Decentralization versus Coordination for an Incumbent Chain and an Entrant Chain under a Stackelberg Game

Zonghong Cao, Ju Zhao and Chengtang Zhang

Abstract—**This paper considers the issue of channel structure selection when an incumbent supply chain faces a potential entrant supply chain. Each chain can choose its channel structure, namely, decentralization or coordination. Specifically, both the incumbent manufacturer and the entrant manufacturer can choose to sell their products by themselves or through their exclusive retailers. Our objective is to discuss whether the entrant chain should enter the retail market and, if so, how the dominant manufacturer of each chain strategically selects the channel structure, and how the asymmetric cost information affects the equilibrium structure. The results show that (1)Under asymmetric information game, the chain without competitive advantage is more likely to exit market when the intensity of price competition increases. (2)Under the symmetric information game, both coordination and decentralization can be the optimal structure for the entrant chain and the optimal entry depends on the incumbent chains action. In contrast, under the asymmetric information game, the entrant chain prefers coordinated structure rather than decentralized structure. (3)As the entrant products competitiveness increases, the incumbent manufacturer will switch from coordinated structure to decentralized structure. (4)When the price competition intensity increases, the entrant manufacturer will change coordinated structure into decentralized structure.**

Index Terms—**Channel structure, Entrant supply chain, Power imbalance, Stackelberg game, asymmetric information**

I. Introduction

IT is common in real life that an incumbent firm will deal with the entry of new firms. Can the incumbent or entrant manufacturer gain competitive edge by choosing centralized channel structure? As we all know, there are some companies gain the advantage by operating centralized channel. For example, Dell sells its PC by its own direct channel and have been developed rapidly after entry the market; Zara sells through its own retail channels. Lin et al. [1] point that forward integration extends a manufacturer's operational reach to product retailing, tightening its grip on the demand side, and may be beneficial for a manufacturer's profitability. However, there are also many researches discussed the optimal channel structure under chain-to-chain competition and showed that decentralized channels may outperform centralized channels (McGuire and Staelin [2], Moorthy [3], Gupta and Loulou [4], Xiao and Choi [5], Liu and Tyagi [6]). A strategic reason for why channel decentralization can benefit firms is that channel decentralization incentives firms to differentiate their products more, and soften the competition consequently (Liu and Tyagi [6]). However, the majority of literature ignore the effects of a possible incursion of a supply chain on the optimal structure strategy of the incumbent chain. This gives rise to several interesting discussions: which is the optimal channel structure for the entry manufacturer, centralization or decentralization? With the entry of a new entrant chain, how should the incumbent members adjust their channel structures? Whats the equilibrium structure for the two chain? Furthermore, how do the price competition intensity, the relative product power and information asymmetry affect answers to these questions?

To address these questions, we develop a dynamic game model of an incumbent chain and an entrant chain. An incumbent manufacturer sells its product by its own channel, or through an incumbent retailer. An incursive manufacturer also can sell its product by its own channel, or through an incursive retailer. Under each chain, the manufacturer plays a manufacturer-Stackelberg (mS) game with its retailer. We assume that the incumbent chain and the entrant chain play a Stackelberg game, where the incumbent chain is the leader and the entrant chain is the follower. We investigate the effect of the entry on the channel structure. Different from the literature without entry, we find that the equilibrium channel does depend on the intensity of price competition. For the weak intensity of price competition, coordination is an equilibrium structure for both the two chains; whereas decentralization is an equilibrium channel structure if the intensity is fierce. However, if the intensity is moderate, the equilibrium is the hybrid channel structure, in which the incumbent chain chooses coordination and the entrant chain chooses decentralization. In addition, we investigate the effect of asymmetric cost information on equilibrium structure. We find that there are two main observations distinguished from the symmetric information game. Under the symmetric information game, both coordination and decentralization can be the optimal structure for the entrant chain. In contrast, under the asymmetric information game, the entrant chain prefers coordination rather than decentralization. Under the asymmetric information game, the chain without competitive advantage is more likely to exit markets when the intensity of price competition increases.

This paper is closely related to the literature on the chain-to-chain competition. McGuire and Staelin [2] consider the strategic decentralization for two chains where each manufacturer must decide whether to integrate into retailing or sell their products through an exclusive retailer via a wholesale

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price contract. They conclude that decentralization may lead to a higher total channel profit. But, Boyaci and Gallego [7] show that coordination is the dominant strategy between two competing chains, each consisting of one manufacturer and one retailer. Some related researches declare that the optimal channel structure depends on the degree of competition (Moorthy [8]), the degree of substitutability and process innovation (Gupta and Loulou [4]), market type (Wang et al. [9]), risk sensitivity (Xiao and Choi [5]), contract termination risk (Niu et al. [10]) and supply risk (Shou et al. [11]). There are also some papers investigate chain structure under new market, such as MTO (Xiao et al. [12]), green supply chain (Xing et al. [13]), and so on. All the above papers investigate that the two existing chains in market determine their channel strategies, decentralization or centralization. In contrast, this paper considers the optimal channel structures for the incumbent chain and the entrant chain and find that the equilibrium structures dependent of the entrant products competitiveness. In addition, all the above papers assume that the powers of two chains are equal, specifically, the two chains determine their strategies simultaneously. However, in this paper, we consider the incumbent chain and the incursive chain play a two-echelon Stackelberg game, i.e., a leader-follower relationship. There are only a limited number of papers that consider a leader-follower relationship between the two chains (Wu et al. [14]; Li et al. [15]; Wei and Zhao [16]; Amin-Naseri and Azari Khojasteh [17]). Different from these literature only discussing competition issue, we analyze entry decision and its impact on a splitting fraction of the profit of the coordinated chain.

Another stream of related literature is about entry issue. Most of the earlier literature consider a single firm entry (Gaskins [18]) or multiple entrants (Ashiya [19]). For the two-echelon supply chain models, some literature study on the entry issue, including a downstream entry under a vertical structure consisting of an incumbent supplier and an incumbent retailer (Xiao and Qi [20]) or n retailers (Tyagi [21]), an upstream entry under a retailer-dominated supply chain (Zhou et al. [22]), and chain-to-chain competition with the new entrant chain (Rezapour and Farahani [23]). Different from their researches, in this research, we mainly discuss the effect of a potential entrant chain on channel structure choices for an incumbent chain.

II. Model description

Consider an incumbent supply chain (SC_1) consisting of one incumbent manufacturer (M_1) and an incumbent retailer (R_1). M_1 sells its product (product 1) through R_1. In such a market, there exists an entrant manufacturer (M_2), who produces a partially substitutable product (product 2) and sells to the same market through its retailer (R_2). Denote the production cost, the wholesale price, the retail price, and the market demand for product i by c_i, w_i, p_i and D_i (i=1, 2), respectively. The demand for product i is given by

$$D_i = \frac{a_i - p_i - \theta(a_{3-i} - p_{3-i})}{1-\theta^2}, i = 1,2 \qquad (1)$$

where a_i represents the market size of product i, and $\theta \in [0, 1)$ represents the channel substitutability, i.e., the intensity of price competition. The demand functions in Equation (1) come from the consideration of the utility function of a representative consumer (i.e., $U(D_1, D_2) = \sum_{i=1}^{2}(a_i D_i - p_i D_i - \frac{D_i^2}{2}) - \theta \cdot D_1 \cdot D_2$), which have been widely adopted in previous literature.

As a benchmark, we first discuss the decision of SC_1 without entry. In such a case, The demand is $D_1 = a_1 - p_1$. If they make decisions independently, the profits for them are $\Pi_{M_1}^B = \frac{(a_1-c_1)^2}{8}$ and $\Pi_{R_1}^B = \frac{(a_1-c_1)^2}{16}$. If they choose to cooperate with each other, the profit for the whole chain is $\Pi_{C_1}^I = \frac{(a_1-c_1)^2}{4}$.

Obviously, the lack of coordination between two partners' pricing decisions makes the channel profit reduce by $\frac{(a_1-c_1)^2}{16}$. Next, we consider how M_1 designs a profit sharing (PS) contract to modify R_1's profit so that R_1 is willing to coordinate their pricing decision coherent with the channel-optimal one. Assume that M_1 offer R_1 a cost c_1 in change for that R_1 returns M_1 a percentage $(1-\rho_1)$ of R_1's profit. The percentage $\rho_1 \in (0, 1)$ is determined by the two players' bargain powers. The stronger R_1's bargain power is, the larger the percentage ρ_1 is. Under the PS contract, the profits for the two partners are $\Pi_{M_1}^{B-C} = \frac{(1-\rho_1)(a_1-c_1)^2}{4}$ and $\Pi_{R_1}^{B-C} = \frac{\rho_1(a_1-c_1)^2}{4}$. If $0.25 < \rho_1 < 0.5, \Pi_{M_1}^{B-C} > \Pi_{M_1}^B$ and $\Pi_{R_1}^{B-C} > \Pi_{R_1}^B$. Thus, the feasible condition for the PS contract is $0.25 < \rho_1 < 0.5$.

After SC_2 enters the market, we assume that there is a leader-follower relationship between SC_1 and SC_2. In each supply chain, $M_i (i = 1, 2)$ can adopt one of the two channel structures, namely decentralization (D) and coordination (C). When M_i chooses D, M_i sells through R_i at the wholesale price w_i, where M_i and R_i make their decisions independently; while when M_i uses C, M_i provides a PS contract to R_i to achieve the supply chain coordination. Thus, there are four possible scenarios: DD (decentralized SC_1 and decentralized SC_2), DC, CD and CC.

We use backward induction to find the best response of each player under the four channel structures, respectively, and then discuss the channel equilibrium structure under symmetric and asymmetric cost information game.

III. Equilibrium analysis

We initially discuss the channel choice of M_2 given that M_1 has adopted D or C, respectively, and subsequently analyze the equilibria of the channel game in which it is a leader-follower relationship between SC_1 and SC_2.

Denote $\Omega = \frac{a_2-c_2}{a_1-c_1}$, which represents the ratio of the net market size (the market size minus the cost) of product 2 to that of product 1. Thus, Ω reflects the relative product power of product 2 over product 1. If $\Omega > 1$, it indicates the entrant product is superior to the incumbent product, and vice versa. The optimal pricing and the demand for each product are listed as Table I. We can verify that the two products coexist in the market under structure xy $(x, y \in \{C, D\})$ when $\Omega_L^{xy} < \Omega < \Omega_U^{xy}$, where Ω_L^{xy} and Ω_U^{xy} are listed in Tabel II. Under structure xy, if the product 2's market size is very small or the product 2's cost is very high, i.e., the competitiveness of product 2 is too weak ($\Omega \leq \Omega_L^{xy}$), M_2 would not enter since the demand is zero; otherwise, if the competitiveness of product 2 is too strong ($\Omega \geq \Omega_U^{xy}$), product 1 will be dropped out of the market. Thus, only when $\Omega_L^{xy} < \Omega < \Omega_U^{xy}$, the two products will coexist in a market under structure xy. In addition, it is easy to find that Ω_L^{xy}

TABLE I
THE MARGINAL REVENUES AND DEMANDS UNDER DIFFERENT STRUCTURES

	DD	DC	CD	CC
u_{M_1}	$\frac{(4-3\theta^2-\theta\Omega)A}{2(4-3\theta^2)}$	$\frac{(2-\theta^2-\theta\Omega)A}{2(2-\theta^2)}$	$\frac{(4-3\theta^2-\theta\Omega)A}{2(4-3\theta^2)}$	$\frac{(2-\theta^2-\theta\Omega)A}{2(2-\theta^2)}$
u_{R_1}	$\frac{(4-3\theta^2-\theta\Omega)A}{4(4-3\theta^2)}$	$\frac{(2-\theta^2-\theta\Omega)A}{4(2-\theta^2)}$	——	——
D_1	$\frac{(4-3\theta^2-\theta\Omega)A}{16(1-\theta^2)}$	$\frac{(2-\theta^2-\theta\Omega)A}{8(1-\theta^2)}$	$\frac{(4-3\theta^2-\theta\Omega)A}{8(1-\theta^2)}$	$\frac{(2-\theta^2-\theta\Omega)A}{4(1-\theta^2)}$
u_{M_2}	$\frac{[(16-15\theta^2)\Omega-(4-3\theta^2)\theta]A}{8(4-3\theta^2)}$	$\frac{[(8-7\theta^2)\Omega-(2-\theta^2)\theta]A}{8(2-\theta^2)}$	$\frac{[(8-7\theta^2)\Omega-(4-3\theta^2)\theta]A}{4(4-3\theta^2)}$	$\frac{[(4-3\theta^2)\Omega-(2-\theta^2)\theta]A}{4(2-\theta^2)}$
u_{R_2}	$\frac{[(16-15\theta^2)\Omega-(4-3\theta^2)\theta]A}{16(4-3\theta^2)}$	——	$\frac{[(8-7\theta^2)\Omega-(4-3\theta^2)\theta]A}{8(4-3\theta^2)}$	——
D_2	$\frac{[(16-15\theta^2)\Omega-(4-3\theta^2)\theta]A}{16(4-3\theta^2)(1-\theta^2)}$	$\frac{[(8-7\theta^2)\Omega-(2-\theta^2)\theta]A}{8(2-\theta^2)(1-\theta^2)}$	$\frac{[(8-7\theta^2)\Omega-(4-3\theta^2)\theta]A}{8(4-3\theta^2)(1-\theta^2)}$	$\frac{[(4-3\theta^2)\Omega-(2-\theta^2)\theta]A}{4(2-\theta^2)(1-\theta^2)}$

Note: $A = a_1 - c_1$, u_{M_i} and u_{R_i} are unit marginal revenue for M_i and R_i, respectively.

TABLE II
THE NOTATIONS

	DD	DC	CD	CC
Ω_L^{xy}	$\frac{(4-3\theta^2)\theta}{16-15\theta^2}$	$\frac{(2-\theta^2)\theta}{8-7\theta^2}$	$\frac{(4-3\theta^2)\theta}{8-7\theta^2}$	$\frac{(2-\theta^2)\theta}{4-3\theta^2}$
Ω_U^{xy}	$\frac{4-3\theta^2}{\theta}$	$\frac{2-\theta^2}{\theta}$	$\frac{4-3\theta^2}{\theta}$	$\frac{2-\theta^2}{\theta}$
Ω_y	Ω_D	Ω_C	Ω_D	Ω_C
K_x	K_D	K_D	K_C	K_C

Note: $\Omega_D = \frac{\theta}{1+2\sqrt{\frac{1-\theta 2}{4-3\theta^2}}} < \theta$, $\Omega_C = \frac{\theta}{1+\sqrt{\frac{2(1-\theta^2)}{2-\theta^2}}} < \theta$,

$$K_D = \frac{[(16-15\theta^2)\Omega-(4-3\theta^2)\theta](2-\theta^2)}{[(8-7\theta^2)\Omega-(2-\theta^2)\theta](4-3\theta^2)},$$
$$K_C = \frac{[(8-7\theta^2)\Omega-(4-3\theta^2)\theta](2-\theta^2)}{[(4-3\theta^2)\Omega-(2-\theta^2)\theta](4-3\theta^2)}.$$

TABLE III
THE PAYOFF MATRIX OF STRUCTURE GAME

	$SC_2(D)$	$SC_2(C)$
$SC_1(D)$	$\Pi_{C_1}^{DD}, \Pi_{C_2}^{DD}$	$\Pi_{C_1}^{DC}, \Pi_{C_2}^{DC}$
$SC_1(C)$	$\Pi_{C_1}^{CD}, \Pi_{C_2}^{CD}$	$\Pi_{C_1}^{CC}, \Pi_{C_2}^{CC}$

increases with θ while Ω_U^{xy} decreases with θ. It means that the higher the price competition intensity is, the smaller the range of Ω is to ensure two products coexist in the market.

Lemma 1. (1)Under structure $Dy(y \in \{C, D\})$, the following properties hold: (i)$p_1^{Dy} < p_1^B, \Pi_{M_1}^{Dy} = 2\Pi_{R_1}^{Dy}$; (ii)If $\Omega < \theta$, then $D_1^{Dy} > D_1^B$; (iii)If $\Omega < \Omega_y$, then $\Pi_{M_1}^{Dy} > \Pi_{M_1}^B$. (2)Under structure $Cy(y \in \{C, D\})$, the following properties hold: (i)$p_1^{Cy} < p_1^{B-C}$; (ii)If $\Omega < \theta$, then $D_1^{Cy} > D_1^{B-C}$;(iii)If $\Omega < \Omega_y$, then $\Pi_{C_1}^{Cy} > \Pi_{C_1}^{B-C}$.

Lemma 1 shows that (1) the entry can decrease the marginal revenues for the incumbent members and reduce product 1's retail price. Thus the competition can weaken the negative effect of double-marginalization caused by the excessively high retail price. This result has also been established in the literature (Gaskins [18]) and (Boyaci and Gallego [7]). (2) If product 2's competitiveness is weak ($\Omega < \theta$), the entry would increase the product 1's demand, and if it very weaker ($\Omega < \Omega_y < \theta$), the increased demand could compensate for the loss of marginal revenues, as a result, the profits for the incumbent members will increase. This means that the entry of the weak competitive firm benefits the strong competitive enterprise. (3) Under structure Dy, as the leader of the incumbent chain, M_1's profit is always two times that of the follower R_1. The results show that the leader in a chain has the first-mover advantage.

Given that M_1 chooses structure x ($x \in \{C, D\}$), whether M_2 is willing to coordinate SC_2 or not depends on whether the two partners' profits are less than the profits if they choose D. Therefore, as long as the profit in C is more than that in D, M_2 will choose C.

Lemma 2. Suppose that M_1 adopts structure x ($x \in \{C, D\}$), the following properties hold: (1)If $K_x > 1.15$, M_2 chooses D; (2)If $K_x \leq 1.15$ and $\frac{K_x^2}{4} < \rho_2 < 1 - \frac{K_x^2}{2}$, M_2 offers the PS contract to coordinate SC_2.

Lemma 2 shows that whether $M_2's$ selection depends on Ω and θ. It means that although the PS contract can coordinate supply chain, C may not always better than D.

To observe the impact of θ and Ω on M_2's channel selection strategy given that M_1 chooses D and C, respectively, we draw the isoline $K_x = 1.15$ ($x \in \{C, D\}$) in the rectangle area $\{(\theta, \Omega) : 0 < \theta < 1, 0 < \Omega < 3\}$ (see the left subplot and the right subplot of Fig. 1). The whole dashed area in which the structure xC is feasible ($\Omega_L^{xC} < \Omega < \Omega_U^{xC}$) is divided by the isoline $K_x = 1.15$ into two sub-areas. For any (θ, Ω) within the left sub-area of this isoline, M_2 will choose C. When parameter pair (θ, Ω) drops into the right side of the isoline, M_2 will choose D. From Fig. 1, we can conclude as follows: (1)$M_2's$ structure selection mainly depends on the price competition intensity θ. (2) For a relatively weak and medium-sized price competition intensity, M_2 chooses C, whereas for the fierce competition intensity, M_2 chooses D.

A. Equilibria of channel game

In order to discuss the structure equilibrium, we assume that $\Omega_L^{CC} < \Omega < \Omega_U^{CC}$, which means the four structures are all feasible. If the profit of the coordinated chain is more than that of the decentralized chain, both players can obtain higher profits in the coordinated structure as long as the profit sharing ratio is in an appropriate range, and the manufacturers will choose C. It means that, under the PS contract, the two chains have the same structure equilibrium no matter whether it is obtained from the overall chain's perspective or from the manufacturer's perspective. Therefore, we will just discuss the equilibrium structure only from the overall chain's perspective. Table 3 shows the payoff matrix of channel game.

Theorem 1. The structure equilibrium between the two chains are as follows,
(1)When $\Omega_L^{CC} < \Omega < \theta$ (i.e., $K_C > K_D$), (i)If $K_C > 1.15$ and $\rho_1^{L1} < \rho_1 < \rho_1^U$, CD will be the structure equilibrium; (ii)If $K_C \leq 1.15$, $\rho_1^{L1} < \rho_1 < \rho_1^{U1}$ and $\frac{{K_C}^2}{4} < \rho_2 < 1 - \frac{{K_C}^2}{2}$, CC will be the structure equilibrium, where $B = \frac{(4-3\theta^2)(2-\theta^2-\theta\Omega)^2}{(2-\theta^2)(4-3\theta^2-\theta\Omega)^2}$ and $(\rho_1^{L1}, \rho_1^{U1}) = (B/2, 1-B)$ when $K_C > 1.15 > K_D$, otherwise $(\rho_1^{L1}, \rho_1^{U1}) = (0.25, 0.5)$.
(2)When $\theta \leq \Omega < \Omega_U^{CC}$ (i.e., $K_C \leq K_D$), (i)If $K_C > 1.15$ and $\rho_1^{L2} < \rho_1 < \rho_1^{U2}$, CD will be the structure equilibrium; (ii)If $K_D > 1.15 \geq K_C$, there are two cases: if $\rho_1^{L2} < \rho_1 < \rho_1^{U2}$, $\frac{{K_D}^2}{4} < \rho_2 < 1 - \frac{{K_D}^2}{2}$, and $B > 0.375$, CC will be the structure equilibrium ; otherwise, DD will be the structure equilibrium; (iii)If $K_D \leq 1.15$, $\rho_1^{L2} < \rho_1 < \rho_1^{U2}$ and $\frac{{K_D}^2}{4} < \rho_2 < 1 - \frac{{K_D}^2}{2}$, CC will be the equilibrium

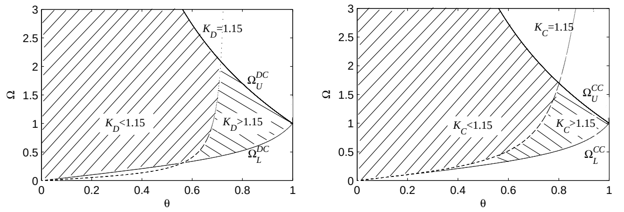

Fig. 1. The Impact of θ and Ω on The Entrant Chain's Structure

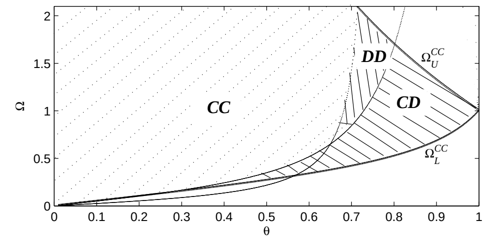

Fig. 2. The Structure Equilibria

structure, where $(\rho_1^{L2}, \rho_1^{U2}) = (1/(8B), 1 - 1/(4B))$ when $K_D > 1.15 > K_C$, otherwise, $(\rho_1^{L2}, \rho_1^{U2}) = (0.25, 0.5)$.

Theorem 1 shows that, with the presence of the entrant chain, the structure C may not be the optimal strategy, which is different from the single chain, whereas the PS contract can still coordinate the supply chain. However, the entry changes the proportion of profit allocation, which reflect the bargain power of the incumbent chain. We derive from Lemma 1 and 2 that if $\Omega < \Omega_D (< \Omega_C < \theta)$, the entry makes the incumbent chain's profit increase. Thus, the entry of a weak chain benefits the incumbent chain.

Based on Theorem 1, we draw the structure equilibria in the rectangle area $\{(\theta, \Omega) : 0 < \theta < 1, 0 < \Omega < 2\}$(shown by Fig. 2). The whole dashed area in which $\Omega_L^{CC} < \Omega < \Omega_U^{CC}$ is divided by the isoline $K_D = 1.15$ and $K_C = 1.15$ into three sub-areas. we can conclude as follows: (1)The structure equilibrium mainly depends on the price competition intensity θ. For a relatively weak and medium-sized competition intensity, the structure equilibrium is CC. If the intensity is fierce, the entrant chain always chooses D while the equilibrium structure of the incumbent chain depends on K_C. (2) The decentralization may the better channel structure only when the intensity of price competition is fierce. (3)In our discussion, DC never appears in the equilibria. It seems that the incumbent chain has more chance to choose centralized structure while the entrant chain has more chance to choose decentralized structure.

In order to analyze the impact of θ and Ω on the profits and structure equilibria, we discuss how the profits vary with θ in three cases: in presence of the weak entrant ($\Omega = 0.5$), the strong entrant ($\Omega = 2$) and the equal entrant chain ($\Omega = 1$), shown by Figs. 3, 4 and 5, respectively.

From Fig. 3, we can obtain that the entrant chain's profit is always declining, whereas the incumbent chain's profit decreases first and then increases with θ. it means that the competition is always bad for the weak chain, while the fierce price competition is favorable for the strong chain. If the price competition is moderate or weak ($\theta < 0.59$), the incumbent chain will choose C, the entrant chain will choose C as well. Therefore, CC is the equilibrium structure; if the price competition is strong ($\theta > 0.59$), the incumbent chain will choose C, while the entrant chain chooses D. Therefore, CD is the equilibrium structure.

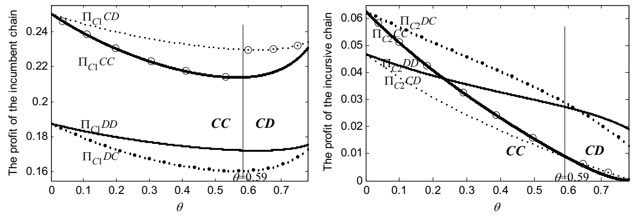

Fig. 3. The Impact of θ on the Profits ($a_1 - c_1 = 1, \Omega = 0.5$)

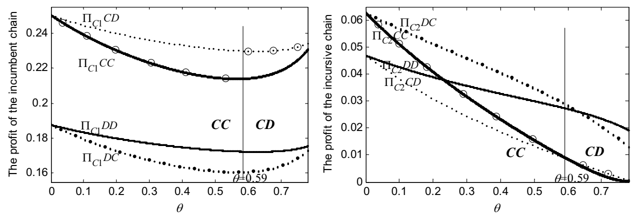

Fig. 4. The Impact of θ on the Profits ($a_1 - c_1 = 1, \Omega = 2$)

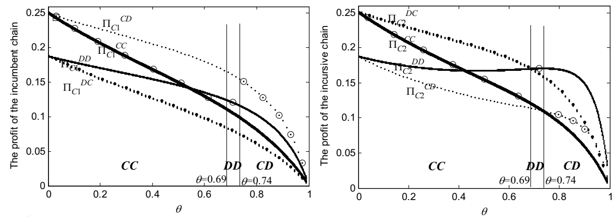

Fig. 5. The Impact of θ on the Profits ($a_1 - c_1 = 1, \Omega = 1$)

Fig. 4 shows that with the increase of price competition intensity, the incumbent chain's profit is always declining, but the entrant chain's profit decreases first and then increases, which indicates that the competition is always bad for the weak chain, while the fierce competition is favorable for the strong chain. If the price competition is not strong ($\theta < 0.70$), the incumbent chain will choose C, the entrant chain will choose C as well. Therefore, CC is the equilibrium structure. However, if the price competition is strong ($\theta > 0.70$), DD is the equilibrium structure.

Based on Figs. 3 and 4, we derive that how the price competition intensity effect on the chain profits depends on the chain's competitiveness rather than the leader-follower relationship. Specifically, as θ increases, the profit of the weak chain declines no matter it is the entrant (in Fig. 3) or the incumbent (in Fig. 4); the strong chain's profit declines firstly and then increases, no matter it is the incumbent (in Fig. 3) or the entrant (in Fig. 4). However, the leader-follower relationship influences the structure equilibrium. In the case that the incumbent chain is strong, C is the optimal structure. In the case that the incumbent is weak, if the intensity of price competition is weak, C is its optimal choice; if the intensity is strong, D is its optimal strategy. Fig. 4 shows that the optimal structure of the incumbent chain changes from C to D so that the optimal structure of the entrant chain changes from C to D as well. As a result, the incumbent chain's profit increases. Thus, if the price competition is intense, the incumbent chain can get much more profit by taking its first-moving advantage (choose structure first).

Fig. 5 shows how the two chains' profits vary with θ when $\Omega = 1$. The results show that (1)If the intensity of price competition is not too intense ($\theta < 0.69$), CC is the equilibrium structure, and there is a second-mover advantage for the entrant chain since $\Pi_{C_1}^{CC} < \Pi_{C_2}^{CC}$ (Proof can be found in Appendix). In addition, $\Pi_{C_1}^{DD} > \Pi_{C_1}^{CC}$ and $\Pi_{C_2}^{DD} > \Pi_{C_2}^{CC}$ when $0.6 < \theta < 0.69$, both chains' profits in DD are more than that in the equilibrium structure. It means that "prisoner's dilemma" appears here in the game between the two chains. CC is the unique equilibrium structure, but both chains can achieve better performances under DD than under CC. (2) If the intensity of price competition is moderate ($0.69 < \theta < 0.74$), DD is the equilibrium structure. It is obvious that $\Pi_{C_1}^{DD} < \Pi_{C_2}^{DD}$, which means there is also a second-mover advantage. (3) If the intensity of price competition is strong ($\theta > 0.74$), CD is the equilibrium structure. Since $\Pi_{C_1}^{CD} > \Pi_{C_2}^{CD}$, the incumbent chain has the first mover advantage when the price competition is intense.

B. Equilibrium strategies under asymmetric cost information

In this section, we assume that SC_1 has full knowledge about its own cost c_1, but has little knowledge about the cost c_2 for the entrant chain. The entrant chain has full knowledge about c_1 and c_2. Specifically, we assume that the production cost c_2 is, ex ante, random which can be either low ($c_2 = c_L$) with probability λ and high ($c_2 = c_H$) with probability $1-\lambda$, where $0 < c_L < c_H < a_2$. M_2 and R_2 know the true production cost privately, whereas M_1 and R_1 know only the prior distribution. Let $\overline{c} = \lambda c_L + (1-\lambda)c_H$, representing the expected cost, and $\sigma^2 = \lambda(c_L - \overline{c})^2 + (1-\lambda)(c_H - \overline{c})^2$ be the variance of the cost distribution.

By backward induction, we consider the decision of SC_2 firstly. Because SC_2 has complete information, similar to the symmetric information game, we can obtain the best response wholesale price and retail price to retail price p_1 under DD

$$w_2^{i-ADD} = \frac{a_2 + c_i - \theta(a_1 - p_1)}{2},$$

$$p_2^{i-ADD} = \frac{3a_2 + c_i - 3\theta(a_1 - p_1)}{4}, i = H, L.$$

Recall that SC_1 does not observe the true production cost c_2, but anticipates the SC_2's decision. Thus, R_1 chooses its retail price as the solution to

$$\max_{p_1} \pi_{R_1} = \frac{(4-3\theta^2)(a_1 - p_1)(p_1 - w_1)}{4(1-\theta^2)} - \frac{\theta[\lambda(a_2 - c_L) + (1-\lambda)(a_2 - c_H)](p_1 - w_1)}{4(1-\theta^2)}.$$

R_1's optimal price is $p_1^{ADD} = \frac{(4-3\theta^2)(a_1+w_1)-(a_2-\overline{c})}{2(4-3\theta^2)}$, Substituting p_1^{ADD} to M_1's expected profit function leads to the wholesale price $w_1^{ADD} = \frac{(4-3\theta^2)(a_1+c_1)-(a_2-\overline{c})}{2(4-3\theta^2)}$. Thus, we get equilibrium profits for all the partners under structure DD in the asymmetric cost information game. Similar to the above analysis under structure DD, it is easy to obtain the profits for all the partners under structure DC, CD and CC, respectively. The results are listed in Table IV.

Lemma 3. Under structure $xy(x, y \in \{C, D\})$, the following properties hold: (1)$\frac{\partial \pi_{M_1}^{xy}}{\partial \overline{c}} > 0, \frac{\partial \pi_{R_1}^{xy}}{\partial \overline{c}} > 0, \frac{\partial \pi_{M_1}^{xy}}{\partial (\sigma^2)} = 0, \frac{\partial \pi_{R_1}^{xy}}{\partial (\sigma^2)} = 0$, (2)$\frac{\partial \pi_{M_2}^{xy}}{\partial \overline{c}} < 0, \frac{\partial \pi_{R_2}^{xy}}{\partial \overline{c}} < 0, \frac{\partial \pi_{M_2}^{xy}}{\partial (\sigma^2)} > 0, \frac{\partial \pi_{R_2}^{xy}}{\partial (\sigma^2)} > 0$.

Lemma 3 states that the profits for M_1 and R_1 only depends on the expected cost, and have no concern with the variance. It means that when the incumbent players know only the prior distribution, they replace the true production cost with the expected cost. Correspondingly, the profits for M_1 and R_1 increases with the expect cost. However, the profits for M_2 and R_2 decrease with the expect cost. It is consistent with our instinct. In addition, the profits for M_2 and R_2 increase with the variance. It means that the entrant partners can benefit from the uncertainty of the cost.

Under asymmetric information game, denote $\overline{\Omega} = \frac{a_2 - \overline{c}}{a_1 - c_1}$, which represents the ratio of the net expect market size (the market size minus the expect cost) of product 2 to that of product 1. The channel structure depend on all parameters of the model. Therefore, these parameters have a significant impact on the equilibrium channel structure. To explore the role of these parameters, we consider the following data: $a_1 = 2, c_1 = 1, \lambda = 0.6, c_L = 0.7$ and $c_H = 1.2$. We can get $\Pi_{c_1}^{B-C} = 0.25$. Table V shows numerical results.

From Table V, we have the following observations. (1) Under the equilibrium structure, SC_1's profit always decreases with the intensity of price competition θ, but SC_2's profit may increase with θ. Specifically, when SC_2 has a more absolute advantage in competitive ability than SC_1 (say, $\overline{\Omega} = 2$). It implies that the price competition always hurts the leader SC_1. However, the follower SC_2 can benefit from the fierce price competition if it's product has a more comparative advantage in competitive ability than the leader's product. (2)Under any available structure (i.e., both chains exist in the market), the incumbent chain SC_1 is always worse off after SC_2's entry even if the incumbent product has an absolute advantage (say, $\overline{\Omega} = 0.5$). Besides, when the two products have the same competitive ability (say, $\overline{\Omega} = 1$), under the equilibrium structure CC, the follower's profit is higher than the leader's profit. It implies that there is a second-mover's advantage. (3) The two chains encounter a prisoner's dilemma when the price competition intensity is moderate (see the italic when $\overline{\Omega} = 1$ and θ=0.55, 0.60 and 0.65). CC is the unique equilibrium structure, but both chains can achieve better performances under DD than under CC. If one player intends to select D but its rival does not, then it ends up with the lowest profit. Thus, selecting the "safe" strategy (i.e., C) is the equilibrium choice for the two chains.

It is worth to mention that there are two main observations distinguished from the symmetric information game.(1)Under the symmetric information, both C and D can be the optimal structure for the entrant chain. In contrast, under the asymmetric information, the entrant chain prefers C rather than D. Given that SC_1 adopts $D(C)$, if SC_2 chooses C, the uncertainty of the cost can brings SC_2 the extra profit $\frac{\sigma^2}{4(1-\theta^2)}$ caused by the variance of the cost; and SC_2 can obtain the extra profit $\frac{3\sigma^2}{16(1-\theta^2)}$ if it adopts D. Thus, SC_2 prefers C rather than D. On the other hand, given that SC_2 adopts $D(C)$, SC_1 always chooses C. Therefore, CC is always the equilibrium structure for the both chains when CC is an available structure. This is differ from equilibrium structures under the symmetric information. (2)Under the

TABLE IV
THE PROFITS UNDER DIFFERENT STRUCTURES

	DD	DC	CD	CC
π_{M_1}	$\frac{[(4-3\theta^2-\theta\overline{\Omega})A]^2}{32(1-\theta^2)(4-3\theta^2)}$	$\frac{[(2-\theta^2-\theta\overline{\Omega})A]^2}{16(1-\theta^2)(2-\theta^2)}$	$\frac{[(4-3\theta^2-\theta\overline{\Omega})A]^2}{16(1-\theta^2)(4-3\theta^2)}$	$\frac{[(2-\theta^2-\theta\overline{\Omega})A]^2}{8(1-\theta^2)(2-\theta^2)}$
π_{R_1}	$\frac{[(4-3\theta^2)-\theta\overline{\Omega})A]^2}{64(1-\theta^2)(4-3\theta^2)}$	$\frac{[(2-\theta^2)-\theta\overline{\Omega})A]^2}{32(1-\theta^2)(2-\theta^2)}$	——	——
π_{M_2}	$\frac{\frac{[(B_1+3B_2-B_3)A]^2}{16(4-3\theta^2)^2}+\sigma^2}{8(1-\theta^2)}$	$\frac{\frac{[(B_1+B_2)A]^2}{16(2-\theta^2)^2}+\sigma^2}{4(1-\theta^2)}$	$\frac{\frac{[(B_1+B_2-B_3)A]^2}{4(4-3\theta^2)^2}+\sigma^2}{8(1-\theta^2)}$	$\frac{\frac{(B_1A)^2}{4(2-\theta^2)^2}+\sigma^2}{4(1-\theta^2)}$
π_{R_2}	$\frac{\frac{[(B_1+3B_2-B_3)A]^2}{16(4-3\theta^2)^2}+\sigma^2}{16(1-\theta^2)}$	——	$\frac{\frac{[(B_1+B_2-B_3)A]^2}{4(4-3\theta^2)^2}+\sigma^2}{16(1-\theta^2)}$	——

Note: $\overline{\Omega}=\frac{a_2-\overline{c}}{a_1-c_1}$, $B_1=(4-3\theta^2)\overline{\Omega}-(2-\theta^2)\theta$, $B_2=4(1-\theta^2)\overline{\Omega}$, $B_3=2(1-\theta^2)\theta$.

TABLE V
THE EFFECT OF θ AND $\overline{\Omega}$ ON THE PROFITS UNDER DIFFERENT STRUCTURES

	DD	DC	CD	CC
$(\theta,\overline{\Omega})$	(π_{C_1},π_{C_2})	(π_{C_1},π_{C_2})	(π_{C_1},π_{C_2})	(π_{C_1},π_{C_2})
(0.05, 0.5)	(0.1853, 0.0559)	(0.1831, 0.0745)	(0.2470, 0.0537)	(**0.2441, 0.0715**)
(0.10, 0.5)	(0.1833, 0.0539)	(0.1791, 0.0717)	(0.2444, 0.0496)	(**0.2388, 0.0660**)
(0.15, 0.5)	(0.1815, 0.0522)	(0.1755, 0.0690)	(0.2419, 0.0459)	(**0.2341, 0.0609**)
(0.20, 0.5)	(0.1798, 0.0506)	(0.1724, 0.0666)	(**0.2398, 0.0426**)	(0.2298, NA)
(0.30, 0.5)	(0.1770, 0.0480)	(0.1671, 0.0621)	(**0.2360, 0.0367**)	(0.2228, NA)
(0.40, 0.5)	(0.1747, 0.0461)	(0.1631, NA)	(0.2330, NA)	(0.2175, NA)
(0.40, 2.0)	(0.1173, 0.7624)	(0.0656, 0.9498)	(0.1564, 0.7005)	(**0.0875, 0.8912**)
(0.50, 2.0)	(0.0974, 0.7891)	(0.0402, 0.9393)	(0.1298, 0.7148)	(**0.0536, 0.8810**)
(0.60, 2.0)	(0.0742, 0.8298)	(0.0173, 0.9268)	(0.0989, 0.7459)	(**0.0231, 0.8796**)
(0.70, 2.0)	(0.0464, 0.8877)	(0.0015, 0.9073)	(0.0619, 0.8018)	(**0.0020, 0.8907**)
(0.75, 2.0)	(0.0306, 0.9238)	(NA, 0.8925)	(0.0408, 0.8440)	(NA, 0.9040)
(0.40, 1.0)	(0.1543, 0.1808)	(0.1258, 0.2253)	(0.2058, 0.1482)	(**0.1677, 0.1882**)
(0.50, 1.0)	(0.1454, 0.1820)	(0.1116, 0.2165)	(0.1939, 0.1416)	(**0.1488, 0.1735**)
(0.55, 1.0)	(*0.1405, 0.1835*)	(0.1043, 0.2119)	(0.1873, 0.1390)	(**0.1390, 0.1664**)
(0.60, 1.0)	(*0.1350, 0.1857*)	(0.0966, 0.2069)	(0.1800, 0.1370)	(**0.1288, 0.1595**)
(0.65, 1.0)	(*0.1288, 0.1885*)	(0.0885, 0.2014)	(0.1718, 0.1355)	(**0.1180, 0.1527**)
(0.70, 1.0)	(0.1217, 0.1919)	(0.0799, 0.1952)	(**0.1622, 0.1346**)	(0.1065, NA)

Note: The bold denotes the equilibrium structure, and "NA" represents "not available".

asymmetric information game, the chain without competitive advantage is more likely to exit markets when the intensity of price competition θ increases(seen the sets including "NA" in Table V, which means the profit is negative).

IV. DISCUSSION AND IMPLICATIONS

A. *Theoretical contributions*

The prior literature mainly focused on equilibria structure between the two chains (Wu et al. [14], Li et al. [15]), ignoring the issue of entry decision, whereas, most of the earlier literature considered a single firm entry (Gaskins [18])or multiple entrants (Ashiya[19]). This paper has concentrated on a channel structure choice game between an incumbent chain and an entrant chain, and has discussed the impact of entry on the equilibria structure, thereby enriching literature in this area. The theoretical contributions of this paper are shown as follows.

Corroborating the studies (Wu et al. [14], Li et al. [15]), the competition between the two chains can exert significant influence on pricing strategies for the partners. It reaffirms the argument that the competition forces the firms to reduce pricing. It is therefore not surprising to see that the competition between the firms can weaken the negative effects of double marginalization on the overall supply chain profit, and increase more consumer surpluses.

With the absence of entry, PS contract can coordinate the whole supply chain. Our study suggests that PS contract can still achieve the supply chain coordination with the present of entry. However, the entry changes the proportion of profit allocation. Besides, the intensity of price competition has been found to exert a significant influence on the equilibria structure. Specifically, if the intensity of price competition is weak, the structure equilibrium is CC for the incumbent and the entrant chains choose coordinated channels, whereas CD is an equilibrium channel structure for the fierce intensity of price competition.

B. *Implications for practice*

As we all know, with the development of technology and the globalization of economy, the market competition becomes more and more intensive. It is common phenomenon that the incumbent firm has to face the threat of the entrant new firm. How do the entry of a new firm affect on the optimal strategies and profits of the incumbent members? and can the incumbent supply chain gain competitive edge by choosing centralized channel structure? This study has focused on channel structure selection between the incumbent chain and the entrant chain. The findings provide recommendations to the partners in decision-making.

Both of the incumbent chain and the entrant chain should strive to enhance the competitive ability of product by expanding the market size and decreasing the cost. And they should enlarge the differentiation between the two products to avoid the intense price competition.

V. Conclusion

This paper develops a dynamic game model of an incumbent chain and an entrant chain. We study the two chain's optimal strategies. The result shows that the entry can decrease the profit for the incumbent chain unless the entrant product competitiveness is very weak. Besides, the equilibrium structure does depend on the intensity of price competition. In addition, we find that there are two main observations distinguished from the symmetric information. One is that under the symmetric information game, both coordination and decentralization can be the optimal structurer for the entrant chain. In contrast, under the asymmetric information game, the entrant chain prefers C rather than D. the other is that under the asymmetric information game, the chain without competitive advantage is more likely to exit markets when the intensity of price competition increases.

Future research may include two aspects. This paper only studies the problem of entry from the perspective of pricing without considering non-price factors, such as service level and advertising effect. It can be extended by introducing non-price factors into the model and extended further by considering uncertain demand. In addition, we can consider other measures of incumbent chain (such as creating innovative product, merger and acquisition downstream retailer) with the presence of the entrant chain.

Appendix

Proof of Theorem 1. (1) If $\Omega_L^{CC} < \Omega < \theta$, then $K_C > K_D$. There will be three cases discussed as follows. (I) In the case $K_C > K_D > 1.15$, according to Lemma 2, if SC_1 chooses D, SC_2 will choose D as well. Then, the profits for M_1 and R_1 would be $\Pi_{M_1}^{DD}$ and $\Pi_{R_1}^{DD}$, respectively. And if SC_1 selects C, SC_2 will choose D. And the profits for M_1 and R_1 will be $\Pi_{M_1}^{CD} = (1-\rho_1)\Pi_{C_1}^{CD}$ and $\Pi_{R_1}^{CD} = \rho_1\Pi_{C_1}^{CD}$, respectively. Therefore, when $\Pi_{R_1}^{DD}/\Pi_{C_1}^{CD} = 0.25 = \rho_1^{L1} < \rho_1 < \rho_1^{U1} = 1 - \Pi_{M_1}^{DD}/\Pi_{C_1}^{CD} = 0.5$, M_1 chooses C. (II) In the case $K_C > 1.15 \geq K_D$, according to Lemma 2, if SC_1 chooses D, SC_2 will choose C. And the profits of M_1 and R_1 will be $\Pi_{M_1}^{DC}$ and $\Pi_{R_1}^{DC}$, respectively. According to Lemma 2, if SC_1 chooses C, SC_2 will choose D, then the profits of M_1 and R_1 will be $\Pi_{M_1}^{CD} = (1-\rho_1)\Pi_{C_1}^{CD}$ and $\Pi_{R_1}^{CD} = \rho_1\Pi_{C_1}^{CD}$, respectively. It is easy to prove that $\Pi_{C_1}^{CC} > \Pi_{C_1}^{CD} = (\Pi_{M_1}^{CD} + \Pi_{R_1}^{CD})$. Therefore, M_1 would choose C if $\Pi_{R_1}^{DC}/\Pi_{C_1}^{CD} = \rho_1^{L1} < \rho_1 < \rho_1^{U_1} = 1 - \Pi_{M_1}^{DC}/\Pi_{C_1}^{CD}$. (III) In the case $1.15 \geq K_C > K_D$, according to Lemma 2, if SC_1 selects D, SC_2 will select C. And the profits of M_1 and R_1 will be $\Pi_{M_1}^{DC}$ and $\Pi_{R_1}^{DC}$, respectively. According to Lemma 2, if SC_1 selects C, SC_2 selects C as well. And the profits of M_1 and R_1 will be $\Pi_{M_1}^{CC} = (1-\rho_1)\Pi_{C_1}^{CC}$ and $\Pi_{R_1}^{CC} = \rho_1\Pi_{C_1}^{CC}$. Since $\Pi_{C_1}^{CC} > \Pi_{C_1}^{DC} = (\Pi_{M_1}^{DC} + \Pi_{R_1}^{DC})$, M_1 would select C if $\Pi_{R_1}^{DC}/\Pi_{C_1}^{CC} = 0.25 = \rho_1^{L_1} < \rho_1 < \rho_1^{U_1} = 1 - \Pi_{M_1}^{DC}/\Pi_{C_1}^{CC} = 0.5$
(2) If $\theta \geq \Omega < \Omega_U^{CC}$, then $K_D > K_C$. There will also be three cases discussed as follows. Similar to the above proof, we can prove that, in the cases $K_D > K_C > 1.15$ and $1.15 > K_D > K_C$, if $0.25 = \rho_1^{L_2} < \rho_1 < \rho_1^{U_2} = 0.5$, M_1 selects C. In the case $K_D > 1.15 \geq K_C$, according to Lemma 2, if SC_1 selects D, SC_2 will choose D as well. Then profit of M_1 is $\Pi_{M_1}^{DD}$ and the profit of R_1 is $\Pi_{R_1}^{DD}$. And if SC_1 selects C, SC_2 will select C as well. Then the profit of M_1 and R_1 will be $\Pi_{M_1}^{CC} = (1-\rho_1)\Pi_{C_1}^{CC}$ and $\Pi_{R_1}^{CC} = \rho_1\Pi_{C_1}^{CC}$. Therefore, if $\Pi_{C_1}^{CC} > \Pi_{C_1}^{DD} = (\Pi_{M_1}^{DD} + \Pi_{R_1}^{DD})$, M_1 selects C; and if $\Pi_{C_1}^{CC} < \Pi_{C_1}^{DD}$, M_1 chooses D.

If $\Omega = 1, \Pi_{C_1}^{CC} < \Pi_{C_2}^{CC} \Leftrightarrow 2(2-\theta^2)(2+\theta)^2 < (4+2\theta-\theta^2)^2 \Leftrightarrow 0 < 4\theta^3 + 3\theta^4$.

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