The Advantages Of Cooperative Game Model In Enterprises Interaction In Vertical Marketing Channels By Varying Small Values Of Parameters Of The Advertising Cost Response Function

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Abstract: Research of business interaction in marketing channels is often associated with the necessity to study the optimal business game scenarios, which provide the best implementation of enterprises business behavior strategies and maximize their profits. In such situations involvement of game-theoretic modeling apparatus in the process of determining key factors influencing profits formation of manufacturers and retailers, contributes to a better understanding of the cause and the effect relationships between the magnitude of profits, interpreted in the form of indicators of business strategies, and creates the prerequisites for finding ways of sharing joint profits in marketing channels. The purpose of study is to find optimal values in terms of channel members profits maximizing of the parameters of the advertising cost response function, in which the manufacturer and the retailer by agreement make decisions on the implementation of business game strategies, including pricing strategies and strategies for generating joint advertising costs. The paper presents a numerical experiment on the possible values of the parameters of the advertising cost response function, which takes into account the recommendations of the practice of enterprises functioning in distribution channels. Mathematical calculations have been made, which allow to build a model of cooperative game of the manufacturer and the retailer, based on the non-dimensional form of retail price values as well as values of joint advertising costs. The optimal solution of cooperative game, which within the numerical experiment is presented as the possible maximum values of profits of the manufacturer, the retailer and the vertical marketing channel, is made. The comparative analysis of the solutions of cooperative game and non-cooperative game, which involves the formation of Nash equilibrium, is given to determine the benefits of cooperative game model for both participants of the vertical marketing channel in terms of maximizing their profits and profit of the channel as a whole. The results obtained can be an information base for further calculations and comparisons of cooperative and non-cooperative models as interactions between participants of supply chains. In addition, the results of numerical simulations form the initial base for comparisons with other variants of cooperative game model, which involve changing a range and a step change of output values of the model.

Index Terms: advertising cost response function, business game strategy, cooperative game, Nash equilibrium, profit, retail price, transfer price.

1 INTRODUCTION

IN the process of functioning of enterprises in marketing channels, an important aspect is the creation of an effective mechanism for their interaction, which is able to maximize their profits in short and long term, as well as create the preconditions for improving financial planning of enterprises, including planning of their costs. In this context, consideration should be given to the possibility of creating favorable conditions for optimizing the costs of enterprises involved in distribution channels through their joint participation in product promotion to end consumers.

It is convenient to consider the mechanism of such interaction on the example of the participants of duopoly, in particular in marketing channel, where one manufacturer and one retailer interact. Thus, exploring the features of joint interaction between the manufacturer and the retailer in the decision-making process regarding the implementation of the main business game strategies, which are pricing strategies, as well as strategies for generating joint costs for product promoting in distribution channel, plays an important role. This interaction involves the use of the concept of joint or cooperative advertising during construction and implementation of a game-theoretic model. In the present study, cooperative advertising is reflected in practical terms as the share of joint advertising costs incurred by the manufacturer and the retailer which are the participants of the vertical marketing channel, in the process of promoting the product to end consumers. Since the proposed study includes the main aspects of building the game-theoretic model of business interaction between the manufacturer and the retailer, it is worth considering the positions of both channel participants as rational, that is, based on mutual agreement of the manufacturer and the retailer to make decisions on the implementation of basic business strategies. Thus, the manufacturer's and the retailer's business game strategies that help building the model of their cooperative game are planned actions to set transfer and retail prices, as well as the shares of joint advertising costs. Consensual decision-making on the implementation of these strategies is designed to maximize profit in vertical marketing channel, so it is an urgent issue of the practice of distribution channels.

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2 THEORETICAL BASIS

Cooperative advertising plays a key role in the process of finding the optimal solution to channel profit maximization, since cooperative game model represents a set of managed parameters and model variables. Cooperative advertising and retail price are able to influence the level of consumer demand for the product and thus coordinate the product sales in marketing channel. Being the driving force of changing product demand, cooperative advertising is designed to maximize channel profit, that is, to create favorable opportunities for the manufacturer and the retailer in the distribution of joint profits. In the process of building cooperative game model, it is important to identify its components, such as manufacturer's and retailer's shares of joint advertising costs, which form cooperative advertising costs that [1], [3], [4], [6], [9], [10], define as the ratio of the manufacturer's coverage of all or part of the retailer's costs for product promotion. To build cooperative game-theoretic model, we use the proposed in [9] that refers to [8], multiplicative model, which is mathematically represented as follows:

$$G(w, v, p_r) = l(p_r) \times F(w, v), \quad (1)$$

where w - the share of the retailer's costs for joint product promotion; v - the share of the manufacturer's costs for joint product promotion; p_r - retail price per unit of product.

The component $F(w, v)$ of function (1) characterizes the advertising cost response function and, according to [5], can be submitted in the following form:

$$F(w, v) = A - \frac{B}{w^{\alpha} \times v^{\beta}}, \quad (2)$$

where A - the scattered asymptote of product sales; B - estimation parameter; α, β - quasi-advertising elasticity respectively for the retailer and the manufacturer.

The component $l(p_r)$ of function (1) characterizes the linear relationship between the retail price per unit of product and the volumes of its sale and, according to [7] and [9], can be represented as follows:

$$l(p_r) = a - b \cdot p_r, \; a, b \in R, \quad (3)$$

where a, b - estimating the parameters of the linear pairwise regression equation, which are positive constants.

Given (2)-(3), the consumer demand function (1) has the form:

$$G(w, v, p_r) = (a - b \cdot p_r) \times (A - \frac{B}{w^{\alpha} \times v^{\beta}}); \quad (4)$$

$$a, b > 0, \; A, B, w, v > 0, \; \alpha, \beta \in (0;1)$$

We will consider function (4) as a profit function, which in the light of pricing strategies and strategies of joint advertising costs can be represented in such form:

for the manufacturer

$$\Pi_m = p_t \cdot (1 - p_r) \cdot \left(\frac{A}{(B)^{\frac{1}{\alpha+\beta+1}}} - \frac{1}{w^{\alpha} \cdot v^{\beta}} \right) - k \cdot w - v \quad (5)$$

for the retailer

$$\Pi_r = (p_r - p_t) \cdot (1 - p_r) \cdot \left(\frac{A}{(B)^{\frac{1}{\alpha+\beta+1}}} - \frac{1}{w^{\alpha} \cdot v^{\beta}} \right) - (1 - k) \cdot w \quad (6)$$

for the channel

$$\Pi_{ch} = p_r \cdot (1 - p_r) \cdot \left(\frac{A}{(B)^{\frac{1}{\alpha+\beta+1}}} - \frac{1}{w^{\alpha} \cdot v^{\beta}} \right) - w - v, \quad (7)$$

where p_t - transfer price per unit of product; k - the rate of the manufacturer's participation in the costs of the retailer's product advertising.

Consider equation (7), which reflects the mathematical record of the channel profit function in non-dimensional form, thus it is convenient in further calculations and implementation of a numerical experiment. To build cooperative game model, we take into account that the existence of cooperation between the manufacturer and the retailer implies their joint decision-making regarding the implementation of business game strategies. Unlike non-cooperative game variants, the cooperative game model is focused on finding optimal scenarios of interaction between the manufacturer and the retailer that maximize channel profit, that is, reflect the coordinated business strategies of both participants of the vertical marketing channel.

As can be seen from the mathematical record of equation (7), the channel profit depends on three variables, namely on the retail price and the shares of joint advertising costs of the manufacturer and the retailer. To solve the problem of maximizing the channel profit function, it is necessary to check the necessary and the sufficient conditions for the existence of an extremum of function (7):

$$\max_{p_r, w, v} \Pi_{ch} = \max_{p_r, w, v} \left[p_r \cdot (1 - p_r) \cdot \left(\frac{A}{(B)^{\frac{1}{\alpha+\beta+1}}} - \frac{1}{w^{\alpha} \cdot v^{\beta}} \right) - w - v \right] \quad (8)$$

The necessary condition for the existence of an extremum can be written as follows:

$$\begin{cases} (\Pi_{ch})'_{p_r} = 0, \\ (\Pi_{ch})'_{w} = 0, \\ (\Pi_{ch})'_{v} = 0 \end{cases} \quad (9)$$

Findings of first-order partial derivatives for the system of equations (9) led to the fact that:

$$\begin{cases} (1 - 2 \cdot p_r) \cdot \left(\frac{A}{(B)^{\frac{1}{\alpha+\beta+1}}} - \frac{1}{w^{\alpha} \cdot v^{\beta}} \right) = 0, \\ \alpha \cdot w^{-(\alpha+1)} \cdot v^{-\beta} \cdot p_r \cdot (1 - p_r) - 1 = 0, \\ \beta \cdot w^{-\alpha} \cdot v^{-(\beta+1)} \cdot p_r \cdot (1 - p_r) - 1 = 0 \end{cases} \quad (10)$$

From the first equation of system (10) we find that $p_r = 0{,}5$. Having solved the second and the third equations of system (10) and considering that $p_r = 0{,}5$, we get the solutions that represent the model of cooperative game:

$$\begin{cases} p_r^{co} = \frac{1}{2}, \\ v^{co} = \frac{\beta}{\alpha} \cdot w^{co}, \\ w^{co} = \left(\frac{\alpha}{4} \cdot \left(\frac{\alpha}{\beta} \right)^{\beta} \right)^{\frac{1}{\alpha+\beta+1}} \end{cases} \quad (11)$$

As retail price p_r and shares of joint advertising costs for product promotion for the manufacturer (v) and the retailer (w) may acquire values equivalent to those generated by the cooperation of the channel members, it can be assumed that the channel profit is maximized by any value of the manufacturer's participation rate in the advertising costs of the retailer, taking into account the range (0;1) chosen for numerical experiment. At the same time, as can be seen from the mathematical record of functions (5)-(6), the profit functions of the manufacturer and the retailer also depend on the variables k, p_t, which indicates the necessity to prove the adequacy of cooperative game model to the conditions of practice of marketing channels functioning. To perform numerical experiment of the possibilities of using cooperative game model in the process of enterprises activity in marketing channels, we substantiate and calculate the components of the model (11) A, B, which implies the need for a detailed study of the linear function (3). Considering the nature of the advertising cost response function (2), its components A, B, according to [2], satisfy the following conditions: $A = 2$, whereas a significant advertising campaign cannot substantially expand sales (more than twice); $B = 0{,}5 \cdot w^{\alpha} \cdot v^{\beta}$, because the manufacturer's enhanced advertising campaign cannot increase their product sales (more than 50%). Therefore, we take into account non-dimensional values of the components A, B, given in the following form:

$$A = 2 \times \frac{a^2}{b}, \qquad B = 0{,}5 \times \frac{a^2}{b} \times w^{\alpha} \times v^{\beta} \quad (12)$$

In order to find significant estimates of the parameters a, b of the linear pairwise regression equation, we present the results of observation of a selective set by volume $n = 36$ corresponding to the nature of function (3). The observational data on the average monthly retail price per unit of product and the average monthly volume of its sales make it possible to construct the following equation:

$$Y = -0{,}0758228 \cdot X + 4285277{,}9 \quad (13)$$

The main numerical characteristics of equation (13) are given in table 1:

Table 1

The Main Numerical Characteristics of the Model of Linear Pairwise Regression $Y = a + b \cdot X$

Parameter estimates	Parameter Estimation b	Parameter Estimation a
	-0,0758228	4285277,9
The coefficient of determination R^2	0,92126125	10153,425
F - Fisher criteria	397,807713	34

As can be seen from the data of table 1, with an 8% probability of making a mistake, it can be argued that regression model constructed in (13) best describes the linear dependence between retail price p_r and product sales in the marketing channel. The further numerical experiment is about finding the optimal parameter α, β values, which affect the formation of the shares of joint advertising costs in the profit model (11) and which change in the range (0;1) with a step $s = 0{,}1$. To determine the optimal in terms of channel profit maximization values of parameters α, β that satisfy the conditions of the system (11), we consider two cases of changing values in accordance with given range and step of change. First, consider the option where for each α from the set of values $\alpha = \{0{,}1;0{,}2;0{,}3;0{,}4;0{,}5;0{,}6;0{,}7;0{,}8;0{,}9\}$ parameter β satisfies the condition $\beta \in (0;1)$. Then we swap α, β, and in the second case for each β from the set of values $\beta = \{0{,}1;0{,}2;0{,}3;0{,}4;0{,}5;0{,}6;0{,}7;0{,}8;0{,}9\}$ we consider α that satisfies the condition $\alpha \in (0;1)$. Then we define for each case the maximum values of channel profits and choose the best option in which the profit is the highest. Finally, we compare the obtained result with non-cooperative Nash game, in which the channel participants simultaneously and independently make decisions on the implementation of the main game strategies, and prove that cooperative game provides higher profit for the marketing channel. We use the mathematical notation of Nash game solution proposed in [9], which implies the formation of Nash equilibrium:

$$\begin{cases} w = \left(\frac{\alpha}{9} \cdot \left(\frac{\alpha}{\beta} \right)^{\beta} \right)^{\frac{1}{\alpha+\beta+1}}, \\ v = \frac{\beta}{\alpha} \cdot w, \\ p_t = \frac{1}{3}, \\ p_r = \frac{2}{3}, \\ k = 0. \end{cases}, \quad (14)$$

3 METHODOLOGY

In the research process such scientific methods as analysis and synthesis, method of economic-mathematical modeling (in the process of constructing a theoretical-game cooperative model and searching for solutions of optimization problem), system method (in determining the relationship between price strategies and strategies of joint advertising costs formation), method of formalization (in the process of mathematical calculations), methods of probability theory and mathematical analysis (including the method of investigating the function of several variables) were used.

4 RESULTS

Preliminary analysis of the change of parameters α, β showed that the results of numerical experiment do not depend on the order of change of parameters values. Therefore, it is sufficient to consider the first case of changing α, β, that is when parameter $\beta \in (0;1)$ for each value $\alpha \in (0;1)$ that change with a step $s = 0{,}1$. The calculations made for $\alpha, \beta \in (0;1)$ allow us to assert that the largest values of channel profits acquire at $\alpha = 0{,}9$, that is they increase with increasing parameter α values. Therefore, in order to provide recommendations on the possibility of using cooperative game for maximizing the channel profit, it is necessary to analyze the data from table 2, reflecting the main components of channel profit model.

Table 2

Baseline to Evaluate the Potential of Cooperative Game Model to Maximize Channel Profit

α	β	w	v	p_r	Π_{ch}
0,9	0,1	0,5294	0,0588	0,5	16880079,48
0,9	0,2	0,5672	0,1260	0,5	36990305,78
0,9	0,3	0,5897	0,1966	0,5	74455331,47
0,9	0,4	0,6020	0,2676	0,5	139912984,70
0,9	0,5	0,6071	0,3373	0,5	248183442,90
0,9	0,6	0,6069	0,4046	0,5	419042291,40
0,9	0,7	0,6029	0,4689	0,5	677909833,90
0,9	0,8	0,5960	0,5298	0,5	1056420369,00
0,9	0,9	0,5870	0,5870	0,5	1592843626,00

As can be seen from the data in table 2, the channel profit (Π_{ch}) acquires the maximum value at $\alpha = \beta = 0{,}9$. In this situation, the strategies of generating joint advertising costs are equivalent for both participants of the vertical marketing channel ($w = v$). Thus, provided that $\alpha = \beta = 0{,}9$ at the retail price level $p_r = 0{,}5$, the position of the manufacturer and the retailer are mutually consistent and mutually beneficial, which is reflected in the maximum possible value of channel profit. It is worth noting that for each pair of α, β values, except $\alpha = \beta = 0{,}9$, the share of joint advertising costs of the retailer exceeds the corresponding share of joint advertising costs of the manufacturer ($w > v$), which reflects the disadvantage position of the retailer compared to the manufacturer. Coordinated interaction between the participants of the vertical marketing channel is achieved at $\alpha = \beta = 0{,}9$ and is considered as optimal variant of business game, which ensures the full implementation of game strategies of both channel participants and maximizes the channel profit. The graphical representation of channel profit maximization model under the conditions of cooperative game is represented in Fig. 1:

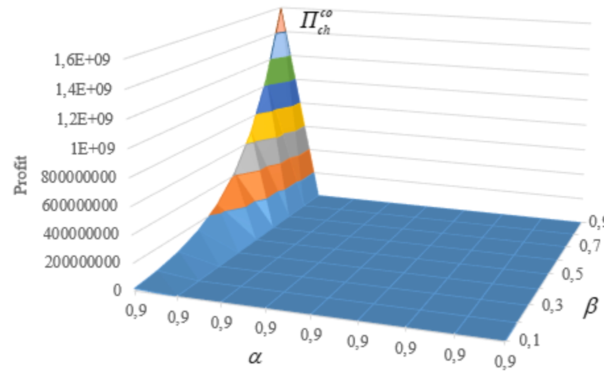

Fig. 1. *Channel profits model, reflecting cooperative interaction between the manufacturer and the retailer*

In order to determine the effectiveness of cooperative game model for channel profit maximization in terms of the decision-making characteristics of channel members in the implementation of business game strategies, we perform numerical experiment on the possibilities of using non-cooperative Nash game model, which involves simultaneous, independent and uncoordinated decision making by the manufacturer and the retailer for the implementation of business strategies. The mathematical record of Nash game solution, proposed in (14), takes into account the fixed levels of transfer price p_t and retail price p_r, as well as the zero rate of the manufacturer participation in the product promotion costs of the retailer. As in the case of cooperative game, we consider two options for changing the parameter α, β values to determine the optimal ratio for maximizing profits in the marketing channel. In the first case for each α from the set of values $\alpha = \{0{,}1;0{,}2;0{,}3;0{,}4;0{,}5;0{,}6;0{,}7;0{,}8;0{,}9\}$ parameter β satisfies the condition $\beta \in (0;1)$; in the second case for each β from the set of values $\beta = \{0{,}1;0{,}2;0{,}3;0{,}4;0{,}5;0{,}6;0{,}7;0{,}8;0{,}9\}$ parameter α satisfies the condition $\alpha \in (0;1)$. Preliminary analysis of the channel profit values in the first case made it possible to determine that channel profit reaches the maximum value at $\alpha = 0{,}9$. To compare the results of numerical experiment, depending on the peculiarities of changing the parameter α, β values, we use the data given in table 3:

Table 3

Data on Nash Equilibrium Formation at $k = 0$, $\alpha = 0{,}9$, $\beta \in (0;1)$ *With a Step Change* $s = 0{,}1$

α	β	w	v	p_t	p_r	Π_m	Π_r	Π_{ch}
0,9	0,1	0,3529	0,0392	0,3333	0,6667	9188351,66	9188351,35	18376703,01
0,9	0,2	0,3855	0,0857	0,3333	0,6667	20125718,20	20125717,90	40251436,10
0,9	0,3	0,4079	0,1360	0,3333	0,6667	40460501,84	40460501,57	80921003,40
0,9	0,4	0,4231	0,1881	0,3333	0,6667	75896752,39	75896752,15	151793504,50
0,9	0,5	0,4330	0,2406	0,3333	0,6667	134335317,20	134335317,00	268670634,10
0,9	0,6	0,4388	0,2925	0,3333	0,6667	226255498,50	226255498,40	452510996,90
0,9	0,7	0,4413	0,3433	0,3333	0,6667	365044849,20	365044849,10	730089698,30
0,9	0,8	0,4414	0,3923	0,3333	0,6667	567259605,60	567259605,50	1134519211,00
0,9	0,9	0,4394	0,4394	0,3333	0,6667	852803266,30	852803266,30	1705606533,00

Data from table 3 make it possible to assert that the channel profit reaches the maximum value at $\alpha = \beta = 0{,}9$. In this situation, the shares of joint advertising costs for the manufacturer (v) and the retailer (w) are equilibrium, and the retail price exceeds the transfer price ($p_r > p_t$), which satisfies the conditions of business game. In the second case, when the parameter $\alpha \in (0;1)$ for each value $\beta \in (0;1)$ changes with a step $s = 0{,}1$, preliminary analysis of the channel profit values showed that the channel profit maximization occurs at $\beta = 0{,}9$. For comparative analysis, the results of numerical experiment are given in the form of table 4:

Table 4

Data on Nash Equilibrium Formation at $k = 0$, $\beta = 0{,}9$, $\alpha \in (0;1)$ *With a Step Change* $s = 0{,}1$

α	β	w	v	p_t	p_r	Π_m	Π_r	Π_{ch}
0,1	0,9	0,0392	0,3523	0,3333	0,6667	9188351,35	9188351,664	18376703,01
0,2	0,9	0,0857	0,3855	0,3333	0,6667	20125717,90	20125718,20	40251436,10
0,3	0,9	0,1360	0,4077	0,3333	0,6667	40460501,57	40460501,84	80921003,40
0,4	0,9	0,1881	0,4231	0,3333	0,6667	75896752,15	75896752,39	151793504,50
0,5	0,9	0,2406	0,4330	0,3333	0,6667	134335317,00	134335317,20	268670634,10
0,6	0,9	0,2925	0,4388	0,3333	0,6667	226255498,40	226255498,50	452510996,90
0,7	0,9	0,3433	0,4413	0,3333	0,6667	365044849,10	365044849,20	730089698,30
0,8	0,9	0,3923	0,4414	0,3333	0,6667	567259605,50	567259605,60	1134519211,00
0,9	0,9	0,4394	0,4394	0,3333	0,6667	852803266,30	852803266,30	1705606533,00

As can be seen from the data in table 4, the channel profit is maximized when $\alpha = \beta = 0{,}9$. As in the previous case, under this condition, the retail price exceeds the transfer price ($p_r > p_t$), and the shares of joint advertising costs for the manufacturer and the retailer are equilibrium. Comparison of the data from table 3 and table 4 makes it possible to state that the magnitudes of the channel profits do not depend on the change of parameters α, β, so in the general case they can be represented as surface in Fig. 2 indicating any of the alternatives of changing α, β:

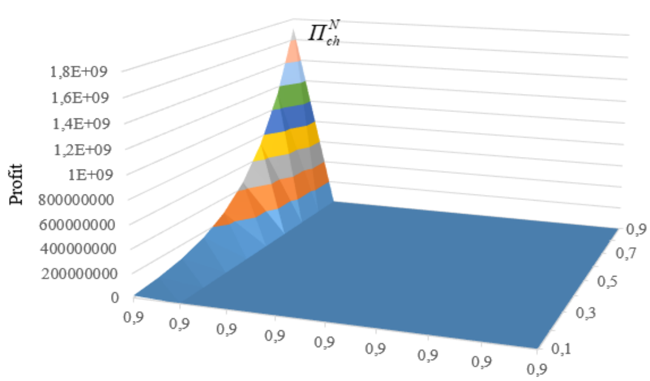

***Fig. 2**. Channel profits model provided Nash equilibrium*

Thus, channel profits maximization for both types of business games (non-cooperative Nash game and cooperative game) is achieved provided that $\alpha = \beta = 0{,}9$. Therefore, these α, β values can be considered as optimal for given conditions of business games. Let us determine the effectiveness of cooperative game model by comparing the results of its numerical experiment with the results of numerical experiment provided Nash equilibrium. To do this, we use the data from table 5:

Table 5

Summary Data on Cooperative game and Nash game Scenarios

Indicators	Cooperative game	Nash game
Channel profit (Π_{ch})	1592843626,00	1705606533,00
Manufacturer's share of joint advertising costs for product promotion (v)	0,5870	0,4394
Retailer's share of joint advertising costs for product promotion (w)	0,5870	0,4394
Retail price per unit of product (p_r)	0,5	0,67

Data from table 5 indicates that the channel profit value in the case of Nash game exceeds the corresponding profit value in the case of cooperative game. At the same time, the equilibrium shares of joint advertising costs of the manufacturer and the retailer under the conditions of non-cooperative game are less than the corresponding equilibrium shares of joint advertising costs in the case of manufacturer and retailer cooperation. Thus, taking into account the same conditions for both game scenarios for numerical experiment in the construction of regression model, it can be argued that there are favorable opportunities for the implementation of cooperative game model in the practice of channel members' activity.

5 CONCLUSION

Numerical experiment confirms that in the case of cooperative game, the shares of joint advertising costs of the manufacturer and the retailer are bigger than the shares in the case of Nash game. Despite this, each of the channel members seeks to minimize their own costs and get higher profits, which becomes possible in the case of cooperation and with regard to pricing strategies. It can be argued that, through cooperative game, there is an agreement between the manufacturer and the retailer, which involves their joint activity in pricing and is reflected in the retail price level, which is less than the corresponding price in Nash game. In view of this, the cooperative game option is more attractive to both the manufacturer and the retailer, as a higher level of retail price may indicate the possibility of its overestimation, due to the overestimation of the manufacturer's transfer price. At the same time, optimization of the costs of the manufacturer and the retailer is aimed at achieving maximum profit in the marketing channel, the value of which under the conditions of cooperation is less than the amount of profit that can be obtained in Nash game. This situation can be explained from the standpoint of Nash equilibrium, which implies that there is no agreement between the manufacturer and the retailer in the decision-making process regarding the implementation of the main game strategies. Although Nash equilibrium is capable of generating higher profit than cooperative game, compared to the cooperative game, it is considered as a less acceptable variant of business game given the specifics of the implementation of pricing strategies of the manufacturer and the retailer, as well as their strategies for generating joint advertising costs. In addition, if parameter α, β values are selected in a larger range than given, the channel profit under the conditions of cooperative game will exceed the corresponding profit under Nash game, which can be verified by numerical experiment.

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