Research on Dual-Channel Supply Chain Equilibrium with the Considering of Distributional and Peer-Induced Fairness Preference of Retailer

Lin-li MENG
Management School, Shanghai Normal University Tianhua College, Shanghai, China

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Abstract. A Stackelberg game model is built to research on the impact of retailer’s distributional and peer-induced fairness preference on dual-channel supply chain equilibrium. It points out that (i) the retail price is increasing with the distributional fairness, and the wholesale price and direct sale price is decreasing with distributional fairness; (ii) the retail price is decreasing with the distributional fairness, and the wholesale price and direct sale price is increasing with distributional fairness. And the impact of peer-induced fairness preference on the supply chain can partially decrease the impact of distributional fairness on the supply chain, which has been verified by numerical analysis.

Introduction

With the attractive growth rate of electronic commerce, thousands of manufacturers, such as IBM, Nike, Apple, Huawei and Lenovo in different industry segments, have begun to sell products to potential consumers directly online while continuing to sell through the traditional brick-and-mortar retailers. The prevailing tendency of mixed distribution channels is significantly changing the historical relationship between manufacturer and retailers, which has become one of academic research focus for recent years.

In 2003, Chiange finds that a direct online channel can effectively reduce the double marginalization in a retailer market and increase the supply chain profits[1]. While Tsay and Agrawal have demonstrated that a direct online channel isn’t always bad for retailers[2], Cattani finds that when consumers think that the direct online channel is more convenient than traditional sales channels, manufacturers would choose different pricing strategies which would hurt retailers[3].

None of the above studies consider the behavioral characteristics of decision makers. In 2007, Cui et al. introduce fairness concerns into traditional single-channel supply chain, and formally model fairness based on the notion of “inequity aversion” (Fehr and Schmidt,1999), the authors show that if the retailer is fair-minded, or if both members of the supply chain are fair-minded, then the supplier can design a wholesale price contract to coordinate the supply chain[4]. Lijun Ma finds that retailers’ distributional fairness preference will increase their bargaining power in a two-stage supply chain model[5].

There are several researches on the impact of fairness concerns on the balanced strategy of dual-channel supply chain. Wei Xing et al. show that when the manufacturer is the leader of the dual-channel supply chain, the market share of the retailer can influence the importance of the manufacturer to the retailer’s fairness concern, and the retailer's fairness concern can alleviate the bilateral effect of the supply chain[6]. Cheng et al. suggest that direct price will not be influenced by fairness preference, while retail price and wholesale price will be influenced by fairness preference in dual-channel supply chain in which manufacturer is the leader[7].

All above researches assume that retailers only concern on comparisons with manufacturers' profits, but in fact manufacturers' profits come from two channels, which are the transaction process with the retailers and direct online channel. The different way manufacturers get profits has different meanings for retailers. Manufacturers are the suppliers for retailers in the transaction
process with the retailers who have distributional fairness preference, while in the direct online channel manufacturers are the competitors for retailers who have peer-induced fairness preference. Therefore, there are two kinds of the retailers’ fairness preferences, distributional fairness preference and peer-induced fairness preference. In this paper we will discuss the influence of these two fairness preferences on the dual-channel supply chain equilibrium.

The rest of the paper is organized as follows. The subsequent section formulates the model. Section 3 and Section 4 separately describe the basic model without fairness and the general model with both distributional and peer-induced fairness. Section 5 presents the numerical analysis and management suggestions. Section 6 gets the conclusions.

Model Descriptions

We build a dual-channel supply chain composed of one manufacturer and one retailer, where the manufacturer, as the leader of the supply chain, simultaneously opens traditional retail channel and online direct channel to sell the same product. Assuming the information between manufacturer and retailer completely symmetrical, the manufacturer firstly set the wholesale price \( w \) and the online direct channel price \( p_d \), and make sure the whole sales price not higher than the online direct channel price \( p_d \), in order to keep the retailer from purchasing through online direct channel. Then retailer chooses its retail price \( p_r \), according the whole sales price the online direct channel price in a Nash game. Therefore, the decision making between the manufacturer and the retailer constitutes a Stackelberg game.

In this paper, we assume that the demands of the traditional channel and the online direct channel are linear functions of retail price and direct online price:

\[
D_r = \delta a - p_r + e_1 p_d \tag{1}
\]

\[
D_r = (1 - \delta) a - p_d + e_2 p_r \tag{2}
\]

\( a \) is the basic market demand of the product, \( \delta \) is the market share of traditional channel, \( e_1 \) and \( e_2 \) mean the cross-price elasticity of the traditional channel and the online direct channel. For the sake of model analysis we assume that \( e_1 = e_2 = e, 0 < e < 1 \).

For the convenience of explanation and brevity in analysis part, we assume that the marginal costs of the manufacturer and the retailer are zero, without loss of generality. Therefore, the manufacturer’s profit function from the transaction process with the retailers, the manufacturer’s profit function earned from online direct channel and retailer’s profit function are given by

\[
\pi_{mr} = w D_r \tag{3}
\]

\[
\pi_{md} = p_d D_d \tag{4}
\]

\[
\pi_r = (p_r - w) D_r \tag{5}
\]

In the next two subsections, we consider two general versions of the model. We first study a basic model with no fairness preferences, followed by a full model with both distributional and peer-induced fairness preferences. We refer to them as Models I and II, respectively.

Dual-Channel Supply Chain Equilibrium without fairness: Model I

If there is no fairness the manufacturer and the retailer will take actions in order to maximize their profits. We solve the game by backward induction. Here, the profit function of retailer is \( \pi_r \), conditional on a wholesale price offer \( w \) and the online direct channel price \( p_d \), retailer’s best response function is as follows:

\[
P_r = \frac{(\delta a + e p_d + w)}{2} \tag{6}
\]

Substituting this best response function into the manufacturer’s profit function \( \pi_m = \pi_{mr} + \pi_{md} \), and the manufacturer will choose the wholesale price offer and the online direct channel price to
maximize its profit.

$$\max \pi_{md} = wDr + pdDd$$

s.t. \(pd \geq w\) \hspace{1cm} (7)

**Proposition 1** characterizes the optimal wholesale price, the online direct channel price and retail price at equilibrium.

**Proposition 1:** If there is no fairness in dual-channel supply chain, the optimal optimal wholesale price, the online direct channel price and retail price at equilibrium are as follows:

\[
\begin{align*}
    w^* &= \frac{(2 - \delta)a + \delta ae}{2(3 + e)(1 - e)} \quad \delta > \frac{1}{2} \\
    p^*_d &= \frac{(2 - \delta)a + \delta ae}{2(3 + e)(1 - e)} \quad \delta \leq \frac{1}{2} \\
    p^*_r &= \frac{(1 - \delta)a + \delta ae}{2(1 - e^2)} \quad \delta > \frac{1}{2} \\
    p^*_e &= \frac{\delta a(5 - 4e - e^2) + 2a(1 + e)}{4(3 + e)(1 - e)} \quad \delta > \frac{1}{2} \\
    w &= \frac{\delta a + 2a(1 - \delta)ae}{2(1 - e^2)} \quad \delta \leq \frac{1}{2}
\end{align*}
\]

Note that when the market share of retailer is less than 50%, manufacturer will choose the lower wholesale price; otherwise the manufacturer will set the wholesale price much higher and equal the online direct channel price.

**Dual-Channel Supply Chain Equilibrium with Both Distributional and Peer-induced Fairness Preference: Model II**

In this section, we extend the basic model to allow retailer to have distributional fairness preference and peer-induced fairness preference. Specifically, the retailer cares not only about his own profit, but also his profit relative to the manufacturer’s profits from direct online sale revenue and wholesale revenue. Retailer’s revised utility is modeled as follows:

\[
Ur = \pi_r - \lambda(\pi_{mr} - \pi_r) - \rho(\pi_{md} - \pi_r)
\]

Where \(\lambda \geq 0\) is the distributional fairness parameter and \(\rho \geq 0\) is the peer-induced fairness parameter. When \(\pi_r\) is less than \(\pi_{mr}\) or \(\pi_{md}\), retailer’s utility will decrease with the increasing of their profit difference. Otherwise, retailer’s utility will increase with the increasing of their profit difference.

Because manufacturer has no fairness, its utility function is its profit function \(\pi_m\). We still solve the game by backward induction. Here, the utility function \(U_r\) of retailer is conditional on a wholesale price \(w\) and the online direct channel price \(p_d\). Retailer’s best response function is as follows:

\[
p^*_r = \frac{\delta a + (1 + \lambda)ep_d + (1 + 2\lambda + \rho)w}{2(1 + \lambda + \rho)}
\]

Substituting this best response function into the manufacturer’s profit function , and the manufacturer will choose the wholesale price and the online direct channel price to maximize its profit.

$$\max \pi_d = wDr + pdDd$$

s.t. \(pd \geq w\) \hspace{1cm} (10)
Proposition 2 characterizes the optimal wholesale price, the online direct channel price and retail price at equilibrium.

Proposition 2: when retailer has distributional and peer-induced fairness preferences and manufacturer has no fairness in dual-channel supply chain, the optimal wholesale price, the online direct channel price and retail price at equilibrium are as follows:

\[
\begin{align*}
    w^* &= \frac{a(1 + \lambda + \rho)(2 - \delta + \delta e)}{2((3 + 4\lambda + 3\rho) - (2 + 3\lambda + 3\rho)e - (1 + \lambda)e^2)} \\
    &\quad \text{for } \delta > A \\
    &\quad \text{for } \delta \leq A \\
    p_d^* &= \frac{a(1 + \lambda + \rho)(2 - \delta + \delta e)}{2(1 + 2\lambda + \rho)} \\
    &\quad \text{for } \delta > A \\
    &\quad \text{for } \delta \leq A \\
    p_r^* &= \frac{Be(2 + 3\lambda + 3\rho)}{2(1 + 2\lambda + \rho)} \\
    &\quad \text{for } \delta > A \\
    &\quad \text{for } \delta \leq A \\
    A &= \frac{2 + 2\lambda + \rho - (2 + 3\lambda + 3\rho)e}{8(1 + 2\lambda + \rho)(1 + \lambda + \rho) - [(2 + 3\lambda + 3\rho)^2 + 4(1 + 2\lambda + \rho)(1 + \lambda)e^2]}
\end{align*}
\]

Note that when the market share of retailer is less than A, which is the threshold of retailer’s market share, manufacturer will choose a lower wholesale price; otherwise the manufacturer will set the wholesale price much higher and equal the online direct channel price. And when \(\delta = 0, \rho = 0\) the model reduces back to the basic model and \(A = 0.5\).

As a consequence of Proposition 2, we can easily proof that \(\partial A/\partial \lambda > 0, \partial A/\partial \rho > 0, \partial p_d/\partial \lambda > 0, \partial p_d/\partial \rho > 0, \partial p_r/\partial \lambda > 0, \partial p_r/\partial \rho > 0, \partial w/\partial \lambda > 0, \partial w/\partial \rho > 0\), so we have the following three corollaries.

Corollary 1: When the retailer’s peer-induced fairness preference is fixed, the retailer’s market share threshold increases as the retailer’s distributional fairness preference increases; and when the retailer’s distributional fairness preference is certain, the retailer’s market share threshold decreases as the retailer’s peer-induced fairness preference increases.

Corollary 2: When the retailer’s peer-induced fairness preference is certain, with the increase of the retailer’s distributional fairness preference, the optimal wholesale price and the online direct channel price is decreasing, and the traditional retail price is increasing.

Corollary 3: When the retailer’s distributional fairness preference is certain, with the increase of the retailer’s peer-induced fairness preference, the optimal wholesale price and the online direct channel price is increasing, and the traditional retail price is decreasing.

Corollary 1 states that the relationship of retailer’s market share threshold and its distributional and peer-induced fairness preference. Retailer’s market share threshold will change with the retailer’s distributional and peer-induced fairness preference parameter, so that the manufacturer and retailer will take different actions.

Corollary 2 shows that when the retailer’s peer-induced fairness preference is certain, the increase of his distributional fairness preference will reduce its utility. From retailer’s jealousy and revenge, he will choose a higher traditional sale price, which will reduce demand. Therefore, the retailer’s action reduces his own profit but shrinks the manufacturer’s slice by even more. Consequently, in equilibrium, the supplier set a lower wholesale price to reduce the negative effect of retailer’s distributional fairness preference on retailer. In order to increase his profit, the manufacturer will lower the online direct channel price to increase the direct demand.

Corollary 3 predicts that when the retailer’s distributional fairness preference is certain, the
increase of his peer-induced fairness preference will reduce its utility. In order to increase his utility, the retailer will set a lower traditional sale price, which will increase his demand. And the manufacturer will choose a higher online direct channel price to reduce the negative effect of retailer’s peer-induced fairness preference on retailer. However, the manufacturer will set a higher wholesale price to ensure his profit.

**Numerical Experiments and Analysis**

To gain further insight into the influence of retailer’s distributional and peer-induced fairness preference on the dual-channel supply chain equilibrium, we use some numerical tests. In these numerical tests, we assume that the market share of retailer is $\delta=0.60$, the basic demand is $a=20$, the cross-price coefficients and elasticity of the transnational channel and the online direct channel is $e=0.30$, the retailer’s distributional and peer-induced fairness preferences range from $[0,10]$. Using MatLab 7.11 to compute, the optimal results is shown in Figure. 1-7.

**Figure 1.** Retailer’s Market Share Threshold as $\lambda$ and $\rho$ Vary. **Figure 2.** Traditional Sale Price as $\lambda$ and $\rho$ Vary.

**Figure 3.** Wholesale Price as $\lambda$ and $\rho$ Vary. **Figure 4.** Online Direct Channel Price as $\lambda$ and $\rho$ Vary.

Figure 1 plots retailer’s market share threshold as the distributional and peer-induced fairness preferences increase. The results show that the retailer’s market share threshold increases with its distributional fairness preference increase, while keeping peer-induced fairness preference fixed at the estimated values; the threshold decreases with its peer-induced fairness preference increase, while keeping distributional fairness preference fixed at the estimated values; and the effect of
distributional fairness preference on retailer’s market share threshold is significantly higher than that of peer-induced fairness preference. Note that this observation lends further support to Corollary 1. In this numerical test the threshold ranges from [0.741, 0.448]. These results mean that when retailer’s market share is fixed, a higher distributional fairness preference or a lower peer-induced fairness preference may make manufacturer choose a lower wholesale price to maximize his profit. Otherwise, manufacturer choose a higher wholesale price, which equals the online direct channel price, to maximize his profit.

Now we investigate the impact of the distributional and peer-induced fairness parameter on the optimal retail price, wholesale price and the direct online channel price, which separately shows in Figure 2, Figure 3 and Figure 4. The results confirm the Corollary 2 and 3. There is a black solid line in Figure 2, 3 and 4, which is the retailer’s market share. The left side of the line means that the retailer’s market share is bigger than the retailer’s market share threshold, so the optimal traditional retail price equals the online direct channel price from the Figure 3 and 4, confirming Position 2. While on the right side of the line the optimal traditional retail price is less than the online direct channel price, as showed in Position 2. But the optimal traditional retail price decreases more sharply than online direct channel price as distributional fairness preference increases on this side. The reasons are as follows. When the retailer’s peer-induced fairness preference is fixed, the increase of his distributional fairness preference will reduce its utility. From retailer’s jealousy and revenge, he will choose a higher traditional sale price, which will reduce traditional retail channel demand and that lowers the manufacturer’s profits. In order to reduce the negative utility of this fairness preference, manufacturer will lower the wholesale price; and he will choose a lower online direct channel price to guarantee his profit. Because the increase of traditional retail price will increase direct sales, the manufacturer don’t have to reduce the online direct channel price too much.

From these figures we also find that all the optimal prices firstly change sharply and then level off with the retailer’s fairness preference increase, indicating that when the retailer just generates the fairness preference the supply chain reaction is more sensitive at first, but as the the retailer’s fairness preference increases, the manufacturer gradually adapts to this situation, so the sensitivity decreases.

To further investigate the impact of the distributional and peer-induced fairness parameter on the supply chain equilibrium, we compute the retailer’s equilibrium profit, the manufacturer’s equilibrium profit and the supplier’s equilibrium profit in Figure 5, 6 and 7. As showed in Figure 5, 6 and 7, with the retailer’s distributional fairness preference increasing, the retailer’s equilibrium profit increases, while the manufacturer’s equilibrium profit and the supplier’s equilibrium profit decrease; and with the retailer’s peer-induced fairness preference increasing, the retailer’s
equilibrium profit decreases, while the manufacturer’s equilibrium profit and the supplier’s equilibrium profit increase. These indicate the retailer’s distributional fairness preference make him getting more profit, but it reduces the profits of manufacturers and the entire supply chain; and the retailer’s peer-induced fairness preference reduce his profit, but it increases the profits of manufacturers and the entire supply chain. In summary, we conclude that the retailer’s distributional fairness preference brings negative effects to the supply chain and the retailer’s peer-induced fairness preference can offset the negative effects of distributional fairness preference. In this sense, manufacturer as the leader of dual-channel supply chain should take measures to improve the retailer's peer-induced fairness preference, such as promoting the sales market competition, at the same time take actions to reduce the retailer's distributional fairness preference, such as revenue sharing, cost sharing in order to improve the efficiency of the dual-channel supply chain.

Conclusions
In this paper, we examine the impact of traditional retailer’s distributional and peer-induced fairness preferences on a dual-channel supply chain equilibrium. We show that it is optimal for the manufacturer to make a lower wholesale price and a lower online direct channel price when the retailers has distributional fairness preference than when he have no fairness; and while the retailer’s distributional fairness preference is fixed, it is optimal for the manufacturer to make the wholesale price and online direct channel price higher than when the retailer only has distributional fairness preference. Finally, we structurally estimate our models using the experimental data. We show that in a dual-channel supply chain the retailer has different fairness preferences to the manufacturer’s profit coming from the transaction process with the retailers and online direct channel sales, which have different influence on the supply chain equilibrium: the retailer’s distributional fairness preference will make retailer a higher profit and reduce the manufacturer’s and supply chain profits, while the retailer’s peer-induced fairness preference will offset the negative effect of his distributional fairness preference on the dual-channel supply chain.

In reality, enterprises are not completely economic rational, so in the process of cooperation enterprises will take actions to meet their irrational needs when they feel being treated unfairly. In a dual-channel supply chain management, as the leader of the supply chain, manufacturer must give full consideration to fairness preferences of retailers, and according to fairness preferences of retailers to take different actions of coordination in order to improve the overall supply chain performance. this is the implications of this paper for supply chain management.

References


