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A study on the manufacturing decision-making and optimization of hybrid-channel supply chain for original equipment manufacturer

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ABSTRACT

OEM production model can achieve an effective integration of internal and external resources, and the brand owner's brand premium and manufacturer's production advantage are the key elements of the model. When manufacturers have both OEM channels and direct sales, the competition and cooperation relationships between them and the brand owners become even more complicated when the hybrid channels exist. In order to better study the operation and management of the supply chains of OEM production with the hybrid channels, the operating conditions and optimization mechanism for the supply chain of OEM production with the hybrid channels were analyzed under both a centralized and decentralized decision making scenarios through the construction of a two-stage closed-loop supply chain model involving both manufacturers and brand owners. We found that the existence of hybrid channel depends on the brand owner's premium level which is limited by the manufacturer's production costs. There is a section on the premium level of brand owner and the hybrid channel exists in both a decentralized and a centralized decision making paradigms. By optimizing manufacturers' production costs and brand owner's premium level, the profits of both parties involved in the supply chain of OEM production with the hybrid channels, as well as the general profit of the system, can be improved. The system profit under a centralized decision making scenario is greater than that of a decentralized case. If the redistribution is made for the increase in the optimized system profit by leveraging the profit stratified ratio of OEM channels of a decentralized decision making approach, then there is a possibility of achieving the Pareto optimization.

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1. Introduction

Globalization of market economic system, trade globalization and globalization of production and enterprises pose certain challenges (mainly competition in time and efficiency) while bringing about opportunities for contemporary enterprise development. OEM can achieve a chained alliance cooperation through "horizontal integration" to realize the goal of effective integration of internal and external enterprise resources. In channel selection, manufacturers are still adopting the "copycat culture" (initial brand) oriented direct sales channel and "brand culture" (powerful brand) oriented OEM channel as well as hybrid channel model of the two. Manufacturers open up direct sales channel in which they provide primary commodities (products lacking

brand premium) directly to consumers while providing OEM service for branding business to dominate the OEM channel. This is the research context of this paper – OEM supply chain based on hybrid channels. We aim to answer three major questions in this paper: 1) under which circumstance should branding business and manufacturer establish a hybrid-channel OEM supply chain? 2) How a manufacturer chooses its channel cooperation candidates and the decision-making method based on the production advantages of the manufacturer and the level of brand premium of the branding business? 3) How to create the optimization mechanism according to the difference between its optimization objectives and those of its partner?

The existing work in literature related to research problem of this paper is mainly focused on three aspects – OEM, hybrid channel and supply chain optimization. More Specifically, most work about OEM lay their emphasis on the transformation & upgrade of OEM mode and competitive strategies, which touched the issues regarding whether it's appropriate for manufacturers to initiatively give up brand creation and weaken market force, whether manufacturer can find a proper evolving process for brand development, and whether competition rules between OEMs can purely concentrate on production cost control, and how to evaluate the appropriateness of the input and output of the OEM mode. Hu Jun [1] taking OEMs in Pearl River Delta as examples, discussed about the pathway selection for sustainable growth OEMs from the prospective of the global value chain outsourcing system. It summarized the most common growth pattern – overall rise, individual ascending and horizontal spanning for OEMs. Many researchers[2-4] studied the decision-making problem between production and outsourcing of two OEMs which produce substitutable goods during the process of lowering manufacturing cost, and proposes that organizational flatness is an antecedence to the mass customization capability and the supply chain planning and corporation coordination mediates [5]. They found that with an increasing level of product substitutability, competition would drive the two OEMs to realize profit maximization by formulating low price and reducing investment cost. Moreover, outsourcing mechanism also warns OEMs not to rely on cost reduction to weaken cut-throat competition, but instead, they should pay more attention to enhance its ability as accessories supplier when providing outsourcing services. About hybrid channel, there are some literatures [6-8] established models to discuss about dual hybrid structural pattern of distribution channels – entity and network distribution channel of manufacturer and retailer, conducted game analysis respectively on the decentralized control and centralized control accompanied by numerical experiment, studied price competition strategies of manufacturer and distributor in order to guide pricing decision of dual hybrid channel distribution enterprises, and finally demonstrated the importance for manufacturer and retailer to concentrate on core competitive advantages to build and promote channel integration on expanding potential market capacity. Danand Agatz[9-10] aimed at the multi-channel supply chain composing of a retailer with a electronic channel, a manufacturer with a direct distribution channel. About decision-making optimization of supply chain, Scholars introduced the concept of effective inventory level, studied inventory control in supply chain coordination and cooperation process, and put forward that cost sharing contract could realize a win-win situation between supplier and buyer in the overall optimization [11-13]. Galić [14] suggest and test evolutionary algorithm of multiple criteria solver (MCS) for asphalt supply chain optimization. Successful enterprise should reasonably balance quantity of self-made products and quantity of products entrusted to OEMs and reasonably select OEMs by relying on idea of overall benefit maximization in supply chain management and establishment of strategic partners [15]. Zhang [16] explore the optimization tactics of a dual-channel production and distribution network based on pre-sale mode to address the current situation of overstocked inventories in the apparel industry.

This paper describes a two-level closed-loop supply chain consisting of one manufacturer and one branding business [17-19]. Under centralized decision-making pattern, it discusses whether hybrid-channel OEM supply chain could obtain an overall optimization when the manufacturer and the branding business carry out cooperative game, and whether participants could reach Pareto optimization based on profit compensation and contact sharing. Under decentralized decision-making scenario, our paper also discussed manufacturer and branding business to carry out non-cooperative game and explored whether they could obtain decision-making and prof-

it optimization of system and participants through optimization of decision-making parameters. Through a comparison between the decentralized and centralized decision-making in hybrid-channel OEM supply chain, it solved the operating conditions and optimization mechanism of hybrid-channel OEM supply chain.

2. Problem and symbols

2.1 Description of our research problem

This paper described a two-level closed-loop supply chain consisting of one manufacturer and one branding business with the parameter conditions in dual channel selection under the requirements of production cost of manufacturer and brand premium ability of branding business.

Hybrid-channel centralized decision-making I (Integrated Hybrid Channel) is shown in Fig. 1 and its channel environment can be described as follows. The manufacturer manufactures products at unit cost c and exploits direct sales channel and OEM channel. OEM channel forms seamless strategic alliance with branding business and sets the wholesale price as $w^I = 0$; the manufacturer and branding business, as a whole, conduct decision-making optimization and jointly formulate optimal prices p_o^I and p_d^I of OEM channel and direct sales channel. In the aspect of market demand, under hybrid-channel centralized decision-making situation, market demand Q_d^I of direct sales channel and market demand Q_o^I of OEM channel are respectively expressed in the following demand functions:

$$Q_d^I = \left(a - bp_d^I\right) + r[(p_o^I - v) - p_d^I] \tag{1}$$

$$Q_o^I = [a - b(p_o^I - v)] + r[p_d^I - (p_o^I - v)] \tag{2}$$

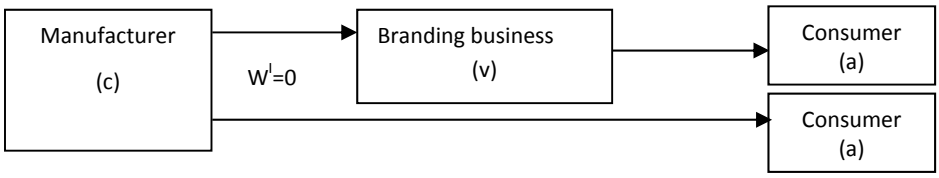

Fig. 1 Channel structure – hybrid channel (centralized decision making)

The manufacturer simultaneously explores the direct sales channel and OEM channel, namely hybrid channel as shown in Fig. 2. It is simply labeled as pattern H. The branding business in this pattern firstly proposes its profit level g^H, the manufacturer makes decisions according to profit level of the branding business and its own unit production cost c, and then formulates optimal wholesale price w^H of OEM channel and optimal price p_d^H of direct sales channel to maximize its profit. At this time, the market price of the branding business in OEM channel is $p_o^H = w^H + g^H$.In the aspect of market demand, the brand effect of branding business in OEM channel continuously retains pricing advantage v for its products in the market. In addition, substitution effect of products exists between channels, therefore we introduce here the channel demand transfer coefficient r ($r > 0$). The essence of channel transfer derives from the cognitive difference of consumers for paid price when purchasing products: the price paid by consumers in the direct sales channel is the sales price p_d^H of its product, while the price paid by consumer to obtain a product in OEM channel is the sales price p_d^H, together with the corresponding brand ue v.So the net price paid to obtain the product is $p_o^H - v$. To sum up, we express the market demand Q_d^H in the direct sales channel and the market demand Q_d^H in OEM channel in hybrid channel respectively using the following demand functions:

$$Q_d^H = \left(a - bp_d^H\right) + r[(p_o^H - v) - p_d^H] \tag{3}$$

$$Q_o^H = [a - b(p_o^H - v)] + r[p_d^H - (p_o^H - v)] \tag{4}$$

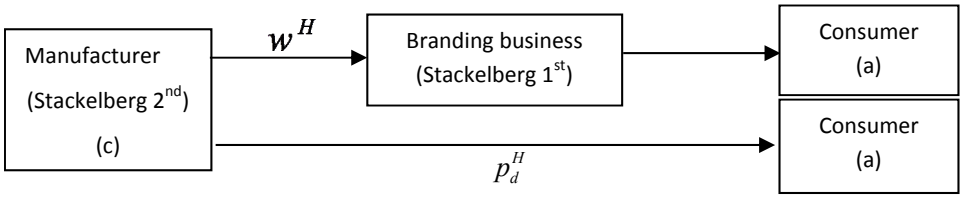

Fig. 2 Channel structure – hybrid channel (disperse decision making)

2.2 Symbol description

Major parameters are described in Table 1.

Table 1 parameter description

Symbol		Symbol description
Participant	M	Manufacturer
	R	Branding business
Price	w	Wholesale price of manufacturer
	p	Unit price of promoting products
	g	Unit profit level of branding business
	c	Unit production cost of manufacturer (private information of manufacturer)
	v	Brand premium of branding business
	r	Channel transfer coefficient
Demand	b	Price demand elasticity coefficient
	a	Market demand of direct sales channel or OEM channel (assumed being equal)
	Q	Channel demand
Superscript/subscript	R	Branding business
	M	Manufacturer
	D	Single direct sales channel of manufacturer
	O	Single OEM channel of manufacturer
	H	Hybrid channel
Target	I	Centralized decision making
	π	Yield returns

3. Model building

3.1 Centralized supply chain model (I)

Here, the total profit function of supply system is $\pi_S^I = \left(p_d^I - c\right)Q_d^I + (p_o^I - c)Q_o^I$
Optimization objective of the system:

$$\max \pi_S^I = \left(p_d^I - c\right)Q_d^I + (p_o^I - c)Q_o^I \tag{5}$$

3.2 Disperse supply chain model (C)

The profit function of branding business is $\pi_R^H = g^H Q_o^H$ and that of the manufacturer is $\pi_M^H = \left(p_d^H - c\right)Q_d^H + (w^H - c)Q_o^H$.

In the case of hybrid channel, the branding business specifies the product profit level g^H according to its profit maximization goal $max\,\pi_R^H$, and then the manufacturer specifies wholesale prices w^H and p_d^H according to decision-making goal $max\,\pi_M^H$. The decision-making objective is expressed as below:

$$\begin{cases} \max \pi_R^H = g^H Q_o^H & (6) \\ \text{s.t.} \quad w^H = \arg\ max\ \pi_M^H & (7) \\ p_d^H = \arg\ max\ \pi_M^H & (8) \\ \max\limits_{w^H,\, p_d^H} \pi_M^H = \left(p_d^H - c\right) Q_d^H + (w^H - c) Q_o^H & (9) \end{cases}$$

Its equilibrium solution is shown in Table 2.

Table 2 performance comparison of the centralized decision making and decentralized decision making in hybrid channel

Hybrid channel		Centralized decision making I^*	Decentralized decision making H^*	$\Delta(I^* - H^*)$
Direct sales channel	Price	$p_d^{I^*} = \frac{a+bc}{2b}$	$p_d^{H^*} = \frac{a+bc}{2b}$	0
	Sales volume	$Q_d^{I^*} = \frac{a-bc-rv}{2}$	$Q_d^{H^*} = \frac{(a-bc)(2b+3r)}{4(b+r)} - \frac{rv}{4}$	$-\frac{r(a-bc+bv+vr)}{4(b+r)} < 0$
	Profit	$\pi_{M_d}^{I^*} = \frac{(a-bc)(a-rv-bc)}{4b}$	$\pi_{M_d}^{H^*} = \frac{(a-bc)(2ab+3ar-3bcr-r^2v-2b^2c-bvr)}{8b(b+r)}$	$-\frac{(a-bc)r(a-bc+bv+vr}{8b(b+r)} < 0$
OEM channel	Wholesale price		$w^{H^*} = \frac{ab+bvr+b^2v+3b^2c+2bcr+2ar}{4b(b+r)}$	
	Price	$p_o^{I^*} = \frac{a+bv+bc}{2b}$	$p_o^{H^*} = \frac{3ab+3bvr+3b^2v+b^2c+2bcr+2ar}{4b(b+r)}$	$-\frac{a-bc+bv+vr}{4(b+r)} < 0$
	Sales volume	$Q_d^{I^*} = \frac{a+bv-bc+rv}{2}$	$Q_o^{H^*} = \frac{a+bv+rv-bc}{4}$	$\frac{a-bc+bv+vr}{4(b+r)} > 0$
			$\pi_{M_O}^{H^*} = \frac{(ab+bvr+b^2v+3b^2c+2bcr+2ar)(a-bc+bv+vr)}{16b(b+r)}$	
	Profit		$\pi_R^{H^*} = \frac{(a-bc+bv+vr)^2}{8(b+r)}$	
		$\pi_o^{I^*} = \frac{(a+bv-bc)(a+bv-bc+rv)}{4b}$	$\pi_o^{H^*} = \pi_{M_O}^{H^*} + \pi_R^{H^*}$	$\frac{(a+bv-bc+rv)[b(a+bv-bc+rv)+2r(a-bc)]}{16b(b+r)} > 0$
Total profit		$\pi_s^{I^*} = \frac{(a+bv-bc)^2}{2b} + \frac{v(2bc+rv-bv-2a)}{4}$	$\pi_s^{H^*} = \pi_{M_d}^{H^*} + \pi_o^{H^*} + \pi_R^{H^*}$	$\frac{(a-bc+bv+vr)^2}{16(b+r)} > 0$

4. Decision-making mode analysis of hybrid channel

4.1 Precondition of existence for hybrid channel

Considering from the prospective of manufacturers, existence of hybrid channel relies on simultaneous establishment of two channels, namely products per unit of manufacturer in both direct sales channel and OEM channel are of profitability ($p_d^{H^*} > c$ and $w^{H^*} > c$) and realizability of its corresponding yield capacity ($Q_d^{H^*} > 0$ and $Q_o^{H^*} > 0$).

$$\begin{cases} \text{Direct sales channel：} p_d^{H^*} = \frac{a+bc}{2b} > c、 Q_d^{H^*} = \frac{(a-bc)(2b+3r)}{4(b+r)} - \frac{rv}{4} > 0; \\ \text{OEM channel：} w^{H^*} = \frac{ab+bvr+b^2v+3b^2c+2bcr+2ar}{4b(b+r)} > c、 Q_o^{H^*} = \frac{a+bv+rv-bc}{4} > 0; \end{cases}$$

The following can be obtained: $0 < c < \frac{a}{b}$ and $0 < v < \left(\frac{2}{r} + \frac{1}{b+r}\right)(a - bc)$.

4.2 Lessons leant from the optimization from decentralized decision making to centralized decision making

Within the interval range $(0 < c < \frac{a}{b}, \frac{a-bc}{\sqrt{b(b+r)}} < v < \left(\frac{2}{r} + \frac{1}{b+r}\right)(a - bc);\ 0 < r < 9.332b)$which has been realized in the decentralized decision making mode, we compare the game results of the decentralized decision-making mode and centralized decision-making in hybrid channel (as shown in Table 2), which show that the total profit level of hybrid-channel OEM supply chain can finally reach its optima.

Based on the Table 2, when implementing the centralized decision making mode for hybrid-channel OEM supply chain within the range of $(0 < c < \frac{a}{b};\ \frac{a-bc}{\sqrt{b(b+r)}} < v < \left(\frac{2}{r} + \frac{1}{b+r}\right)(a - bc); 0 < r < 9.332b)$, phenomena such as decreasing sales volume in direct sales channel and lowering price in OEM channel will certainly appear. The precondition for hybrid channel to be optimized is to ensure the sustainability of the hybrid channel, which requires non-negativity of sales volume of in the direct sales channel in centralized decision-making mode and profitability of the market price in OEM channel, namely:

(1) $p_o^{I^*} = \frac{a+bv+bc}{2b} > c \Rightarrow v > \frac{bc-a}{b}$:

($\because 0 < c < \frac{a}{b}$, $\therefore \forall\ v > 0$ both lead to $v > \frac{bc-a}{b}$, $\therefore$ this condition is a relaxed constraint.

(2) $Q_d^{I^*} = \frac{a-bc-rv}{2} > 0 \Rightarrow 0 < v < \frac{a-bc}{r}$:

- $0 < r < 1.618b$: The intersection interval between the centralized and the decentralized decision-making modes is $\frac{a-bc}{\sqrt{b(b+r)}} < v < \frac{a-bc}{r}$. Where the hybrid-channel OEM supply chain can still be maintained in group decision-making mode, and there is a possibility of optimization. During the process of group decision making in the remaining interval $\frac{a-bc}{r} < v < (a - bc)(\frac{2}{r} + \frac{1}{b+r})$. Direct sales channel will confront an unrealizable sales volume ($Q_d^{I^*} < 0$), resulting in a self-termination of the hybrid channel.
- $1.618b \le r < 9.332b$: During the process of implementing a centralized decision making in the valid interval of the decentralized decision-making mode in hybrid-channel OEM supply chain $\frac{a-bc}{\sqrt{b(b+r)}} < v < (a - bc)(\frac{2}{r} + \frac{1}{b+r})$, there are phenomena like an unrealizable sales volume ($Q_d^{I^*} < 0$) in direct sales channel and a self-termination of the hybrid channel.

Deduction: Channel transfer coefficient is relatively small, when premium effect level of branding business is the range of $\frac{a-bc}{\sqrt{b(b+r)}} < v < \frac{a-bc}{r}$, OEM supply chain can maintain the existence of the

hybrid channel by using the centralized decision-making mode. That's to say, only when the above conditions are met can hybrid-channel OEM supply chain be optimized.

After parameter requirements of optimization precondition are satisfied, the comparison of the optimization results between the decentralized and the centralized decision making which leads to the following interpretations:

- When implementing the centralized decision making in hybrid channel, the overall profit income of supply system is improved when compared with that of the decentralized decision-making process. The total system profit increases by $\frac{(a-bc+bv+vr)^2}{16(b+r)}$ when compared with that in the hybrid-channel decentralized decision making. Such increment is an increasing function of the brand premium level v of branding business and the production cost advantages of manufacturer (a decreasing function of production cost c), namely the stronger the brand premium effect of branding business and the production cost advantages of the manufacturer, the more effective the optimization of total system profit will be.
- In the hybrid-channel centralized decision-making process, the market unit price of OEM channel will decrease by a larger margin, which can more effectively promote the increase of sales in OEM channel and facilitate the profit growth in OEM channel. The direct sales pricing of manufacturer in direct sales channel will remain unchanged, decreased pricing of OEM channel will result in channel transfer of market demand and lowering sales volume in direct sales channel, the profit level of direct sales channel will be lowered as well. Thus, it can be seen that the focus of optimization of the centralized decision making mode on hybrid-channel OEM supply chain lies in OEM (profit of OEM channel increases by $\frac{(a-bc+bv+vr)[b(a+bv+vr-bc)+2r(a-bc)]}{16b(b+r)}$), and direct sales channel is not the optimization objective of the centralized decision-making mode (profit of direct sales channel is reduced by $\frac{(a-bc)r(a-bc+bv+vr)}{8b(b+r)}$).
- In hybrid-channel centralized decision making, branding business implements optimized compensation for the manufacturer with its profits obtained from OEM channel, and attentions should be paid to two dimensions: (1) Make up for the lower profit in the direct sales channel (the amount of profit compensation in the direct sales channel is $\frac{(a-bc)r(a-bc+bv+vr)}{8b(b+r)}$); (2) Compensation for operating cooperation ($w^I = 0$) of the manufacturer in OEM channel (after branding business reserves its own profit income level $\pi_R^{H^*} = \frac{(a+bv-bc+vr)^2}{8(b+r)}$ in decentralized decision-making mode and compensates for profit amount $\frac{(ab+brv+b^2v-b^2c-2bcr+2ar)(a+bv-bc+vr)}{16b(b+r)}$ which can be obtained from OEM channel by the manufacturer in the decentralized decision-making mode, and then the net increment $\frac{(a+bv-bc+vr)^2}{16(b+r)}$ of total system profit will be shared). It can be seen from this compensation mechanism that both participants can obtain reserved earnings in decentralized decision-making process, and it's obviously that the redistributed amount of net increment of total optimized system profit is additional income of two participants, and the existence of the Pareto optimization is apparent.

5. A calculated example

Through a simulated calculation, this section will analyze the effect of the parameters of hybrid channel (i.e., brand premium v of branding business, manufacturer production cost c and channel transfer coefficient r) under different decision-making modes. The detailed results of this calculated example are shown in Table 3, Table 4, and Table 5. Parameters in all the three tables meet the precondition for decision-making optimization in hybrid channel, namely $0 < c < \frac{a}{b}$,

$0 < r < 1.618b$ and $\frac{a-bc}{\sqrt{b(b+r)}} < v < \frac{a-bc}{r}$. The profit sharing mechanism of hybrid-channel OEM supply chain under centralized decision-making mode is specified as: after compensating participants for their deserved profits using decentralized decision-making mode, the system net increment of OEM channel in the decentralized decision-making mode are shared between the manufacturer and branding business based on the profit hierarchy coefficient $K_{OEM}^{H^*} = \frac{\pi_{M_o}^{H^*}}{\pi_R^{H^*}}$ (namely ratio of wholesale profit income of manufacturer in OEM channel under decentralized decision-making mode in hybrid-channel OEM supply chain to sales profit income of branding business).

Here, we define manufacturer channel profit ratio as $K_M^{H^*} = \frac{\pi_{M_d}^{H^*}}{\pi_{M_o}^{H^*}}$, which is the ratio of the profit income of manufacturer's direct sales channel under decentralized decision-making mode in hybrid-channel OEM supply chain to the profit income of OEM under centralized decision-making mode in hybrid-channel OEM supply chain. We define centralized decision-making mode in hybrid channel, and define manufacturer channel profit ratio $K_M^{I^*}$ as ratio of shared income in direct sales channel and that in OEM channel under decentralized decision-making mode in hybrid channel namely $K_M^{I^*} = \frac{\pi_{M_d}^{I^*}}{\pi_o^{I^*} - [\pi_R^{H^*} + \frac{1}{1+K_{OEM}^{H^*}}(\pi_s^{I^*} - \pi_s^{H^*})]}$; profit hierarchy ratio $K_{OEM}^{I^*}$ of OEM channel is ratio between manufacturer profit and branding business income in OEM channel according to new profit sharing mechanism after centralized decision making in hybrid-channel OEM supply chain, namely $K_{OEM}^{I^*} = \frac{\pi_o^{I^*}}{\pi_R^{H^*} + \frac{1}{1+K_{OEM}^{H^*}}(\pi_s^{I^*} - \pi_s^{H^*})} - 1$.

5.1 Influence of brand premium of branding business on the decision-making profit in hybrid channel

We set $a = 10, b = 2, r = 2$, and $c = 2$ and the value range for brand premium level v when hybrid channel is built is $(1.414, 2.000)$. We then select five data points within premium range to conduct simulated calculation. By observing simulation results in Table 3 and drawing channel profit and participant profit curve, we can obtain the following findings:

- In the decentralized decision-making mode, with the elevation of brand premium level of branding business, profit incomes of both manufacturer and branding business are increased, as well as the total system profit. It can be seen from the results in the Table 2 that the profit increase is mainly from OEM while the profit level of the direct sales channel exhibits a decreasing tendency. It can also be seen through the channel profit ratio $K_M^{H^*}$ of the manufacturer that its reliance on the profit of OEM channel is more profound. As for the profit hierarchy $K_{OEM}^{H^*}$ of OEM channel, brand premium of branding business improves profitability of OEM channel, based on which branding business will obtain higher profit hierarchy than manufacturer (value of $K_{OEM}^{H^*}$ will become increasingly smaller).
- In the centralized decision-making process in hybrid channel, with elevated brand premium level of branding business, the variation tendency of participant profit is similar to that in the decentralized decision-making mode, but variation amplitude of the centralized decision-making mode is more prominent, which leads to $K_M^{I^*} < K_M^{H^*}$. This can be explained as: the manufacturer sacrifices more profits in the direct sales channel for its cooperation in OEM channel. To achieve the return for cooperating in centralized decision making, the manufacturer can claim for a higher compensation of OEM channel, so the profit hierarchy ratio $K_{OEM}^{I^*}$ in OEM channel will slightly increase ($K_{OEM}^{I^*} > K_{OEM}^{H^*}$). However, with an elevated brand premium level, the centralized decision-making mode will cause more performance loss (that is the difference between the profit under centralized decision-making mode and that under decentralized decision-making mode), namely decreasing degree of $K_M^{I^*}$ is greater. A higher brand premium level means that status of branding business is more and more important, so on the whole, the profit hierarchy ratio $K_{OEM}^{I^*}$ of OEM channel under the centralized decision-making mode presents a decreasing tendency.

Table 3 calculated example – Influence of brand premium of branding business on decision-making profit in hybrid channel

a	10.000	r	2.000	v	Lower limit	Upper limit	
b	2.000	c	3.000		1.414	2.000	
v			1.500	1.600	1.700	1.800	1.900
Hybrid channel (decentralized decision making)	Total system profit		7.688	8.070	8.468	8.880	9.308
	Total profit of manufacturer		4.563	4.690	4.823	4.960	5.103
	Total profit of branding business		3.125	3.380	3.645	3.920	4.205
	Profit of direct sales channel (manufacturer)		1.750	1.700	1.650	1.600	1.550
	Profit of OEM channel		5.938	6.370	6.818	7.280	7.758
	Profit hierarchy $K_{OEM}^{H^*}$ of OEM channel		0.900	0.885	0.870	0.857	0.845
	Channel profit ratio $K_M^{H^*}$ of manufacturer		0.622	0.569	0.520	0.476	0.436
Hybrid channel (centralized decision making)	Total system profit		9.250	9.760	10.290	10.840	11.410
	Total profit of manufacturer		5.303	5.483	5.671	5.865	6.065
	Total profit of branding business		3.947	4.277	4.619	4.975	5.345
	Profit of direct sales channel (manufacturer)		0.500	0.400	0.300	0.200	0.100
	Total profit of OEM channel		8.750	9.360	9.990	10.640	11.310
	Profit hierarchy $K_{OEM}^{I^*}$ of OEM channel		1.217	1.189	1.163	1.139	1.116
	Channel profit ratio $K_M^{I^*}$ of manufacturer		0.104	0.079	0.056	0.035	0.017
Optimized profit increment of supply system			1.563	1.690	1.823	1.960	2.103

5.2 Influence of manufacturer production cost on decision-making profit of hybrid channel

We set $a = 10, b = 2, r = 2$ and $v = 1.5$, the value range of therequired production cost c when hybrid channel is built is $(2.879, 3.500)$. We take five data points within production cost range to conduct a simulated calculation. The simulation results are presented in Table 4. The following findings can be obtained from the results:

- In hybrid-channel decentralized decision-making mode, with a significant improvement of production cost advantages (production cost becomes lower and lower), the profit income of manufacturer and branding business increase, as well as the total profit of the system. It can be seen from the details in the Table 2 that the profit increase of the manufacturer comes from both the direct sales channel and OEM channel, but in terms of the degree of increase, as can be seen through the increasing tendency of the channel profit ratio $K_M^{H^*}$ of the manufacturer, profit increase from the direct sales channel is more significant. Thus, the cost advantage is extremely beneficial to the two channels and the overall system, and it is more effective on the performance improvement of the manufacturer in the direct sales channel. In the meantime, cost advantage of a manufacturer is also a symbol of its status in OEM channel. A lower cost means a higher profit hierarchy ratio $K_{OEM}^{I^*}$ in OEM channel. With a prominent increase of cost advantages, the value of $K_{OEM}^{I^*}$ will become increasingly large.
- In hybrid-channel centralized decision making, with increasingly prominent production cost advantages, the profit variation is largely similar to that in the decentralized decision-making mode, namely the profits of participating enterprises, the two channels and the whole supply system all increase. However, the degree of profit increase of the direct sales channel is slower than that of the decentralized decision-making mode ($K_M^{I^*} < K_M^{H^*}$).

That's to say, the manufacturer gives up more profits of the direct sales channel in order to help achievethe optimization objectives of the centralized decision making in OEM channel. The manufacturer, therefore, can obtain more compensation from OEM channel as a return of its cooperation in the centralized decision-making process. The profit hierarchy ratio $K_{OEM}^{I^*}$ in OEM channel will certainly increase ($K_{OEM}^{I^*} > K_{OEM}^{H^*}$) as the result. However, with the elevation of production cost advantages, performance improvement of the direct sales channel is always possible, so it's observed from overall tendency that the channel profit ratio $K_M^{I^*}$ of the manufacturer is on a rise. The proportion of the profit income of the manufacturer in direct sales channel against its total profit increases. A lowering production cost means that the status of the manufacturer in OEM channel becomes more and more important, so the profit hierarchy ratio $K_{OEM}^{I^*}$ of OEM channel presents an increase tendency.

Table 4 calculated example – Influence of manufacturer production cost *c* on decision-making profit in hybrid channel

a	10.000	*r*	2.000	*c*	Lower limit	Upper limit	
b	2.000	*v*	1.500		2.879	3.500	
c			3.400	3.300	3.200	3.100	3.000
Hybrid channel (decentralized decision making)	Total profit		5.888	6.309	6.750	7.209	7.688
	Manufacturer total profit		3.243	3.548	3.870	4.208	4.563
	Branding business total profit		2.645	2.761	2.880	3.001	3.125
	Profit of direct sales channel (manufacturer)		1.000	1.169	1.350	1.544	1.750
	Total profit of OEM channel		4.888	5.141	5.400	5.666	5.938
	Profit hierarchy $K_{OEM}^{I^*}$ of OEM channel		0.848	0.862	0.875	0.888	0.900
	Channel profit ratio $K_M^{I^*}$ of manufacturer (direct sales channel/OEM channel)		0.446	0.491	0.536	0.579	0.622
Hybrid channel (centralized decision making)	Total profit		7.210	7.690	8.190	8.710	9.250
	Manufacturer total profit		3.849	4.187	4.542	4.914	5.303
	Branding business total profit		3.361	3.503	3.648	3.796	3.947
	Profit of direct sales channel (manufacturer)		0.080	0.170	0.270	0.380	0.500
	Total profit of OEM channel		7.130	7.520	7.920	8.330	8.750
	Profit hierarchy $K_{OEM}^{I^*}$ of OEM channel		1.122	1.147	1.171	1.194	1.217
	Channel profit ratio $K_M^{I^*}$ of manufacturer		0.021	0.042	0.063	0.084	0.104
Optimized profit increment of supply system			1.323	1.381	1.440	1.501	1.563

6. Conclusion

This paper discussed the influence of different parameter intervals on channel model selection for manufacturer and branding business, solved the conditions for building a hybrid channel and unraveled the optimization mechanism of the hybrid-channel OEM supply chain. In addition, the paper discussed and verified the feasible optimization schemes for hybrid-channel OEM supply chain, including those for optimizing decision-making parameters and decision-making mode. This paper presented the following important findings: (1) it is possible to realize profit performance improvement of the two parties in a hybrid-channel OEM supply chain and the whole system by optimizing decision-making parameters; (2) In terms of the total profit level of the supply system, the centralized decision-making mode is superior to the decentralized decision-

making mode. In the centralized decision-making mode, after the profits created by OEM channel is used towards compensating the reserved profit performance of direct sales channel and OEM channel of manufacturer, the optimized profit increment of the system can be redistributed based upon the profit hierarchy ratio of the OEM channel using the decentralized decision-making mode, and the possibility exists for achieving the Pareto optimization.

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