Optimal strategies of a dual-channel supply chain under different market powers

Chunhua Tang
College of Economics and Trade, Hunan University, Changsha 410079, China

Shujin Zhu
Hunan Province Key Laboratory of Logistics Information and Simulation Technology, Changsha 410079, China

Abstract: We examine the effect of firms’ market powers on the optimal strategies and profits of partners and make comparisons under different structures in a dual-channel supply chain, where the manufacturer provide a value-added service to differentiate the product for the customer to some extent. We consider centralized decision and decentralized decision cases where supply chain partners have different market power structures, including the Manufacturer-Stackelberg, Retailer-Stackelberg and Nash Game. We find that the direct sale price and added value are unchanged under different power structures. However, dominating power structures always lead to inefficiency for the whole dual-channel supply chain. The more power one of the channel partners has, the larger profit loss the whole supply chain will suffer.

Keywords: pricing; dual channels; supply chain; market power; game theory; equilibrium

1. Introduction

The dual-channel supply chain is increasingly adopted for marketing products, where the direct sale channel and the traditional retail channel are implemented together (Cai, 2010). Over the last few years, many manufacturers (such as Nike, Hewlett Packard, Apple and Lenovo) have started selling their products directly to their customers (Chen et al., 2012). The manufacturers benefit from a web-based direct channel, since it helps the manufacturers saving cost, increasing sale revenue, expanding new market segments and avoiding retailer domination (Huang et al., 2012). The direct sale has also changed customers’ purchase patterns. Consequently, an increasing number of manufacturers have adopted direct sales to explore the new market (Cai, 2010). Competition issues based on firms’ market power structure regarding the dual-channel supply chain have evoked considerable interests from both academicians and practitioners (Chiang et al., 2003). Market power structure between the manufacturer and the retailer affects the optimal pricing and production strategies in a dual-channel supply chain (Zhang et al., 2012).

The member’s optimal strategies in the dual-channel supply chain are closely related to the market power structure that refers to a member's relative ability to control the decision making process, the more powerful firm moves first in a Stackelberg game (Zhang et al., 2012). There are different power structures in real-world dual-channel supply chains. Larger manufacturers (for example, Microsoft and P&G) play a more dominant role than the downstream smaller firms. Larger retailers (for example, WalMarkt and Carrefour) play a more dominant role than the upstream smaller firms. Sometimes, both manufacturer and retailer have the identical market power, and they
determine their strategies independently and simultaneously (Wei et al., 2013). The related literature has barely addressed the issue of optimal pricing and production strategies under different market power structures in dual-channel supply chain, which motivates us to reply the following research questions: What is the manufacturer’s optimal added value if considering the value-added cost in dual-channel supply chain? What are the optimal pricing strategies of dual-channel supply chain? Which power structure is the best for the partners and the whole dual-channel supply chain under pricing competition respectively? How do the channel parameters and market power structure affect the optimal pricing and production strategies?

In this paper, we present two main issues associated with market power in a dual-channel supply chain. In the first issue, we study the optimal added value and pricing strategies under four different market power structures, including a centralized decision and three decentralized decisions. In the second issue, we investigate the impacts of different market power structures on the optimal strategies and make comparisons in different relative channel status, and establish some relative interesting and valuable managerial insights.

Comparing with existing literatures, our contribution can be listed in the following respects. Firstly, we consider a new business model integrated the traditional retail channel and direct channel, where the direct channel is differentiated by the manufacturer to provide a value-added service for the customer to some extent. Secondly, we model optimal strategies under the four different market power structures in a dual-channel supply chain. Thirdly, we compare the optimal strategies of a dual-channel supply chain under different decision scenarios and explore the impact of power structure on the performances of the partners and the whole dual-channel supply chain.

This study provides some interesting observations. First, direct sale price and value added to consumers purchasing through direct channel keeps unchanged regardless of the market power structure. Second, both channel partners have incentives to gain more power for higher profits, whereas optimal decision in the integrated channel is of high efficiency for the whole supply chain and brings the biggest welfares to consumers. The more power one of the channel partners has, the larger profit loss the whole supply chain will suffer. Third, either the manufacturer or the retailer dominates the market, their optimal equilibrium performances are equivalent except for the decision of wholesale price, and then the distribution of revenues among partners.

The remainder of this paper is organized as follows. Section 2 introduces the published relative literature. In Section 3, we briefly describe the problem. In Section 4, we detail the models and key results, including the channel integration model in Section 4.1, the manufacturer-leader’s Stackelberg game (MS) model in Section 4.2, the retailer-leader’s Stackelberg game (RS) model in Section 4.3 and the Nash game (NG) model in Section 4.4. Section 5 discusses the comparison results of different decisions and managerial insights. We conclude the results and some future research directions in Section 6.

2. Related Literature

This paper related to the literature on power structures in supply chain management and the literature on pricing policy in marketing. We provide a brief review of the literature for each of the power structures and pricing policy. In power structures, there exist a number of studies on various power structures in a supply
Optimal strategies of a dual-channel supply chain under ...

Tang and Zhu/Argos Special Issue 2016-part2/pp.1-20

chain. Most of conclusions from recent literature are that the member always benefits from playing the leader's role in Stackelberg game. Ma et al. (2012) investigates the dominance strategies exerted by the dominant manufacturer, aimed at maintaining its dominant position in the channel system. Wu et al. (2012) characterizes vertical competition and horizontal competition between the supplier and the retailers. Zhao et al. (2012) studies wholesale prices and retail prices decisions with four different scenarios in fuzzy environments. Wei et al. (2013) investigates effects of relative channel power on pricing decisions under different power structures in a dual exclusive channel setting. Ma et al. (2013) investigates the supply chain channel strategies when demand depends on quality and marketing effort under different supply chain power structures. Different from the previous works, our paper investigates the optimal decisions, makes comparisons under different power structures and analyzes the influence of the power structure on the optimal strategies in a dual-channel supply chain setting.

Another area related to this paper is pricing policy in the multi-channel supply chain. Pricing policy of a dual-channel supply chain has received increasing attentions in the past few years. Pricing policy has clearly turned into a significant tool to realize the maximization revenue of supply chain members in the last two decades. A detailed review related to pricing policy can be found in the literature by Soon (2011). Recently, pricing policy is adopted to manipulate demand and control the production and services in the dual or multiple supply chain system (Zhang et al., 2012). Studies of channel structures have experienced growing popularity in the last few years. Chiang et al. (2003) find that the direct channel is beneficial to retailers when the wholesale price decreases. Swaminathan and Tayur (2003) review relevant analytical models and discuss the strengths and limitations of different models in dual supply chains. Yao and Liu (2003) examine the customer diffusion between two channels and points out that both channels have stable demands under certain conditions. Dumrongsiri et al. (2008) study the pricing and service quality models in a dual-channel supply chain. Yan (2008) studies the optimal prices decision based on a price-setting game in dual-channel supply chains. Cai (2010) discusses the impacts of different channel structures and channel coordination on profits of supply chain partners and the whole system. Hua et al. (2010) compare the optimal delivery lead time and prices between a centralized decision and decentralized decision dual-channel supply chain. Dan et al. (2012) compare the optimal price between centralized decision making and decentralized decision making. However, studies on the optimal policy under different market power structures in a dual-channel supply chain are limited. Zhang et al. (2012) investigate effects of product substitutability and relative channel status on pricing decisions under different power structures of a dual exclusive channel system, where each manufacturer distributes two substitutable products to a single exclusive retailer.

There are several differences between our model and the aforementioned studies. First, we consider a value-added service by the manufacturer to the product thereby differentiating the product to some extent. To keep the analytical model tractable, following Samar et al. (2008), Chen et al., (2012) and Huang et al, (2012), we consider a linear demand function with regard to self-price and cross-price sensitivities which integrate the value-added and reflect the substitution of dual-channel. Second, we model the four different decision scenarios and make detailed comparisons. The manufacturer simultaneously decides the added value and direct price under each decision scenario. The extant literature hardly address the added value decision except Samar et al. (2008), who consider a retailer’s value-adding decision in a dual-channel hi-tech supply chain based on a manufacturer’s Stackelberg game.
3. Problem description

We examine a dual-channel supply chain consisting of a direct sale channel in addition to the traditional retail channel, which is composed of a manufacturer and a retailer. The manufacturer may sell the products to the retailer, and may also sell the products to end customers directly by adding value for the customer. For instance, the manufacturer customizes the individual product, frees return shipping, and offers more professional training and technical guide in the direct sale channel, which enhance the utility for the customers. Let \( v \) be the value added to the basic product by the manufacturer to differentiate the product to some extent. The price of the end customers in retail channel and direct sale channel are \( p_r \) and \( p_d \) respectively. The effective price to the customer for the augmented product is \( p_d - v \) because of the additional value compared to the basic product sold in the direct channel (Samar et al., 2008). The cost to the manufacturer for adding a value \( v \) is \( c_v \) per unit. Similar to the study in Chen et al. (2008), we further assume a quadratic cost function for the manufacturer value-adding process, \( c_v = \frac{mv^2}{2} \) where \( m \) is an efficiency parameter for the manufacturer’s value-added cost. We assume that there is only one product for sale in the end market. The retailer is charged the wholesale price \( w \) by the manufacturer, and the retail margin on product is \( m_r = p_r - w \) (Zhang et al., 2012). The decision variables in our model is \( p_r \) for the retailer and \( p_d \) and \( v \) for the manufacturer, maximizing their own profit functions based on their market power.

Similarly as the analysis of Samar et al. (2008), we assume that the customers can migrate between two channels and this migration is proportional to the price difference between \( p_d - v \) and \( p_r \). Therefore, the end market demand for the two channels can be formulated as follows:

\[
D_r = a - p_r + \beta(p_d - v),
\]

\( (1) \)

\[
D_d = a - (p_d - v) + \beta p_r,
\]

\( (2) \)

Where \( D_r \) and \( D_d \) are the retail sale demand and the direct sale demand respectively, \( a \) is the base potential demand. Eq. (1) and Eq. (2) imply that each channel’s demand depends on the retail price \( p_r \) and the effective price of direct sale price \( p_d - v \). \( \beta \) reflects the coefficient of cross-price sensitivity, which captures the degree of competition between the two channels and the migration rate (Huang et al., 2012), \( 0 < \beta < 1 \) indicates the cross-price effects are lower than the self-price effects. We assume that \( p_d \geq w \). Otherwise, the retailer will prefer to obtain products from the direct channel.

With the above assumptions and notations, the retailer’s profit function is determined by

\[
\pi_r = (p_r - w)D_r,
\]

\( (3) \)

The manufacturer’s profit function is determined by
Optimal strategies of a dual-channel supply chain under ...

Tang and Zhu/ Argos Special Issue 2016-part2/pp.1-20

\[ \pi_m = (p_d - c_r)D_d + wD_r \]  

(4)

The profit function of the whole dual-channel supply chain is

\[ \pi = \pi_r + \pi_m = (p_d - c_r)D_d + p_rD_r \]  

(5)

4. Game models

We first consider a cooperative game based on channel vertical integration in the centralized dual-channel supply chain in order to obtain a baseline. The pricing policy between the direct channel and the retail channel can be modelled as differentiated non-cooperative games in the decentralized dual-channel supply chain (Chen et al., 2012). In this section, we present a cooperative game model and three non-cooperative games model by considering different market power structures between the manufacturer and the retailer.

4.1 Channel integration

We consider channel integration case as a baseline for making comparisons. In channel integration (or centralized decision) case, the two channels are vertically integrated as a single firm and the profits for the channel reach the highest under this scenario. Maximizing the joint channel profit in Eq.(5) and taking the first-order condition about the optimal prices \( p_r \) and \( p_d \) and value added \( v \) and solving them simultaneously, we obtain the following optimal decision.

**Proposition 1.** In the channel integration model, the optimal pricing and production strategies of members can be listed as follows.

\[
\begin{align*}
p^0_d &= \frac{-3-2am+3\beta}{4m(-1+\beta)} \\
p^0_r &= \frac{a}{2(1-\beta)} \\
v^0 &= \frac{1}{4m} \\
D^0_d &= \frac{1+2am}{4m} \\
D^0_r &= \frac{a-\beta}{2} \\
D^0 &= \frac{1+4am-\beta}{4m}
\end{align*}
\]

(6)

The nonnegative demand for retailer requires

\[ 2am - \beta \geq 0 \]  

(7)

The optimal total profit for an integrated channel is given by

\[ \pi^0 = \frac{1+4am}{16m^2} + \frac{a^2}{2-2\beta} \]  

(8)
From Proposition 1 we find that the optimal retail price are independent of the manufacturer’s decision. It only relates to the base potential demand $a$ and the coefficient of cross-price sensitivity $\beta$. Also, the retailer will increase its retail price when $a$ or (and) $\beta$ increases. Increasing $a$ will increase the base potential demand, and increasing $\beta$ will attract more customers away from the direct channel, and the retailer will increase its revenue. An important managerial insight obtained from here is that the retailer should increase $a$ and $\beta$ by operational and marketing means such as, offering flexible purchase and return policy, quality warranty and service plan or promotion advertisement.

We can find that the optimal value added by the manufacturer is independent of the other parameters except for the manufacturer’s value-added cost. The managerial insight we get from here is that the manufacturer should only pay more attention to its own cost in the process of adding value regardless of the retailer’s cost structure, and should trade off the added value and value-added cost.

4.2 Decision models in MS Game

The manufacturer-Stackelberg (MS) game scenario emerges in a dual-channel supply chain where there exist one larger manufacturer (e.g. Microsoft, Intel and P&G) and one relatively smaller retailer. The manufacturer dominates the market and acts as a leader and the retailer is the follower. The manufacturer first decides the wholesale price, direct sale price and value added to maximize his profit based on retailer’s response, the retailer subsequently decides the retail prices after observing the manufacture’s decisions. The MS model can be described as follows:

$$\max_{p_d,v,w} \pi_m = (p_d - c_r)(a - (p_d - v) + \beta p_r) + w(a - p_r + \beta(p_d - v)) \quad (9)$$

$p_r(p_d, w, v)$ is the retailer’s response function and can be derived from solving the retailer’s optimization problem

$$\max_{p_r} \pi_r = (p_r - w)(a - p_r + \beta(p_d - v)) \quad (10)$$

We solve this MS game from a backward direction. Given the manufacturer’s decisions introduced above, we can obtain the response function of the retailer as follows:

$$p_r = \frac{1}{2}(a + w - v\beta + \beta p_d) \quad (11)$$

The manufacturer knows the retail’s response and adopts it to maximize his profit. Therefore, we have the following Proposition 2.

**Proposition 2.** In the MS model, the optimal strategies can be obtained as follows.
From Proposition 2 we know that the wholesale price is independent of the manufacturer’s cost and only depends on the base potential demand $a$ and the coefficient of cross-price sensitivity $\beta$. Obviously, the direct price is higher than the wholesale price, it prevents the retailer from purchasing products in the direct channel. The optimal value added is also independent of the retailer’s decision.

### 4.3 Decision models in RS Game

The retailer-Stackelberg (RS) game scenario represents a dual-channel supply chain where there exist one larger retailer (e.g. Walmart and Carrefour) and one relatively smaller manufacturer. The retailer controls the market and acts as the leader, and the manufacturer is the follower. The retailer first decides the retail price, then the manufacturer subsequently decides the wholesale price, direct sale price and value added to maximize his profit after observing the decisions of the retailer. The RS model is obtained as follows:

$$\max_{p_r} \pi_r = (p_r - w)(a - p_r + \beta(p_d - v))$$

$p_d(p_r), w(p_r), v(p_r)$ is the manufacturer’s response function and can be obtained from the manufacturer’s optimization problem

$$\max_{p_d, v, w} \pi_m = (p_d - \frac{mv^2}{2})(a - (p_d - v) + \beta p_r) + w(a - p_r + \beta(p_d - v))$$
Given the retailer’s decisions, the manufacturer’s response function satisfies the following equations:

\[ a + v + \frac{mv^2}{2} + w\beta - 2p_d + \beta p_r = 0 \]  \hspace{1cm} (15)

\[ -\frac{mv^2}{2} - w\beta + p_d - mv(a + v - p_d + \beta p_r) = 0 \]  \hspace{1cm} (16)

\[ a - 2w - m_r + \beta(-v + p_d) + \beta(-\frac{mv^2}{2} + p_d) = 0 \]  \hspace{1cm} (17)

Equivalent to Eq. (17), we have

\[ a - w - p_r + \beta(-v + p_d) + \beta(-\frac{mv^2}{2} + p_d) = 0 \]  \hspace{1cm} (18)

The manufacturer’s reaction functions can be obtained with above equations. Maximizing the retailer’s profit with manufacturer’s reaction functions, we can get the following optimal decision in RS model.

**Proposition 3.** In the RS model, the optimal decisions can be obtained as follows.

\[
\begin{align*}
  w_{RS}^* &= \frac{1}{8} \left( \frac{\beta}{m} + \frac{2a(1+\beta)}{1-\beta} \right) \\
p_r^{*RS} &= \frac{1}{8} \left( \frac{2a(3-\beta)}{1-\beta} - \frac{\beta}{m} \right) \\
p_d^{*RS} &= \frac{3+2am-3\beta}{4m(1-\beta)} \\
v_{RS}^* &= \frac{1}{m} \\
D_r^{*RS} &= \frac{a - \beta}{4} - \frac{\beta}{8m} \\
D_d^{*RS} &= \frac{2 - \beta^2 + 2am(2+\beta)}{8m} \\
D_{RS}^* &= \frac{2 - \beta - \beta^2 + 2am(3+\beta)}{8m} \\
\pi_r^{*RS} &= \frac{(-2am+\beta)^2}{32m^2} \\
\pi_m^{*RS} &= \frac{4a^2m^2(5+3\beta) + (1+\beta)(4 - 3\beta^2) - 4am(-4 + \beta + 3\beta^2)}{64m^2(1-\beta)} \\
\pi_r^{*RS} &= \frac{(-2 + \beta)(-1 + \beta)(2 + \beta) - 4am(-1 + \beta)(4 + \beta) + 4a^2m^2(7 + \beta)}{64m^2(1-\beta)}
\end{align*}
\]  \hspace{1cm} (19)
4.4 Nash Game model

The Nash game (NG) scenario arises in a dual-channel supply chain where a manufacturer and a retailer have the identical market power and the same bargaining power. They determine their strategies independently and simultaneously. The NG model can be obtained as follows:

$$\max_{p_d,v,w} \pi_m = (p_d - \frac{mv^2}{2})(a - (p_d - v) + \beta p_r) + w(a - p_r + \beta(p_d - v))$$  \hspace{1cm} (20)

$$\max_{p_r} \pi_r = (p_r - w)(a - p_r + \beta(p_d - v))$$  \hspace{1cm} (21)

**Proposition 4.** In the NG model, the optimal decisions can be obtained as follows.

\[
\begin{align*}
    w_{NG}^* &= \frac{-4am - \beta - 2am\beta + \beta^2}{12m(-1 + \beta)} \\
    p_{r,NG}^* &= \frac{-8am + \beta + 2am\beta - \beta^2}{12m(-1 + \beta)} \\
    p_{d,NG}^* &= \frac{-3 - 2am + 3\beta}{4m(-1 + \beta)} \\
    v_{NG}^* &= \frac{1}{m} \\
    D_{r,NG}^* &= \frac{a - \beta}{3} \frac{1}{6m} \\
    D_{d,NG}^* &= \frac{3 - \beta^2 + 2am(3 + \beta)}{12m} \\
    D_{NG}^* &= \frac{(1 - \beta)(3 + \beta) + 2am(5 + \beta)}{12m} \\
    \pi_{r,NG}^* &= \frac{(-2am + \beta)^2}{36m^2} \\
    \pi_{m,NG}^* &= \frac{(-4am(-1 + \beta)(9 + 5\beta) + 4a^2m^2(13 + 5\beta) + (-1 + \beta)(-9 + 5\beta^2)}{144m^2(1 - \beta)} \\
    \pi &= \frac{((-3 + \beta)(-1 + \beta)(3 + \beta) - 4am(-1 + \beta)(9 + \beta) + 4a^2m^2(17 + \beta))}{144m^2(1 - \beta)}
\end{align*}
\]

5. Comparisons and managerial implications

In this section, we make comparisons and analyze the performances in different market power structures. After that, we derive some managerial insights based on comparisons and sensitivity analysis.

5.1 Comparison and analysis of the equilibrium solutions

The following Proposition summarizes the results indicating which power structure is the best for the partners and the entire dual-channel supply chain respectively, under
Optimal strategies of a dual-channel supply chain under ... Tang and Zhu/Argos Special Issue 2016-part 2/pp.1-20

pricing competition. The proofs are straightforward.

**Proposition 5.** For the manufacturer, the MS is the best followed by the NG and then RS. For the retailer, the RS is the best followed by the NG and then MS. However, the dual-channel supply chain as a whole benefits most from an integrated channel.

Firstly, we investigate prices in all the four models and obtain the results following. The direct sale prices and added value are unchanged in different decision models, and the optimal value added by the manufacturer is independent of the retailer’s decision. We have the following equalities hold by comparisons.

\[(I) \; p_d^0 = p_d^{MS^*} = p_d^{RS^*} = p_d^{NG^*}; \quad (II) \; \nu^0 = \nu^{MS^*} = \nu^{RS^*} = \nu^{NG^*} = \frac{1}{m}\]

The retail price is the highest when either the manufacturer or the retailer dominates the supply chain, i.e. in MS or RS models, while in the integrated channel it is the lowest.

\[(III) \; p_r^0 \leq p_r^{NG^*} \leq p_r^{MS^*} = p_r^{RS^*}\]

Equalities hold when Eq. (7) holds, or \(2am - \beta = 0\).

Furthermore, the resultant demands in different decision models satisfy the following inequalities and equalities.

\[(IV) \; D_d^0 \leq D_d^{NG^*} \leq D_d^{RS^*} = D_d^{MS^*}\]

\[(V) \; D_r^{MS^*} = D_r^{RS^*} \leq D_r^{NG^*} \leq D_r^0\]

Again, equalities hold when \(2am - \beta = 0\).

Associated with retail prices and direct sale prices, the demand levels for direct channel and retail channel are equal in MS and RS respectively, so does the total demand in both decision models. Consumers make their purchase decision upon the relative product price between direct and retail channels. In MS and RS models, relative direct sale price is lower, resulting in higher demand for direct channel. On the opposite, relative higher retail price results in lower demand for retail channel among all the models. While in the integrated channel, the highest relative direct sale price induces the lowest demand for the direct channel and the lowest retail price leads to the highest demand for the retail channel. Consumers switch their demand among the two channels, and relative price determines the choice of demand from different channels. However, from the angle of total requirements for the product, consumers only care the absolute product price, either from the direct or retail channel, and lower prices induce higher demand, so we can obtain

\[(VI) \; D^{MS^*} = D^{RS^*} \leq D^{NG^*} \leq D^0\]

Equalities hold only when \(\beta = 1\), that means self-price and cross-price have the same effects (we have already supposed that \(0 < \beta < 1\), then equalities can be ignored in our discussions).

The manufacturer charges the highest (lowest) wholesale price in the MS (RS) as
expected:
(VII) \( w^{RS^*} \leq w^{NG^*} \leq w^{MS^*} \)

Then we compare the profits of the manufacturer and the retailer in different models. As expected, the manufacturer makes the largest profit in MS, followed by in NG and then RS. And on the contrary, the retailer obtains the most in RS and the least in MS.

(VIII) \( \pi^r_{MS^*} \leq \pi^r_{NG^*} \leq \pi^r_{RS^*} \)
(IX) \( \pi^m_{MS^*} \leq \pi^m_{NG^*} \leq \pi^m_{RS^*} \)

As the individual member of a supply chain gains more powers in pricing decision, its profit grows larger, however profit’s growth speed is lower. Interestingly the differences between the largest and the lowest profits for both the manufacturer and the retailer are the same, i.e.

(X) \( \pi^m_{MS^*} - \pi^m_{RS^*} = \pi^r_{RS^*} - \pi^r_{MS^*} \)

Then the following comparison result of the profits of the dual-channel supply chain in different models is apparent:

(XI) \( \pi^m_{MS^*} = \pi^r_{RS^*} = \pi^m_{NG^*} = \pi^m_{RS^*} \)

Discussion 1. Sensitivity Analysis of the Parameter \( a \).

It is intuitive to verify that the prices, including prices of direct sale, retail and wholesale in MS, RS and NG models are all positively related with parameter \( a \). We select to illustrate the changes of optimal retail price, direct sale price and the wholesale price with the base potential demand in NG model because their performances are moderate among all the situations we have considered. The other models can be analyzed similarly, so we omit them for saving space. The variation of prices with the base potential demand in NG model is depicted in Fig 1., the parameters are endowed with values as \( \beta=0.6, \ m=0.02 \) and \( a \in [80,240] \).

![Fig 1. Variations of optimal prices with \( a \) in NG model](image-url)
From Fig 1 we know that the optimal retail price, direct sale price and wholesale price increase with an increase in the base potential demand in NG model, so it is in MS and RS models. Fig 1 also shows that, as base potential demand increases, retail price grows faster than direct sale price. Because the base demand (i.e. need for autogenic) reflects the level of customers’ dependence on the product, retailers’ market power becomes stronger as the base potential demand increases, and then retailers will charge higher for more profit.

Fig 2 demonstrates that the maximum demands of direct channel, retail channel and the whole supply chain will increase in the base potential demand in NG model. Moreover, $D_r > D_c$ can be obtained straightforwardly. Similar results can be obtained in MS and RS models.

**Insight 1** The optimal prices of direct sale, retail and wholesale will increase with the base potential demand in whatever model. Furthermore, both manufacturer and retailer, and the whole supply chain will benefit from the increase of the base demand, due to the increase in demands in higher prices.

![Graph](Image)

**Fig 2. Variations of maximum demands with $a$ in NG model.**

**Discussion 2.** Sensitivity Analysis of the Parameter $m$.

Here we investigate how the changes of cost parameter $m$ affect the optimal prices and profits. The variations of optimal prices, maximum demands and profits in different models are displayed in Figs. 3-5 respectively, where parameters are set as follow $\beta=0.6$, $a=80$ and $m\in[0.01,0.02]$. 
Optimal strategies of a dual-channel supply chain under ...

Tang and Zhu/ Argos Special Issue 2016-part2/pp.1-20

**Fig 3. Variations of the optimal prices with $m$ in NG model.**

Fig 3. shows that the direct sale and wholesale prices will decrease with the increasing of the parameter $m$, whereas the retail price will increase with $m$ in NG models. The similar conclusions can be obtained in MS and RS models. The parameter $m$ possesses great impact on the direct sale price through directly affecting the manufacturer’s cost.

**Fig 4. Variations of maximum demands with $m$ in NG model.**

Fig 4. illustrates that the maximum demand for direct sale channel decreases with the parameter $m$, but the increase of $m$ has an reverse effect on demand for retail channel. The demand for the entire dual-channel supply chain decreases with $m$ increasing in the two contrary forces.

From Fig 5., conclusions can be drawn as following in NG model:

1. The retailer’s maximum profit $\pi^*_r$ increases as $m$ increases.

2. The maximum profit of manufacturer $\pi^*_m$ decreases as $m$ decreases. However this
Optimal strategies of a dual-channel supply chain under ...

Tang and Zhu/ Argos Special Issue 2016-part2/pp.1-20

decrease is larger than the increase of retailer’s, resulting in the decrease of the total profit of the supply chain.

Similar results can be obtained in MS and RS models.

**Insight 2** In whatever model, the increase of the direct channel cost parameter causes the decrease of the optimal direct sale price, and the increase of the optimal retail price. Retailer benefits from the change due to the higher demand for the retail channel. However, the manufacturer suffers a loss in the rise of cost and, as a whole, the supply chain’s profit decreases because of the decrease in total demand.

![Fig 5. Variations of maximum profits with m in NG model.](image)

**Discussion 3.** Sensitivity Analysis of the Parameter $\beta$.

This part we discuss how the parameter $\beta$ affects the optimal prices and profits. We display the optimal prices, demands and profits in MS model and the integrated channel in Figs 6-11., where parameters are endowed with values as $a = 80$, $m = 0.02$ and $\beta \in [0.4, 0.8]$. From Fig 6 to 8, we have the following results for MS model:

1. The optimal prices of direct sale, retail, and wholesale all increase with cross-price sensitivity $\beta$. However, the difference between direct sale price and retail price gets smaller as $\beta$ increases.

2. The maximum demand for retail channel decreases as $\beta$ increases.

3. The maximum demands for direct sale channel and the whole supply chain increase with $\beta$.

4. The retailer’s maximum profit $\pi^*_{r}$ decreases with increasing cross-price sensitivity $\beta$. On the contrary, $\pi^*$ and $\pi^*_d$ increase as $\beta$ increases.

Similar influence mechanism between parameter $\beta$ and the optimal prices, maximum
Insight 3 The optimal prices of direct sale, retail and wholesale increase with cross-price sensitivity parameter $\beta$ in all the scenarios where there exists market power. When competition between direct channel and retail channel gets intense, the manufacturer who owes the authority to decide wholesale price will make use of his advantages to raise his revenue. The retailer’s profit decreases because of the decrease in demand caused by the higher retail price as $\beta$ increases.

**Fig 6. Variations of optimal prices with $\beta$ in MS model.**

**Fig 7. Variations of maximum demands with $\beta$ in MS model.**
There are some differences in the performances of optimal prices and demands of the integrated channel. According to Figs. 9-11, we have the following results.

(1) The optimal prices of direct sale and retail increase as $\beta$ increases and their differences keep unchanged with $\beta$.

(2) The increasing of $\beta$ causes no change to the maximum demand for direct sale channel for the unchanged difference between direct sale price and retail price.

(3) The maximum demand for retail channel decreases as $\beta$ increases in that the effective price customers pay for the product from direct channel is lower than they should pay for retailer, i.e. $p_d - v < p_r$. Intuitively, the demand for the supply chain decreases with $\beta$.

(4) The maximum profit of the whole supply chain increases with $\beta$. This is because of the marked increase of prices, which counteracts the slight decrease of total demand and reverses the negative impact of competition on the profit.
Optimal strategies of a dual-channel supply chain under …
Tang and Zhu/Argos Special Issue 2016-part2/pp.1-20

Fig 9. Variations of optimal prices with $\beta$ in the integrated channel.

Fig 10. Variations of maximum demands with $\beta$ in the integrated channel.
5.2 Numerical example

In this subsection, we briefly discuss the results of our extensive numerical to verify some of the analytical findings and gain more managerial insights. The parameters values used in this numerical experiment are listed as $a = 80$, $m = 0.02$ and $\beta = 0.6$. The equilibrium results are described in Tables 1 and 2.

From Table 1, it can be found that direct sale price are the same in all the scenarios, $p_d^* = 137.5$. Retail price achieves highest in MS and RS models ($p_r^* = 116.25$) and the lowest in the integrated channel ($p_r^* = 100$). In RS model the optimal wholesale price is lowest and the retailer can obtain the biggest margins $m_r$. While in MS model, the wholesale price is the highest and the smallest margins can be obtained.

<table>
<thead>
<tr>
<th>Decision scenario</th>
<th>$p_d$</th>
<th>$p_r$</th>
<th>$w$</th>
<th>$m_r$</th>
<th>$v$</th>
</tr>
</thead>
<tbody>
<tr>
<td>The integrated channel</td>
<td>137.5000</td>
<td>100.0000</td>
<td>_</td>
<td>_</td>
<td>50.0000</td>
</tr>
<tr>
<td>MS model</td>
<td>137.5000</td>
<td>116.2500</td>
<td>100.0000</td>
<td>16.2500</td>
<td>50.0000</td>
</tr>
<tr>
<td>RS model</td>
<td>137.5000</td>
<td>116.2500</td>
<td>83.7500</td>
<td>32.5000</td>
<td>50.0000</td>
</tr>
<tr>
<td>NG model</td>
<td>137.5000</td>
<td>110.8330</td>
<td>89.1667</td>
<td>21.1667</td>
<td>50.0000</td>
</tr>
</tbody>
</table>

Table 2. Maximum demands and profits under different decision scenarios.

<table>
<thead>
<tr>
<th>Decision scenario</th>
<th>$D_d$</th>
<th>$D_r$</th>
<th>$D$</th>
<th>$\pi_m$</th>
<th>$\pi_r$</th>
<th>$\pi$</th>
</tr>
</thead>
<tbody>
<tr>
<td>The integrated channel</td>
<td>52.5000</td>
<td>32.5000</td>
<td>85.0000</td>
<td>_</td>
<td>_</td>
<td>9156.2500</td>
</tr>
<tr>
<td>MS model</td>
<td>62.2500</td>
<td>16.2500</td>
<td>78.5000</td>
<td>8628.1300</td>
<td>264.0630</td>
<td>8892.1900</td>
</tr>
<tr>
<td>RS model</td>
<td>62.2500</td>
<td>16.2500</td>
<td>78.5000</td>
<td>8364.0600</td>
<td>528.1250</td>
<td>8892.1900</td>
</tr>
<tr>
<td>NG model</td>
<td>59.0000</td>
<td>21.1667</td>
<td>80.1667</td>
<td>8569.4400</td>
<td>469.4440</td>
<td>9038.8900</td>
</tr>
</tbody>
</table>

From Table 2, we know demand for the supply chain with dual-channel achieves highest in the integrated channel and the lowest in MS and RS models, namely, $D^* = 85$.
and $D^* = 78.5$. The manufacturer prefers MS model because of the higher profit it obtains than other scenarios ($\pi_m^* = 8628.13$), whereas in RS model the retailer will acquire more ($\pi_r^* = 528.125$). For the whole supply chain, the total profit reaches highest in the integrated channel ($\pi^* = 9156.25$).

Customers benefit most from the lowest prices and the biggest demands for the product in the integrated channel. From above illustrations, we know the manufacturer and retailer integrate as a whole will bring the largest profit, then the integrated channel is the best choice for the society. Any form of market power causes a loss in the social welfare. However an integrated contract holds only when the manufacturer can obtain no less than $\pi_m^* = 8628.13$, and the retailer no less than $\pi_r^* = 528.125$. Straightforwardly, the participants won’t truly cooperate since $\pi^* = 9156.25$ in the integrated channel is smaller than the sum of $\pi_m^* = 8628.13$ in MS model and $\pi_r^* = 528.125$ in RS model. Either the manufacturer or the retailer chooses to take advantage of its market power for more revenues. A market of a monopolistic manufacturer or a monopolistic retailer achieves the same welfare, the lowest demand and total profit, the difference only exists in the assignment of revenues. If both the manufacturer and the retailer have some power but neither can dominate the market, the performances will be better with a demand of $D^* = 80.1667$ and total profit of $\pi^* = 9038.89$. From the analysis above, Insight 4 can be derived.

**Insight 4** Social welfares are negatively correlated with the degree that the participants control the market. The dominator can increase its own profit, but to the whole supply chain and customers it means loss.

### 6· Conclusions and Further Research

In this paper, we analyze the pricing decisions in a dual-channel supply chain under different market power structures. First, we establish one pricing model in a centralized decision model and three decentralized decision models through Stackberg game and obtain the corresponding optimal direct sale prices, added values, wholesale prices and retail prices. Second, we provide some comparisons of equilibrium results in different models and make an analysis to investigate how some key parameters affect the optimal pricing, production and corresponding profits. Some valuable managerial insights have been derived accordingly. Third, a numerical example has been adopted to compare the equilibrium performances in different models.

There are some limitations about our work. Firstly, our assumed demand for both channels are linear, equilibriums will be different if non-linear demands are considered in the models. Secondly, we considered the problem under symmetric information. An extension to information asymmetric could be observed and studied. Thirdly, considering a dual supply chain of two manufacturers or retailers or more will lead to more practical managerial insights. These limitations remain to be dissolved in future research.

### References

2. Cai, Gangshu (George) (2010). Channel Selection and Coordination in Dual-


