Three stage game research of dual-channel supply chain of fresh agricultural products under consumer preference

Zhenguo Liu, Zhiqiang Yu, Shuangshuang Zhang and Jianliang Peng*

Department of Computer and Information Engineering Management, Zhejiang Gongshang University, Zhejiang Province, China
Email: liuzhenguo08@163.com
Email: m13083988610@163.com
Email: 15967156096@163.com
Email: pengjl@mail.zjgsu.edu.cn
*Corresponding author

Abstract: Double channel conflict between fresh agricultural products is the focus of the urgent problems. With consumer service preference, this article build a three-stage dynamic game model of the integration of resources during the fresh produce supply chain online and offline distribution to study the effect of the variables in the fresh agricultural products supply, finally through the case analysis, to verify the validity of the method of three stage game of dual-channel supply chain of the distribution of resources integration of fresh agricultural products. The research results have important guiding value to the management of dual-channel supply chain of the distribution of resources integration of fresh agricultural products.

Keywords: fresh agricultural products; dual-channel supply chain; three stage game; consumer preference; the integration of resources.


Biographical notes: Zhenguo Liu received his Master of Engineering in Computer and Information from the University of Zhejiang Gongshang in 2015. He majors in logistics engineering. He is committed to studying the professional research work during the school period. Currently, he works in NetEase Koala with good performance.

Zhiqiang Yu is a graduate student at the Zhejiang Gongshang University, major in Logistics Engineering in the Department of Computer and Information. He devotes himself to scientific study. During school days, he takes part in design process of multiple projects, and that gives him professional knowledge.

Shuangshuang Zhang is a Master’s degree student at the Zhejiang Gongshang University. In the first semester, she gained more experience dealing with various things. Scientific research must be done independently. This cultivation of independence and sense of responsibility are of great benefit to her. But
perhaps, the most important is that her thinking is intensely rigorous. When looking at any question, she fully scrutinise it to find any uncertain issues. She believes this kind of thought is essential to become an excellent researcher.

Jianliang Peng is a Professor at the School of Computer and Information Engineering in the Zhejiang Gongshang University. He is a motivated and industrious individual. For him, teaching and advising students has been a delightful pleasure.

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1 Introduction

Due to the special nature of fresh produce and consumer buying habits, the future direction of fresh produce on a dual channel of distribution is the combination of the high efficiency trade of fresh produce online and the high delivery service experience offline. Most research and discussion is a two-channel supply chain pricing, ordering strategy, interest and other issues in the present study of the literature dual-channel supply chain. Hua et al (2010) researched delivery time and price strategy of the supply chain by Game Research on basic methods of centralised decision and decentralised decision mode, finally prove the channel member price strategy by direct online channel delivery time. Huang et al. (2012) researched the dual channel under the background of production based on the demand disruption management and find the effect of the market size. Yu and Liu (2012) analysed pricing strategies on both sides as well as the level of promotional in retailers. Hu and Li (2015) analyses the pricing decision of the dual channel supply chain under the different rights structure of the channel based on the consideration of the service level of the traditional retail channel. Before the emergence of fresh produce dual-channel conflicts, some scholars has put forward the corresponding coordination policy for conventional conflicts and problems about the distribution channel in general products. Cattan and Sebastian (2011) proposed that in the early stage of the network channel, the network and traditional channels can be used to avoid the conflict with the retailer. Li (2013) researched the coordination mechanisms in dual-channel supply chain based on Steinberg game and evolutionary game differential game, differential game, evolutionary game and other methods. Chiang (2014) studied the supply chain structure of the manufacturer and through the design of the combination model of the revenue sharing and inventory cost, the network direct marketing channels and traditional retail channels can be coordinated. Modak and Panda (2015) take the corporate social responsibility into account to coordinate the supply chain. Gallego and Hu (2014) researched the pricing problem with the impact of product attributes and the current price. Although the above research has played a role in promoting the research on the game and coordination of the dual channel supply chain, but less research on the game and coordination of the dual channel supply chain of fresh agricultural products. At present, the develop momentum of China’s fresh agricultural electricity business is strong and dual channel flow of Fresh agricultural products has become the norm, in this paper,
the characteristics of the supply chain of fresh agricultural products are combined with the research of the existing dual channel supply chain, three stage dynamic game model of supply chain integration of fresh agricultural products supply chain based on online and offline is constructed by joining consumer decision-making model.

2 System description

Physical retailers improve the level of distribution services for network channels to provide terminal distribution services and reduce the distribution service difference between the physical distribution channels in the meantime. In addition, the food company gives a certain economic compensation to the physical retailer based on their distribution service investment of network channel to ensure the completion of resource integration.

3 Distribution model of dual channel supply for fresh agricultural products

The specific model structure is shown in Figure 1.

Figure 1 The circulation model of the dual channel supply chain for fresh products

The main parameters of the model are as follows:

- $Ce$ the cost that food company supply to the network channel
- $Cr$ the cost that food company supply to the retailers
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$Pe$ network sales price of fresh produce
$Pr$ physical sales price of fresh produce
$He$ distribution service level of network channel
$Hr$ physical retail channel distribution service level
$H_0$ minimum delivery service standards
$D$ total potential demand for fresh agricultural products
$De$ sales of network channel for fresh agricultural products
$Dr$ sales of physical channel for fresh agricultural products
$\lambda$ service cost coefficient
$X$ customer service satisfaction preference
$W$ wholesale price of agricultural products in the physical channel
$b1, b2, f$ the price sensitivity coefficient of the network and the physical channel and the cross price competition coefficient between the channels
$U$ utility when consumers buy fresh produce
$M$ consumer service satisfaction payment factor
$C$ marginal cost of channel flow

4 Three-stage dynamic game analysis

4.1 The third stage: consumer channel decision

This article assumes that the consumer’s utility function is:

$$U_i = mx(H_i - H_0) - P_i \quad i = e, r \tag{1}$$

The effectiveness that customers choose the network channels and physical channels to buy fresh produce are:

$$U_e = mx(H_e + h - H_0) - P_e = mxh - P_e$$

$$U_r = mx(H_r - H_0) - P_r = mhx - P_r$$

4.1.1 Consumers choose to buy fresh produce through the network channels

The conditions to be satisfied that Consumers choose to buy fresh produce through the network channels are:

$$U_e = mxh - P_e \geq U_r = mhx - P_r, \quad x \leq \frac{P_r - P_e}{m(H_r - h)}$$
Consumers will choose the network channels to purchase agricultural products and then the market demand through the network channels can be expressed as:

$$D_e = D_e \cdot \frac{P_e - P_x}{mX(H_r - h)} - b_2 P_e + fP_e$$

**Conclusion 1**: when m (the value of coefficient of consumer distribution service satisfaction) is higher, the consumers are more inclined to purchase agricultural products through the physical retail channels with better distribution services.

### 4.1.2 Consumers choose to buy fresh produce through the physical channel

The conditions to be satisfied that consumers choose to buy fresh produce through the physical retail channels:

$$U_e = mxh - P_e < U_r = mxH_r - P_r, x > \frac{P_r - P_e}{m(H_r - h)}$$

Consumers will choose to physical channels buy fresh produce and the demand in physical channels is:

$$D_e = D_e \left(1 - \frac{P_r - P_e}{mX(H_r - h)}\right) - b_2 P_r + fP_r$$

### 4.2 The second stage: price and distribution service decision

In the second stage, this paper assumes that the marginal cost of the fresh agricultural products in the network channel and the physical channel are $C_e$ and $C_r$ and $C_p = C_r = C$.

#### 4.2.1 The analysis of the dual channel supply chain before the integration of distribution resources

Before the integration of distribution resources is implemented by the dual channel supply chain and the two channel distribution is dissociative, the respective profit and demand functions in the food companies and the physical retailers are:

$$\pi_e = (P_e - C_e)D_e + (w - C_e)D_e$$  \hspace{1cm} (2)

$$\pi_r = (P_r - w)D_r - \lambda H_r^2$$  \hspace{1cm} (3)

$$D_e = D_e \left(1 - \frac{P_r - P_e}{mXH_r}\right) - b_2 P_e + fP_r, D_e = D_e \frac{P_r - P_e}{mXH_r} - b_2 P_e + fP_r$$

With the reverse induction method to find the equilibrium price, the optimal retail price can be received:

$$P_e^* = \frac{Dw + DP_e + DH_rXm + H_rP_eXf + H_rXbwm}{2D + 2H_rXbwm}$$

The first derivative of $\pi_e^*$ and $\pi_r^*$ for $H_r$ are:
Conclusion 2: When the dual channel distribution is detached, the total profit of the fresh agricultural products supply chain is a decreasing function of the difference of service delivery, that means it is not conducive to the profit of fresh agricultural products supply chain and the increase of total profit of the supply chain when the distribution service among different channels is distinguishing.

4.2.2 Analysis of supply chain under the integration of distribution resources

When the integration strategy of the distribution resources is implemented in the dual channels and the physical retailer to provide distribution services for agricultural products in network sales channels. Under the integration strategy of the distribution resources.

\[ \pi_c = (P_c - C - P_{th})D_c + (w - C)D_r \]  
\[ \pi_r = (P_r - w)D_r + P_{th}D_r - \lambda(H_r + h)^2 \]

\[ A = \frac{D}{mX(H_r - h)} \], the demand in each channel can be expressed as:

\[ D_c = A(P_c - P_r) - b_1P_r + fP_r, \quad D_r = D - A(P_r - P_c) - b_2P_r + fP_c \]

and the optimal retail price is:

\[ P^*_r = \frac{w(A - b_2) + (A - Ah - htf - f)P_c}{(2A - 2b_2)} \]

Then the food company’s price decision-making problem can be translated into solving the following planning issues:

\[ \max \pi_c = (P_c - C - P_{th})D_c + (w - C)D_r \]
\[ \text{s.t.} \quad P_c > w \]

The Lagrange function can be constructed as follows:

\[ L(P_c, P_r, w, \delta) = (P_c - C - P_{th})D_c + (w - C)D_r + \delta(P_c - w) \]  

The optimal network sales price and the retail price can received by derivation and substitution and the food company profit, the profit of the retailer and the total profit function of the supply chain are expressed as:

\[ \pi^*_c = (P^*_c - C - P^*_{th})D^*_c + (w^* - C)D^*_r \]  
\[ \pi^*_r = (P^*_r - w^*)D^*_r + P^*_{th}D^*_r - \lambda(H_r + h)^2 \]  
\[ \pi^* = \pi^*_c + \pi^*_r \]

Conclusion 3: Conclusion shows that in a certain range, it is conducive to the improvement of fresh agricultural products supply chain parties benefit, effectively increase the total profit of the supply chain and achieve the double channel win by
improving the distribution services of the physical retailers to network channels (Modak and Panda. 2015).

4.3 The first stage: the decision of the compensation coefficient of distribution service

According to the second stage, the decision-making results of price and service level in the food company and the physical retailer can give us the total profit function of fresh agricultural products supply chain:

$$\pi^* = (P_0^* - C) D_0^* + (P_0^* - C) D_2^* + \lambda (H_r + h)^2$$

By the first derivative of $\pi^*$ for $t$ and make it equal to 0, we can know when the total profit of fresh agricultural products supply chain is the largest, the food company determine the optimal distribution of the real retailer service compensation coefficient. Because the parameter expression $H_r^*$ and $h^*$ are more complex and contains higher power, this paper will not give the optimal compensation coefficient $t^*$, but the specific expressions can be obtained by numerical calculation and here will not be given in detail.

5 Example analysis

5.1 Profit impact analysis

In this paper, the profit of each member when the input of distribution service is between $(0, 3)$ in the supply chain and the profit gap are calculated when $H_r = 3.5$ and it remains unchanged. The calculation result is shown in Figure 2.

Figure 2 Effect of distribution service input on profit
Conclusion 4: with the increase of the distribution service investment, the difference of distribution service between channels is smaller, the profit and profit margin of the food companies and the physical retailers are increased.

Figure 3  Effect of distribution service input on price

5.2 Price impact analysis

Keep the retailer increase value of logistics input \( h = 2.6 \), find differences in the effects of logistics distribution service channels between the pressure analysis on dual channel optimal price of agricultural products.

Conclusion 5: along with the difference of logistics service channels increased, the difference of fresh agricultural products supply chain network channels and physical channels for sales of agricultural products prices are increasing with the logistics service and low pressure drop and the influence of network channel price by the logistics service difference is bigger.

5.3 Market impact analysis

When \( H_r = 3.5 \) and it remains unchanged. The calculation result is shown in Figure 4.

Conclusion 6: with the pressure of retailers’ service logistics network channels increase value increase, sales network channel market significantly improved. At the same time as the market potential demand pressure constant, with the increase of network sales channels, sales channel market entities will reduce pressure.
6 Summary

In this paper, we consider the consumer as the decision-making body into the supply chain decision-making model. With the changes in retailer’s distribution service inputs, we analysis the price of fresh agricultural products, market demand and profit for each member of the supply chain under the integration strategy of distribution resources through the analysis of the supply chain of the three-stage dynamic game and the comparative analysis of the game decision making of supply chain of fresh agricultural products before and after the integration of distribution resources. Results show, the integration of distribution resources in the dual channel supply chain of the Fresh produce can effectively improve the distribution service ability of agricultural products network channel, the performance of dual channel circulation of fresh agricultural products and that can reduce the distribution service differences between the double channels of fresh agricultural products and ease the dual channel conflict to achieve the double channel members of a win-win situation.

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