Contract Design among Supply Chain Nodes

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Abstract: Currently, self-optimizations among participants lead to low efficiency in the entire supply chain. Due to the lack of mutual constraint organizations, thus participants take nodes contracts as the implementation basis for supply chain management. This paper starts with the coordination and current status of contract design in supply chain, and then analyzes its characteristics and applicable nodes. Furthermore, the article explores the merits and drawbacks of independent contract design by calculating the expected return function of each node. Finally, it raises the combination contract theory of supply chain node, and designs combinations contract among supply chain nodes.

Keywords: supply chain coordination; supply chain node; combination contract; profit distribution

1. Introduction

The supply chain management theory and practice have aroused increasing concern these years, how to coordinate different companies among supply chain is the core aspect of supply chain management. Therefore, under the condition of information sharing, how to make the appropriate and effective contract design is a vital issue to cope with. Excellent contract design will help involved companies to form a more close dynamic operation alliance, which will harmonize the performance of each company with the goal of supply chain and sharpen the competitive edge of the entire supply chain.

2. Analysis of contract coordination

Supply chain coordination refers to the application of supply chain process management approach in decision-making and planning systems, developing an effective management mechanism to coordinate market, production, purchasing, sales, and logistics. At the same time, in order to improve the overall operational efficiency, supply chain coordination will based on market demand and use scrolling and integrated planning approach to make timely and appropriate adjustments on sales targets, financial targets, inventory targets, service targets and production targets.

Supply chain coordination mechanism is designed based on key factors among members in the supply chain, such as business flow, logistics, capital flow and information flow etc. This helps members to achieve building strategic partnership, reasonable allocation of profits, sharing of market risk, improving of information sharing level, reduction of inventory, and all these contribute to total costs reduction and the maximum of profits. Up to now, there is no universally acknowledged classification method in supply chain mechanism, referring to the academic materials; this mechanism can be classified into two levels [1]:

![Hierarchical model of supply chain coordination](image1)

From a macro-level perspective, the inter-coordination actually refers to mutual coordination among suppliers, manufacturers and sellers, including the coordination of logistics, business flow, capital flow and information flow etc.; From the micro-level aspect, the inner-coordination refers to each node enterprise's internal interdepartmental coordination of activities, including the coordination departments of new product development, raw material procurement, production, inventory, sales.[2]

On the other hand, at the macro level, according to the position and role of enterprises in the chain, the intercoordination can be divided into the following two levels:

![Coordination among node enterprises.](image2)

3. Design for independent supply chain contract model

3.1. Wholesale Price Contract
Wholesale price contract is also called pricing contract, which means retailers decide order quantity according to demand and wholesale price on the market, and suppliers will organize the production depend on order quantity by retailers while retailers are full responsible for inventory. [3]

In this contract, supplier will definitely earn profits while risks are taken by retailers. During the life cycle of a product, when the wholesale price decreases, suppliers pay retailers a credit guarantee for unsold products. [4]

We assume that for completing orders, it may incur three related costs for suppliers: production costs, inventory costs and delay costs. Since the uncertainty exists in the process of production and logistics, actual response time \( t \) for suppliers is a random variable. Because the actual response time \( t \) obeys the asymptotic exponential distribution and thus it might be assumed that it subordinates the exponential distribution with \( \theta \) as the parameter. \( 1/\theta \) refers to suppliers’ average response time to complete the order, its density function is: \( f(t)=\theta e^{-\theta t} \) \( \text{for} \ t>0 \).

The supplier’s expected profit function per unit time can be expressed as:

\[
\Pi_s = \max \{P_s - C_s - \alpha \int_0^{\theta} f(t) \, dt \ | \ \int_0^{\theta} (t - T_s) f(t) \, dt \}.
\]

(1)

The decision variables for suppliers are \( T_s \) and \( P_s \). \( \alpha \int_0^{\theta} f(t) \, dt \) is the expected inventory cost, \( \beta \int_0^{\theta} (t - T_s) f(t) \, dt \) refers to the expected delay cost.

3.2. Buyback Contract

Buyback contract is that manufacturers allow retailers to return back unsold products at the returning price in the end of the selling season, manufacturers and retailers share the risks caused by the uncertain market demands.

The reason why manufacturers choose to repurchase contract is due to fear of retailers will sell the excess products at a discount after the selling season, which is damage for brands. This is especially common in selling high-end products. Besides, some vendors choose buyback contracts because they want to re-allocate the excessive relationship among retailers, repurchase policy will result in the retailers’ irrational order quantity.

The manufacturing costs consist of three parts: parts procurement costs, manufacturing costs and shortage costs caused by suppliers’ delayed delivery. Since the fast respond and not allowed ‘early delivery under ATO (assemble to order) mode, manufacturers’ finished products costs and components costs will not be taken in to consideration. [5]

\[
\Pi_{bs} = \max \{P - (P_c - C_s - \delta \int_0^{\theta} f(t) \, dt) \ | \ \int_0^{\theta} (t - T_s) f(t) \, dt \}.
\]

(2)

Manufacturers’ decision variable is \( P \), \( \delta \int_0^{\theta} (t - T_s) f(t) \, dt \) is the shortage costs due to the expected delayed delivery from suppliers.

3.3. Revenue sharing contract

Revenue sharing contract allows manufacturers to set the wholesale price and share the profits from distributors. This contract can alleviate the price competition among downstream retailers in a better way, conflicts among distributors will also be eliminated as well.

In this contract, the node enterprises will apportion total revenue according to a certain proportion. Vendors will deliver products to manufacturers depending on the pre-agreed transfer fee \( P_c \) and delivery date \( T_s \). They pursue is to maximize the profits of the entire supply chain.

Total cost of supply chain including raw material suppliers’ production costs, inventory costs, delay costs and manufacturers’ production costs, material shortages costs. Therefore, the expected benefits function can be expressed as follows:

\[
\Pi_{rs} = \max \{P - (P_c - C_s - \alpha \int_0^{\theta} f(t) \, dt) - (P_c - C_s - \delta \int_0^{\theta} f(t) \, dt) \ | \ \int_0^{\theta} (t - T_s) f(t) \, dt \}.
\]

(3)

The decision variable is the final unit price \( P \) and suppliers’ delivery time \( T_s \); Suppliers’ expected inventory cost is \( \alpha \int_0^{\theta} (t - T_s) f(t) \, dt \) the expected delay cost; \( \delta \int_0^{\theta} (t - T_s) f(t) \, dt \) is the shortage cost caused by suppliers’ delayed delivery which is expected by suppliers.

3.4. Elastic quantity contract model

Elastic quantity contract refers to distributors reserve some products before the selling season, according to which that manufacturers organize the production, and after obtaining certain market demands, distributors’ will define the final purchase amount within the amount of products that suppliers can provide. Elastic quantity contract can better predict distributors to predict market demand more accurately, thereby increase expected profits.

We can assume that \( D \) represents a selling season’s total demand \( D > 0 \), \( F \) represents the distribution function of demand, \( f \) represents the probability density function of demand, \( F \) is differentiable and strictly monotonically increasing. \( X \) represents the random customer demand, \( F(0)=0 \), \( \mu=E(D) \).

Now assume that retail price is \( p \), the unit cost paid by suppliers is \( C_s \), marginal cost generated by distributors is \( c_r \), marginal costs of distributor is incurred by acquiring one unit product not by selling the product. Distributors cannot meet the needs of each unit which results in penalty cost \( g_r \), likewise, penalty cost \( g_s \) also exists in manufacturers For simplicity, assuming that \( c_s = c_r + c_p \), \( g_s = g_r + g_p \). The residual value of unsold products per unit from manufacturers and distributors is \( v \).

During the determining process of model data, \( S \) (q) represents expected sales, then:

\[
S(q) = q(1-F(q)) - \int_0^{\mu} x f(x) \, dx - \int_0^{\mu} F(x) \, dx.
\]

(4)

In the elastic quantity contract, the unit price of products provided by vendor is \( w_q \), but when there is unsold products from distributor, the supplier should compensate distributors.
4. Independent supply chain contract model analysis

Under independent contract system, the transaction between manufacturers and distributors, distributors and retailers are only through the wholesale price contracts, namely the manufacturer provides products to downstream distributors at wholesale prices, then distributor provides products to end-product retailers at another wholesale price. At this point, if each node company only focus on its own profits while ignoring the supply chain as a whole system, then retailers may order from distributor based on demand and wholesale prices; Whilst distributors will also order the same quantity of products from upstream manufacturers, in order to meet the retailer's order quantity and provide products to end-product retailers at another wholesale price. At this point, if each node company only focus on its own profits the wholesale price contracts, namely the manufacturer provides products to downstream distributors at wholesale prices, then distributor contracts have their own operations process and management complexity, thus different actors may not have the same preference during the transaction, for some participants prefer buyback contract, while other participants may prefer revenue sharing contract and so on. If the combination of different types of contracts can achieve coordination of three level supply chain, then various economic entities with different preferences will have more options. So considering the combination of different types of contracts under the supply chain coordination has not only theoretical significance, but also practical significance [6].

5. Supply chain portfolio contract design

Supply chain contract portfolio management is decisions portfolio that apply modern portfolio management ideas, theories and methods to design, combine, implement and manage a number of different procurement contracts, such as the wholesale price contract, elastic quantity contract, repurchase contracts or revenue sharing contract, etc, achieving lower supply chain inventory risks and costs, high service level.

As long as the proper setting of contract parameters, coordination and profits sharing will be achieved under contract portfolio. The overall supply chain revenue will be reasonably allocated to participants involved, but the profits each actor assigned are depend on the position and ability to game with other enterprises. Contract type and parameters needed to be negotiated beforehand.

This chapter will take mobile phone industry as an example to describe the application of different supply chain contracts.

5.1 Between Manufacturers and Suppliers - Revenue Sharing Contract

Material suppliers determine a wholesale price under cost, then for compensating suppliers’ loss, manufacturers return a certain percent (the percentage is negotiated in advance) of incomes to suppliers. This will ultimately ensure that both income levels are higher than the decentralized control state, so that reach the optimal supply chain performance.

Suppliers produce short-cycle types of products and the products are provided to retailers below unit product production to help retailers obtain some profits. Retailers are faced with random demand, they have to decide the price and order quantity to reach maximized profits because of the short life cycle.

In the development of mobile phones, the manufacturer gives product drawing to factory, and factory design the mold model based on the drawing. In this process, if the model does not match requirements, it will be abandoned, and then manufacturers and factories will share the losses. Especially the innovation on smart phones incurs high pressure on upstream suppliers; even a tiny change on components requires lots of testing and production process adjustments. This can be solved by signing profits sharing contract, so that symbiotic relationship can be formed between factories and manufacturers. In this highly specialized society, manufacturers need to optimize resources and corporate with factories; in order to survival, factories have to take over the business orders for production.

After the phones are produced, elastic quantity contract can be signed between manufacturers and distributors. Retailers are allowed to change the initial order quantity after observing the demands. Usually, the distributor will issue an order to the manufacturer before the selling season, distributors then organize the production based on this order. When the distributor knows the actual market needs, re-adjust order quantities is allowed.

5.2 Between manufacturers and distributors – elastic quantity contract
The coordination system under the current market environment is not perfect. Usually, distributors sign order contract with manufacturers according to the forecast of demands, after signing the contract, manufacturers will invest in the facilities and organize the production to meet the requirements of distributors. In this case, the downstream distributors may submit an initially overly optimistic demand forecast, which will motivate upstream manufacturers to establish a high production capacity. This is to meet the non-normal conditions of the high market demand. But when demand is lower than the actual manufacturing levels, extra producing ability is a waste. Once manufacturers recognize this motivation, facing with overly optimistic demand forecasts, manufacturers will build a more conservative production capacity [7]. When high demand comes, manufacturers’ conservative production ability will result in the shortage of production. The lack of coordination between upstream and downstream participants will seriously affect the performance of the entire supply chain.

Given such circumstances, in the combination of theory and practice, elastic quantity contract gradually becomes popular. In this contract, the maximum fluctuation ratio of each order is limited, manufacturers are obliged to meet the highest amount of products supplied which is to prevent manufacturers reducing production capacity as a result of supply shortage; In the meanwhile, distributors must purchase the minimum quantity of products as signed in the contract, in case of distributors overestimated demand and cause overproduction. Through optimization model of elastic quantity contract to define the best elasticity ratio, namely the best upper and lower fluctuation limits of distributors’ order quantity. Between the upper and lower limits, increase of the order quantity from distributors can promote the supply chain to reach optimal performance, and reduce the vicious effects caused by double marginalization between manufacturers and distributors [8].

In the mobile phone market, limited by the range of products and self-technical strength, most distributors tend to offer power management, multimedia and peripheral devices. But in the recent years, with the major appliance stores and specialty chains involved into the mobile distribution channel, the channel steps into diversified development stage. The reshuffle of mobile phone companies brings large potential opportunities, a number of regional distributors are moving towards national range; Some emerging companies never hesitate to investing a large amount of money into this industry for sharing the large pie; larger distributors are surging not only in the area of distribution but also extends to the distal end in the industrial chain of megastores. Phone distribution industry is moving towards brand, scale, specialization, integration direction, generally regional agency, and direct style of the distribution system and appliance chain sales model. Here we discuss only regional agency that agency distribution methods. Typically distributors selling season before the first manufacturer of a product to the order quantity, the manufacturer according to the order quantity of production, when the distributor knows the expected sales of a demand, the distributor can be adjusted according to actual situation re-order quantity. Quantity flexibility contract currently in the electronics and computer industries have been more widely used. Distributors to implement numerical flexibility contract can not only increase sales' profits, they can also increase the manufacturer's profit. Quantity flexibility contract is intended to enable buyers and sellers together to share the risk and benefits, prompting serious buyer demand forecasting and planning of orders. Quantity flexibility contract procurement of goods distributors improves the average number of efforts to motivate distributors to increase market demand forecast expected profits, and ultimately increase the overall efficiency of the supply chain.

5.3 Between distributors and retailers - buy-back contract, wholesale price contract

Buy-back contract is to protect retailers, guiding retailer to increases order quantity, so that the risk of uncertain are shared both by distributors and retailers. This is often used in the perishable goods sales channels. Balancing between marginal revenue and marginal costs is to achieve the supply chain’s coordination. In the wholesale price contract, suppliers plan the production according to retailers’ order quantity, retailers are responsible for handling excess inventory. Therefore, supplier's profits are determined, retailers are fully responsible for market risk.

Under the buy-back contract, retailers’ order quantity is not only sensitive to wholesale price, but also distributor will repurchase the excess products. Retailers will first announce potential maximum order quantity and repurchase price, these will be important criteria when distributors adjust their wholesale price, then retailers can decide the optimal order quantity. Under the buy-back contract, retailer's optimal order quantity is less than the order quantity in wholesale price contract, and retailers’ profits are less than retailer’s profits in wholesale price contract, the total supply chain profits are less than that under wholesale price contract.

With increasingly fierce competition in the mobile phone market, enhancing self-strength makes the retailer the backbone of distribution channel, the retail terminal will naturally become distributor’ battleground. With the changing of market, role of distributors has shifted as well, they are no longer traditional merchants only towards profit-oriented products, but ones that provide market distribution coverage, implement replenishing to ensure the logistics supply, help manufacturers to manage retail terminals’ management and compete for the limited resource. The interaction between the two would make the relationship between distributors and retailers from the previous trading relations into partnership, the two must complement each other in order to promote sales maximization. Distributors can take advantage of their experience to help retailers manage inventory and analyze market data, which will enable retailers to better serve the ultimate customer. And this will in turn improves distributors’ own business. Buy-back contract is a way that distributor share the risk with retailers, caused by retailers’ order uncertainty. Buy-back contract will prevent discount on the remaining product sales after the selling season, which is damage for suppliers’ brands reputation.

In the buy-back contract, distributors share part of the risk. Because of the risk reduction for retailers, they will only order from distributors when the in-store inventory decreases to an reasonable level, together with the current sales and estimate for future sales in a certain sales cycle. Retailers' irregular orders force distributors to increase inventory, which largely affects the supply chain efficiency. If distributors can help retailers to plan orders and frequency based on the actual terminal’ sales, reducing order quantity and increase frequency, which will facilitate reducing terminals’ inventory.

6. Conclusions

This paper analyzes key factors in supply chain management, defines the significance of supply chain coordination. Furthermore, it introduces the general methods for supply chain coordination, and explores the coordination issues of portfolio contract under market demands. Finally, the paper designs a contract portfolio with nodes signing different contracts, such as wholesale price contract, buy-back contracts, revenue sharing contract and quantity discount contract based on the independent contract design. This design helps different actors to set the contract parameters through negotiation, coordination and profits reasonably distributed will be achieved as a result.

References

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