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Research Article

Study on the Dynamic Pricing Revenue Distribution Model of Fresh Agricultural Products Supply Chain

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Abstract: This study divides the sales cycle of fresh agricultural products into two stages according to the features of fresh agricultural products, establishes two pricing strategies according to its sales and through constructing an centralized-control model of supply chain under the constraints of revenue sharing contract and through analyzing different prices in the two stages, it summarizes the sales strategies of retailers and supplier and the anticipated sales, proposes to coordinate the operation of fresh agricultural products supply chain by adjusting the revenue coefficient in the revenue sharing contract. After comparing the revenue of decentralized-control supply chain model and centralized-control supply chain model, this study concludes that centralized-control supply chain model will have higher revenue.

Keywords: Dynamic pricing, fresh agricultural products, revenue distribution, supply chain

INTRODUCTION

Agriculture plays an important role in the world economy. However, the production of most agricultural products is affected by a lot of external factors, such as the weather changes, seeds quality and culture methods, which are not in full control by the supply chain members (Sun, 2013; Samuel *et al*., 2008; Xiao *et al*., 2008). Ordinary customers usually prioritize freshness while choosing fresh agricultural products. If the freshness of a certain product is lower than a customer's expectation or lower than other products, the customer will less likely to buy this product. Moreover, the freshness of fresh agricultural products will decrease over time. In this case, if a kind of agricultural products keeps a fixed price when it arrives at the market, its sales will inevitably be poor. In daily life, normally a seller begins to lower the prices of fresh agricultural products as the freshness lowers. In this way, it increases customers' purchasing desire and quickly reduces the stock of fresh agricultural products to lower sales cost. In order to solve the problem that fresh agricultural products' change of quality greatly influences its selling price, people who participate in the supply chain of fresh agricultural products are required to coordinate their production and operation activities so that they are able to respond quickly to customers demands.

Properly designed supply contracts are an effective means to share the demand and supply risk and and better coordinate the decentralized supply chain. It is widely recognized that the supplier and retailer can both benefit from coordination and thereby improve the overall performance of the supply chain as a whole. Many well known contract forms such as buy-back, revenue-sharing, quantity flexibility, sales rebate, two part tariff and quantity discount have shown to coordinate the supply chain (Gong *et al*., 2008; Zhou and Xie, 2010; Qi *et al*., 2004; Xiao *et al*., 2005). In this study, a dynamic pricing revenue distribution model of fresh agricultural products supply chain is studied. For the convenience of studying, this study simply defines the supply chain of fresh agricultural products as consists of one supplier and one retailer, with two stages. Although in real life, the supply chain of fresh agricultural products is much more complicated than the model in this study, their operation and decision-making methods are similar. So this supply chain model of fresh agricultural products is worth promoting.

LITERATURE REVIEW

As a new management idea and operation mode for companies, supply chain management has caught more and more attention both at home and abroad in recent years, in which it is the key and core point to establish a strategic cooperative partnership. The supply chain of agricultural products is a network in the processes of production and circulation, which is formed by all the

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node enterprises providing agricultural products and related services for consumers. The participating enterprises in this chain are producers of agricultural products, logistic centers (wholesale markets), various kinds of logistic companies, retailers and consumers. Lu (2011) shows that the index system for the selection and evaluation of cooperation partners in the supply chain of agricultural products and based on IL-WGA operators, the selection and evaluation is made so that the decision making process of selecting cooperation partners in the supply chain of agricultural products is verified for its scientific nature. In practical operations, many instant factors need to be considered with the changes of environment and the development of science and technology and meanwhile, companies from different industries and with different backgrounds need to make suitable adjustments to the system and methods for selecting a partner. Sun (2013) observes that one-supplier-one-retailer fresh agricultural product supply chain. There are abundant opportunities for research on extensions ranging from multiple suppliers, multiple periods and longer supply chains.

Huang (2012) proposed by American Supply Chain Council and Characteristics of Chinese Agricultural Product Supply Chains (abbr. CAPSC) based on the famous Supply Chain Operations Reference-model (abbr. SCOR), Li (2010) begins with exploratory research for constructive strategies of CAPSC Management. The first is to briefly introduce agricultural products supply chain and related concept of SCOR-model. The Second is to analyze characteristics of CAPSC and currently existing problems in CAPSC. The last is to give some constructive strategies for improving performance of CAPSC Management based on the SCOR-model in the E-commerce environment. Because the SCOR-model is seldom applied in Agricultural Product Supply Chains, the research fruits in the study are just a meaningful attempt and innovation. On the basis of introducing the meanings and characteristics of supply chain management and agricultural supply chain management, analyzes the information flow's attributes throughout the process of agricultural supply and the technological attributes of Internet of Things, finally, the designing method and architecture of integrated information platform of agricultural supply chain management based on internet of things was discussed in detail. In many industries, capacity decisions are fixed for the sales horizon and cannot be changed in the short run. Pricing policies that are responsive to sales can be an effective tool to enhance revenues, given that demand is price sensitive. Changes in prices are perceived differently by customers, i.e., an increase in price relative to a previous price is seen as a loss whereas a price reduction is seen as a gain. Gunnar and Abhijit (2009) develop a demand adaptive pricing policy to improve inventory management for non-perishable products at the presents of menu cost and reference price.

Furthermore, the proposed policy provides management with a tool that aids in price changing decisions, namely when and how much to change it. Mahmoudzadeh *et al*. (2013) develop a dynamic production/pricing problem, in which decisions should be made in each period confronting with uncertain demand and return. The manufacturer is able to control the demand and return by adjusting selling price and acquisition price respectively, also she can stock inventories of used and new products to deal with uncertainties. Modeling a nominal profit maximization problem, they go through robust optimization approach to reformulate it for the uncertain case. He and Sethi (2008) consider a supply chain in which a manufacturer sells an innovative durable product to an independent retailer over its life cycle. They assume that the product demand follows a Bass-type diffusion process and that it is determined by the market influences, retail price of the product and shelf space allocated to it. They consider the following retailer profit optimization strategies:

- The myopic strategy of maximizing the current-period profit
- The far-sighted strategy of maximizing the life-cycle profit

They characterize the optimal dynamic shelf-space allocation and retail pricing policies for the retailer and wholesaler pricing policies for the manufacturer. They compute also these policies numerically. Chen *et al*. (2010) study the optimal pricing and replenishment decisions in an inventory system with a price-sensitive demand, focusing on the benefit of the inventory-based dynamic pricing strategy. They find that demand variability impacts the benefit of dynamic pricing not only through the magnitude of the variability but also through its functional form (e.g., whether it is additive, multiplicative, or others). They provide an approach to quantify the profit improvement of dynamic pricing over static pricing without having to solve the dynamic pricing problem. They also demonstrate that dynamic pricing is most effective when it is jointly optimized with inventory replenishment decisions and that its advantage can be mostly realized by using one or two price changes over a replenishment cycle. Cai *et al*. (2010) consider a supply chain in which a distributor procures from a producer a quantity of a fresh product, which has to undergo a long-distance transportation to reach the target market. During the transportation process, the distributor has to make an appropriate effort to preserve the freshness of the product and his success in this respect impacts on both the quality and quantity of the product delivered to the market. The distributor has to determine his order quantity, level of freshness keeping effort and selling price, by taking into account the wholesale price of the producer, the cost of the freshness-keeping effort, the likely spoilage of the product during transportation and the possible demand for the product in the market. The producer, on the other hand, has to determine the wholesale price based on its effect on the order quantity of the distributor. They develop a model to study this problem and characterize each party's optimal decisions in both decentralized and centralized systems.

METHODOLOGY

Hypothesis: In this study, the constructed supply chain of fresh agricultural products consists of one supplier and one retailer and has two stages. Assume that,

- H_1 : The supplier and retailer are mutually independent and without interference
- H_2 : The supplied product meets market demands
- H_3 : The ordering lead time of fresh agricultural products is long enough
- H_4 : Only one ordering opportunity is provided
- H_5 : The value of residual products is zero

The Retailer needs to predict market demands of fresh agricultural products before sales and then determine the retail purchase volume and the prices of two stages. Specific process can be stated simply as: in the supply chain of fresh agricultural products, the retailer first sign a revenue sharing contract with the supplier; after that, the retailer decide how many products to purchase from the supplier and determine the agricultural products prices of two stages; the supplier then provides the retailer with the fresh agricultural products of the stipulated quantity and with the stipulated price as in the revenue sharing contract; in this supply chain, only after retailer has finished the sales, does revenue generate and the two parties start distributing revenues according to the revenue sharing contract. All the above steps belong to the revenue sharing supply chain of fresh agricultural products, as shown in Fig. 1.

In revenue sharing supply chain of fresh agricultural products, due to uncertain market demands the selling price influences demands. Suppose that $D_i(p_i, \varepsilon_i) = d_i(p_i) + \varepsilon_i$, $i = 1, 2$ demonstrates the demands in stage one and stage two. And customers' sensitivity to price in stage i is shown as $d_i(p_i) = a_i - b_i p_i$, $i = 1, 2$. When $a_i>0$, it represents the basic demands of fresh agricultural products market in stage i. When $b_i>0$, it represents customers' sensitivity to price of fresh agricultural products in stage i. ε_i is the random market factor in stage i which is irrelevant to selling price but can't be eliminated. In $f_i(\varepsilon_i)$, $F_i(\varepsilon_i)$, $F_i(\varepsilon_i)$ is a continuously differentiable CDF (cumulative distribution function) and $F(0) = 0$; $f_i(\varepsilon_i)$ is a probability density function. The demands in stage one and stage two influenced by the selling price of fresh agricultural products p_i is an independent decreasing function $D_i(p_i)$; moreover, we should note that over time, the quality of fresh agricultural products and customers' purchasing desire are decreasing. Therefore, the selling price of stage two should be $p_2<p_1$: $z1 = Q- d_1(p_1)$, and from $S_1(p_1) = \min[Q, D_1, (p_1, \varepsilon_1)]$ we can calculate the retailer's expected sales in stage one is:

$$
\begin{aligned}
E\left[S_1(p_1)\right] &= E\left\{\min\left[Q, D_1(p_1,\varepsilon_1)\right]\right\} = E\left[d_1(p_1) + \min\left(z_1,\varepsilon_1\right)\right] \\
&= d_1(p_1) + \left[\int_0^{z_1} \varepsilon_1 f_1(\varepsilon_1)d\varepsilon_1 + \int_{z_1}^{\infty} z_1 f_1(\varepsilon_1)d\varepsilon_1\right] \\
&= d_1(p_1) + \left[z_1 F_1(z_1) - \int_0^{z_1} F_1(\varepsilon_1)d\varepsilon_1 + z_1(1-F_1(z_1))\right] \\
&= d_1(p_1) + \left[z_1 - \int_0^{z_1} F_1(\varepsilon_1)d\varepsilon_1\right]
\end{aligned} \tag{1}
$$

From $S_2(p_2) = \min[\max(Q- D_1(p_1),0), D_2(p_2)]$, we can calculate the retailer's expected sales in stage one is:

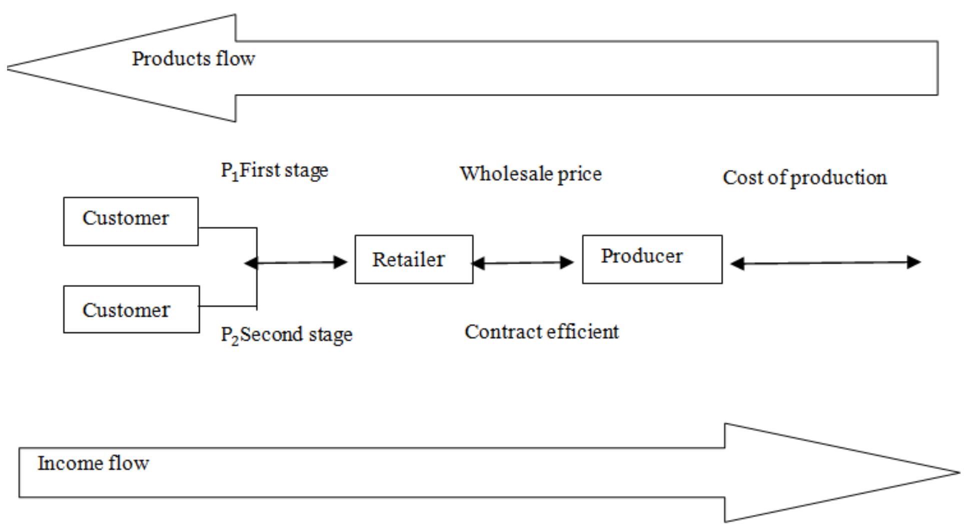

Fig. 1: Revenue sharing supply chain of fresh agricultural products

$$E(S_2(p_2)) = E\left\{\min\left[\max\left(z_2 + d_2(p_2), 0\right), (\varepsilon_2 + d_2(p_2))\right]\right\}$$
$$= \int_0^{z_1} f_1(\varepsilon_1)d\varepsilon_1\left[z_1 - \varepsilon_1 - \int_0^{z_2} F_2(\varepsilon_2)d\varepsilon_2\right] \tag{2}$$
$$= \int_0^{z_1} F_1(\varepsilon_1)d\varepsilon_1 - \int_0^{z_1}\int_0^{z_2} f_1(\varepsilon_1)F_2(\varepsilon_2)d\varepsilon_1 d\varepsilon_2$$

Constructing dynamic pricing model: From the above, under the constraints of revenue sharing contract, the retailer's expected profit is:

$$\prod_R = E\left[\varphi p_1 S_1(p_1) + \varphi p_2 S_2(p_2) - w(d_1(p_1) + z_1)\right]$$
$$= \varphi p_1\left\{d_1(p_1) + \left[z_1 - \int_0^{z_1} F_1(\varepsilon_1)d\varepsilon_1\right]\right\} + \varphi p_2\left\{\int_0^{z_1} F_1(\varepsilon_1)d\varepsilon_1 - \int_0^{z_1}\int_0^{z_2} f_1(\varepsilon_1).\right.$$
$$- w(d_1(p_1) + z_1) \tag{3}$$

So the supplier's expected profit is:

$$\prod_S = E[(1-\varphi)p_1S_1(p_1) + (1-\varphi)p_2S_2(p_2) + w(d_1(p_1)+z_1) - c(d_1(p_1)+z_1)]$$
$$= (1-\varphi)p_1\left\{d_1(p_1) + \left[z_1 - \int_0^{z_1} F_1(\varepsilon_1)d\varepsilon_1\right]\right\} + (1-\varphi)p_2\left\{\int_0^{z_1} F_1(\varepsilon_1)d\varepsilon_1 - \int_0^{z1}\int_0^{z2} f_1(\varepsilon_1)F_2(\varepsilon_2)d\varepsilon_1 d\varepsilon_2\right\}$$
$$+ w(d_1(p_1)+z_1) - c(d_1(p_1)+z_1) \tag{4}$$

So the estimated profit of fresh agricultural products supply chain is:

$$\prod_C = \prod_R + \prod_S$$
$$= E\left[(p_1S_1(p_1) + p_2S_2(p_2)) - c(d_1(p_1) + z_1)\right]$$
$$= p_1\left\{d_1(p_1) + \left[z_1 - \int_0^{z_1} F_1(\varepsilon_1)d\varepsilon_1\right]\right\} + p_2\left\{\int_0^{z_1} F_1(\varepsilon_1)d\varepsilon_1 - \int_0^{z1}\int_0^{z2} f_1(\varepsilon_1)F_2(\varepsilon_2)d\varepsilon_1 d\varepsilon_2\right\}$$
$$- c(d_1(p_1) + z_1) \tag{5}$$

All the above is the dynamic pricing revenue distribution model of fresh agricultural products supply chain.

RESULTS ANALYSIS

Concentrate decision-making profit of fresh agricultural products supply chain: As mentioned earlier, before making order, the retailer and supplier need to sign a revenue sharing contract. The purpose of this is to increase profit of the entire fresh agricultural products supply chain as well as improve the level of control over every member on the supply chain under the premise of maximum profit. From the above simulation quantitative analysis, derivative operation of (z_1, p_1, p_2) is demanded for Eq. (5), so:

$$\frac{\partial \Pi_C}{\partial z_1} = (p_1 - c) - (p_1 - p_2)F_1(z_1) - p_2\int_0^{z_1}\int_0^{z_2} f_1(\varepsilon_1)f_2(\varepsilon_2)d\varepsilon_1 d\varepsilon_2 \tag{6}$$

$$\frac{\partial \Pi_C}{\partial p_1} = d_1(p_1) + p_1 d_1(p_1) + z_1 - \int_0^{z_1} F_1(\varepsilon_1)d\varepsilon_1 - cd_1(p_1) \tag{7}$$

$$\frac{\partial \Pi_C}{\partial p_2} = \int_0^{z_1} F_1(\varepsilon_1)d\varepsilon_1 - \int_0^{z_1}\int_0^{z_2} f_1(\varepsilon_1)F_2(\varepsilon_1)d\varepsilon_1 d\varepsilon_2 + p_2 d_2(p_2)\int_0^{z_1} f_1(\varepsilon_1)F_2(z_2)d\varepsilon_1 \tag{8}$$

Then we calculate the second-order partial derivatives of Eq. (6), (7) and (8), respectively and the results are:

$$H_1 = \frac{\partial^2 \Pi_C}{\partial z_1^2} = -(p_1 - p_2)f_1(z_1) - p_2\int_0^{z_1} f_1(\varepsilon_1)f_2(z_2)d\varepsilon_1 < 0$$

$$\frac{\partial^2 \Pi_C}{\partial z_1 \partial p_1} = 1 - F_1(z_1)$$

$$\frac{\partial^2 \Pi_C}{\partial z_1 \partial p_2} = F_1(z_1) - \int_0^{z_1}\int_0^{z_2} f_1(\varepsilon_1)f_2(\varepsilon_2)d\varepsilon_1 d\varepsilon_2 + p_2 d_2(p_2)\int_0^{z_1} f_1(\varepsilon_1)f_2(z_2)d\varepsilon_1$$

$$\frac{\partial^2 \Pi_C}{\partial p_1^2} = 2d_1(p_1) = -2b_1$$

$$\frac{\partial^2 \Pi_C}{\partial p_1 \partial p_2} = 0$$

$$\frac{\partial^2 \Pi_C}{\partial p_2^2} = -4b_2\int_0^{z_1}\int_0^{z_2} f_1(\varepsilon_1)f_2(\varepsilon_2)d\varepsilon_1 d\varepsilon_2 - 4b_2^2 p_2\int_0^{z_1} f_1(\varepsilon_1)f_2(z_2)d\varepsilon_1$$

So,

$$H_2 = \begin{vmatrix} \frac{\partial^2 \Pi_C}{\partial z_1^2} & \frac{\partial^2 \Pi_C}{\partial z_1 \partial p_1} \\ \frac{\partial^2 \Pi_C}{\partial p_1 \partial z_1} & \frac{\partial^2 \Pi_C}{\partial p_1^2} \end{vmatrix} > 0$$

and

$$H_3 = \begin{vmatrix} \frac{\partial^2 \Pi_C}{\partial z_1^2} & \frac{\partial^2 \Pi_C}{\partial z_1 \partial p_1} & \frac{\partial^2 \Pi_C}{\partial z_1 \partial p_2} \\ \frac{\partial^2 \Pi_C}{\partial p_1 \partial z_1} & \frac{\partial^2 \Pi_C}{\partial p_1^2} & \frac{\partial^2 \Pi_C}{\partial p_1 \partial p_2} \\ \frac{\partial^2 \Pi_C}{\partial p_2 \partial z_1} & \frac{\partial^2 \Pi_C}{\partial p_2 \partial p_1} & \frac{\partial^2 \Pi_C}{\partial p_2^2} \end{vmatrix} < 0 \tag{9}$$

From Eq. (9), we can see that the Hesse matrix is negative, which means that the profit of fresh agricultural products supply chain is maximum. Suppose the value of Eq. (6), (7) and (8) equal to zero respectively, then we can calculate the optimal price for the retailer in stage one and stage two, or the value of (z_1, p_1, p_2). To calculate the expression formula, we must understand the distribution of $(\varepsilon_1, \varepsilon_2)$. Now, the value of (z_1, p_1, p_2) is needed in Eq. (5), so that the maximum profits of members on the supply chain based on centralized- control revenue sharing contract are generated.

Retailer's decision-making profit of fresh agricultural products supply chain: Under the constraints of revenue sharing contract, the retailer's expected profit is shown in Eq. (3). The derivative operation of (z_1, p_1, p_2) is needed to calculate the retailer's expected profit, or:

$$\frac{\partial \Pi_R}{\partial z_1} = \varphi p_1 - w - (p_1 - p_2)\varphi F_1(z_1) - p_2\varphi \int_0^{z_1}\int_0^{z_2} f_1(\varepsilon_1) f_2(\varepsilon_2) d\varepsilon_1 d\varepsilon_2 \quad (10)$$

$$\frac{\partial \Pi_R}{\partial p_1} = \varphi(d_1(p_1) + p_1 d_1(p_1) + z_1 - \int_0^{z_1} F_1(\varepsilon_1) d\varepsilon_1) - w d_1^{`}(p_1) \quad (11)$$

$$\frac{\partial \Pi R}{\partial p_2} = \varphi(\int_0^{z_1} F_1(\varepsilon_1) d\varepsilon_1 - \int_0^{z_1}\int_0^{z_2} f_1(\varepsilon_1) F_2(\varepsilon_2) d\varepsilon_1 d\varepsilon_2) + \varphi p_2 d_2^{`}(p_2) \int_0^{z_1} f_1(\varepsilon_1) F_2(z_2) d\varepsilon_1 \quad (12)$$

Supposing the value of Eq. (10), (11) and (12) equal to zero, respectively, then the optimal prices of retailer in stage one and stage two are generated, which are (z_1^*, z_1^*, p_2^*). As mentioned earlier, the expression formula can be calculated after we understand the distribution of $(\varepsilon_1, \varepsilon_2)$.

Apparently, under the constraints of revenue sharing contract, the retailer should determine a pricing strategy which can increase the revenue of supply chain to meet the centralized-control revenue level as mentioned earlier. So, $z_1 = z_1^*, p_1 = p_1^*, p_2 = p_2^*$ and from Eq. (8) and (12), we can see that if their value equals to 0, respectively, then $p_2 = p_2^*$. The result is needed in Eq. (6) and (10), so that $\varphi = wc$, which is consistent with the result of Eq. (7) and (11).
Therefore it is needed in Eq. (3) and (4):
So,

$$\Pi_R = \varphi \Pi_C, \Pi_S = (1-\varphi)\Pi_C \quad (13)$$

After the retailer has determined the pricing strategies of stage one and stage two, he or she needs to decide the ordering strategy as well, or how many fresh agricultural products should be ordered from the supplier. This requires us to understand the relationship between the optimal ordering quantity Q^* and the prices and demands of stage one and two, shown as follows:
Make the value of Eq. (7) equals to zero:

Then $d_1(p_1) + p_1 d_1^{`}(p_1) + z_1 - \int_0^{z_1} F_1(\varepsilon_1) d\varepsilon_1 - c d_1^{`}(p_1) = 0$

From $Q = z_1 + d_1(p_1)$,

So $Q = p_1 d_1^{`}(p_1) - \int_0^{z_1} F_1(\varepsilon_1) d\varepsilon_1 - c d_1^{`}(p_1)$

Then it is proved that retailer's strategy for determining ordering quantity is influenced only by the sales of stage one, which is consistent with real conditions. In daily life, the revenue of fresh agricultural products comes mainly from stage one. In other words, sales revenue largely depends on the sales volume of normal pricing, not the sales volume of stage two. In addition, it is proved that the relationship between price of stage one and price of stage two is:

$$p_1 > p_2 \text{ ,and } p_1 = \frac{c}{[1 - F_1(z_1)]} + \frac{[F_3(z_1) - F_1(z_1)]}{[1 - F_1(z_1)]} p_2$$

As shown in formula (6), we can see that:

$$F_3(z_1) = \int_0^{z_1}\int_0^{z_2} f_1(\varepsilon_1) f_2(\varepsilon_2) d\varepsilon_1 d\varepsilon_2$$

$$(p_1 - c) - (p_1 - p_2)F_1(z_1) - p_2 F_3(z_1) = 0$$

and $[1 - F_1(z_1)]p_1 = c + [F_3(z_1) - F_1(z_1)]p_2$

so $p_1 = \dfrac{c}{[1 - F_1(z_1)]} + \dfrac{[F_3(z_1) - F_1(z_1)]}{[1 - F_1(z_1)]} p_2$, and $p_2 > c$

then $p_1 > \dfrac{p_2}{[1 - F_1(z_1)]} + \dfrac{[F_3(z_1) - F_1(z_1)]}{[1 - F_1(z_1)]} p_2 = (1 + \dfrac{F_3(z_1)}{[1 - F_1(z_1)]}) p_2 > p_2$

From the result, we can see that the strategy of setting higher price for stage one than stage two is correct.

The decision-making profit of fresh agricultural products supplier: For fresh agricultural products supplier is also under the constraints of revenue sharing contract, his or her revenue depends on his supplying strategy as well as the pricing strategy of retailer. Under the condition of information transparency, the supplier should consider the retailer's response to the wholesale pricing strategy of fresh agricultural products so that he or she decides the wholesale pricing strategy. Therefore, while making pricing strategy, the supplier must take into consideration its influence on all members of the supply chain in order to gain maximum profit and further maximize revenue of the supply chain. To illustrate this point, we calculate and compare the revenue of decentralized-control supply chain with the revenue of centralized-control supply chain under revenue sharing contract. Meanwhile, we calculate the numerical range of revenant sharing coefficient which can realize the Pareto optimum: when w is given, the expected profit function of fresh agricultural products retailer is:

$$\Pi_R^D = p_1\left\{d_1(p_1) + \left[z_1 - \int_0^{z_1} F_1(\varepsilon_1) d\varepsilon_1\right]\right\} + p2\left\{\int_0^{z_1} F_1(\varepsilon_1) d\varepsilon_1 - \int_0^{z_1}\int_0^{z_2} f_1(\varepsilon_1) F_2(\varepsilon_2) d\varepsilon_1 d\varepsilon_2\right\} - w(d_1(p_1) + z_1) \quad (14)$$

The expected profit function of fresh agricultural products supplier is:

$$\Pi_S^D = (w - c)[(d_1(p_1) + z_1)] \quad (15)$$

From Eq. (14) and (15) we can see that when there is only one sales cycle, the retailer's and supplier's expected profit function can be seen as a special expression under the constraints of supply chain revenue sharing contract, or when $\varphi = 1$.

$\varphi = 1$ is taken into Eq. (10), (11) and (12), so that the optimal solution under decentralized-control supply chain z_1^D, p_1^D, P_2^D is obtained.

If z_1^D is taken into Eq. (15) and the Equation's partial with respect to w is calculated, so that we can get the optimal wholesale pricing strategy of fresh agricultural products supplier under the condition of decentralized-control supply chain. Furthermore, after the optimal strategy is taken into Eq. (14) and (15), we can get the value of $\Pi_R^{D^*}$ and $\Pi_S^{D^*}$.

Considering retailer's and supplier's revenues under the constraints of revenue sharing contract is higher than that of decentralized-control supply chain, we must guarantee $\Pi_R > \Pi_R^{D^*}, \Pi_S > \Pi_S^{D^*}$.

Take Eq. (13) into the domain of revenue sharing coefficient φ and:

$$\frac{\Pi_R^{D^*}}{\Pi_C} < \varphi < 1 - \frac{\Pi_S^{D^*}}{\Pi_C}$$

From this formula, we can see that retailer's and supplier's revenue under centralized-control supply chain is higher than that of decentralized-control supply chain.

CONCLUSION

In the fresh agricultural products supply chain, every member is under the constraints of revenue sharing contract. As the value of revenue coefficient increases, the expected profit of retailer increases while the expected profit of supplier decreases. Therefore, in revenue sharing contract, the revenue coefficient determines the bargaining position of the retailer and the supplier. In daily production and operation, before some rural cooperatives come into full effect, individual peasants are completely at disadvantage in bargaining with large-scale retailers or supermarkets. Therefore, rural cooperatives are needed to adjust revenue sharing coefficient in bargaining with large-scale retailers, to realize the reasonable profit distribution of the entire supply chain, to coordinate the production and sales activities of fresh agricultural products and to further improve resilience of the supply chain and increase its competitiveness.

This study establishes a centralized-control supply chain model under revenue sharing contract which covers the two stages of sales cycle and through the analysis of pricing for stage one and two, it summarizes the sales strategy of retailer and supplier and their expected sales volume. Furthermore, this study puts forward that the revenue coefficient of the revenue sharing contract can be adjusted to coordinate the operation of fresh agricultural products supply chain. After comparing the revenue of decentralized-control supply chain and the revenue of centralized-control supply chain, this study concludes that the later model can generate higher revenue.

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