Asia-Pacific Journal of Operational Research
Vol. 35, No. 3 (2018) 1850014 (27 pages)

DOI: 10.1142/S0217595918500148

Distribution Channel Strategies and Retailer Collusion in a Supply Chain with Multiple Retailers

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Received 1 October 2016
Revised 9 March 2017
Accepted 26 December 2017
Published 26 April 2018

Previous literature suggests that without regulations firms have incentives to collude by fixing price or reducing quantity. This paper sets up an infinitely repeated game to examine the interplay between the manufacturer's channel strategy and the downstream retailers' collusive behavior. The results show that the manufacturer can deter retailer collusion by strategically changing its channel strategy. This effect occurs when the discount rate (used to calculate the present value of future profits) is relatively large and the manufacturer's direct selling efficiency is relatively high (i.e., the variable cost of direct selling is relatively low). With the deterrence of direct selling, retailers abandon collusion and "*no collusion*" is a win-win strategy for both levels in the supply chain. However, when the manufacturer is not efficient in direct selling or the discount rate is small, direct selling is not effective in deterring retailer collusion and the manufacturer is worse off. These findings provide insights into channel strategies and supply chain management.

Keywords: Channel strategy; retailer collusion; direct selling; game theory.

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1. Introduction

In the absence of regulations, firms have incentives to collude. Friedman shows that "patient, identical Cournot duopolists can "implicitly collude" by each producing half of the monopoly output" (Fudenberg and Tirole, 1991, p. 155). Research joint ventures contracts may also facilitate horizontal collusion by imposing subtle restraints specifying "the division of the product market" (Tirole, 2003, p. 414). In general, price- or quantity-fixing agreements are believed to allow firms to maintain a higher price or supply a smaller quantity and obtain higher profits at the expense of social welfare. Consequently, policy makers often institute antitrust laws (e.g., the Sherman Act of the U.S.) to prohibit firms' collusive behavior.

In a decentralized supply chain, collusion may take place among retailers. Retailers that act cooperatively to reduce order quantity can make themselves better off at the expense of the manufacturers. Manufacturers have filed many lawsuits against retailers that *may* have colluded. Prior research suggests that manufacturers can undermine retailer collusion under certain conditions by imposing a resale price floor (Overvest, 2012). However, manufacturers have gradually lost leverage to retailers over the past decades (May, 2000) and may not be able to impose resale price restrictions (Zhou and Zhao, 2013). Meanwhile, the dual-channel strategy is a widely considered alternative to helping manufacturers regain leverage (Liu and Zhang, 2006; Wang *et al.*, 2016). Indeed, as the Internet has made it easier to establish direct online stores, manufacturers increasingly rely on direct selling along with the independent retailer channel (Khouja *et al.*, 2010; Yu *et al.*, 2017). By entering the realm of direct sales, manufacturers can enjoy higher profit margins, have closer contact with the end customers (Stern *et al.*, 1996), and regulate the retailers' pricing behavior (Chiang *et al.*, 2003).

This paper examines the role of manufacturers' channel strategy in regulating the downstream retailers' collusive tendencies. In particular, we study whether and when the manufacturer's direct channel entry can deter retailer collusion and change the vertical interaction in a repeated game. This paper intends to answer the following research questions. First, will the manufacturer alter its channel strategies because of retailer collusion? Prior literature suggests that the manufacturer will adopt the direct channel if its variable cost of direct selling is below a threshold (Arya *et al.*, 2007). This paper examines whether this still holds if the retailers may engage in collusion. Second, can the manufacturer effectively deter retailer collusion by changing its channel strategy? In a channel with one manufacturer and multiple retailers, conventional wisdom suggests that the retailers always prefer collusion. We examine whether and when the manufacturer's direct selling can induce the retailers to abandon collusion.

To answer these research questions, we study an infinitely repeated game with one manufacturer and n retailers. In each period, the manufacturer may strategically choose a channel strategy (and direct channel output q_0 if relevant) and wholesale price to induce the retailers not to collude. If the retailers dare to deviate and collude in a certain period, the manufacturer will punish the retailers in future periods by changing its channel strategy. However, if the retailers do not collude, the manufacturer will maintain the same channel strategy in the next period. Whether the manufacturer's punishment can deter collusion depends on retailers' long-run profits in the "*no collusion*" versus "*collusion*" scenario.

This research provides some intriguing findings. First, consistent with prior literature, we establish that the manufacturer adopts the dual-channel strategy when its variable cost of direct selling is relatively low. However, it relies much more on direct selling (i.e., sells greater volume through its direct channel) when the retailers collude. Second, under certain circumstances, the manufacturer's dual-channel strategy can strategically deter retailer collusion. Given a relatively large discount rate (used to calculate the present value of future profits), when the variable cost of direct selling is sufficiently low, the manufacturer's threat of punishment is effective and retailers will not collude in anticipation of the manufacturer's direct selling in future periods. This is because direct sales can more than compensate for the manufacturer's sales loss due to retailer collusion and drive down the retail price, which in turn hurts the collusive retailers. However, when the manufacturer is highly inefficient in direct selling or the retailers discount future profits with a relatively small discount rate, the manufacturer cannot efficaciously deter collusion and retailer collusion will make the manufacturer worse off.

The remainder of the paper is organized as follows. Section 2 reviews related literature. Section 3 sets up the infinitely repeated game to examine the manufacturer's channel strategy and the retailers' collusion decision. Section 4 concludes and discusses future research directions.

2. Related Literature

This research is closely related to two streams of literature, regarding horizontal collusion and the manufacturer's channel strategy. Substantive research has examined the vertical practices that may facilitate horizontal collusion (Shaffer, 1991; Asker and Bar-Isaac, 2014), especially collusion among manufacturers. For example, prior research investigates the anti-competitive effects of resale price maintenance (Jullien and Rey, 2007) and exclusive territories (Piccolo and Reisinger, 2011). More recent work by Reisinger and Thomes (2016) examines the effect of channel structure on the tacit collusion among manufacturers. Other related works focus on the stability or sustainability of collusion (e.g., Hasnas and Wey, 2015). For instance, Colombo (2013) explores the relationship between product differentiation and the stability of collusion when collusion is costly.

However, few studies examine the collusive behavior among retailers in a decentralized supply chain. Prior literature finds that retailers may form a buying group and collusively curtail output down to the monopoly level (Doyle and Han, 2014). Moreover, to coordinate the retail price, retailers can adopt low-price guarantees

(Liu, 2013) or use their mutual manufacturer to share private information (Sahuguet and Walckiers, 2016; Shamir, 2016). Some research shows that manufacturers' resale price maintenance may deter retailers' collusive behavior under selected circumstances (Overvest, 2012). In a similar vein, this paper also examines retailer collusion from the perspective of vertical interaction in a supply chain and investigates how the manufacturer's channel strategy affects the retailers' collusion decision.

Related literature on manufacturer channel strategy examines the determinants and benefits of a manufacturer's dual-channel strategy or direct channel entry. Prior research suggests that direct channel entry may depend on the efficiency of the direct channel, the size of the retail-captive segment (Khouja *et al.*, 2010), the price and service differences across channels (Dumrongsiri *et al.*, 2008), consumers' sensitivity to the price differential across channels (Kumar and Ruan, 2006), and the proportion of service- versus price-sensitive consumers (Chun *et al.*, 2011). More recent research suggests that the manufacturer's direct channel entry also depends on the retailer's service investment in reducing product returns (Xia *et al.*, 2016).

In terms of the benefits, direct channel entry helps manufacturers reduce demand uncertainty and gain higher profits despite the existence of more efficient independent retailers (Cao *et al.*, 2010). Direct channel entry also plays a strategic role in the manufacturers' channel management (Rhee and Park, 2000; Chiang *et al.*, 2003; Cai, 2010). Chiang *et al.* (2003) find that the direct channel may not generate significant sales but can induce the retailer to lower the retail price and alleviate the "double marginalization" problem. Similarly, Chun *et al.* (2011) show that a direct channel enables the manufacturer to regulate the retailer's pricing behavior, making both parties better off. Hsiao and Chen (2014) suggest that when customers vary in the extent to which they shop in the physical channel (retail stores) versus over the Internet (online), the capability to operate a direct online channel allows the manufacturer to counterbalance the retailer's pricing power. It is worth noting that a direct channel does not always force down the retail price. When service investment has a positive externality across channels, direct channel entry can increase the retail price (Bell *et al.*, 2002; Tsay and Agrawal, 2004). To the best of our knowledge, little research has examined the strategic role of a manufacturer's direct channel entry in regulating retailers' collusive behavior. We propose in this paper that the manufacturer may prevent retailer collusion by strategically changing its channel strategy.

3. The Model

Consider a supply chain with one manufacturer and n retailers. We identify the manufacturer by m and the retailers by $i \in N, N = \{1, \ldots, n\}(n > 1)$. The manufacturer sells a product to the retailers that, in turn, sell to end consumers. The manufacturer may additionally establish its own store to sell the product directly. The market is characterized by a linear downward-sloping price function $p = a - Q$, where a represents the maximum potential demand and Q is the total demand or selling quantity.[a] We denote retailer i's order by q_i. The total demand is thus $Q = \sum_{i=1}^{n} q_i$ in the absence of direct selling. If the manufacturer establishes a direct channel with sales q_0, then the total demand is $Q = q_0 + \sum_{i=1}^{n} q_i$.

Without loss of generality, we assume that the manufacturer's production cost is zero, and that the variable costs of selling the product for the retailers and the manufacturer are zero and $c_m (c_m > 0)$, respectively.[b] We also assume that the retailers are symmetric and that either all or none of them engage in collusion with each other. Therefore, when the retailers collude, each receives an equal share of the cooperative profits. Finally, firms discount future profits with a common discount rate δ $(0 < \delta < 1)$. Table 1 describes our mathematical notation.

Figure 1 shows the event sequence of the model. In the first period, the manufacturer decides whether to induce the retailers not to collude and then chooses its channel strategy (and direct sales q_0 if relevant) and wholesale price accordingly. The retailers then decide whether to collude in submitting their order quantities. If the manufacturer decides to induce no collusion and retailers collude in one period, the manufacturer will punish them by changing its channel strategy in

Table 1. Modeling notation.

Notation	Description
m	Manufacturer
n	Total number of retailers
i	Retailer identifier, $i = 1, 2, \ldots, n$
N	Set that contains all the retailers
p	Retail price of the product
a	Maximum potential demand
Q	Total demand or selling quantity in the market
q_i	Order quantity of retailer i
q_r	Retailers' total order quantity under "*collusion*"
q_0	Direct sales of the manufacturer
c_m	Variable cost of direct selling
δ	Discount rate
w	Wholesale price of the product
π_m	Manufacturer's profit
π_i	Retailer i's profit
π_r	Retailers' cooperative profit under "*collusion*"

[a]The price function is equivalent to the standard inverse demand curve $Q = a - p$. Note that when $p = 0$, $Q = a$. In standard economics, "a" represents the maximum addressable market (i.e., the maximal potential demand). In other words, if the product is given away for free, the demand will be "a."

[b]c_m stands for the variable cost of direct selling incurred by the manufacturer. This construct has been used in the prior literature (e.g., Chiang *et al.*, 2003; Bernstein *et al.*, 2009). In addition, it makes sense that retailers have a lower variable selling cost, because they are more efficient in order processing, customer support, and information gathering. Prior research makes similar assumptions (e.g., Arya *et al.*, 2007).

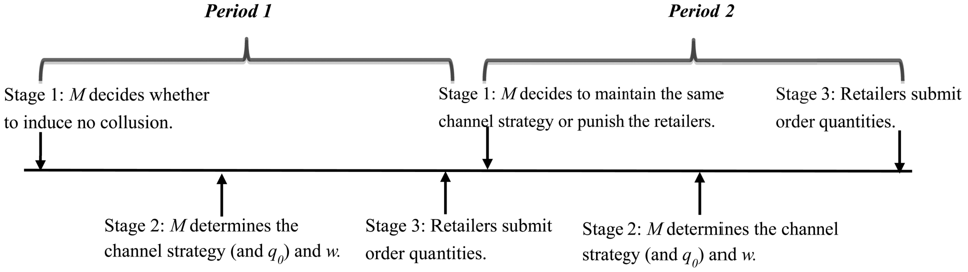

Fig. 1. An illustration of the event sequence in the first two periods.

future periods; otherwise the manufacturer will maintain the same channel strategy. We assume that the manufacturer detects collusion by observing retailers' order quantities at the end of each period. If the manufacturer anticipates that its punishment will be effective, it will choose the channel strategy that induces no collusion. However, if the punishment will not be effective, the manufacturer will choose its optimal channel strategy and wholesale price in anticipation of retailer collusion. Given the manufacturer's channel strategy and wholesale price, the retailers decide whether to collude by anticipating the potential punishment in future periods.

To help readers better understand the organization of the following sections, we use Fig. 2 to illustrate the possible decision paths for the firms (i.e., the different scenarios and sub-scenarios). In this figure, each node represents a firm (i.e., manufacturer or retailer) and each path or branch indicates a decision.

The manufacturer (m) first decides either to induce "*no collusion*" ("*NC*") (path a') or treat retailers as a cartel (path a''), and chooses its channel strategy and wholesale price accordingly. In the former case, retailers will then decide whether to deviate given the manufacturer's wholesale price and channel strategy. This constitutes the "*stage game*," which is played repeatedly by the firms until the retailers deviate by colluding. There are two scenarios in the "*stage game*," namely the "*deviation*" scenario (i.e., path $a' - b'$) and the "*NC*" scenario (i.e., path $a' - b''$).[c] If the retailers deviate in one period, then the manufacturer will punish the retailers by treating them as a cartel (path c').[d] The path c'' "*not punish*" is shown as a dotted line because, as the following sections will demonstrate, the manufacturer never chooses this path in equilibrium. When the manufacturer punishes the retailers, it treats them as a cartel and then chooses its wholesale price and channel strategy. The retailers then will have to collude in all future periods, which is termed the "*collusion with manufacturer punishment*" scenario (i.e., path $c' - d'$) in the following sections.

[c]In Fig. 2, we have highlighted the "*stage game*" with a rectangle.
[d]In our repeated game, treating retailers as a cartel serves as a punishment. This is because in case of retailer collusion the manufacturer will sell greater volume through the direct channel, which will drive down the retail price and diminish the retailers' profits.

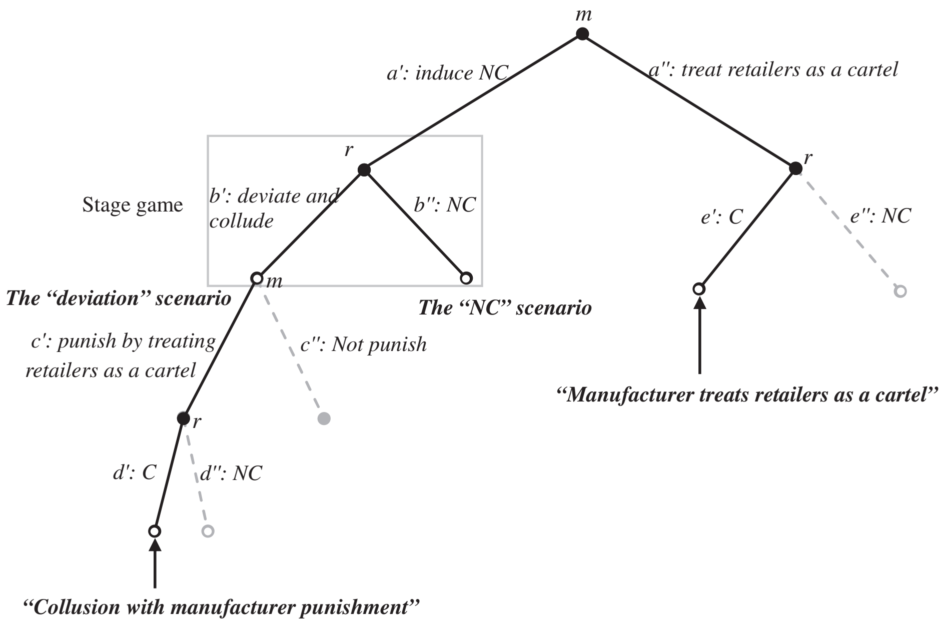

Fig. 2. Firm decisions and sub-scenarios.

If the manufacturer chooses to treat the retailers as a cartel from the very beginning (i.e., a'' in Fig. 2), it can be easily shown that the retailers will always collude (i.e., path $a'' - e'$). This sub-game repeats over infinite periods and is the same as the "*collusion with manufacturer punishment*" scenario. Therefore, we will not examine the "*manufacturer treats retailers as a cartel*" scenario (path $a'' - e'$) separately.

In the following analyses we first derive the equilibrium in the "*NC*" scenario (path $a' - b''$) and the "*deviation*" scenario (path $a' - b'$) of the "*stage game*," and then derive the equilibrium in the "*collusion with manufacturer punishment*" scenario (path $c' - d'$). Based on the equilibrium results of these sub-scenarios, we obtain the firms' discounted profits in "*collusion*" versus "*no collusion*" cases over infinite periods, and examine whether the manufacturer's punishment is effective in deterring retailer collusion.

3.1. "*Stage game*": *The* "*NC*" *scenario*

In this scenario, the manufacturer first chooses the channel strategy and wholesale price in anticipation of no retailer collusion, and then the retailers submit their order quantities in a competitive fashion. We compare two cases to derive the manufacturer's channel strategy: (i) the manufacturer adopts the retail-only channel strategy, and (ii) the manufacturer adopts the dual-channel strategy that uses a direct channel alongside n independent retailers.

Retail-only channel strategy (RO) in the "NC" scenario. We denote this scenario as "*NC_RO*", which represents "*no collusion*; *retail-only*" channel strategy. When the manufacturer adopts the retail-only channel strategy, it sells the product only through the independent retailers.

In the first stage, the manufacturer sets its wholesale price w^{NC_RO} to maximize its profit, denoted as

$$\pi_m^{NC\_RO} = w^{NC\_RO} \sum_{i \in N} q_i^{NC\_RO}. \tag{1}$$

In the second stage, given the wholesale price w^{NC_RO}, each retailer i chooses $q_i^{NC\_RO}$ to maximize its own profit:

$$\pi_i^{NC\_RO} = (p^{NC\_RO} - w^{NC\_RO}) q_i^{NC\_RO}. \tag{2}$$

In the above equation, $p^{NC\_RO} = a - Q^{NC\_RO} = a - q_i^{NC\_RO} - \sum_{j \in N, j \neq i} q_j^{NC\_RO}$. We derive the subgame perfect equilibrium using backward induction. The manufacturer's equilibrium wholesale price and profit are:

$$w^{*NC\_RO} = \frac{a}{2} \quad \text{and} \quad \pi_m^{*NC\_RO} = \frac{n}{4(n+1)} a^2.^{\mathrm{e}} \tag{3}$$

The retailers' equilibrium output, retail price, and profit are:

$$q_i^{*NC\_RO} = \frac{1}{2(n+1)} a, \quad p^{*NC\_RO} = \frac{n+2}{2(n+1)} a, \quad \text{and} \quad \pi_i^{*NC\_RO} = \frac{1}{4(n+1)^2} a^2. \tag{4}$$

Equation (4) shows that as the number of retailers increases, the downstream competition intensifies and each retailer's profit decreases. As n approaches infinity, each retailer's profit approaches zero. In contrast, the manufacturer's profit increases as the downstream competition intensifies (i.e., $\frac{\partial \pi_m^{*NC\_RO}}{\partial n} > 0$).

Dual-channel strategy (D) in the "NC" scenario. We denote this scenario as "*NC_D*", which represents "*no collusion*; *dual-channel*" strategy. When the manufacturer adopts the dual-channel strategy, it sells the product through the retailers as well as the direct channel.

In the first stage, the manufacturer chooses the wholesale price w^{NC_D} and direct sales $q_0^{NC\_D}$ to maximize:

$$\pi_m^{NC\_D} = (p^{NC\_D} - c_m) q_0^{NC\_D} + w^{NC\_D} \sum_{i \in N} q_i^{NC\_D}. \tag{5}$$

Given the manufacturer's w^{NC_D} and $q_0^{NC\_D}$, each retailer i then chooses $q_i^{NC\_D}$ to maximize:

$$\pi_i^{NC\_D} = (p^{NC\_D} - w^{NC\_D}) q_i^{NC\_D}. \tag{6}$$

[e]We add an asterisk "*" in the superscript to indicate that these are the equilibrium results.

In Eqs. (5) and (6), $p^{NC\_D} = a - q_0^{NC\_D} - q_i^{NC\_D} - \sum_{j \in N, j \neq i} q_j^{NC\_D}$. The subgame perfect equilibrium is shown in Proposition 1. Please refer to the appendix for proof of Proposition 1.

Proposition 1. *Under the dual-channel strategy*:

(1) *When $c_m < \frac{1}{n+1}a$, the manufacturer's equilibrium wholesale price, direct output, and profit are*:

$$\begin{aligned} w^{*NC\_D} &= \frac{a}{2}, \quad q_0^{*NC\_D} = \frac{1}{2}(a - (n+1)c_m), \quad \textit{and} \\ \pi_m^{*NC\_D} &= \frac{1}{4}(a - c_m)^2 + \frac{n}{4}c_m^2. \end{aligned} \tag{7}$$

The retailers' equilibrium output, retail price, and profit are:

$$q_i^{*NC\_D} = \frac{1}{2}c_m, \quad p^{*NC\_D} = \frac{1}{2}(a + c_m), \quad \textit{and} \quad \pi_i^{*NC\_D} = \frac{1}{4}c_m^2. \tag{8}$$

(2) *When $c_m \geq \frac{1}{n+1}a$, the direct channel has no sales. The equilibrium wholesale price and manufacturer profit are*:

$$w^{*NC\_D} = \frac{a}{2} \quad \textit{and} \quad \pi_m^{*NC\_D} = \frac{n}{4(n+1)}a^2. \tag{9}$$

The retailers' equilibrium output, retail price, and profit are:

$$\begin{aligned} q_i^{*NC\_D} &= \frac{1}{2(n+1)}a, \quad p^{*NC\_D} = \frac{n+2}{2(n+1)}a, \quad \textit{and} \\ \pi_i^{*NC\_D} &= \frac{1}{4(n+1)^2}a^2. \end{aligned} \tag{10}$$

The manufacturer's channel strategy in the "NC" scenario. Comparing the equilibrium outcomes in the retail-only and the dual-channel settings, we derive the manufacturer's channel strategy in the absence of retailer collusion.

Theorem 1. *Expecting that retailers do not collude, when $c_m < \frac{1}{n+1}a$, the manufacturer adopts a dual-channel strategy. When $c_m \geq \frac{1}{n+1}a$, the manufacturer relies only on the retail channel.*

Theorem 1 suggests that in the absence of retailer collusion, the manufacturer's channel strategy depends on its efficiency in direct selling. Consistent with prior research, we find that the manufacturer will adopt the dual-channel strategy if it is sufficiently efficient in direct selling (i.e., $c_m < \frac{1}{n+1}a$). As the downstream competition intensifies (i.e., the number of retailers increases), the manufacturer needs to be more efficient in direct selling for the dual-channel strategy to be preferable. However, if the manufacturer's efficiency in direct selling is relatively low, it prefers the retail-only channel strategy. The detailed equilibrium results of the "*NC*" scenario are summarized in the second column of Table 2.

Table 2. Equilibrium results in the "*NC*" scenario of the stage game and the "*collusion with manufacturer punishment*" scenario.

	The "*NC*" scenario of the stage game	"*Collusion* with manufacturer punishment"
$c_m < \frac{1}{n+1}a$	$w^{*NC\_D} = \frac{a}{2}$, $q_0^{*NC\_D} = \frac{1}{2}(a-(n+1)c_m)$, $q_i^{*NC\_D} = \frac{1}{2}c_m$, $p^{*NC\_D} = \frac{1}{2}(a+c_m)$, $\pi_i^{*NC\_D} = \frac{1}{4}c_m^2$, $\pi_m^{*NC\_D} = \frac{1}{4}(a-c_m)^2 + \frac{n}{4}c_m^2$	$w^{*P\_D} = \frac{1}{2}a$, $q_0^{*P\_D} = \frac{1}{2}(a-2c_m)$, $q_i^{*P\_D} = \frac{1}{2n}c_m$, $p^{*P\_D} = \frac{1}{2}(a+c_m)$, $\pi_i^{*P\_D} = \frac{1}{4n}c_m^2$, $\pi_m^{*P\_D} = \frac{1}{4}(a-c_m)^2 + \frac{1}{4}c_m^2$
$\frac{1}{n+1}a \le c_m < \frac{a}{2}$	$w^{*NC\_RO} = \frac{a}{2}$, $q_i^{*NC\_RO} = \frac{1}{2(n+1)}a$, $p^{*NC\_RO} = \frac{n+2}{2(n+1)}a$, $\pi_i^{*NC\_RO} = \frac{1}{4(n+1)^2}a^2$, $\pi_m^{*NC\_RO} = \frac{n}{4(n+1)}a^2$	
$c_m \ge \frac{a}{2}$		$w^{*P\_RO} = \frac{a}{2}$, $q_r^{*P\_RO} = \frac{1}{4}a$, $p^{*P\_RO} = \frac{3}{4}a$, $\pi_i^{*P\_RO} = \frac{1}{16n}a^2$, $\pi_m^{*P\_RO} = \frac{1}{8}a^2$

Notes: The settings in which the manufacturer adopts the dual-channel strategy are highlighted in grey. In other cases, the manufacturer adopts the retail-only channel strategy.

3.2. "*Stage game*": *The* "*deviation*" *scenario*

We further examine the equilibrium in the "*deviation*" scenario of the "*stage game*," where the retailers deviate from "*NC*" and collude in one period. In this scenario, the manufacturer first chooses its channel strategy and wholesale price to induce the retailers not to collude. Therefore, the manufacturer's channel strategy and wholesale price remain the same as those in the "*NC*" scenario. In particular, when $c_m < \frac{1}{n+1}a$, the manufacturer adopts a dual-channel strategy and otherwise it adopts the retail-only strategy (see Theorem 1). Given the manufacturer's channel strategy (and q_0 if relevant) and wholesale price, we can easily derive the optimal retail output and firm profits by maximizing the collusive retailers' profits.

Retail-only (RO) channel in the "deviation" scenario. We denote this scenario as "C_RO", which represents "*collusion; retail-only channel*" strategy. Recall that when $c_m \geq \frac{1}{n+1}a$, the manufacturer adopts the retail-only channel strategy and its optimal wholesale price is $w^{*C\_RO} = w^{*NC\_RO} = \frac{a}{2}$ (see Proposition 1). However, since the retailers deviate and collude, they maximize their cooperative profits by choosing the total output $q_r^{C\_RO}$:

$$\pi_r^{C\_RO} = (p^{C\_RO} - w^{C\_RO})q_r^{C\_RO}, \quad q_r^{C\_RO} = \sum_{i \in N} q_i^{C\_RO}. \tag{11}$$

In the above equation, $p^{C\_RO} = a - q_r^{C\_RO}$. Given that $w^{*C\_RO} = \frac{a}{2}$, solving the first-order condition associated with Eq. (11) yields

$$q_i^{*C\_RO} = \frac{q_r^{*C\_RO}}{n} = \frac{1}{4n}a. \tag{12}$$

w^{*C_RO} and $q_i^{*C\_RO}$ can be readily employed to obtain the equilibrium retail price:

$$p^{*C\_RO} = \frac{3}{4}a. \tag{13}$$

Substituting w^{*C_RO} and $q_i^{*C\_RO}$ into the profit functions (i.e., Eqs. (1) and (11)), we derive the manufacturer's and each retailer's profits for the stage game:

$$\pi_m^{*C\_RO} = \frac{1}{8}a^2 \quad \text{and} \quad \pi_i^{*C\_RO} = \frac{1}{16n}a^2. \tag{14}$$

Dual-channel strategy (D) in the "deviation" scenario. We denote this scenario as "C_D", which represents "*collusion; dual-channel*" strategy. Recall that the manufacturer adopts the dual-channel strategy when $c_m < \frac{1}{n+1}a$, and its wholesale price and direct sales are $w^{*C\_D} = w^{*NC\_D} = \frac{a}{2}$ and $q_0^{*C\_D} = q_0^{*NC\_D} = \frac{1}{2}(a-(n+1)c_m)$, respectively. If the retailers deviate and collude, they choose $q_r^{C\_D}$ to maximize

$$\pi_r^{C\_D} = (p^{C\_D} - w^{*C\_D})q_r^{C\_D} = (a - q_r^{C\_D} - q_0^{*C\_D} - w^{*C\_D})q_r^{C\_D}. \tag{15}$$

It can be shown that the retailers' optimal output is $q_r^{*C\_D} = \frac{n+1}{4}c_m$. Then the manufacturer's optimal profit can be readily derived as:

$$\pi_m^{*C\_D} = \frac{1}{8}(2a^2 - 4ac_m + c_m^2(3 + 2n - n^2)). \tag{16}$$

Each retailer's optimal output, retail price, and profit are

$$q_i^{*C\_D} = \frac{n+1}{4n}c_m, \quad p^{*C\_D} = \frac{1}{4}(2a + (n+1)c_m), \quad \text{and} \quad \pi_i^{*C\_D} = \frac{(n+1)^2}{16n}c_m^2. \tag{17}$$

The equilibrium outcomes of the "*deviation*" scenario are summarized in Proposition 2. In this scenario, although the manufacturer's channel decision is the same as that in the "*NC*" scenario, the corresponding firm profits are different. The reason is that when retailers deviate from what the manufacturer desires, both the retail quantity and the retail price change.

Proposition 2.

(1) *When $c_m < \frac{1}{n+1}a$, the manufacturer adopts the dual-channel strategy and $w^{*C\_D} = \frac{a}{2}$, $q_0^{*C\_D} = \frac{1}{2}(a - (n+1)c_m)$, if retailers deviate and collude,*

$$\begin{aligned} q_i^{*C\_D} &= \frac{n+1}{4n}c_m, \quad p^{*C\_D} = \frac{1}{4}(2a + (n+1)c_m), \quad \textit{and} \\ \pi_i^{*C\_D} &= \frac{(n+1)^2}{16n}c_m^2. \end{aligned} \tag{18}$$

The manufacturer's corresponding profit is

$$\pi_m^{*C\_D} = \frac{1}{8}(2a^2 - 4ac_m + c_m^2(3 + 2n - n^2)). \tag{19}$$

(2) *When $c_m \geq \frac{1}{n+1}a$, the manufacturer chooses the retail-only channel strategy and $w^{*C\_RO} = \frac{a}{2}$, if retailers deviate and collude,*

$$q_i^{*C\_RO} = \frac{1}{4n}a, \quad p^{*C\_RO} = \frac{3}{4}a, \quad \textit{and} \quad \pi_i^{*C\_RO} = \frac{1}{16n}a^2. \tag{20}$$

The manufacturer's corresponding profit is

$$\pi_m^{*C\_RO} = \frac{1}{8}a^2. \tag{21}$$

We compare the retailers' equilibrium profits in the "*deviation*" scenario with that in the "*NC*" scenario (see the second column of Table 2) and examine whether it is incentive-compatible for the retailers to deviate in a single-shot game. Corollary 1 summarizes the results.

Corollary 1. *In a certain period, the retailers are better off while the manufacturer is worse off when the retailers collude. In particular, when $c_m < \frac{1}{n+1}a$, $\pi_i^{*C\_D} > \pi_i^{*NC\_D}$ and $\pi_m^{*C\_D} < \pi_m^{*NC\_D}$; when $c_m \geq \frac{1}{n+1}a$, $\pi_i^{*C\_RO} > \pi_i^{*NC\_RO}$ and $\pi_m^{*C\_RO} < \pi_m^{*NC\_RO}$.*

Consistent with conventional wisdom, collusion makes the retailers better off and the manufacturer worse off. The retailers benefit from collusion in a single-shot game because collusion enables them to collectively act like a monopolist toward the marketplace. However, after detecting the collusion, the manufacturer will punish the retailers in subsequent periods, which impairs the retailers' future profits. We next examine the sub-scenario in which the manufacturer punishes the deviating retailers.

3.3. *The "collusion with manufacturer punishment" scenario*

If the retailers collude in period t ($t = 1, 2, \ldots$), the manufacturer will punish them in subsequent periods by changing its channel strategy. It is straightforward to show that the retailers' best response is to collude. In this scenario, the manufacturer first determines the channel strategy (and the direct output q_0 if relevant) and wholesale price by treating the collective of retailers as a monopolist. Then the retailers submit their order quantities in a collusive fashion.

Retail-only (RO) channel with manufacturer punishment. We denote this scenario as "P_RO", which refers to "*punishment*; *the retail-only channel*" strategy. In this setting, retailers maximize their cooperative profit as shown in Eq. (11). Solving the first-order condition for Eq. (11) yields the best-response function of the retailers:

$$q_r^{P\_RO}(w^{P\_RO}) = \frac{1}{2}(a - w^{P\_RO}). \tag{22}$$

Substituting Eq. (22) into the manufacturer's profit function yields $\pi_m^{P\_RO} = w^{P\_RO} q_r^{P\_RO} = (a - w^{P\_RO})w^{P\_RO}/2$, and maximizing this leads to the equilibrium wholesale price $w^{*P\_RO} = \frac{a}{2}$. Then, the market-clearing price and the retail output are

$$p^{*P\_RO} = \frac{3}{4}a \quad \text{and} \quad q_r^{*P\_RO} = \frac{1}{4}a. \tag{23}$$

The manufacturer's and retailers' equilibrium profits are

$$\pi_m^{*P\_RO} = \frac{1}{8}a^2 \quad \text{and} \quad \pi_i^{*P\_RO} = \frac{1}{16n}a^2. \tag{24}$$

Dual-channel strategy (D) with manufacturer punishment. We denote this scenario as "P_D", which refers to "*punishment*; *the dual-channel*" strategy. In a dual-channel setting with manufacturer punishment, retailer i's and the manufacturer's respective profits are

$$\begin{aligned} \pi_i^{P\_D} &= \frac{1}{n}(p^{P\_D} - w^{P\_D})q_r^{P\_D}, \\ \pi_m^{P\_D} &= (p^{P\_D} - c_m)q_0^{P\_D} + w^{P\_D} q_r^{P\_D}. \end{aligned} \tag{25}$$

In Eq. (25), $p^{P\_D} = a - q_r^{P\_D} - q_0^{P\_D}$. We derive the subgame perfect equilibrium using backward induction and summarize the results in Proposition 3.

Proposition 3. *In the dual-channel setting, the subgame-perfect equilibrium with manufacturer punishment is as follows*:

(1) *When* $c_m < \frac{1}{2}a$, *the manufacturer's equilibrium wholesale price, direct output, and profit are*

$$\begin{aligned} w^{*P\_D} &= \frac{1}{2}a, \quad q_0^{*P\_D} = \frac{1}{2}(a - 2c_m), \quad \textit{and} \\ \pi_m^{*P\_D} &= \frac{1}{4}(a - c_m)^2 + \frac{1}{4}c_m^2. \end{aligned} \tag{26}$$

In turn, the retailers' equilibrium output, retail price, and profit are

$$q_i^{*P\_D} = \frac{1}{2n}c_m, \quad p^{*P\_D} = \frac{1}{2}(a + c_m), \quad \textit{and} \quad \pi_i^{*P\_D} = \frac{1}{4n}c_m^2. \tag{27}$$

(2) *When* $c_m \geq \frac{1}{2}a$, *the direct channel incurs no sales. The manufacturer's equilibrium wholesale price and profit are*

$$w^{*P\_D} = \frac{1}{2}a \quad \textit{and} \quad \pi_m^{*P\_D} = \frac{1}{8}a^2. \tag{28}$$

The retailers' equilibrium output, retail price, and profit are

$$q_i^{*P\_D} = \frac{1}{4n}a, \quad p^{*P\_D} = \frac{3}{4}a, \quad \textit{and}\ \pi_i^{*P\_D} = \frac{1}{16n}a^2. \tag{29}$$

Channel strategy with manufacturer punishment. Comparing the equilibrium in the above two settings, the manufacturer's channel strategy is derived and summarized in Theorem 2.

Theorem 2. *Under manufacturer punishment, when* $c_m < \frac{1}{2}a$, *the manufacturer adopts a dual-channel strategy; when* $c_m \geq \frac{1}{2}a$, *the manufacturer relies only on the retail channel.*

The detailed equilibrium results are shown in the third column of Table 2. As illustrated by Theorem 2, in anticipation of retailer collusion, the manufacturer chooses the dual-channel strategy in future periods when its direct selling efficiency is relatively high (i.e., $c_m < \frac{a}{2}$). Compared to the "*NC*" scenario of the stage game (see Theorem 1), in presence of retailer collusion the manufacturer chooses to sell direct with $q_0^{*P\_D} = \frac{1}{2}(a - 2c_m)$ even if it is relatively less efficient in direct selling (i.e., $\frac{a}{n+1} \leq c_m < \frac{a}{2}$) (see Fig. 3). Therefore, in the presence of retailer collusion, the manufacturer relies more on direct sales.

In the "*collusion*" scenario, we also compared the manufacturer's payoff with punishment versus without punishment. Proposition 4 summarizes the results.

Proposition 4. *Compared to "collusion" without punishment, the manufacturer is better off or indifferent when punishing the retailers by treating them as a monopolist.*

Therefore, in a repeated game with infinite periods, if the retailers ever collude in one period, the manufacturer always has incentive to punish the retailers by

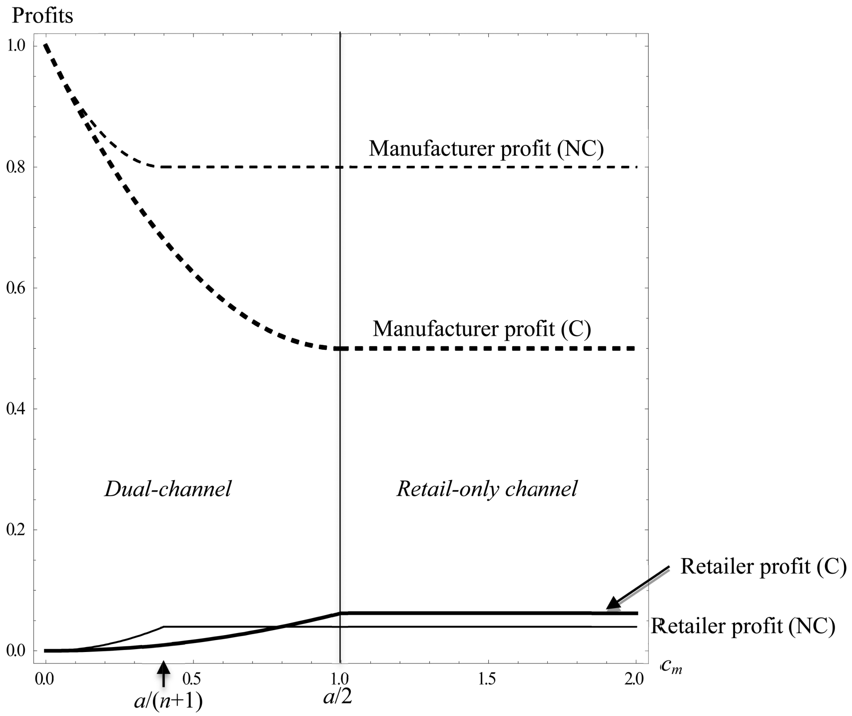

Fig. 3. Firm profits in "*NC*" versus "*collusion*" (C) *scenario* ($a = 2$, $n = 4$).

changing its channel strategy in future periods. It is worth noting that the "*collusion with manufacturer punishment*" scenario is equivalent to the "*manufacturer treats retailers as a cartel*" scenario (i.e., path $a'' - e'$ in Fig. 2), which we will not examine. In the next section, we derive the conditions under which the manufacturer's punishment is effective in deterring retailer collusion and the manufacturer's optimal channel strategy in a repeated game.

3.4. *The deterrence effect of the manufacturer's channel strategy*

If retailers do not collude, their discounted profits over infinite periods are the single-period profit multiplied by $1/(1 - \delta)$ (see the second column of Table 3). If the retailers collude, they gain higher short-run profits in the "*deviating*" period (see Corollary 1) but experience lower profits in all future periods due to the manufacturer's punishment. The retailers' discounted profits in the "*collusion*" scenario are shown in the third column of Table 3.

We then derive the role of the manufacturer's channel strategy in deterring retailer collusion by comparing the retailers' profits over infinite periods in the "*no collusion*" versus "*collusion*" scenario (see Theorem 3 and the fourth column of Table 3). Figure 4 provides a graphical illustration.

Table 3. Deterrence effect of the manufacturer's channel strategy.

	"*No collusion*"	"*Collusion*"	Is Deterrence Effective?
$c_m < \frac{1}{n+1}a$	$\pi_i^{*NC} = \frac{1}{(1-\delta)}\frac{c_m^2}{4}$	$\pi_i^{*C} = \frac{(n+1)^2}{16n}c_m^2 + \frac{\delta}{(1-\delta)}\frac{c_m^2}{4n}$	Effective if $\frac{n-1}{n+3} = \delta_1 < \delta < 1$, the manufacturer *sells directly* with $q_0^{*NC\_D} = \frac{1}{2}(a-(n+1)c_m)$.
			If $\delta \le \delta_1$, the deterrence is not effective and the manufacturer *sells directly* with $q_0^{*C\_D} = \frac{1}{2}(a-2c_m)$.
$\frac{1}{n+1}a \le c_m < \frac{\sqrt{n}}{n+1}a$	$\pi_i^{*NC} = \frac{1}{(1-\delta)}\frac{a^2}{4(n+1)^2}$	$\pi_i^{*C} = \frac{1}{16n}a^2 + \frac{\delta}{(1-\delta)}\frac{c_m^2}{4n}$	Effective if $\frac{a^2(n-1)^2}{(n+1)^2(a^2-4c^2)} = \delta_2 < \delta < 1$, the manufacturer adopts the *retail-only channel strategy.*
			If $0 < \delta \le \delta_2$, the deterrence is not effective and the manufacturer *sells directly* with $q_0^{*P\_D} = \frac{1}{2}(a-2c_m)$.
$\frac{\sqrt{n}}{n+1}a \le c_m < \frac{1}{2}a$		$\pi_i^{*C} = \frac{1}{16n}a^2 + \frac{\delta}{(1-\delta)}\frac{c_m^2}{4n}$	Not effective and the manufacturer adopts a *dual-channel strategy* with direct sales $q_0^{*P\_D} = \frac{1}{2}(a-2c_m)$.
$c_m \ge \frac{1}{2}a$		$\pi_i^{*C} = \frac{1}{16n}a^2 + \frac{\delta}{(1-\delta)}\frac{a^2}{16n}$	Not effective and the manufacturer adopts the *retail-only channel strategy*.

Theorem 3. *Over infinite periods, the equilibrium results are:*

(1) *When* $c_m < \frac{1}{n+1}a$, *the manufacturer's punishment is effective if* $\frac{n-1}{n+3} = \delta_1 < \delta < 1$. *The manufacturer adopts the dual-channel strategy with* $q_0 = \frac{1}{2}(a-(n+1)c_m)$ *and retailers do not collude. If* $\delta \leq \delta_1$, *the manufacturer's punishment is not effective and retailers collude. In this case, the manufacturer still adopts the dual-channel strategy but relies more on the direct channel with* $q_0 = \frac{1}{2}(a-2c_m)$.

(2) *When* $\frac{1}{n+1}a \leq c_m < \frac{\sqrt{n}}{n+1}a$, *the manufacturer's punishment is effective if* $\frac{a^2(n-1)^2}{(n+1)^2(a^2-4c^2)} = \delta_2 < \delta < 1$. *In this case, the manufacturer adopts the retail-only channel strategy and retailers do not collude. However, if* $0 < \delta \leq \delta_2$, *the punishment is not effective and retailers collude. The manufacturer will adopt the dual-channel strategy (instead of the retail-only channel strategy) with* $q_0 = \frac{1}{2}(a-2c_m)$.

(3) *When* $\frac{\sqrt{n}}{n+1}a \leq c_m < \frac{a}{2}$, *the manufacturer's punishment is not effective and retailers will always collude. In this case, the manufacturer adopts the dual-channel strategy with direct sales* $q_0 = \frac{1}{2}(a-2c_m)$.

(4) *When* $c_m \geq \frac{a}{2}$, *the manufacturer's punishment is not effective and the retailers will always collude. However, the manufacturer adopts the retail-only channel strategy because it is highly inefficient in direct selling.*

According to Theorem 3 and Fig. 4, the parameter space can be divided into four areas. We discuss the equilibrium in each area. In *area I* where the manufacturer is highly efficient in direct selling (i.e., $c_m < \frac{1}{n+1}a$) and the discount rate is sufficiently large (i.e., $\delta > \delta_1$), the manufacturer adopts the dual-channel strategy and no collusion is the optimal decision for the retailers. In this situation, two forces jointly

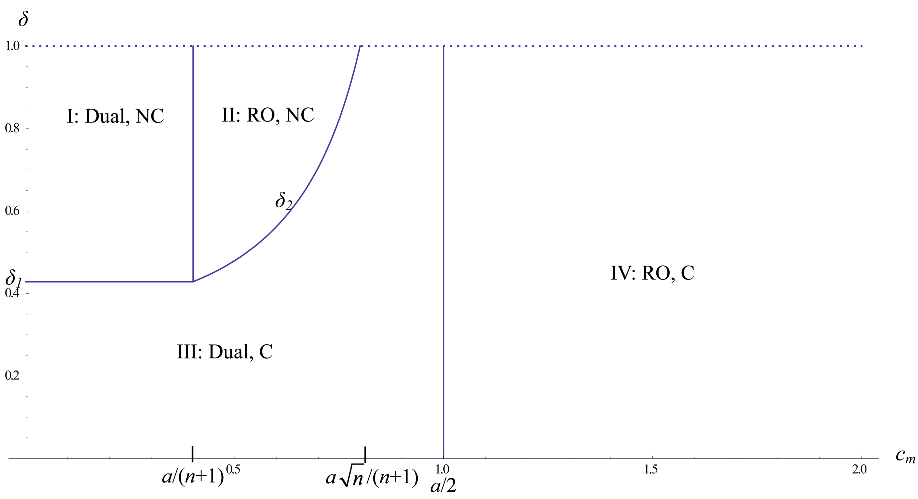

Fig. 4. The manufacturer's channel strategy and retailers' collusion decision ($a = 2$, $n = 4$).

induce the retailers to abandon collusion. First, the large discount rate endows the reduction in future profits (under manufacturer punishment) with a greater impact upon the retailers' long-run profits. We call this the "discounting effect." Second, since the manufacturer has high efficiency in direct selling, once aware of the retailers' collusion it will increase its direct sales and reduce the collusive retailers' profits in future periods. We call this the "deterrence effect of direct selling." Because of the discounting effect and the deterrence effect, the retailers' one-time gain cannot offset the future profit loss created by the manufacturer's punishment, inducing the retailers to abandon collusion. These findings suggest that the manufacturer's high efficiency in direct selling may deter retailers from collusion.

In *area II* where the manufacturer's efficiency in direct selling is moderate (i.e., $\frac{1}{n+1}a \leq c_m < \frac{\sqrt{n}}{n+1}a$) and the discount rate is large (i.e., $\delta > \delta_2$), the manufacturer will adopt the retail-only channel strategy to induce no collusion and the retailers do not collude. Note that δ_2 increases with c_m, indicating that as the manufacturer becomes less efficient in direct selling, the discount rate needs to be larger for the retailers to give up collusion. In other words, when the deterrence effect of direct selling becomes smaller, the discounting effect needs to be stronger to deter retailers from collusion. In addition, it is worth noting that the retail-only channel strategy is also more profitable for the manufacturer. This interesting finding indicates that no collusion with retail-only channel strategy is win-win for the manufacturer and the retailers. However, if the retailers dare to collude in one period, the manufacturer will switch to the dual-channel strategy and rely more on the direct channel. Thus, the manufacturer can deter retailer collusion by strategically refraining from direct selling.

In *area III*, when the manufacturer is relatively efficient in direct selling (i.e., $c_m < \frac{\sqrt{n}}{n+1}a$), the discount rate has to be relatively small for the retailers to benefit from collusion and thus the manufacturer's punishment is less severe for the retailers. To attenuate the adverse effect of retailer collusion, the manufacturer sells the product through both the retail and the direct channel. When the manufacturer is relatively inefficient in direct selling (i.e., $\frac{\sqrt{n}}{n+1}a \leq c_m < \frac{a}{2}$), the deterrence effect of direct selling is not evident and the retailers will always collude, no matter how large the discount rate. In this case, the manufacturer still adopts the dual-channel strategy, trying to counteract the negative impact of retailer collusion through direct selling.

Finally, when the manufacturer is highly inefficient in direct selling (i.e., $c_m \geq \frac{a}{2}$), it is too costly for the manufacturer to sell directly even if the retailers collude. As a result, the manufacturer has to fully depend on the retail channel and the dual-channel strategy is no longer a viable option.

To sum up, in contrast to the retail-only regime in which retailers always benefit from horizontal collusion, when the manufacturer can sell through the direct channel, the retailers will contemplate collusion only when the manufacturer's direct selling efficiency is sufficiently low or the discount rate is relatively small. The retailers will abandon collusion when the discount rate is large and the manufacturer's direct selling efficiency is relatively high. A large discount rate makes the manufacturer's punishment more consequential while efficiency in direct selling makes the manufacturer's encroachment a real threat. Both effects make collusion less profitable for retailers in the long run.

4. Conclusion

This paper examines whether and when the manufacturer's channel strategy may dampen the downstream retailers' collusive tendencies. We use a game-theoretic model with infinite periods to illuminate the interplay between the manufacturer's channel strategy and retailer collusion, and obtain a number of interesting findings.

- The presence of retailer collusion changes the upstream manufacturer's channel strategy, making the manufacturer consider the retail channel less attractive and rely more on direct selling.
- If the manufacturer may change channel strategy over time, collusion may not be the optimal strategy for the retailers even when they can sustain collusion at no cost, so that "*no collusion*" can be win-win for both parties under certain conditions.
- When firms weigh profits of future periods more heavily (i.e., when the discount rate is large) and the manufacturer is highly efficient in direct selling, the dual-channel strategy allows the manufacturer to undercut collusive retailers and thus deters their collusion.
- When the discount rate is sufficiently large and the manufacturer is relatively efficient in direct selling but not efficient enough to severely undercut the collusive retailers, the manufacturer strategically refrains from direct selling (i.e., adopting the retail-only channel strategy) and its efficiency in direct selling deters the retailers from colluding.

These findings suggest that the manufacturer can regulate the retailers' collusive behavior by strategically changing its channel strategy. This research extends prior understanding of horizontal (retailer) collusion by connecting that body of literature to the manufacturer's channel strategy. Related prior research focuses mainly on the vertical practices that may facilitate or hinder horizontal collusion. This paper proposes conditions under which the manufacturer's channel structure may play a strategic role in deterring retailer collusion. In a repeated game where the manufacturer can change its channel strategy, we find that the retailers will not collude when they discount future profits with a large discount rate (i.e., the discounting effect) and the manufacturer is relatively efficient in direct selling (i.e., the deterrence effect of direct selling).

This research also contributes to the literature regarding manufacturer use of direct channels. Prior research suggests that the direct channel enables manufacturers to obtain higher margins and better serve customers (Stern *et al.*, 1996), and to regain leverage in the manufacturer-retailer interaction. Chiang *et al.* (2003) point out that establishing a direct channel may bring indirect benefits to the manufacturer even if the direct channel handles no sales. Our finding that direct channel entry may deter retailer collusion adds to the understanding of the strategic role of manufacturers' channel strategy and complements prior research on manufacturer-retailer interaction.

This research has several limitations awaiting future research. First, the direct channel may differ from the retail channel in many dimensions (e.g., service quality and convenience). We have focused only on what can be captured in the difference in variable cost across channels. Future research may examine other distinctive attributes of the channel types. Second, in modelling retailer collusion, we have a relatively strong assumption that either all or none of the retailers engage in collusion (Clarke, 1983) and that collusion incurs no cost. Future research may explore the situation where some subset of the retailers engages in collusion or sustaining collusion is costly. Finally, more channel and supply chain configurations can be the basis of future research. For instance, retailers may also adopt their own multi-channel strategies and the upstream layer may contain more than one manufacturer.

Appendix A.

Proof of Proposition 1. When retailers do not collude, in the dual-channel setting each retailer chooses quantity $q_i^{NC\_D}$ to maximize its own profit in Eq. (6). Performing the maximization yields $2q_i^{NC\_D} = a - w^{NC\_D} - q_0^{NC\_D} - \sum_{j\in N, j\neq i} q_j^{NC\_D}$. Jointly solving n first-order conditions (corresponding to n retailers) provides:

$$q_i^{NC\_D}(w^{NC\_D}, q_0^{NC\_D}) = \frac{1}{n+1}(a - w^{NC\_D} - q_0^{NC\_D}). \tag{A.1}$$

Therefore, when $a - w^{NC\_D} - q_0^{NC\_D} > 0, q_i^{NC\_D}(w^{NC\_D}, q_0^{NC\_D}) = \frac{1}{n+1}(a - w^{NC\_D} - q_0^{NC\_D})$; when $a - w^{NC\_D} - q_0^{NC\_D} \leq 0, q_i^{NC\_D}(w^{NC\_D}, q_0^{NC\_D}) = 0$. Now consider the first stage of the subgame, in which the manufacturer chooses $w^{NC_D}$and $q_0^{NC_D}$to maximize the profit in Eq. (5).

(1) When $a - w^{NC\_D} - q_0^{NC\_D} \leq 0$, $q_i^{*NC\_D} = 0$. No sales occur in the retail channels. The manufacturer's optimal direct output is $q_0^{*NC\_D} = \frac{1}{2}(a - c_m)$. In this case, in the dual-channel strategy setting, the manufacturer sets $w^{*NC\_D} = \frac{1}{2}(a + c_m)$. The manufacturer's optimal profit is:

$$\pi_m^{*NC\_D} = \frac{1}{4}(a - c_m)^2 \tag{A.2}$$

(2) When $a - w^{NC\_D} - q_0^{NC\_D} > 0$, $q_i^{NC\_D}(w^{NC\_D}, q_0^{NC\_D}) = \frac{1}{n+1}(a - w^{NC\_D} - q_0^{NC\_D})$ as given by Eq. (A.1). Substituting (A.1) into Eq. (5), the manufacturer chooses w^{NC_D} and $q_0^{NC\_D}$ to maximize

$$\begin{aligned}\pi_m^{NC\_D}(w^{NC\_D}, q_0^{NC\_D}) &= \left(a - c_m - q_0^{NC\_D} - \frac{n}{n+1}(a - w^{NC\_D} - q_0^{NC\_D})\right)\\ &\quad \times q_0^{NC\_D} + \frac{n}{n+1}w^{NC\_D}(a - w^{NC\_D} - q_0^{NC\_D}).\end{aligned} \tag{A.3}$$

It can be verified that the Hessian matrix of Eq. (A.3) is negative definite. The F.O.C. provides $q_0^{*NC\_D} = \frac{1}{2}(a - (n+1)c_m)$. Therefore, when $c_m < \frac{1}{n+1}a$, $q_0^{*NC\_D} = \frac{1}{2}(a-(n+1)c_m)$, and then $w^{*NC\_D} = \frac{1}{2}a$. Note that $a - w^{NC\_D} - q_0^{NC\_D} > 0$, and substituting w^{*NC_D} and $q_0^{*NC\_D}$ into $q_i^{NC\_D}(w^{NC\_D}, q_0^{NC\_D}) = \frac{1}{n+1}(a - w^{NC\_D} - q_0^{NC\_D})$ provides $q_i^{*NC\_D} = \frac{1}{2}c_m$. Further substituting $w^{*NC\_D}, q_0^{*NC\_D}$, and $q_i^{*NC\_D}$ into $p^{NC\_D} = a - q_0^{NC\_D} - \sum_{j\in N} q_j^{NC\_D}$ and Eq. (6) yields $p^{*NC\_D} = \frac{1}{2}(a+c_m)$ and $\pi_i^{*NC\_D} = \frac{1}{4}c_m^2$. The manufacturer's optimal profit can also be readily derived:

$$\pi_m^{*NC\_D} = \frac{1}{4}(a - c_m)^2 + \frac{n}{4}c_m^2. \tag{A.4}$$

When $c_m \geq \frac{1}{n+1}a$, $q_0^{NC\_D} = \frac{1}{2}(a-(n+1)c_m) \leq 0$. The optimal solution occurs on the boundary, i.e., $q_0^{*NC\_D} = 0$. In this case, the manufacturer's profit is $\pi_m^{NC\_D} = \frac{n}{n+1}w(a - w)$. Therefore, $w^{*NC\_D} = \frac{1}{2}a$. The manufacturer's optimal profit is:

$$\pi_m^{*NC\_D} = \frac{n}{4(n+1)}a^2. \tag{A.5}$$

Combining (1) and (2) it can be verified that when $c_m < \frac{1}{n+1}a$, the manufacturer's profit in Eq. (A.4) is greater than that in Eq. (A.2), and when $c_m \geq \frac{1}{n+1}a$, the manufacturer's profit in Eq. (A.5) is greater than that in Eq. (A.2). Therefore, in the dual-channel strategy setting, the manufacturer never sets a wholesale price that is too high to induce any retail sales. This completes the proof of Proposition 1. □

Proof of Theorem 1. The proof of Proposition 1 is readily employed to show that when $c_m < \frac{1}{n+1}a$, the manufacturer's optimal profit in the dual-channel setting is larger than that in the retail-only channel setting. That is, $\pi_m^{*NC\_D} = \frac{1}{4}(a - c_m)^2 + \frac{n}{4}c_m^2 > \pi_m^{*NC\_RO} = \frac{n}{4(n+1)}a^2$. Thus, in this case, the manufacturer adopts the dual-channel strategy with sales occurring in both channels. When $c_m \geq \frac{1}{n+1}a$, $\pi_m^{*NC\_D} = \frac{n}{4(n+1)}a^2 = \pi_m^{*NC\_RO}$. Therefore, the manufacturer relies only on the retail outlets. □

Proof of Proposition 2. When the retailers deviate and collude in one period, the manufacturer's channel strategy (and q_0 if relevant) and wholesale price remain the same as in the "*no collusion*" scenario.

Recall that when $c_m \geq \frac{1}{n+1}a$, the manufacturer adopts the retail-only channel strategy and its optimal wholesale price $w^{*C\_RO} = w^{*NC\_RO} = \frac{a}{2}$. In the "*deviation*" scenario, the retailers collude, and thus they maximize the cooperative profit by choosing total output $q_r^{C\_RO}$:

$$\pi_r^{C\_RO} = (a - q_r^{C\_RO} - w^{C\_RO})q_r^{C\_RO}, \quad q_r^{C\_RO} = \sum_{i\in N} q_i^{C\_RO}. \tag{A.6}$$

Substituting w^{*C_RO} into Eq. (A.6) and solving the first-order condition associated with Eq. (A.6) yields $q_i^{*C\_RO} = \frac{q_r}{n} = \frac{1}{4n}a$. It can be verified that the second-order condition associated with Eq. (A.6) is negative. w^{*C_RO} and $q_i^{*C\_RO}$ can then be readily employed to obtain the equilibrium retail price $p^{*C\_RO} = a - q_r^{*C\_RO} = \frac{3}{4}a$. Substituting w^{*C_RO} and $q_i^{*C\_RO}$ into the profit functions (i.e., Eqs. (1) and (11)), we can derive the manufacturer's and each retailer's optimal profits:

$$\pi_m^{*C\_RO} = \frac{1}{8}a^2 \quad \text{and} \quad \pi_i^{*C\_RO} = \frac{1}{16n}a^2. \tag{A.7}$$

When $c_m < \frac{1}{n+1}a$ the manufacturer adopts the dual-channel strategy and its wholesale price and direct sales are $w^{*C\_D} = \frac{a}{2}$ and $q_0^{*C\_D} = \frac{1}{2}(a - (n+1)c_m)$, respectively. If the retailers collude, they choose $q_r^{C\_D}$ to maximize

$$\pi_r^{C\_D} = (a - q_r^{C\_D} - q_0^{*C\_D} - w^{*C\_D})q_r^{C\_D}, \quad q_r^{C\_D} = \sum_{i \in N} q_i^{C\_D}. \tag{A.8}$$

Substituting w^{*C_D} and $q_0^{*C\_D}$ into Eq. (A.8) and solving the first-order condition associated with the equation yields $q_r^{*C\_D} = \frac{n+1}{4}c_m$ and $q_i^{*C\_D} = \frac{q_r}{n} = \frac{n+1}{4n}c_m$. We then substitute w^{*C_D}, $q_i^{*C\_D}$, and $q_0^{*C\_D}$ into Eq. (5), and derive the manufacturer's optimal profit:

$$\pi_m^{*C\_D} = \frac{1}{8}(2a^2 - 4ac_m + c_m^2(3 + 2n - n^2)). \tag{A.9}$$

The optimal retail price is

$$p^{*C\_D} = a - q_r^{*C\_D} - q_0^{*C\_D} = \frac{1}{4}(2a + (n+1)c_m). \tag{A.10}$$

The retailer's optimal profit is

$$\pi_i^{*C\_D} = \frac{(n+1)^2}{16n}c_m^2. \tag{A.11}$$

This completes the proof of Proposition 2. □

Proof of Corollary 1. When $c_m < \frac{1}{n+1}a$, it can be shown that $\pi_i^{*C\_D} - \pi_i^{*NC\_D} = \frac{(n+1)^2}{16n}c_m^2 - \frac{1}{4}c_m^2 = \frac{(n-1)^2}{16n}c_m^2$. Thus, $\pi_i^{*C\_D} - \pi_i^{*NC\_D} > 0$. For the manufacturer's profit, $\pi_m^{*C\_D} - \pi_m^{*NC\_D} = \frac{1}{8}(2a^2 - 4ac_m + c_m^2(3 + 2n - n^2)) - \left(\frac{1}{4}(a - c_m)^2 + \frac{n}{4}c_m^2\right) = (1 - n^2)c_m^2$. We assume that there is more than one retailer (i.e., $n > 1$), and therefore $\pi_m^{*C\_D} - \pi_m^{*NC\_D} < 0$.

When $c_m \geq \frac{1}{n+1}a$, the manufacturer chooses to sell the product only through the retail channel. In this case, it can be shown that $\pi_i^{*C\_RO} - \pi_i^{*NC\_RO} = \frac{1}{16n}a^2 - \frac{1}{4(n+1)^2}a^2 = \frac{(n-1)^2}{16n(n+1)^2}a^2 > 0$. For the manufacturer's profit, $\pi_m^{*C\_RO} - \pi_m^{*NC\_RO} = \frac{1}{8}a^2 - \frac{n}{4(n+1)}a^2 = \frac{(1-n)}{8(n+1)}a^2 < 0$.

Therefore, compared to the "*no collusion*" scenario, in the "*deviation*" scenario the retailers are better off while the manufacturer is worse off. This completes the proof of Corollary 1. □

Proof of Proposition 3. When the manufacturer punishes the collusive retailers, in the second stage the retailers choose their total output q_r to maximize the profit

$\pi_i^{P\text{-}D}$ in Eq. (25). Performing the maximization yields:

$$q_r^{P\text{-}D}(w^{P\text{-}D}, q_0^{P\text{-}D}) = \frac{1}{2}(a - w^{P\text{-}D} - q_0^{P\text{-}D}). \tag{A.12}$$

Thus, when $a - w^{P\text{-}D} - q_0^{P\text{-}D} > 0, q_i^{P\text{-}D}(w^{P\text{-}D}, q_0^{P\text{-}D}) = \frac{1}{2n}(a - w^{P\text{-}D} - q_0^{P\text{-}D})$; when $a - w^{P\text{-}D} - q_0^{P\text{-}D} \leq 0, q_i^{P\text{-}D}(w^{P\text{-}D}, q_0^{P\text{-}D}) = 0$.

Now consider the first stage of the subgame, the manufacturer chooses $w^{P\text{-}D}$ and $q_0^{P\text{-}D}$ to maximize the profit $\pi_m^{P\text{-}D}$ in Eq. (25). When $a - w^{P\text{-}D} - q_0^{P\text{-}D} \leq 0$, $q_r^{*P\text{-}D} = q_i^{*P\text{-}D} = 0$. No sales occur in the retail channels. By maximizing $\pi_m^{P\text{-}D}$ with respect to $q_0^{P\text{-}D}$, we obtain the manufacturer's optimal direct output $q_0^{*P\text{-}D} = \frac{1}{2}(a - c_m)$. In this case, the manufacturer sets $w^{*P\text{-}D} = \frac{1}{2}(a + c_m)$. Substituting $w^{*P\text{-}D}$, $q_0^{*P\text{-}D}$, and $q_r^{*P\text{-}D}$ into $\pi_m^{P\text{-}D}$, we can readily derive the manufacturer's optimal profit:

$$\pi_m^{*P\text{-}D} = \frac{1}{4}(a - c_m)^2. \tag{A.13}$$

When $a - w^{P\text{-}D} - q_0^{P\text{-}D} > 0$, $q_i^{P\text{-}D}(w^{P\text{-}D}, q_0^{P\text{-}D}) = \frac{q_r^{P\text{-}D}(w^{P\text{-}D}, q_0^{P\text{-}D})}{n} = \frac{1}{2n}(a - w^{P\text{-}D} - q_0^{P\text{-}D})$. Substituting (A.12) into $\pi_m^{P\text{-}D}$ in Eq. (25), the manufacturer chooses $w^{P\text{-}D}$ and $q_0^{P\text{-}D}$ to maximize

$$\begin{aligned}\pi_m^{P\text{-}D}(w^{P\text{-}D}, q_0^{P\text{-}D}) = {} & \left(a - q_0^{P\text{-}D} - \frac{1}{2}(a - w^{P\text{-}D} - q_0^{P\text{-}D}) - c_m\right) q_0^{P\text{-}D} \\ & + w^{P\text{-}D}\frac{1}{2}(a - w^{P\text{-}D} - q_0^{P\text{-}D}). \end{aligned} \tag{A.14}$$

It can be verified that the Hessian matrix of (A.14) is negative definite. The F.O.C. provides $q_0^{*P\text{-}D} = \frac{1}{2}(a - 2c_m)$. Therefore, when $c_m < \frac{1}{2}a$, $q_0^{*P\text{-}D} = \frac{1}{2}(a - 2c_m)$, $w^{*P\text{-}D} = \frac{1}{2}a$. Note that $a - w^{P\text{-}D} - q_0^{P\text{-}D} > 0$ holds, $q_i^{*P\text{-}D} = \frac{1}{2n}c_m$. Substituting $w^{*P\text{-}D}, q_0^{*P\text{-}D}$, and $q_i^{*P\text{-}D}$ into $p^{NC\text{-}D} = a - q_0^{P\text{-}D} - q_r^{P\text{-}D}$ and $\pi_i^{P\text{-}D}$ in Eq. (25) yields $p^{*P\text{-}D} = \frac{1}{2}(a + c_m)$ and $\pi_i^{*P\text{-}D} = \frac{1}{4n}c_m^2$, respectively. The manufacturer's optimal profit can also be readily derived:

$$\pi_m^{*P\text{-}D} = \frac{1}{4}(a - c_m)^2 + \frac{1}{4}c_m^2. \tag{A.15}$$

When $c_m \geq \frac{1}{2}a$, $q_0^{*P\text{-}D} = \frac{1}{2}(a - 2c_m) \leq 0$. The optimal solution occurs on the boundary, i.e., $q_0^{*P\text{-}D} = 0$. Substituting $q_0^{*P\text{-}D}$ into Eq. (25), we derive the manufacturer's profit as $\pi_m^{P\text{-}D} = \frac{1}{2}w^{P\text{-}D}(a - w^{P\text{-}D})$. Maximizing $\pi_m^{P\text{-}D}$ with respect to $w^{P\text{-}D}$ yields $w^{*P\text{-}D} = \frac{1}{2}a$. Then the manufacturer's optimal profit is:

$$\pi_m^{*P\text{-}D} = \frac{1}{8}a^2. \tag{A.16}$$

It can be verified that when $c_m < \frac{1}{2}a$, the manufacturer profit in Eq. (A.15) is greater than that in Eq. (A.13), and when $c_m \geq \frac{1}{2}a$, the manufacturer profit in Eq. (A.16) is also greater than that in Eq. (A.13). Therefore, in the dual-channel strategy setting, the manufacturer never sets a wholesale price that is too high to induce any retail sales. This completes the proof of Proposition 3. $\square$

Proof of Theorem 2. The proof of Proposition 3 is readily employed to show that when $c_m < \frac{1}{2}a$, the manufacturer's optimal profit in the dual-channel setting is larger than that in the retail-only channel setting. That is, $\pi_m^{*P\_D} - \pi_m^{*P\_RO} = \frac{1}{4}(a - c_m)^2 + \frac{1}{4}c_m^2 - \frac{1}{8}a^2 = \frac{(a-2c_m)^2}{8} > 0$. Thus, in this case, the manufacturer will adopt the dual-channel strategy with sales occurring in both channels. When $c_m \geq \frac{1}{2}a$, $\pi_m^{*P\_D} - \pi_m^{*P\_RO} = \frac{1}{8}a^2 - \frac{1}{8}a^2 = 0$. In this case, we assume that the manufacturer would not bother to establish a direct channel. Therefore, the manufacturer relies only on the retail outlets. □

Proof of Proposition 4. If the retailers collude and the manufacturer does not punish them, the manufacturer's optimal profit $\pi_m^{*C\_D} = \frac{1}{8}(2a^2 - 4ac_m + c_m^2(3 + 2n - n^2))$ when $c_m < \frac{1}{n+1}a$; $\pi_m^{*C\_RO} = \frac{1}{8}a^2$ when $c_m \geq \frac{1}{n+1}a$. However, if the manufacturer punishes the collusive retailers, the manufacturer's optimal profit $\pi_m^{*P\_D} = \frac{1}{4}(a - c_m)^2 + \frac{1}{4}c_m^2$ when $c_m < \frac{1}{2}a$; the manufacturer's optimal profit $\pi_m^{*P\_RO} = \frac{1}{8}a^2$ when $c_m \geq \frac{1}{2}a$.

(1) When $c_m < \frac{1}{n+1}a$, $\pi_m^{*P\_D} - \pi_m^{*C\_D} = \frac{1}{4}(a - c_m)^2 + \frac{1}{4}c_m^2 - \frac{1}{8}(2a^2 - 4ac_m + c_m^2(3 + 2n - n^2))$. It can be easily shown that $\pi_m^{*P\_D} - \pi_m^{*C\_D} = \frac{(n-1)^2c_m^2}{8} > 0$.

(2) When $\frac{1}{n+1}a \leq c_m < \frac{1}{2}a$, $\pi_m^{*P\_D} - \pi_m^{*C\_RO} = \frac{1}{4}(a - c_m)^2 + \frac{1}{4}c_m^2 - \frac{1}{8}a^2$. It can be shown that $\pi_m^{*P\_D} - \pi_m^{*C\_RO} = \frac{(a-2c_m)^2}{8} > 0$.

(3) When $c_m \geq \frac{1}{2}a$, $\pi_m^{*P\_RO} - \pi_m^{*C\_RO} = \frac{1}{8}a^2 - \frac{1}{8}a^2 = 0$.

Taken together, compared to "*collusion*" without punishment, the manufacturer is better off or indifferent when punishing the collusive retailers. This completes the proof of Proposition 4. □

Proof of Theorem 3. (1) When $c_m < \frac{1}{n+1}a$, the retailer's profit over infinite periods in the "*no collusion*" scenario $\pi_i^{*NC} = \frac{1}{1-\delta}\pi_i^{*NC\_D} = \frac{1}{(1-\delta)}\frac{c_m^2}{4}$; in the "*collusion*" scenario $\pi_i^{*C} = \pi_i^{*C\_D} + \frac{\delta}{(1-\delta)}\pi_i^{*P\_D} = \frac{(n+1)^2}{16n}c_m^2 + \frac{\delta}{(1-\delta)}\frac{c_m^2}{4n}$. When the deterrence of the manufacturer's punishment is effective, $\pi_i^{*NC} > \pi_i^{*C}$, i.e., $\frac{1}{1-\delta}\frac{c_m^2}{4} > \frac{(n+1)^2}{16n}c_m^2 + \frac{\delta}{(1-\delta)}\frac{c_m^2}{4n}$. It can be easily shown that this inequality holds only if $\frac{n-1}{n+3} = \delta_1 < \delta < 1$. When the deterrence is effective, the manufacturer sells the product through the direct channel with sales $q_0^{*NC\_D} = \frac{1}{2}(a - (n + 1)c_m)$. However, if $\delta \leq \delta_1 = \frac{n-1}{n+3}$, the deterrence is not effective and in order to punish the collusive retailers the manufacturer will sell more through the direct channel with $q_0^{*P\_D} = \frac{1}{2}(a - 2c_m)$.

(2) When $\frac{1}{n+1}a \leq c_m < \frac{1}{2}a$, the retailer's profit over infinite periods in the "*no collusion*" scenario is $\pi_i^{*NC} = \frac{1}{1-\delta}\pi_i^{*NC\_RO} = \frac{1}{(1-\delta)}\frac{a^2}{4(n+1)^2}$; in the "*collusion*" scenario $\pi_i^{*C} = \pi_i^{*C\_RO} + \frac{\delta}{(1-\delta)}\pi_i^{*P\_D} = \frac{1}{16n}a^2 + \frac{\delta}{(1-\delta)}\frac{c_m^2}{4n}$. When the deterrence of the manufacturer's punishment is effective, $\pi_i^{*NC} > \pi_i^{*C}$, i.e., $\frac{1}{(1-\delta)}\frac{a^2}{4(n+1)^2} > \frac{1}{16n}a^2 + \frac{\delta}{(1-\delta)}\frac{c_m^2}{4n}$. For this inequality to hold, $\delta > \frac{a^2(n-1)^2}{(n+1)^2(a^2-4c_m^2)} = \delta_2$. If $\frac{a^2(n-1)^2}{(n+1)^2(a^2-4c_m^2)} < 1$, then $\frac{1}{n+1}a \leq c_m < \frac{\sqrt{n}}{n+1}a$ has to be satisfied. Therefore, when $\frac{1}{n+1}a \leq c_m < \frac{\sqrt{n}}{n+1}a$,

the deterrence is effective only if $\frac{a^2(n-1)^2}{(n+1)^2(a^2-4c_m^2)} = \delta_2 < \delta < 1$. In this case, the manufacturer adopts the retail-only channel strategy. If $0 < \delta < \delta_2$, the deterrence is not effective and in this case the manufacturer will adopt the dual-channel strategy with $q_0^{*P\_D} = \frac{1}{2}(a - 2c_m)$.

However, when $\delta_2 = \frac{a^2(n-1)^2}{(n+1)^2(a^2-4c_m^2)} > 1$ (i.e., $\frac{\sqrt{n}}{n+1}a \leq c_m < \frac{1}{2}a$), $\pi_i^{*NC} > \pi_i^{*C}$ never holds. In this case, the deterrence is not effective and retailers will collude. To punish the retailers, the manufacturer will adopt the dual-channel strategy with sales $q_0^{*P\_D} = \frac{1}{2}(a - 2c_m)$.

(3) When $c_m \geq \frac{1}{2}a$, the retailer's profit over infinite periods in the "*no collusion*" scenario $\pi_i^{*NC} = \frac{1}{1-\delta}\pi_i^{*NC\_RO} = \frac{1}{(1-\delta)}\frac{a^2}{4(n+1)^2}$; in the "*collusion*" scenario $\pi_i^{*C} = \pi_i^{*C\_RO} + \frac{\delta}{(1-\delta)}\pi_i^{*P\_RO} = \frac{1}{16n}a^2 + \frac{\delta}{(1-\delta)}\frac{a^2}{16n}$. It can be easily shown that $\pi_i^{*NC} - \pi_i^{*C} = \frac{-a^2(n-1)^2}{16n(n+1)^2(1-\delta)} < 0$. Therefore, in this case the deterrence is not effective and the manufacturer will adopt the retail-only channel strategy. This completes the proof of Theorem 3. □

Acknowledgment

This work is financially supported by the National Natural Science Foundation of China (Grant nos. 71172032, 71502182, 71332006, and 71272039). The three authors contributed equally to this research.

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