

A GAME MODEL OF MULTI-CHANNEL DISTRIBUTION BASED ON THE VIRTUAL TRADING COMMUNITY

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ABSTRACT. *From the perspective of consumer utility heterogeneity, the demand functions are built in the multi-channel structure, which consists of one physical retail channel and two e-channels respectively for the manufacturer and the retailer. Different from previous online direct sales channel, the e-channel is operated by the third party – virtual trading community (referred to hereafter as ‘VTC’). And the pricing strategies are analyzed by the game model. In order to explore the role of the VTC, the VTC mode is compared with the traditional online direct sales channel operated independently by the merchants themselves (referred to hereafter as ‘TOD’). The result shows that there is a significant difference in the equilibrium prices between the two operation modes and the cost for channel operation has an important influence on the price. After that, according to the more intense competition characteristic of the VTC, service promoting strategy is introduced and the impacts of service’s cost on equilibrium prices and demands are discussed under different service promoting strategies (i.e., promoting service only in physical retail channel or both physical retail channel and VTC channel). It is found that in a given interval of the service coefficient, the service promoting only in physical retail channel effectively alleviates competition threat from manufacturer’s VTC channel and benefits the retailer, and the service promoting in both channels has an indirect benefit for the retailer by increasing the physical retail channel demand. In the end, the results are demonstrated by numerical examples.*

Keywords: Supply chain management, Multi-channel distribution, Game model, Virtual trading community

1. Introduction. With the rapid development of the e-business, on-line shopping is becoming increasingly popular. Some of the consumers with high brand loyalty often purchase by the online direct sales channel, and the others purchase by the VTC platform such as Tmall, Amazon and E-bay. For the consumers with preference of VTC, the VTC’s checking on the merchants’ qualities improves their trust in online channel, and the whole and different sorts of products clustering in the VTC could meet their various needs better. Meanwhile, for the merchant with low brand impact, the VTC helps the manufacturers save operational cost of e-channel and makes the retailers easier to enter electronic market. In the case, the dual-channel distribution (the manufactures sell the goods by both the physical retail channel and the online direct sales channel) is gradually transformed to the multi-channel (based on the physical retail channel, both the manufacturers and retailers also open e-channel in the VTC). Then, the above theory is probably not fit for the new channel structure. New multi-channel structure increases competition between both the manufacturer and the retailer. The competition is not only from the vertical nodal enterprises and retail-electronic channel, but also from the horizontal VTC-VTC e-channel. Research on the issues of new multi-channel structure brought is significant: it

can meet the e-channel development better. So, how to make more profits for the nodal enterprises based on VTC platform is needing close attention under the multi-channel structure.

Although the VTC brings opportunity to the merchants, compared with the TOD mode, it enhances the competition from the homogeneous products caused by the cluster of similar products, and also increases the competition between the merchants who sell the similar product in the VTC cluster of similar products. The nodal enterprises of the supply chain face bigger challenge. So, they need improve their competition ability through price or service. Hence, based on service promoting, this paper investigates the pricing strategies by the game model in the multi-channel supply chain which consists of one manufacturer and one retailer, and discusses the role of VTC by comparing it with the TOD mode.

At present, the issue of channel competition and conflict in dual-channel supply chain is concerned by more and more scholars as well as the insider [1,2]. Researchers pay attention to the problem using different models from different perspectives. Using the models of separability and optimality, Jia et al. consider the existence conditions and correlation of equilibrium ordering and pricing policies in a three-tier supply chain network [3]. And from the industry characteristics, Zhao et al. consider the optimized ordering strategy and cooperative conditions in a food supply chain with bidirectional [4]. From the perspective of government investment, Leng et al. put forward an effective method of profit analysis in Heilongjiang's grain main-production region [5]. And from the differentiated branding, Yan considers the strategic roles played by differentiated branding and profit sharing in a dual-channel supply chain [6]. From the perspective of competition, Yao et al. discuss the pricing strategy in dual-channel supply chain by the Bertrand and the Stackelberg price competition models and propose an appropriate strategy for the manufacturer to adopt when adding an e-tail channel [7]. And from the perspective of coordination, Tsay [8] and Yan [9] et al. investigate the influence of the service and price on the demand, and give the channel and nodes coordination strategies respectively.

Meanwhile, more and more scholars pay attention to the role of the online direct sales channel in dual-channel supply chain [10,11]. The online direct sales channel will also bring indirect profits to supply chain even without sales from direct sales channel [12]. Retailers will reduce the retail price and improve the service quality in order to evade the competition of direct sales channel [13]. The empirical research finds out that the service quality is a crucial factor for the consumer's acceptance degree of online direct sales channel, and the influence of service quality on the profits is even greater than the price [14]. As a part of service process, Hua et al. find the logistics service lead time has a strong impact on the demand, prices and profits in dual-channel supply chain [15]. S.-H. Chun et al. classify the channel to three modes: an online direct channel only, a brick-and-mortar retailer only, or a dual channel using both offline and online channels. They analyze the optimal channel strategies of a manufacturer from the perspective of consumer heterogeneity and the retail services. And the results show that when the degree of consumer heterogeneity is sufficiently large or the retail service is very high, a manufacturer may use a traditional offline retail channel only, and when the relative consumer heterogeneity is moderate and the proportion of the service sensitive group is relatively small, a manufacturer chooses a dual channel strategy, but when the retail service is not valuable enough for customers, a manufacturer chooses a direct online channel [16]. Xiao et al. analyze the Stackelberg and Bertrand models in the scenario of the manufacturer's online direct channel operated by the retailer, and the retailer may obtain some compensation from the manufacturer for the service. They find that the marginal cost of the

service has a sufficient influence on the channel prices and the demands. There is a positive correlativity between the service cost of manufacturer's online direct channel and the physical retail channel price. When the service in physical retail channel is higher than online direct channel, there is a positive correlativity between the service cost of retailer's and the online direct channel price [17]. J.-C. Lu et al. highlight the importance of service from manufacturers in the interactions between two competing manufacturers and their common retailer, facing consumers who are sensitive to both retail price and manufacturer service. The result shows that as the product market base increases, the competitor also obtains benefits but at a lesser amount than the manufacturer. Furthermore, when one manufacturer has some economic advantage in providing service, the retailer will act to separate market segment by selling the product with low-cost (lower-quality) service at a low price and selling the product with high-cost (high-quality) service at a high price [18]. Kuma implies the promoting service in the physical retail channel may effectively reduce the competition from the manufacturer's online direct channel, alleviate the channel conflict and improve the supply chain's performance [19].

Researches above explore the influence of the service on the equilibrium prices, and give different coordination strategies. However, the service is only for the physical retail channel and the channel structure is only for the dual-channel; that is, the manufacturer sells the product to the retailer by the physical retail channel and meanwhile sells to the consumers by online direct sales channel. It does not involve the third party – VTC, and the retailer does not open e-channel. However, the role of the VTC is becoming increasingly important to the merchants with low brand impact. Different from the researches mentioned before, we consider the e-channel is operated by the third party – VTC, and the channel structure is multi-channel, in which both the manufacturer and the retailer open the e-channel on the VTC platform. This channel structure is infrequent in the previous research. However, in reality, the possibility of the retailer opening the e-channel is increasing. So, our discussion is of real significance to guiding practice.

In our research, we transfer the online direct channel to the VTC mode and expand the dual-channel mode to the multi-channel in the VTC. In the scenario, we explore the pricing strategies by game model and investigate the role of the VTC by comparing it with the TOD mode. Then, we discuss the impacts of service parameters on equilibrium prices under different service promoting strategies (only in the physical retail channel or both the physical retail channel and the VTC channel) based on our results. It has theoretical value and practical meanings to channel selection and competition of the nodal enterprises in the supply chain management.

2. The Basic Models. In the supply chain consisting of one manufacturer and one retailer, the manufacturer and retailer sell the same product. The manufacturer sells the product to the consumer by the VTC channel and the retailer, meanwhile, sells the product by both the physical retail channel and the VTC channel. Figure 1 describes the channel structure of the supply chain.

In the same supply chain, the competitive power of price for the retailer is far lower than the manufacturer. So facing the fierce competition from homogeneous product in VTC and upstream manufacturer, we consider that the retailer expands market share and enhances competitiveness by improving service level.

2.1. The demand functions. From the perspective of consumer utility, researchers have designed various demand functions [20,21]. In our research, we assume satisfaction degree δ of the consumer has heterogeneity to the same product purchasing in different channels (here refers to the physical retail channel and the VTC channel), and δ complies

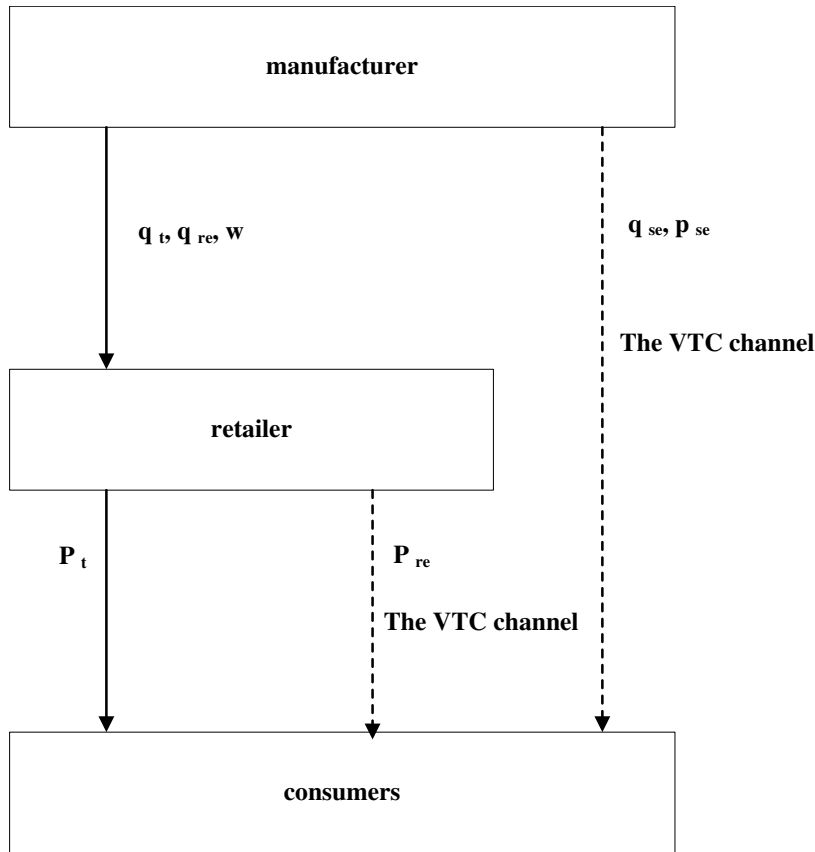


FIGURE 1. The channel structure of the supply chain

with uniform distribution in the interval of $\underline{\delta}$ and $\bar{\delta}$, where $\underline{\delta}$ denotes the consumer's lowest satisfaction degree to purchasing in different channel, and $\bar{\delta}$ denotes the highest satisfaction degree. In the most of researches, the price is viewed a key factor influencing the consumer's satisfaction, and part of them consider the service factor. According to the characteristic of the VTC, we introduce the Internet word of mouth as a new influence factor, and consider the consumer's satisfaction degree is influenced by all the price, service and public praise (or Internet word of mouth). We use k ($k > 0$) to denote the cost coefficient of the consumer's satisfaction degree, which reflects the marginal cost of consumer paying for per unit satisfaction degree purchasing in the VTC. Let subscript s and r denote the manufacturer and the retailer, t and e denote physical retail channel and the VTC channel respectively. In the VTC channel, for the manufacturer and retailer, there is a significant impact of Internet word of mouth on sales volume. We assume m_{se} and m_{re} denote the added value for unit Internet word of mouth in the VTC channel, α and β as the added value coefficient per unit product, reflect the cost of consumer paying for per unit Internet word of mouth added value in the VTC. And v denotes the value-added service for per unit product in the physical retail channel, and γ is the coefficient of value-added service, which reflects the cost of consumer paying for per unit service. According to paper [22], the cost function of value-added service is $c(v) = \frac{1}{2}\eta v^2$, where η denotes the coefficient of service cost. We use w to denote the wholesale price, p_t denote the retail price in the physical retail channel, p_{se} and p_{re} denote the sales price in the VTC channel respectively for the manufacturer and the retailer. From the perspective of consumer satisfaction degree, the consumer will purchase in the VTC channel when the satisfaction degree is higher than that of in physical retail

channel, that is $p_{re} - \beta m_{re} + k(\delta - \underline{\delta}) \leq p_t - \gamma v$ or $p_{se} - \alpha m_{se} + k(\delta - \underline{\delta}) \leq p_t - \gamma v$, and otherwise, will purchase in the physical retail channel. So the critical value δ^* of consumer satisfaction degree purchasing in the VTC is $p_{re} - \beta m_{re} + k(\delta^* - \underline{\delta}) = p_t - \gamma v$ or $p_{se} - \alpha m_{se} + k(\delta^* - \underline{\delta}) = p_t - \gamma v$, that is $\delta r^* = \frac{p_t - \gamma v - p_{re} + \beta m_{re}}{k} + \underline{\delta}$ or $\delta s^* = \frac{p_t - \gamma v - p_{se} + \alpha m_{se}}{k} + \underline{\delta}$. For the same product, consumer will purchase in the VTC only if the consumer satisfaction degree is higher than δ^* .

We assume the base level of demand is 1 (i.e., potential demand if the products are free of charge), and q_t denotes the demand of physical retail channel. q_{se} denotes the VTC channel of manufacturer and q_{re} denotes the retailer's VTC channel, $q_{se}, q_{re} \in [0, 1]$ and $q_t = 1 - q_{se} - q_{re}$. So we have

$$q_{se} = 1 \cdot \int_{\delta s^*}^{\bar{\delta}} \frac{1}{\bar{\delta} - \underline{\delta}} d\delta = 1 + \frac{p_t - \gamma v - p_{se} + \alpha m_{se}}{k(\bar{\delta} - \underline{\delta})} = 1 + a(p_t - p_{se}) + b m_{se} - l v \quad (1)$$

$$q_{re} = 1 \cdot \int_{\delta r^*}^{\bar{\delta}} \frac{1}{\bar{\delta} - \underline{\delta}} d\delta = 1 + \frac{p_t - \gamma v - p_{re} + \beta m_{re}}{k(\bar{\delta} - \underline{\delta})} = 1 + a(p_t - p_{re}) + b m_{re} - l v \quad (2)$$

where $a = \frac{1}{k(\bar{\delta} - \underline{\delta})}$, $b = \frac{\alpha}{k(\bar{\delta} - \underline{\delta})}$, $l = \frac{\gamma}{k(\bar{\delta} - \underline{\delta})}$.

From (1) and (2), we can see the demand of VTC channel increases as retail price and the Internet word of mouth in the VTC channel go up, but there is a decrease as increasing price of VTC channel and the service level in physical retail channel.

2.2. The profit functions. Let c_{st} and c_{rt} denote the marginal costs of the manufacturer and the retailer in the physical retail channel. The manufacturer and the retailer will pay for the commissions of the platform for operating in the VTC. The costs are composed of fix cost and additional service cost. We assume $c_{se}(T, S)$ and $c_{re}(T, S)$ respectively denote the cost functions for the manufacturer and the retailer in the VTC. The cost functions for the manufacturer and the retailer are $c_{se}(T, S) = gT_{se}$ and $c_{re}(T, S) = gT_{re} + \frac{1}{2}uS_{re}^2$, where T denotes the fix cost parameter, S denotes the cost parameter of additional service, g denotes the coefficient for fixed cost, and reflects the operational fee in VTC for per unit period, u denotes the coefficient for additional service cost, and reflects the influence degree of additional service on additional cost.

The profit functions are as follows:

$$\pi_s = (p_{se} - c_{se}(T, S))q_{se} + (w - c_{st})q_t \quad (3)$$

$$\pi_r = (p_{re} - c_{re}(T, S))q_{re} + (p_t - w - c_{rt})q_t - c(v) \quad (4)$$

3. Analysis of the VTC Mode. In our model, the manufacturer and the retailer are completely rational. They decide the prices for maximizing their own profits. And assume the manufacturer and the retailer are risk neutral. We explore the equilibrium prices and profits in the VTC mode.

Lemma 3.1. π_r is concave with respect to (p_{re}, p_t, v) , π_s is concave with respect to p_{se} .

Proof: We derive the follows from the first-order derivative of (3) and (4).

$$\frac{d\pi_r}{dp_{re}} = b m_{re} - l v + a \left(2p_t - 2p_{re} - c_{rt} \right) \frac{u S_{re}^2}{2} + g T_{re} \Big) + 1$$

$$\frac{d\pi_r}{dp_t} = 2l v - b(m_{se} + m_{re}) + a \left(2p_{re} + p_{se} + 2c_{rt} - \frac{u S_{re}^2}{2} - g T_{re} - 4p_t \right) - 1$$

$$\frac{d\pi_r}{dv} = -\eta v$$

The second-order derivative of (3) and (4) are

$$\frac{\partial^2 \pi_r}{\partial p_t^2} = -4a < 0, \quad \frac{\partial^2 \pi_r}{\partial p_{re}^2} = -2a < 0, \quad \frac{\partial^2 \pi_r}{\partial v^2} = -\eta < 0, \quad \frac{\partial^2 \pi_r}{\partial p_t p_{re}} = 2a > 0.$$

So the Hessian matrix of π_r is $H = \begin{bmatrix} -2a & 2a & 0 \\ 2a & -4a & 0 \\ 0 & 0 & -\eta \end{bmatrix}$.

We have $H_{11} = -2a < 0, H_{22} = 4a^2 > 0, H_{33} = \begin{vmatrix} -2a & 2a & 0 \\ 2a & -4a & 0 \\ 0 & 0 & -\eta \end{vmatrix} = -8\eta a^2 < 0$.

So H is negative definite and π_r is strictly jointly concave with respect to (p_{re}, p_t, v) .

Similarly, $\frac{\partial^2 \pi_s}{\partial p_{se}^2} = -2a < 0$, so π_s is strictly jointly concave in p_{se} and π_s has the only one with respect to p_{se} .

Lemma 3.1 shows that π_r has the only optimal value with respect to (p_{re}, p_t, v) and π_s has the only optimal value with respect to p_{se} .

Usually, the manufacturer and the retailer decide independently. They make pricing decision at the same time. There is competition between them. So we can describe the process with non-cooperative game and obtain the solutions by Nash equilibrium model.

Theorem 3.1. *In the VTC mode, as the wholesale price is external variable, the Nash equilibrium pricing strategy for the manufacturer and the retailer is $(p_{re}^*, p_t^*, p_{se}^*, v^*)^T$, where*

$$p_t^* = \frac{ac_{rt} + 2ac_{se} - 2ac_{st} + bm_{se} + 3aw - lv + 2}{3a}$$

$$p_{re}^* = \frac{3ac_{re} + ac_{rt} + 2ac_{se} - 2ac_{st} + 3bm_{re} - 2bm_{se} + 2aw - lv + 5}{6a}$$

$$p_{se}^* = \frac{2ac_{rt} + ac_{se} - ac_{st} - bm_{se} + 3aw + lv + 1}{3a}$$

$$v^* = \frac{(3ac_{re} - 13ac_{rt} + 10ac_{se} - 10ac_{st} - 3bm_{re} + 12bm_{se} - 3alw + 7)l}{9l^2 + 6a\eta}$$

Proof: Let $\frac{d\pi_r}{dp_t} = 0, \frac{d\pi_r}{dp_{re}} = 0, \frac{d\pi_r}{dv} = 0, \frac{d\pi_s}{dp_{se}} = 0$, we have

$$\begin{bmatrix} 2a & -2a & -l & 0 \\ -4a & 2a & 0 & a \\ -2l & l & \eta & 0 \\ -a & 0 & l & 2a \end{bmatrix} \begin{bmatrix} p_t \\ p_{re} \\ v \\ p_{se} \end{bmatrix} = \begin{bmatrix} -1 + ac_{rt} - ac_{re} + lv - bm_{re} + aw \\ 1 - 2ac_{rt} + ac_{re} - 2lv + b(m_{re} + m_{se}) - 2aw \\ lc_{re} - 2l(c_{rt} + w) \\ 1 + aw - ac_{st} + ac_{se} - lv + bm_{se} \end{bmatrix}$$

Let $A = \begin{bmatrix} 2a & -2a & -l & 0 \\ -4a & 2a & 0 & a \\ -2l & l & \eta & 0 \\ -a & 0 & l & 2a \end{bmatrix}, B = \begin{bmatrix} -1 + ac_{rt} - ac_{re} + lv - bm_{re} + aw \\ 1 - 2ac_{rt} + ac_{re} - 2lv + b(m_{re} + m_{se}) - 2aw \\ lc_{re} - 2l(c_{rt} + w) \\ 1 + aw - ac_s + ac_{se} - lv + bm_{se} \end{bmatrix}$.

$$P = \begin{bmatrix} p_t \\ p_{re} \\ v \\ p_{se} \end{bmatrix}$$

Since matrix A is strictly diagonally dominant matrix and the elements on the main diagonal are positive, the matrix A is nonsingular and positive definite.

So we have $(p_{re}^*, p_t^*, p_{se}^*, v^*)^T = A^{-1}B$ and Theorem 3.1 is proved.

3.1. The retailer promoting service only in physical retail channel. According to Theorem 3.1 and the demand functions, we obtain Corollary 3.1.

Corollary 3.1. *In the VTC mode, the impact of service on equilibrium prices and demands when the retailer promoting service only in the physical retail channel is as follows.*

$$(I) \quad \frac{\partial p_{re}^*}{\partial v} = \frac{-l}{6a} < 0, \quad \frac{\partial p_t^*}{\partial v} = \frac{-l}{3a} < 0, \quad \frac{\partial p_{se}^*}{\partial v} = \frac{l}{3a} > 0.$$

$$(II) \quad \frac{\partial q_{se}^*}{\partial v} = -\frac{5l}{3} < 0, \quad \frac{\partial q_{re}^*}{\partial v} = \frac{-7l}{6} < 0, \quad \frac{\partial q_t^*}{\partial v} = \frac{17l}{6} > 0.$$

Corollary 3.1 shows that the retailer promoting service only in the physical retail channel may increase the demand of the physical retail channel and the demand of the VTC channel may transfer to the physical retail channel. Hence, this makes manufacturer’s VTC channel price rising, but retailer’s VTC channel price fall. It indicates that service promoting only in physical retail channel alleviates the competition from the manufacturer’s VTC channel successfully.

In the scenario of retailer promoting service only in physical retail channel, namely, $S_{re} = 0$, the operation costs of VTC channels are only fixed costs for the manufacturer and the retailer, substituting $c_{ie}(T, S) = gT_{ie}$ ($i = r, s$) into the equilibrium variables, we get Corollary 3.2.

Corollary 3.2. *The impact of the fixed cost coefficient on the equilibrium prices in the VTC channel is as follows.*

$$(I) \quad \text{if } k\eta(\bar{\delta} - \underline{\delta}) < \gamma^2 < \frac{6k\eta(\bar{\delta} - \underline{\delta})}{5}, \text{ then } \frac{\partial p_t^*}{\partial g} < 0, \frac{\partial p_{re}^*}{\partial g} < 0, \frac{\partial p_{se}^*}{\partial g} > 0.$$

$$(II) \quad \text{if } \frac{6k\eta(\bar{\delta} - \underline{\delta})}{5} < \gamma^2 < 2k\eta(\bar{\delta} - \underline{\delta}), \text{ then } \frac{\partial p_t^*}{\partial g} > 0, \frac{\partial p_{re}^*}{\partial g} > 0, \frac{\partial p_{se}^*}{\partial g} < 0.$$

Corollary 3.2 suggests that the relationship between the fixed cost coefficient of the VTC channel and the equilibrium prices changes with the parameters of l ($l = \frac{\gamma}{k(\bar{\delta} - \underline{\delta})}$). That implies that the additional service brings different cost of the consumer’s satisfaction degree, and the pricing decision is also different. When $k\eta(\bar{\delta} - \underline{\delta}) < \gamma^2 < \frac{6k\eta(\bar{\delta} - \underline{\delta})}{5}$, we can see the equilibrium prices p_t^* and p_{re}^* decrease with increasing fixed cost coefficient, while p_{se}^* increases with increasing fixed cost coefficient. That implies the manufacturer’s price of the VTC channel goes up, while the retailer’s prices of the VTC channel and physical retail channel go down. This shows that, in a given interval of the service coefficient, the service promoting in the physical retail channel is benefit for the retailer because of the fall prices. While when the service coefficient beyond the range, that is in the domain of $\frac{6k\eta(\bar{\delta} - \underline{\delta})}{5} < \gamma^2 < 2k\eta(\bar{\delta} - \underline{\delta})$, the situation is the opposite. At the same time, the retailer can not benefit from the service promoting as the rise price undermine competitiveness.

3.2. The retailer promoting service in the both physical retail channel and VTC channel. Similar to Corollary 3.1 and Corollary 3.2, when the retailer promotes service in both physical retail channel and the VTC channel, we substitute $c_{re}(T, S) = gT_{re} + \frac{1}{2}uS_{re}^2$ into equilibrium variables, we have Corollary 3.3.

Corollary 3.3. *When the retailer promoting service in the both physical retail channel and VTC channel, the influence trends of v and g on the equilibrium prices and demands are consistent with the scenario of only promoting service in physical retail channel, but the influence degrees are different.*

From Corollary 3.3, we can see whether service promoting only in the physical retail channel or both in the physical retail channel and the VTC channel, there is a same influencing trends of the parameters for service and fix cost on the equilibrium prices and demands and a different influencing degree.

We investigate the influence of additional service charge coefficient on equilibrium prices, and we can obtain Corollary 3.4.

Corollary 3.4. *In the VTC mode, the influence of additional service charge coefficient on equilibrium prices under the retailer promoting service in the both channels of physical retail channel and VTC channel is as follows.*

$$\frac{\partial p_t^*}{\partial u} = -\frac{S_{re}^2 l^2}{6(3l^2 + 2a\eta)} < 0, \quad \frac{\partial p_{se}^*}{\partial u} = \frac{S_{re}^2 l^2}{6(3l^2 + 2a\eta)} > 0, \quad \frac{\partial p_{re}^*}{\partial u} = \frac{3S_{re}^2(8l^2 + 6a\eta)}{3l^2 + 2a\eta} > 0.$$

Corollary 3.4 shows that the retail price decreases with increasing additional service charge coefficient, but the VTC channel prices increase for both the manufacturer and the retailer as the additional service charge coefficient goes up. That is to say, the value-added service indirectly increases the physical retail channel demand. Meanwhile, it makes the VTC price rising, so the manufacturer’s competitiveness falls. Accordingly, there is an indirect benefit for the retailer.

4. Analysis of TOD Mode. We assume the channel structure keep constant. Let c_{se}^0 and c_{re}^0 denote the operational cost for the manufacturer and the retailer in TOD (Accordingly, we use superscript 0 to represent the parameters of TOD). The cost differentials between the TOD mode and the VTC mode are $\Delta c_s = c_{se}^0 - c_{se}$ and $\Delta c_r = c_{re}^0 - c_{re}$ respectively.

Due to the third party – VTC improving the trust level of the consumers to products, the demands maybe different in the two modes. Let Δq_s and Δq_r denote the demand difference (we assume Δq_s and Δq_r are positive, similarly for the negative case). So the physical retail channel demand difference is $\Delta q_t = \Delta q_s + \Delta q_r$ under a certain market benchmark demand.

The profit functions for the manufacturer and the retailer in TOD mode are given by

$$\pi_s^0 = (p_{se}^0 - c_{se}^0)(q_{se} - \Delta q_s) + (w^0 - c_{st})(q_t + \Delta q_t) \tag{5}$$

$$\pi_r^0 = (p_{re}^0 - c_{re}^0)(q_{re} - \Delta q_r) - c(v) + (p_t^0 - w^0 - c_{rt})(q_t + \Delta q_t) \tag{6}$$

We compare the equilibrium prices in VTC with those in TOD as follows.

$$p_t^0 = \frac{\Delta q_s + 2ac_{rt} + ac_{se}^0 - ac_{st} - bm_{se} + 3aw^0 + lv + 1}{3a}$$

$$p_{re}^0 = \frac{ac_{rt} - \Delta q_s + 2ac_{se}^0 - 2ac_{st} + bm_{se} + 3aw^0 - lv + 2}{3a}$$

$$p_{se}^0 = \frac{5 + 2\Delta q_s - 3\Delta q_r + 3ac_{re}^0 + 2ac_{se}^0 + ac_{rt} - 2ac_{st} + 3bm_{re} - 2bm_{se} + 3aw^0 - lv}{6a}$$

We assume the wholesale price keeps invariable, and the incremental demand keeps a certain proportion to the original demand, that is, $w = w^0$ and $\Delta q_s = \lambda q_{se}$. We get

$$\Delta p_t = \frac{c_{se}^0}{3} - \frac{2\Delta c_s}{3} - \frac{c_{rt}}{3} - \frac{c_{st}}{3} - \frac{2}{3a(1-\lambda)} + \frac{1}{a} - \frac{2lv}{3a} + \frac{2bm_{se}}{3a}$$

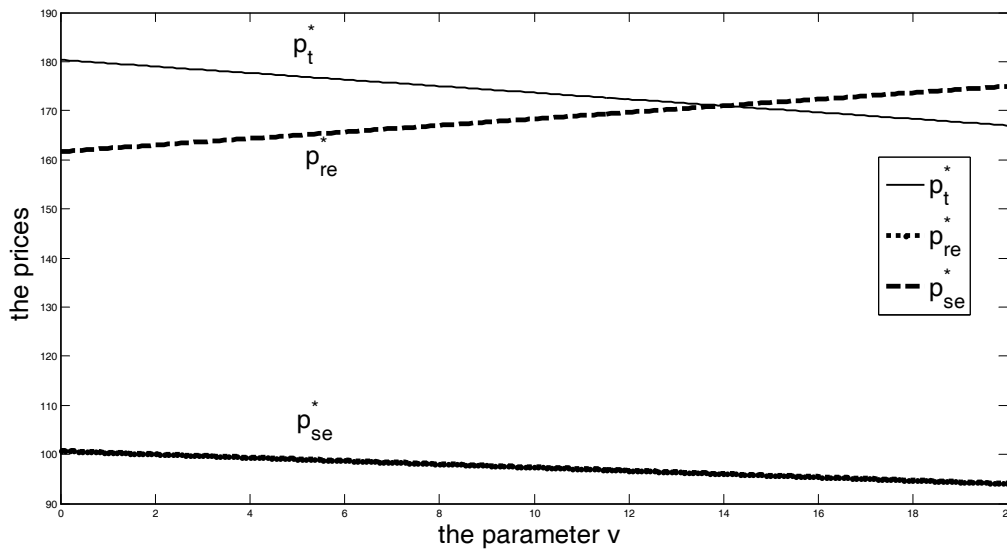
$$\Delta p_{se} = -\frac{2}{3a(1-\lambda)} - \frac{3ac_{re}^0 - 3ac_{rt} + 2a\Delta c_s - 3aw + 3bm_{re} - 3lv - 1}{6a}$$

$$\Delta p_{re} = \frac{c_{re}^0}{2} - \frac{\Delta c_r}{2} - \frac{c_{rt}}{6} - \frac{\Delta c_s}{3} - \frac{c_{se}^0}{3} + \frac{c_{st}}{3} - \frac{w}{2} - \frac{1}{3a(1-\lambda)} + \frac{1}{2a} + \frac{lv}{6a} + \frac{bm_{re}}{2a} - \frac{2bm_{se}}{3a}$$

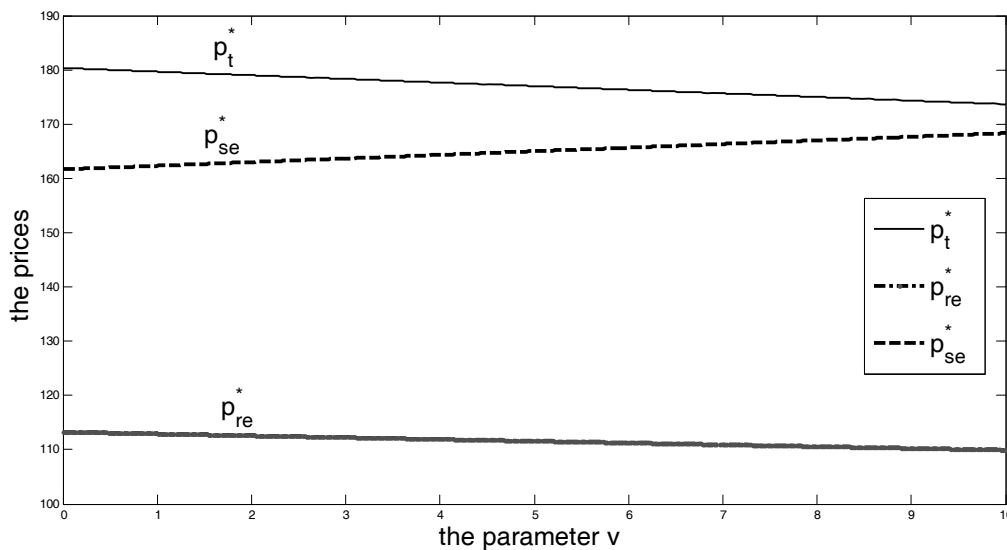
The result shows that there is a significant difference in the equilibrium prices between the two operation modes and the cost for channel operation has an important influence on the price difference.

5. Numerical Example. We now present a simulation example to illustrate the impact of model parameters, namely, v , γ^2 , u and λ on the equilibrium prices as well as on the demands, then we compare the price difference under two different modes.

For our simulation, we use the following parameter values $a = 0.2$, $b = 0.5$, $m_{re} = 4.5$, $m_{se} = 4$, $l = 0.4$, $w = 150$, $h = 2$, $c_{rt} = 3$, $c_{st} = 6$, $T_{re} = 150$, $T_{se} = 400$, $g = 0.1$, $u = 2$. The impacts of value-added service on the equilibrium prices and the demands under different service strategies are shown in Figure 2 and Figure 3.



(a) Promoting the service only in the physical retailing channel



(b) Promoting the service in retailer's two channels

FIGURE 2. Impact of v on the equilibrium prices under different service promoting strategies

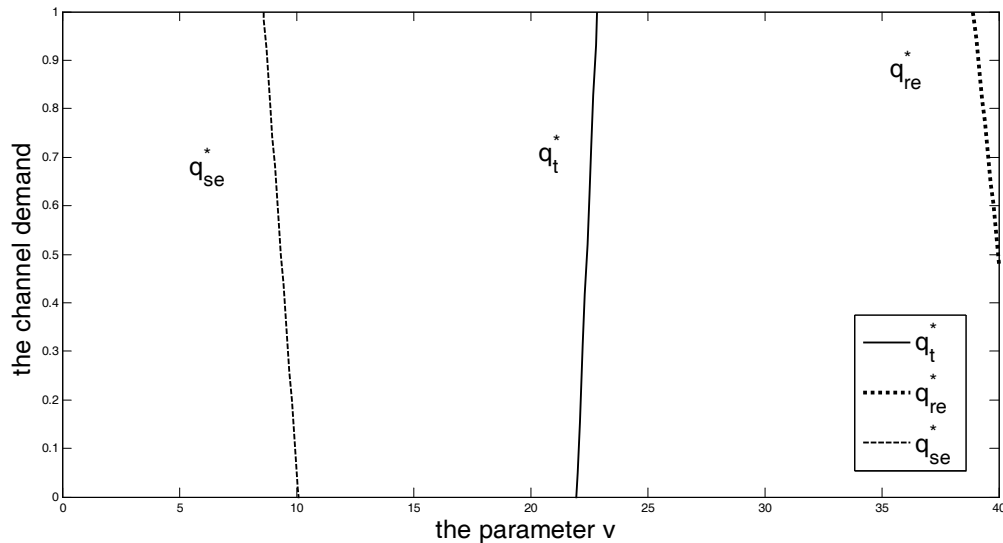


FIGURE 3. Impact of v on the demands in the VTC mode

There is an increasing demand of physical retail channel and a decreasing demand of the VTC channel as the retailer only promotes service in the physical retail channel. So it is reasonable that the service promoting in the physical retail channel is advanced to expanding the demand of physical retail channel. However, it makes the demand of VTC channel decrease for both the manufacturer and the retailer. It implies the demand of e-channel transfers to the physical retail channel under better service of physical retail channel. From Figure 2(a), we can see the price for manufacturer's VTC channel decreases, and also because of the decreased demand of VTC channel (see Figure 3), the profit from manufacturer's VTC channel falls. So it does not benefit the manufacturer when the retailer promotes service only in physical retail channel. And when the basis demand is invariable, the consumers who prefer the retailer increase, there is an advantage to the retailer only promoting in the physical retail channel. From Figure 2(b), we know the price from retailer's VTC channel maybe decreases with the rising value of v , and also seen from Figure 3, the demand of the VTC channel for the retailer decreases, so the profits from retailer's VTC channel fall off. Hence, in the scenario of promoting service in both channels, it is disadvantage to the VTC channel of the retailer. However, it has an uncertainty to the profit from physical retail channel and the manufacturer's VTC channel. If the profit from physical retail channel increases, retailer promotes service in both channels is significant; otherwise, promoting service in both channels is disadvantageous to the retailer. When the value equals in our example, the retail price is lower than the price in VTC channel for manufacturers. At this point, the preference of the consumer for VTC is greater than the physical retail channel, which may be beyond the research scope of this paper.

Figure 4 summarizes the impact of γ^2 on the rate of change for equilibrium prices under different service promoting strategies. We observe that p'_{se} goes up as g increases, p'_{re} and p'_t may go down in γ^2 in $(0, 0.68)$ and $\gamma^2 \in (0.68, 1)$, but the parameters are not monotonic in the whole interval $\gamma^2 \in (0, 1)$. So we know that, as the coefficient of fix cost increases, manufacturer's equilibrium price in VTC changes faster, while the retail price and the retailer's equilibrium price in VTC changes slower. It is interesting that the cost parameter of the consumer's satisfaction degree has different impacts on the equilibrium pricing changes. And in different interval, the impacts are also different.

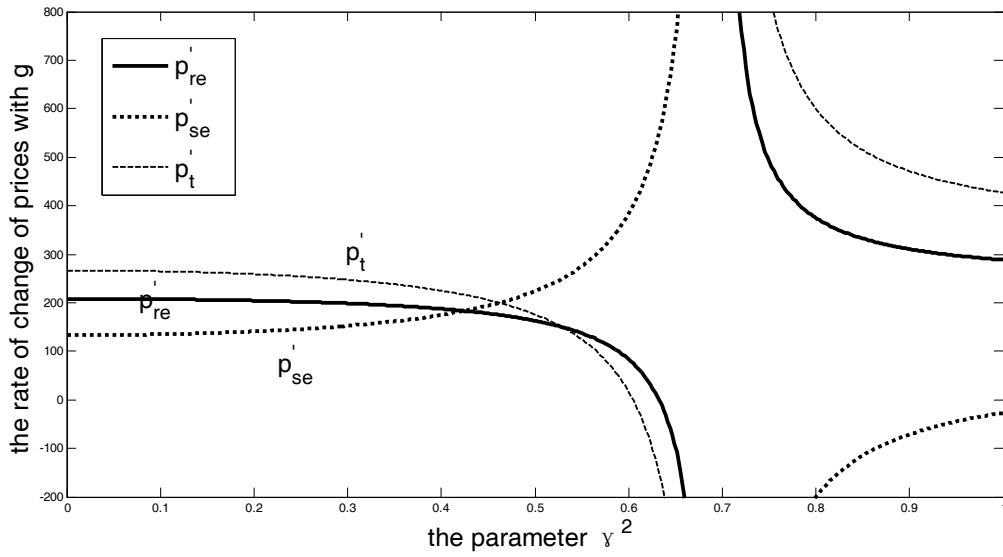


FIGURE 4. Impact of γ^2 on the change of equilibrium prices in the VTC mode

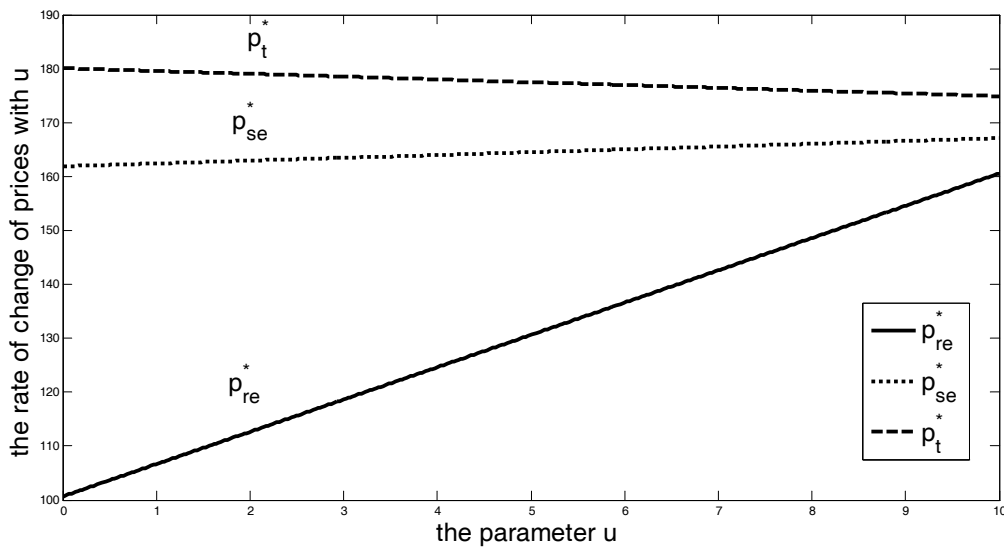


FIGURE 5. Impact of u on the equilibrium prices under promoting service in both channels

Figure 5 indicates that the cost coefficient of additional service has a greater influence on the equilibrium prices. When the retailer promoting service in both channels, the retail price decreases and the VTC channel prices increase for the manufacturer and the retailer as goes up. It implies the value-added service promoting in VTC channel greatly increases the cost of retailer's VTC channel, and the price also rises rapidly. However, it is still lower than the price for the manufacturer's VTC channel. So it is profitable to the retailer.

From Figure 2 to Figure 5, we explore the impact of v , γ^2 and u on the equilibrium prices as well as the demands. Now we discuss the price difference under two different operation modes.

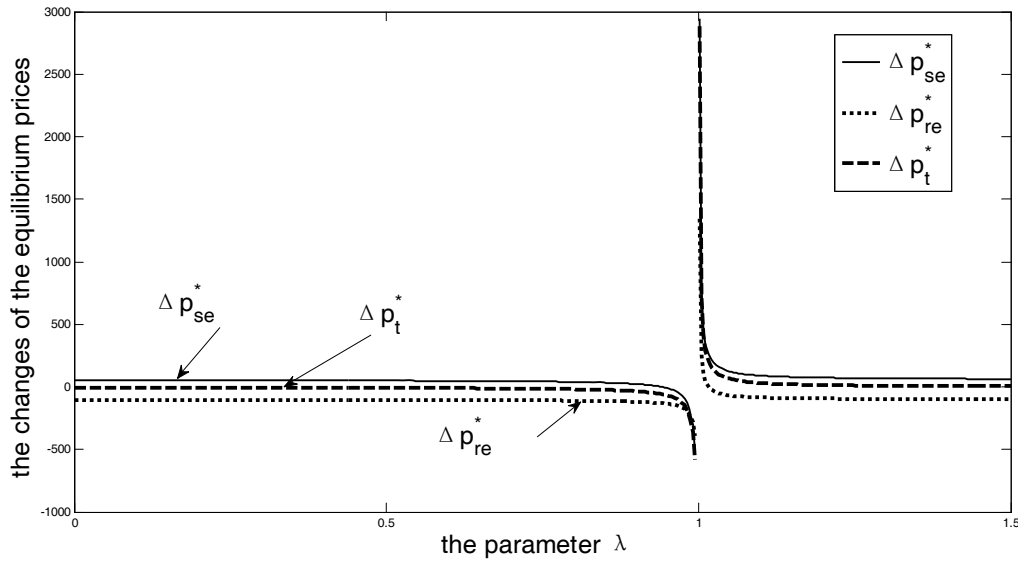


FIGURE 6. The impact of λ on equilibrium price differences between the TED mode and VTC mode

Let $c_{re}^0 = 20$, $c_{se}^0 = 80$, $\Delta c_s = 40$ and $\Delta c_r = 15$, we have Figure 6. From Figure 6, we can see that $\lim_{\lambda \rightarrow 1} \Delta p_t = 0$ when $\lambda \neq 1$, which implies the retail price is invariable whether in TED mode or VTC mode. For $\Delta p_{re} < 0$ and $\Delta p_{se} > 0$, the price for the retailer's in the VTC channel may be lower than the TED channel while the price for the manufacturer's in the VTC channel may be higher than the TED channel. This result shows that the VTC makes the retailer alleviate the pressure of competition, and makes the demand in retailer's VTC channel increase. So the retailer can benefit from the VTC. For the manufacturer, although the price increases in the VTC channel, the VTC makes the whole demand increase, the influence degree of price rising and demand decreasing is lower than the TED mode. So it is also benefit to the manufacturer.

6. Conclusions. Different from the previous research, we transfer the online direct channel to the VTC mode and expand the dual-channel mode to the multi-channel in the VTC. There is an important theoretical value to the enterprises which have used or will use the VTC channel, and regardless of which side – the manufacturer or the retailer, it is helpful to the decisions of pricing and competition. In our research, we analyze the pricing strategies by Nash equilibrium model. For the more intense competition in the VTC, we introduce service promoting strategy and explore the influence of the different service promoting strategies (only in the physical retail channel or both in the physical retail channel and the VTC channel) on the equilibrium pricing in the multi-channel supply chain, as well as comparison between the results with TOD mode. The comparison shows that the equilibrium prices between the two operation modes have a significant difference and the cost for channel operation as an important factor influences the price difference. After the analysis we find that, in a given interval of the service coefficient, the enhancement of the service level in physical retail channel may increase the demand of the physical retail channel, and may promote retailer's own competitiveness effectively by transferring the competition threat from the VTC channel. It is benefit for the retailer, but not benefit for the manufacturer. And the service promoting in both channels has an indirect benefit for the retailer by increasing the physical retail channel demand. However, it is disadvantageous to the VTC channel of the retailer. Meanwhile, we find the retail price is

not influenced by the value-added service parameter, while the price of the VTC channel may be affected a lot. Furthermore, we find the impact trends of fixed cost coefficient (g) and value-added service (v) for per unit product on equilibrium prices are the same: the service promoting in the VTC channel increases the demand from the VTC channel, decreases the equilibrium prices of VTC channel, and increases the retail price. So the VTC is benefit for the manufacturer and the retailer. The modeling approach and the results are useful references for administrations and managerial decisions, for example, the service promoting selection. Except for negative externality from the homogeneous products, the VTC still has a positive externality from complementary products. This problem may need the further research.

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