IMPROVING THE FINANCIAL EFFICIENCY OF THE SUPPLY CHAIN AS A WHOLE BY USING PROGRESSIVE DISCOUNT PRICING AS COORDINATION MECHANISM

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ABSTRACT

A new trend in today's business world is that the traditional vertical single-firm mass production model has been gradually replaced by supply chain production model. The dilemma for the supply chain production model is that on the one hand, suppliers and buyers are separate legal entities and each of them has to look after its own interests first; on the other hand, to ensure the success of supply chain production, supply chain partners must cooperate with each other. To make the cooperation sustainable, the interests of supply chain partners must be synchronized by a coordination mechanism. This study proposes to use the progressive discount pricing as the coordination mechanism. The effectiveness of this mechanism is examined in three different settings. In all these settings, this mechanism can enlarge the total profit of the supply chain system and make all supply chain partners better off. Thus, the goal of improving the financial efficiency of the supply chain as a whole can be realized.

I. INTRODUCTION

For a long period of time, the attention of corporate financial managers was focused mostly on making profits for the stockholders of the firm and maximizing the value of the company. This doctrine was widely accepted and thought to be logical in the past. It is believed that when each firm is pursuing its own interest only, the market force, or the invisible hand as Adam Smith put it, would coordinate the efforts of all the firms into an efficient collective.

In the modern history, the vertical single-firm production model was prevailing for many years. During this period, most business organizations viewed themselves as closed unit independent from others. Raw materials entered factories at one end and

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finished products emerged from the other end. Those firms, particularly giant companies, owned, managed and directly controlled their assets and resources. For example, Ford not only produced all the components and assemblies it needed on the assembly line but also owned mines, timberlands, glassworks, railways and even rubber plantations. Therefore, the duty of financial managers was to work only for the interests of the companies they are working for.

However, in the past several decades, the new trend in business world is that the single-firm mass production model has been gradually replaced by supply chain production model. For this model, many firms wanted to become the so-called lean enterprises. Lean enterprises were building strength in their core competencies and contracting out or outsource the noncritical functions they have found other organizations can perform better, faster, and with lower cost Take Apple as an example, it is roughly estimated that ninety three percent of the cost of sales of a typical Apple computer is purchased content from other firms.

In a nutshell, to ensure the success of supply chain production, the relationship between buyers and suppliers must be changed from win-lose to win-win or from zero-sum to mutual benefit. In another word, both suppliers and buyers in the supply chain should cooperate to improve the financial efficiency of the supply chain as a whole, i.e. to globally optimize the financial performance of the whole supply chain. Therefore, in the last several decades, financial managers, particularly financial managers in supply chain, have spent great efforts in improving the cooperation between firms.

It can be seen that there is a contradiction when supply chain partners try to set up a cooperative relationship. On the one hand, each firm is a separate legal entity and each has to look after its own interests first and wants to maximize its own profit. On the other hand, they must cooperate with each other. The corner stone of a cooperation of a supply chain lies in the mutual benefits of all parties. Under the decentralized condition, to build trust and establish a harmonious relationship among supply chain partners, it is critical to have a mechanism which can be used to synchronize the interests of the supply chain partners so that the inter-organizational inter-dependence can be properly managed. In this research, we propose to use progressive discount pricing as the coordination mechanism to improve the financial efficiency of the supply chain as a whole and also study how this mechanism alters the performance of a supply chain.

The rest of the paper is organized in the following way: Section 2 is a literature review of related research on supply chain coordination. The next three sections present progressive discount pricing models in different settings: Single Retailer and Single Supplier in section 3, Single Retailer and Multiple Suppliers in section 4 and Single Supplier and Multiple Retailers in section 5. Section 6 is a discussion to compare progressive discount pricing with other coordination models.

II. LITERATURE REVIEW

In the last several decades, game theory was frequently used as the basis for analyzing the relationship between firms. Pareto Efficiency theory and Nash

Equilibrium theory are the two most important tools in game theory. However, each of these two theories has some drawbacks when applied to the practice of improving financial efficiency of supply chain as a whole.

Pareto efficiency can be defined as a strategy profile s if there is no other strategy profile that is more efficient; that is, there is no other strategy profile s' such that $U_i(s') \geq U_i\ s$ for every player i and $U_j(s') \geq U_j\ s$ for some player j. In another word, Pareto efficiency is not the global efficiency that financial managers of supply chain want to reach. Nash equilibrium is a profile of strategies such that each player's strategy is an optimal response to the other players' strategy (Fudenberg and Tirole, 1991). Nash equilibriums do not always entail strategies that are preferred by the players as a group. If players act to optimize their own interest first, the result may be suboptimal. Therefore, it is only possible to sustain good behavior of players when the interests of the players can be coordinated by a mechanism which is mutually respected by all players.

In the recent years, the cooperation theory draws great attention from researchers and practitioners. Simply speaking, the basic problem of cooperation for supply chain tries to solve is the contradiction between what is good for the individual company in the short run, and what is good for the whole supply chain as a group in the long run (Axelrod, 2006). Ellram and Feitzinger (1997) also suggest that a company's ultimate goal is to create a supply chain which can maximize the total profit of the whole system. Therefore, to reach the goal of cooperation, there must be a mechanism to coordinate the interests of the supply chain partners.

A coordination mechanism is a mechanism for which the implementation of the optimal strategies by decentralized, self-interested parties may lead to a coordinated outcome and neither violates the individual rationality of the participating parties nor the budget balance of the system (Albrecht, 2010). Supply chain coordination has been the central theme for the majority of supply chain management research. Some studied the possibility and necessity of setting up coordination mechanism. Xu and Beamon (2006) suggest that how to select the appropriate coordination mechanism to manage organizational interdependencies is the biggest challenge to an organization in supply chain. Chen et al (2001) study a distribution channel where a supplier distributes a single product to retailers, who in turn sell the product to consumers. They assumed that supply chain partners typically optimize their own performance based on locally available information. The overall performance of the supply chain can be improved by employing mechanisms to coordinate decisions. Pasternack (1985) showed that perfect coordination can be achieved with a simple constant wholesale price only, set equal to the supplier's per-unit procurement cost. But suppliers are unhappy with the results because their profits vanish.

Other researchers developed different models of coordination mechanisms. Weng (1995) suggests that for a decentralized coordinated system, in order to achieve implementation of the coordinated solution, the buyer has to be offered appropriate quantity discounts in an effort to align his incentives with the overall supply chain and adjust his order profile according to the coordinated solution. Taylor (2002) proposes to

use channel rebates, which are payments from a manufacturer to a retailor based on retailer sales to end consumers, as supply chain coordination. Bernstein and Federgruen (2005) show that coordination can be achieved with a price discount sharing scheme. Constant per-unit wholesale prices can induce perfect coordination under a broad class of demand functions and distributions. Bernstein and Federgruen (2007) study a coordination mechanism to determine the wholesale and retail prices to maximize the profits of the whole supply chain in which several competing retailers served by a common supplier. Cachon and Laviviere (2005) introduce to use revenue-sharing as coordination mechanism in a supply chain. The supplier subsidizes larger order quantities by offering a lower wholesale price and requires the retailer to pay a percentage of the revenue the retailer generates as compensation. Xia et al (2008) study competitive marketplaces with multiple suppliers and multiple buyers dealing with a single product. They propose that a good match between suppliers and buyers should be the first step to achieve supply chain coordination.

III. PROGRESSIVE DISCOUNT PRICING MODEL IN SINGLE RETAILER AND SINGLE SUPPLIER SETTING

This study intends to investigate the equilibrium behavior in a supply chain through a coordination mechanism known as progressive discount pricing. Basically progressive discount pricing is an incentive scheme. This scheme allows the manufacturer gets high profits to recover the costs from the sale of the first batch of products and then lower the wholesale price gradually to induce the retailer to sell more. The most important advantage of this scheme is both manufacturer and retailer can be better off by increasing the sales volume. In this study, for simplicity, a one-period model is employed, but the model can be easily extended to multistage settings. It is also assumed that the supply chain operates in decentralized manner, i.e., all supply chain partners maximize their own profit functions. The supplier charges a wholesale price to retailers; the retailer determines their retail price and order quantities.

First, consider a supply chain with two risk-neutral firms, a manufacturer and a retailer; both are concerned with the mean rather than the variance of their profit. A single product with uniform quality is involved in the transaction between a supplier and a retailer. Retailer faces random demand volume during a given sales season. At the beginning of the period, the supplier and the retailer simultaneously and without cooperation choose a production capacity level and retail price respectively. The order of the retailer is a one-time procurement from the supplier at the beginning of the season and depends only on its own retail price. At the start of the period, the retailer chooses his retail price P_r and the required quantity of the retailer's order for each step is Q and the target quantity to order from the supplier is Q^*. If we denote the steps of discount by n, then $Q^*=nQ$. For the retailer, the same uniform price applies to all units sold. This means that the retailer does not apply price discrimination by segmenting his

markets. The supplier has ample capacity to satisfy the retailer order. The whole sale price of the product $P_s^{(n)}$ (the superscript denotes the steps of discount) will be progressively discounted at a rate of w, so that $P_s^{(n)} = P_s^{(0)} w^{n-1}$. The cost of the product is C_s. It is assumed that $0 < C_s < P_s < P_r$. Thus, the profit of the supplier G_s is:

$$G_s = Q \quad {}_{i=1}^{n}(P_s^{(0)} w^{(i-1)} - C_s) \tag{1}$$

The incremental cash flow or marginal profit for the supplier is:

$$G_S^{(n)} = Q(P_S^{(0)} w^{n-1} - C_s) \tag{2}$$

It can be seen that when $P_S^{(0)} w^{n-1} > C_s$, the marginal profit for the supplier is positive but total profit for the supplier is increasing at a decreasing rate.

Conversely, the retailer will also be better off by ordering more. Under progressive discount pricing, if we denote cost of the retailer by C_r , then the retailer's profit function is:

$$G_r = Q^*(P_r - C_r) \tag{3}$$

Therefore, the total profit of the supply chain is

$$G_T = G_s + G_r = Q \quad {}_{i=1}^{n}(P_s^{(0)} w^{(i-1)} - C_s) + Q^*(P_r - C_r) \tag{4}$$

Under the condition that $P_S^{(0)} w^{n-1} > C_s$ and $P_r > C_r$, G_T is increasing when Q^* increases. When the retailer orders more, both the supplier and retailer will be better off. Essentially, in supply chain, coordination can be achieved if the supplier and retailer can both be better off from the cooperation. Progressive discount pricing encourages retailer to order more so that the "pie" of the total profit is enlarged. Instead of struggling for a small pie by using zero-sum strategy, now the supplier and retailer are sharing the incremental profit. This is a win-win strategy.

Progressive discount pricing can be an important tool in practice. Because of the fierce competition in consumers' product market and volatility in financial markets, many companies are facing downward pressure for their products. To boost their sales, one of the common strategies used by manufacturers is to lower the price of the products so as to attract more end customers. Therefore, the motivation behind the progressive discounting pricing is straightforward: the tradeoff between price and sales volume. Progressive discounting pricing, if properly used, allows the manufacturers to reward retailers who exert more efforts in increasing the sales volume. This behavior is not only advantageous for the retailers but also beneficial to the manufacturer's own strategic, financial and operational goals. Thus progressive discount pricing can increase profits of both manufacturers and retailers and a good cooperation between the manufacturer and retailer can be fostered and sustained. Consequently, by using progressive discount pricing, the supplier can not only let the retailer have lower whole sale price hence higher profits, but also ensure that the retailer will increase the sales volume so that the supplier's own profit will also increase. Obviously this win-win strategy can optimize the financial performance of the whole supply chain.

The following table shows a simulation when w=0.9, Q=100, C_s =0.7, $P_s^0 = 1$.

	$1.00	0.9								
Step	Price	Sale					Total sale	Revenue	Cost	Profit
1	$1.00	100					100	$100.00	70.00	$30.00
2	$0.90	100	100				200	$190.00	140.00	$50.00
3	$0.81	100	100	100			300	$271.00	210.00	$61.00
4	$0.73	100	100	100	100		400	$343.90	280.00	$63.90
5	$0.66	100	100	100	100	100	500	$409.51	350.00	$59.51

IV. PROGRESSIVE DISCOUNT PRICING MODEL IN SINGLE RETAILER AND MULTIPLE SUPPLIERS SETTING

Within this multi-supplier market place, it is assumed that the goods produced by each supplier are the same (the product is homogeneous). Suppliers compete for the buyer's order by offering competitive prices; retailer chooses the supplier partners by comparing the prices offered by all suppliers.

When there are multiple suppliers, retailer can encourage competition among suppliers. When a supplier is facing competition from other suppliers, the supplier must exert its efforts to reduce costs of its products so that its products can be more attractive to the retailer. In many instances, suppliers can also increase the quality and functionality of their products, but essentially products with better quality and functionality can have the same ultimate effect as direct cost reduction. So we focus our attention on the suppliers' efforts to reduce costs. It is also assumed that suppliers will do all their efforts at the outset. Hence we do not need the inter-temporal notation.

There are m independent suppliers indexed by i. The ith supplier's cost of production is $C_s\ i$ per unit sold. $C_s\ i$ is assumed not to depend on output but on efforts exerted by the supplier, denoted by *M(i)*.

$$C_s\ i\ = F(M\ i\ ) \quad \textbf{(5)}$$

where $F(\mathrm{M}\ i\ )$ is a declining function of $M\ i\ $.

The whole sale price offered by the retailer is $P_R^{(n)}$ which is progressively discounted at the rate of w, $P_R^{(n)} = P_R^{(0)} w^{n-1}$. The profit function of supplier i is similar to Equation (1) but we need to add the index:

$$G_s\ i\ = Q\ \ {}_{i=1}^{n}(P_R^{(0)}\, w^{i-1} - C_s(i)) \quad \textbf{(6)}$$

From Equation (6), take partial derivative of $G_s\ i$ with respect to $C_s(i)$, we get $\frac{\partial G_s(i)}{\partial C_s(i)} < 0$. This shows that the supplier can have higher profit when it has lower cost. This implies that progressive discount pricing is a good way to motivate the supplier to reduce the cost. The retailer should also reward suppliers with lower cost.

Similarly, Equation (2) can be rewritten as:

$$G_S{}^n\ (i) = Q(P_R{}^0\ w^{n-1} - C_s(i)) \quad \textbf{(7)}$$

In this equation, we can see that the marginal revenue of the supplier i is $Qp_R^{(0)}w^{n-1}$, and marginal cost of the retailer is $QC_s(i)$. One of the basic principles of microeconomics tells us that the production should expand until marginal revenue (MR) equals marginal cost (MC). Let $MR = MC$, i.e., $P_R^{(0)}w^{n-1} = C_s(i)$, we get:

$$n = \frac{ln\frac{C_S(i)}{P_R^{(0)}}}{\ln w} + 1 \quad \textbf{(8)}$$

From Equation (8), take partial derivative of n with respect to $C_S(i)$, we can see $\frac{\partial n}{\partial C_s(i)} < 0$, that is to say when $C_s(i)$ decreases, the supplier can order more.

From Equation (6) and Equation (8), we can see that when $C_s(i)$ is decreasing, there are two simultaneous impacts. The first is that the profit of the supplier $G_S\ i$ increases. The second is that step n will also increase, which implies that $G_S\ i$ increases and the retailer gets a deeper discount. Therefore, the most cost effective supplier will be more competitive and financially rewarded. Again, this is a win-win situation for both the supplier and the retailer. Therefore, progressive discount pricing can again serve as a good coordinator between the supplier and retailer in this setting.

Substitute Equation (5) into (6), we have

$$G_s\ \ i\ \ = Q\ \ {}_{i=1}^{n}(P_R^{(0)}\, w^{i-1} - F(M\ \ i\ ) \quad \textbf{(9)}$$

Because $F(M\ \ i\ )$ is a declining function of $M\ \ i\ $, *ith* supplier's profit increases when *M(i)* increases.

The following is a simulation when C_s =.65.

	$1.00	0.9								
Step	Price	Sale					Total sale	Revenue	Cost	Profit
1	$1.00	100					100	$100.00	$65.00	$35.00
2	$0.90	100	100				200	$190.00	$130.00	$60.00
3	$0.81	100	100	100			300	$271.00	$195.00	$76.00
4	$0.73	100	100	100	100		400	$343.90	$260.00	$83.90
5	$0.66	100	100	100	100	100	500	$409.51	$325.00	$84.51

In neoclassical economics, the only buyer of a product in a market is called monopsonist. In appearance, the setting of single retailer and multiple suppliers is very similar to monopsony market. However, a critical difference is that monopsonist has the power to dictate terms to its suppliers and often forces sellers to accept a lower price than the socially optimal price. As a result, the relationship between the suppliers and the buyer often becomes tense and distraught.

In practice, the retailer in this single retailer and multiple suppliers setting is often known as the core company and this setting is often referred as "1+N" model. When progressive discount pricing is used as a coordination mechanism, the core company stimulates high levels competition among suppliers. This competition will benefit all supply chain partners and thereby improve the financial efficiency of the whole network. Therefore, unlike monopsonist market in which the relationship between the suppliers and buyers will be damaged, when progressive discount pricing is used, the relationship of supply chain partners is improved. As a result, the financial performance of the whole system is improved. This is a win-win solution.

V. PROGRESSIVE DISCOUNT PRICING MODEL IN MULTIPLE RETAILERS AND SINGLE SUPPLIER SETTING

In a supply chain where a supplier sells to multiple retailers, retailers' sales effort is important in influencing demand. Retailers can exert their sale efforts and boost the demand by various marketing techniques. It is assumed that the retailers have more information to determine the quantity they can sell. At the beginning of the sale season, each retailer places an order with the supplier. The supplier rewards the retailer if the retailer can increase the retail sale volume. When sale volume increases, both supplier and retailers will be better off. Therefore, the retailers have an incentive to cooperate.

In the following explanation, the retailer is the one that supplier picks up as the target partner and the index is omitted. The relationship between the quantity ordered by a retailer Q^* and retailer's sale efforts S can be expressed by Cobb-Douglas Production function:

$$Q^*\ S, M\ = AS^{\alpha}M^{\beta}$$

where Q^*= the target level of the retailer would order,
S=sale efforts of the retailer,
M= manufacturer's efforts of production,
A= total factor productivity,
α and β are the production elasticity of S and M. Both α and β are positive fraction. These values are constants determined by available technology.

If the production function is denoted by $Q^* = Q^*\ S, M\ $, then the partial derivative $\frac{\partial Q^*}{\partial S}$ is the rate at which production changes with respect to the retailer's sale's efforts, also known as marginal production with respect to the retailer's sale's efforts or marginal productivity of the retailer's sale's efforts.

If marginal productivity of the retailer's sale's efforts is assumed to be proportional to the amount of production per unit of the retailer's sale's efforts, then $\frac{\partial Q^*}{\partial S} = \alpha \frac{Q^*}{S}$ for some constant α. If we keep M constant (M=M_0), then this partial differential equation becomes an ordinary differential equation: $\frac{dQ^*}{dS} = \alpha \frac{Q^*}{S}$.

This separable differential equation can be solved by rearranging the terms and integrating both sides:

$$\frac{1}{Q^*} dQ^* = \alpha \quad \frac{1}{S} dS$$

$$\ln\ Q^* \ = \alpha \ln(cS)$$

$$\ln\ Q^* \ = \ln(cS^{\alpha})$$

$$Q^*\ S, M_0 \ = C_1(M_0) S^{\alpha} \qquad \textbf{(10)}$$

Where $C_1(M_0)$ is the constant of integration and it is a function of M_0 since it could depend on the value of M_0.

Now we can consider the order quantity decision for any given level of retailer's sale effort. It is easy to verify that we can restrict our attention to strictly positive effort. From this equation, since α is a positive number, we can see that the retailer's optimal order quantity Q^* is a positive function of *S*. When a retailer exerts more efforts in selling, the quantity of order Q* will increase.

If we denote the average cost of the retailer by C_r and assume that the only cost for the retailer is the whole sale price of the product price charged by the supplier, then

$$C_r = \frac{Q(\ \sum_{i=1}^{N} P_S^{(0)} w^{i-1})}{Q^*} \qquad \textbf{(11)}$$

From Equation (11), we can see that as Q^* increases, the average cost will decrease; therefore average cost C_r is also a function of *S*.

Furthermore, because when the average cost of the product is lower, under the condition of demand uncertainty, the retailer can have more flexibility in pricing. That is to say, P_r is again a function of *S*. Thus, under progressive discount pricing, the retailer's profit function is:

$$G_r = \ Q^*\ S\ (P_r\ S\ - C_r\ S\ ) \qquad \textbf{(12)}$$

To summarize, from Equation (12), we can see that the retailer's profit under a progressive discount pricing can be expressed as a function of a single decision variable, *S*.

Following is a simulation of progressive discount pricing from the vantage of a retailer:

Step	Price	Total sale	Total cost	Average Cost
1	$1.00	100	$100.00	$1.0000
2	$0.90	200	$190.00	$0.9500
3	$0.81	300	$271.00	$0.9033
4	$0.73	400	$343.90	$0.8598
5	$0.66	500	$409.51	$0.8190

Obviously, there is a virtuous circle: when a retailer exerts more sale efforts to increase its sale volume, its cost will be lower; lower cost makes the retailer more competitive than its competitors, this in turn let the retailer sells more and orders more.

The progressive discount pricing model under multiple retailers and single supplier shows that, if any supply chain partner wants to increase its profit, it must exert its efforts to improve the overall efficiency of the whole chain. Only when the efficiency of the whole chain is improved, a firm's share of profits can increase.

VI. CONCLUDING REMARKS

This paper proposes to use progressive discount pricing as a coordination mechanism in a supply chain. Essentially, progressive discount pricing is a form of price discrimination. The manufacturer retrieves higher profit from the sale of the first batch of products and then induces the retailer to sell more by dropping the wholesale price.

In principle, progressive discount pricing is very similar to other coordination instruments. Progressive discount pricing can be viewed as a mirror image of revenue sharing. In revenue sharing, the retailer pays the manufacturer a portion of the retail price for each unit sold to an end consumer. Under progressive discount pricing, the manufacturers give a price discount to retailer before the product is sold to the end user. Both mechanisms are used to expand the total profit of the system so that both suppliers and retailers can be better off.

Progressive discount pricing also has some commonalities with channel rebates. However, for channel rebates, retailer will be rewarded only if their target purchase level exceeds a threshold. For progressive discount pricing, the benefit for both supplier and retailer is increasing continuously by steps. Another big advantage of progressive discount pricing is that under this arrangement, suppliers do not need to have precise knowledge of the demand distribution of the retailer and can know the demand of their products at the beginning of the sale season. The retailers have incentives to cooperate because the retailers are rewarded for their sale efforts.

To summarize, progressive discounting pricing is not only viable in theory but more importantly a powerful instruments in practice. This coordinator can enlarge the

"pie" of the total profit of the supply chain and both supplier and retailer can benefit from sharing the incremental profit. Hence this mechanism can help the supply chain partners to reach the goal of improving the financial efficiency as a whole.

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