be calculated as in Eq. (5).

$$\Pi_i = \left\{ \frac{(x-c)^2}{2^{n+1+i}y} \middle| i = 1; \dots; n+1 \right\} \quad (5)$$

where n is the number of suppliers. Considering the retailer, there are (n+1) members in the supply chain.

On the basis of Eq. (5) the profits of the members can be calculated for sequential supply chains with n suppliers and one retailer if the wholesale prices and the unit costs of the analyzed product are available.

Table 3. Supply chain members' profits

Two-level supply chain (n=1)
$\Pi_R = \frac{(x-c)^2}{16y}$; $\Pi_{SU1} = \frac{(x-c)^2}{8y}$
Three-level supply chain (n=2)
$\Pi_R = \frac{(x-c)^2}{64y}$; $\Pi_{SU2} = \frac{(x-c)^2}{32y}$; $\Pi_{SU1} = \frac{(x-c)^2}{16y}$
Four-level supply chain (n=3)
$\Pi_R = \frac{(x-c)^2}{256y}$; $\Pi_{SU3} = \frac{(x-c)^2}{128y}$; $\Pi_{SU2} = \frac{(x-c)^2}{64y}$; $\Pi_{SU1} = \frac{(x-c)^2}{32y}$
Five-level supply chain (n=4)
$\Pi_R = \frac{(x-c)^2}{1024y}$; $\Pi_{SU4} = \frac{(x-c)^2}{512y}$; $\Pi_{SU3} = \frac{(x-c)^2}{256y}$; $\Pi_{SU2} = \frac{(x-c)^2}{128y}$; $\Pi_{SU1} = \frac{(x-c)^2}{64y}$

The profits of the members of the supply chain in cases of 2–5-level chains if members operate in a decentralized way are summarized in Table 3. The point of this collection is that in the introduced model the new solution falls between the idealistic revenue-sharing contract (when profits are divided equally among the members of the supply chain) and the conventional decentralized setting.

3. Modified revenue-sharing model

With the application of a revenue-sharing contract the total revenue of the retailer is divided among all the supply chain members. The α_i rates of the division depend on the bargaining power of the members. In this setting it is supposed that the individual marginal revenues of the members are equal to that of the centralized setting of the supply chain. With the revenue-sharing contract, maximum

values of the chain members are determined on the basis of demand quantity (q).

The general formula of profit of the *i*th member is given in Eq. (6).

$$\Pi_i = \alpha_i R(q) + w_i q - (w_{i-1} + c_i)q = \alpha_i \Pi^* \qquad (6)$$

where $\alpha_1+\ldots+\alpha_i+\ldots+\alpha_n+\alpha_R=1$.

With the revenue-sharing contract the members of the supply chain divide the profit depending on their negotiation powers, therefore the more dominant a member is the higher rate of profit it can earn. However, in a fair situation they can divide the profit equally. In a perfectly integrated chain this is easy to perform but in real life companies tend to consider their individual decentralized-setting profit as a basis level, even if they are aware of the fact that the profits of the members in a decentralized setting are below those of the centralized setting. Keeping this behavior in mind, a consensus solution seems to be fair. Considering a two-member supply chain, for instance, where one supplier and one retailer are the members, the centralized profits are equal if α=0.5. The equal amount of profits is $\pi^*/2$. In the decentralized setting the supplier's profit at α=0.5 is also $\pi^*/2$ and the retailer's profit is $\pi^*/4$.

To generalize the reallocation of profits the next logic can be suitable. The basis settings are the decentralized wholesale price-based profits and the revenue-sharing contract with equal profits. The latter represents a fair allocation. The consensus solution can be defined as the reallocation of profits in the following manner: let α be settled as the value that facilitates that the extra profits of all members in the centralized setting compared to their original decentralized profits be equal. Let $d(n+1)$ be the extra profit mentioned above, therefore d is the value of equal amount of each members' extra profit. The value of d is calculated generally (n members) by Eqs. (7-8).

$$(n+1)d = \Pi^* - \sum \Pi(DSC) \qquad (7)$$

$$d = \frac{(x-c)^2}{y} \cdot \frac{2^{2n} - \sum_{i=0}^{n} 2^i}{(n+1)2^{2(n+1)}} \qquad (8)$$

where π^* is defined by Eq. (3) and π_i is defined by Eq. (5).

The new profit of a member is calculated by Eq. (9).

$$\pi_i' = \pi_i + d = \alpha_i \pi^* \qquad (9)$$

4. Analysis of a 5-member supply chain

The calculations of the decentralized profits and the profits of the modified model are illustrated in Table 4. The α_i rates are also included in the model. It can be seen that the farther a member is from the market the higher its rate from profit earned. This results from the characteristic of the basic model: the order of rates is the same in the decentralized setting, the differences between them are lower but not equal, which means that the proposed model is between the conventional wholesale price-based decentralized setting and the perfectly fair revenue.

Table 4. Supply chain members' profits according to the decentralized setting and the introduced approach

	Π_i	π_i'	α
RE	$\frac{(a-x)^2}{1024y}$	$\frac{49}{1024}\Pi^*$	$\frac{49}{1024}$
SU_4	$\frac{(a-x)^2}{512y}$	$\frac{53}{1024}\Pi^*$	$\frac{53}{1024}$
SU_3	$\frac{(a-x)^2}{256y}$	$\frac{61}{1024}\Pi^*$	$\frac{61}{1024}$
SU_2	$\frac{(a-x)^2}{128y}$	$\frac{77}{1024}\Pi^*$	$\frac{77}{1024}$
SU_1	$\frac{(a-x)^2}{64y}$	$\frac{109}{1024}\Pi^*$	$\frac{109}{1024}$

One-fifth of the surplus profit (equal reallocation) is given by:

$$d = \frac{(a-x)^2}{y} \frac{225}{5120} \qquad (10)$$

In the decentralized setting the profit of the first supplier (SU_1), which is located the farthest from the end market, is 16 times higher than the profit of the retailer. With the introduced calculation the first supplier's profit is only 2.22 times higher, which means that the reallocation is more balanced than in the decentralized setting.

5. The problem of transfer pricing

Between the members of the supply chain a transfer price can be applied instead of a market price. In the centralized setting of the supply chain, due to its nature, the members can be considered as organizational units of a single enterprise in terms of the contract. This approach facilitates the use and analysis of the theoretical contract types.

If the members are considered as organizational units, the pricing and the consideration of unit costs can be managed as a cost allocation problem. The cost allocation as a problem first occurred in the second half of the 19th century. In the production of single products the direct costs were easily managed but with the increase of production complexity the consideration of indirect costs became necessary [21]. Cost allocation can lead to an advantageous behavior of the decision makers: it reminds them of the existence of overhead cost and the use of service centers [22]. Therefore a certain sense of responsibility can be formed for costs. However, the cost allocation can reflect the power of the organizational units, and the manner of allocation could be the 'playground' of the strong interest groups. This logic reflects the problem of cooperation between supply chain members, too. The transfer pricing acts similarly to the cost allocation mechanism.

Even if a healthy cooperation is realized between the supply chain members and a transfer price can be determined in this manner, legal regulations have precedence over the relative simplicity of cooperation. The OECD Transfer Pricing Guidelines for Multinational Enterprises and Tax Administrations is a base document in transfer pricing [23]. Beyond this, national law also regulates transfer pricing. In order to plan a contract between supply chain members, not only the existing theoretical models but the legal background has to be considered. This makes the pricing more difficult.

6. Conclusions

The introduced model is based on the fact that strategic decision makers tend to operate the supply chain in a decentralized setting. Among other factors, revenue-sharing contract types can facilitate a more balanced and fair operation and profit allocation among the supply chain members. In regard to profit, the introduced model is somewhere between the conventional decentralized setting and the fair revenue-sharing contract. With this balanced position the profit differences among the supply chain members decrease, while perfect equity is avoided. This is of high importance mainly for multinational companies because their transfer prices are influenced by both exchange rates and strict legal regulations.

In the paper a new model was developed in which the extra profit that could be earned by a fair revenue sharing contract compared to the decentralized wholesale price setting is divided among the supply chain members. With this reallocation the total profits of the members become closer to each other. In a five-level sequential supply chain the decentralized setting results in a 16-fold difference in the profit of the first and the last member of the chain. With the application of the introduced model this difference is reduced to 2.22. The limitation of the model is that the legal factors of transfer pricing are not considered in it.

Future directions of the research can be the extension of the model for non-sequential networks and the profound consideration of other soft or behavioral factors of decision-making, i.e. what are the drivers of avoiding a more balanced communication and cooperation of supply chain members.

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