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SUPPLY CHAIN PARTNERS' DECISIONS WITH HETEROGENEOUS MARKETING EFFORTS CONSIDERING CONSUMER'S PERCEPTION OF QUALITY

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Abstract. Consumers' perceived product quality reflects their psychological estimations on product quality, which directly affected by the real product quality provided by the manufacturer and the appearance of products from the retailer. Generally, consumer's willingness-to-pay is affected by their perceived quality. This study explores how consumers' perceived quality affects supply chain decisions with different supply chain structures. To conduct this study, demand function consisted of consumers' perceived quality is built. After that, the retailer and manufacturer's revenues models are formulated. Analytical solutions of supply chain partners, *i.e.*, optimal product quality, wholesale price, packaging investment and retail price, are obtained with Stackelberg games. Investigation on the relations between supply chain circumstances and equilibrium decisions under different supply chain power structurers suggests some novel findings and managerial insights. For example, retailer's optimal product retail price negatively affected by market demand, manufacturer's optimal product quality is proportionate to retailer's packaging investment and *vice versa*.

Mathematics Subject Classification. 91A80.

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1. Introduction

Private Brand (PB) products are a variety of goods that branded and sold by retailers where manufacturers are entrusted to output the goods following some reengaged specifications. The market for PB products began in mid-2000s and have been grown exponentially in recent years. With a high-likelihood that the PB products will continue to grow even larger in future. Due to the fact that the entire retail industry was battered by new retail channel such as cross-border e-commerce and new retail concept stores around 2015, it is imperative for the retailer to attach more emphasis on private brand product and begin to produce customized product in cooperation with some original equipment manufacturers (OEM). For example, Great Value, an OEM producer of Walmart, has more than 600 categories of PB commodities such as biscuit, rice, edible oil, etc. in China. The consumers' perception of quality for Great Value products is partly influenced by Walmart's reputation, which indicates that the products potentially benefit from the reputation of Walmart.

Keywords. consumer perception, private brand, quality, packaging investment.

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Since consumers' willing to pay is directly affected by the price and perceived product quality, the PB supply chain partners prefer homogeneous cooperation with their subsequent advantages to maximize supply chain benefits. Consumers' willingness-to-buy is partly affected by their perceived quality of products, which is determined by the true quality of products and the intuitionally estimation of package. Because the retailer is close to consumers which provides advantages in understanding consumers' psychology in purchasing, the retailer often invests on packages of the products in BP products. Meanwhile, producer has the professional manufacturing abilities and determines the investment in product quality on BP products. A good fit of investments from both the retailer and producer benefits the supply chain and themselves in return. This study exploreS how the supply chain partners make decisions considering consumers' perception of product quality and thereby suggest some managerial insights.

There exists different power structure of supply chain, such as retailer (*e.g.*, WalMart and Carrefour, and others) dominated supply chain and manufacturer (*e.g.*, P&G, COFCO, and others) dominated supply chain. Considering different supply chain power structures, we analyze the supply chain decisions and provides the corresponding comparisons. This study focuses on a three-tier supply chain consisting of one manufacturer, one retailer, and consumers. Based on consumer perception of product quality and packaging investment, a demand model and decision functions are formulated. The supply chain decisions, *i.e.*, product quality, wholesale price, packaging investment, and retail price, are obtained with a Stackelberg game. The contribution of this paper are threefold: (1) A demand model based on product perceived quality is established, and the impact from manufacturer product quality and retailer packaging investment to profit is analyzed. (2) This study suggests some analytical findings by comparing equilibrium solutions with two different supply chain power structurers. (3) The impact of consumer preference on optimal product quality, optimal packaging investment and optimal pricing strategy through a series of simulation experiment is investigated, and some management insights are observed as well.

The remaining chapters of this paper include: Section 2 is literature review, summarizes the current research on product quality and packaging investment of PB and MB and proposes the purpose of this article. Section 3 provides model design and analysis. Section 4 suggest experiment results through simulations. Section 5 concludes this study.

2. Literature review

The research on PB has already existed and mainly focuses on consumer's attitude towards PB and influence factor in purchase decision and the method adopted is mostly empirical research. Richardson *et al.* [19] adopted statistical method to conduct empirical research on the influence factor of PB purchase tendency. Baltas [2] resorted to behavioral analysis to study the combination of factors that attract consumer to purchase PB. Since then, there have been many studies on the relationship between PB and MB. Vaidyanathan and Aggarwal [31] analyzed the impact of PB and MB alliances on both parties. Soberman and Parker [25] demonstrated that higher category prices and higher advertising are consistent with markets where low-priced private labels have become more important. Soberman and Parker [26] made empirical analysis by using game model to explain two evidently contradictory conclusions: manufacturer provides PB products with same quality but lower price to retailer, but empirical study shows that this phenomenon usually leads to a higher average price. Amrouche and Zaccour [1] used game theory, market demand and consumer utility model to study why PB product with low quality exist only in certain product category, how their existence affects MB product pricing and how PB products affect consumer surplus and welfare. Therefore, the research that highly relevant to this paper can be mainly divided into two categories, one is the relationship between product quality and pricing strategy; the other is the impact of retailer packaging investment on pricing strategy.

In early stage, research on product quality and pricing issues focuses on parallel competition decision among multiple single-tier enterprises that could provide alternative product [3]. In recent years, some scholars gradually focus on product quality and market pricing from the perspective of a double-tier supply chain game [4]. Most of these studies assume that upstream manufacturer determines the investment in product quality and downstream retailer makes decision on the retail price in end-product market. Gurnani *et al.* [7] studied the optimization decision of supplier quality investment, retailer sales effort and retail pricing in a variety of different game structures assuming that the market demand for product is a linear function of its quality, retail price, and retailer sales effort. Zhu [37] focused on component quality investment and retail pricing of finished product in a double-layer decentralized supply chain consisting of multiple component suppliers and one single finished product manufacturer. Traditionally, research on product quality and quality investment focuses more on manufacturer while product pricing issue among multi-channel competition in the supply chain focuses more on retailer. Chen *et al.* [4] analyzed whether direct sales channel should be introduced into traditional retail channel and the impact of such channel introduction on pricing and quality decision. Faced with market risks, Zhu *et al.* [38] considered the impact of quality investment with loss in brand business reputation on the order quantity decision by supplier and retailer. Li *et al.* [12] studied online retailer minimal return quantity based on return policy and product quality. Sarkar *et al.* [21, 22] focused on the retailer's optimal decision on replenishment rate with the goal of maximizing profit with the demand related to sales price and credit period. Seifbarghy *et al.* [23] and Zhang *et al.* [35] both focused on the impact of demand change on the overall utility of supply chain after using contract to coordinate product quality investment as well as the on competition for quality investment in double-tier supply chain. Xie *et al.* [33] chose the quality of raw materials as the product quality standard and discussed the quality investment of supply chain in centralized and decentralized situations respectively. Zhang *et al.* [36] also introduced product quality into dual supply chain competition issue. Shaikh *et al.* [24] introduced a credit arrangement decision-making strategy for a double-warehouse system with non-instantaneous deteriorating product. The credit arrangement demand is subject to product price, and two different sales prices in deterioration period and non-deterioration period are considered respectively.

Nowadays, consumers pay increasing attention to consumption experience, and the impact of packaging investment on consumer purchase behavior has gradually increased [14, 18, 28, 32]. Packaging investment is an important influencing factor in retailer pricing decision, and it has attracted increasing attention from scholars in recent years. Consumers not only consider product price and quality in their purchase, but also packaging investment of the merchant. Studies show that packaging dimension affects consumers' judgment on product quality, and by observing the relationship between product dimension and perceived quality, the merchant packaging investment could affect consumer purchase decision [34]. Matsubayashi [15] studied how to make fast decision in the face of price sensitive and quality sensitive consumers when the information of two companies is asymmetric. It is found that product quality has increasingly greater impact on consumer purchase decision, and consumers pay more attention to product quality. Since consumers are more aware of the concept of sustainability, they could play an important role in promoting sustainable packaging. Therefore, enterprise should also consider the impact of sustainable packaging investment in making decision. Magnier *et al.* [13] studied the impact of packaging sustainability on consumer perceived food quality. Nigel *et al.* [17] investigates whether and to what extent consumer perceptions, inferences and attitudes towards packaged product is affected by sustainable packaging. Sarkar *et al.* [20] developed a multi-attribute closed-loop supply chain model of self-healing polymer recyclable transport packaging based on single supplier, single manufacturer and multiple retailers in the framework of budget and storage constraints.

This paper combines and studies the consumers perception of product quality with respect to both real product quality investment by OEM producers and the packaging investment by retailers when the estimate the quality of the product. It also makes contribution to exploring the individual decisions and supply chain performance when the supply chain partners have homogeneous strengths and double marginalization objectives in supply chain operations.

3. Model formulation

This paper proposes a three-tier supply chain consisting of one manufacturer (she), one retailer (he), and consumers. The product produced by manufacturer is sold by retailer, or retailer entrusts manufacturer to process product and then sell by its own (Fig. 1). It is assumed that manufacturer determines product quality

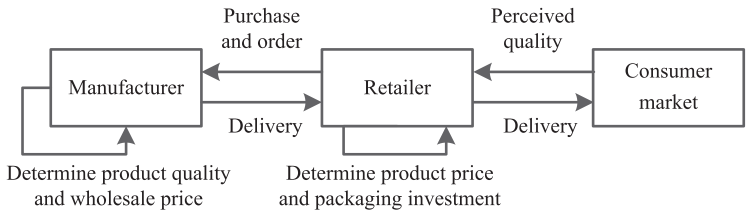

FIGURE 1. The sequence of supply chain decisions.

through production R&D investment, retailer determines product packaging investment through marketing investigation [4,5,7], and market determines total demand based on retail price, quality and packaging investment of product [3, 33]. This study tries to examine supply chain decisions with different power structures, thus it does not consider the delivery time and inventory of decisions makers. The decisions between manufacturer and retailer follows a Stackelberg game, with which calculate the optimal equilibrium decisions are obtained.

Refer to many existing studies, this study has the following assumptions: (1) Manufacturer determines product quality through production R&D investment [4, 7]. (2) Retailer determines product packaging investment through marketing investigation [34]. (3) The market demand is based on the retail price, quality and packaging investment of product [6, 9, 10]. (4) The unit product cost paid by the manufacturer is linearly related to the product quality [33]. To derive the model, the following notation are used (Tab. 1).

3.1. Basic model

The market demand normally affected by many factors, including selling price and product quality, as well as the packaging investment in selling seasons. Thus, refer to many previous studies, *e.g.*, Kuiteing *et al.* [9], Gao *et al.* [6], Kyparisis and Koulamas [10], etc., a linear demand function by equation (3.1) is formulated.

$$D(p_s, q, t) = a - \alpha p_s + \beta(q + \gamma t) \tag{3.1}$$

where a is the market demand base reflecting the inherent consumer demand in the whole market. α is price coefficient reflecting the impact of product price on consumer demand. β is quality coefficient reflecting the impact of consumer perceived quality on consumer demand. $q + \gamma t$ is consumer perceived quality, which means the subjective evaluation on product by consumers after they perceive product quality and packaging [8, 11]. γ is packaging investment coefficient reflecting the influence of retailer packaging investment on consumer demand [4].

Retailers influence consumers' perceived product quality packaging through packaging dimension, material, and design. Therefore, the retailer revenue function is

$$\prod\nolimits_S (p_s, p_m, t) = D(p_s, q, t)(p_s - p_m) - \frac{\eta}{2}t^2 \tag{3.2}$$

where p_m is manufacturer wholesale price, η is cost coefficient in packaging invested by retailer, which can also be understood as the money or effort invested by the retailer in product packaging [29].

The unit cost of manufacturer product is $p_c(q) = k_1 q + k_2$, where k_1 and k_2 demonstrates a linear relationship between production cost per unit and product quality [33]. The fixed cost for manufacturer $C(q) = \frac{v}{2}q^2$, where v is cost coefficient of product quality invested by manufacturer and reveals the difference in production efficiency between different manufacturer. So manufacturer revenue function can be expressed as

$$\prod\nolimits_M (p_m, q, Q) = (p_m - k_1 q - k_2)Q - \frac{v}{2}q^2. \tag{3.3}$$

Q is the retailer order quantity and it is assumed that the manufacturer production capacity can meet the retailer's order quantity. Two types of products, *i.e.*, manufacturer branded product and the PB product, are able to be supplied to retailers. The supply chain decisions including product quality, wholesale price, packaging investment, retail price as well as the supply chain performance, are examined by Stackelberg game models as follows.

3.2. Manufacturer brand product sold by retailer

When manufacturer product already enjoys high popularity, the manufacturer is in the dominant position in supply chain. For example, when Moutai's product is sold in supermarket, the manufacturer has strong control and she can control the supply to retailer. So in this case manufacturer dominates in the Stackelberg game, that is, manufacturer is dominant and retailer is follower. Through backward induction, first the retailer revenue function equation (3.2) is derived with respect to the retail price p_s and product packaging investment t, it shows,

$$\frac{\partial \prod_S}{\partial p_s} = D(p_s, q, t) - \alpha(p_s - p_m) \tag{3.4}$$

$$\frac{\partial \prod_S}{\partial t} = \beta\gamma(p_s - p_m) - \eta t. \tag{3.5}$$

Let $D_e = \frac{\alpha\eta}{\beta\gamma}$, namely Elasticity of demand, it can be deduced from equations (3.4) and (3.5) to get optimal order quantity for retailer. Defined D_b as the base demand for manufacturer as

$$D_b = a - \alpha p_m + \beta q. \tag{3.6}$$

Let $x = 2\frac{\alpha\eta}{\beta\gamma} - \beta\gamma$, it can be deduced from equations (3.4) and (3.5) that the optimal packaging investment for retailer at this time is

$$t = \frac{D_b}{x}\cdot \tag{3.7}$$

The retailer optimal retail price is

$$p_s = p_m + \frac{\eta}{\beta\gamma}t. \tag{3.8}$$

Then, when manufacturer knows retailer decision, the manufacturer revenue function equation (3.3) is derived with respect to wholesale price p_m and product quality q, her optimal decision can be obtained:

$$\frac{\partial \prod_M}{\partial p_m} = Q + (p_m - k_1 q - k_2)\frac{\partial Q}{\partial p_m} \tag{3.9}$$

$$\frac{\partial \prod_M}{\partial q} = (p_m - k_1 q - k_2)\frac{\partial Q}{\partial q} - k_1 Q - vq \tag{3.10}$$

where

$$\frac{\partial Q}{\partial p_m} = \frac{\alpha\eta}{\beta\gamma}\frac{\partial t}{\partial p_m} = -\frac{\alpha^2\eta}{x\beta\gamma} \quad \text{and} \quad \frac{\partial Q}{\partial q} = \frac{\alpha\eta}{\beta\gamma}\frac{\partial t}{\partial q} = \frac{\alpha\eta}{x\gamma},$$

$$\text{let } Q_{\Delta p_m} = -\frac{\alpha^2\eta}{x\beta\gamma}, \quad Q_{\Delta \mathrm{q}} = \frac{\alpha\eta}{x\gamma}\cdot$$

Then equations (3.9) and (3.10) can be simplified as

$$\frac{\partial \prod_M}{\partial p_m} = D_e t + (p_m - k_1 q - k_2)Q_{\Delta pm} \tag{3.11}$$

$$\frac{\partial \prod_M}{\partial q} = (p_m - k_1 q - k_2)Q_{\Delta q} - k_1 D_e t - vq. \tag{3.12}$$

So it can be deduced the optimal product quality for supplier is

$$\begin{aligned} q &= -\frac{1}{v}\left(k_1 D_e + \frac{D_e}{Q_{\Delta p_m}} Q_{\Delta q}\right) t \\ \text{let } Q_t &= -\frac{1}{v}\left(k_1 D_e + \frac{D_e}{Q_{\Delta p_m}} Q_{\Delta q}\right) \\ q &= Q_t t. \end{aligned} \tag{3.13}$$

The optimal product quality for supplier is

$$p_m = \left(k_1 Q_t - \frac{D_e}{Q_{\Delta p_m}}\right) t + k_2. \tag{3.14}$$

Combine equations (3.6), (3.7), (3.8), (3.13), and (3.14) together to get the following equation set

$$\begin{cases} D_b = a - \alpha p_m + \beta q \\ t = D_b / x \\ p_s = p_m + \eta t / \beta\gamma \\ q = Q_t t \\ p_m = \left(k_1 Q_t - D_e / Q_{\Delta p_m}\right) t + k_2 \end{cases}. \tag{3.15}$$

The Proposition 3.1 can be obtained by solving equation (3.15).

Proposition 3.1. *The greater the market demand, the lower the product retail price.*

Since the retailer actual retail price is

$$p_s = \frac{1}{2}\left(x - \beta Q_t\right) t - \frac{a}{2} + \frac{\eta}{\beta\gamma} t = \frac{1}{2}\left(x + \frac{\eta}{\beta\gamma} - \beta Q_t\right) t - \frac{Q}{2}.$$

So when manufacturer product is sold through retailer channel, the greater the market demand, the lower the product retail price.

The optimal wholesale price for manufacturer $p_m = \frac{D_b - a - \beta q}{\alpha} = \frac{1}{2}(x - \beta Q_t)t - \frac{a}{2}$.

And since $D_b = xt$ and $x > 0$, the market demand is directly proportional to the product packaging investment. This shows that although the manufacturer dominates the supply chain, the retailer is closer to the consumer and understands the consumer preference on product packaging, so he has certain influence on market demand. The specific result is shown in Appendix A.

3.3. Retailer entrusts manufacturer to produce PB product

When retailer entrusts manufacturer to produce PB product, retailer is in the dominant position in supply chain. For example, WalMart entrusts manufacturer to produce its PB product, Great Value with price generally 30% lower than that of similar product. Retailer has strong bargaining power and can reduce sale cost by eliminating many intermediate procedure and scale effect. So in this case retailer dominate in the Stackelberg game, that is, retailer is dominator and the manufacturer is follower. The optimal order quantity at this time is market demand, that is,

$$Q = D = a - \alpha p_s + \beta(q + \gamma t). \tag{3.16}$$

Let

$$p_a = p_s - p_m \tag{3.17}$$

where p_a represents the gap between retail price and wholesale price, namely, the gross profit of each product sold by the retailer. p_a is used as the retailer decision variable below.

Through backward induction, first the manufacturer revenue function equation (3.3) is derived with respect to wholesale price and product quality, it shows:

$$\frac{\partial \prod_M}{\partial p_m} = Q - (p_m - k_1 q - k_2)\,\alpha \tag{3.18}$$

$$\frac{\partial \prod_M}{\partial q} = (p_m - k_1 q - k_2)\,\beta - k_1 Q - vq. \tag{3.19}$$

Then it can be deduced the optimal order quantity for retailer is

$$Q = \alpha\,(p_m - k_1 q - k_2)\,. \tag{3.20}$$

Let $c_m^u = \frac{\beta}{\alpha} - k_1$,

$$c_m^u Q = vq. \tag{3.21}$$

The optimal wholesale price for manufacturer is

$$p_m = \frac{C_m}{1+\alpha C_m}(a - \alpha p_a + \beta\gamma t)$$

where

$$C_m = \frac{1}{\alpha} + \left(\frac{\beta}{\alpha} + k_1\right)\frac{c_m^u}{c_m^u \beta - v}\cdot$$

The optimal product quality for manufacturer is $q = \frac{c_m^u}{v - c_m^u \beta}(a - \alpha(p_m + p_a) + \beta\gamma t)$, let $c_m^q = \frac{c_m^u}{v - c_m^u}$, $C_m^1 = \frac{C_m}{1+\alpha C_m}$ then in the case of retailer knows manufacturer decision, retailer revenue function equation (3.2) is derived with respect to gross profit and product packaging investment, his optimal decision can be obtained:

$$\frac{\partial \prod_S}{\partial p_a} = D + p_a\left(-\alpha\left(-\alpha C_m^1 + 1\right) - \alpha\beta c_m^q\left(-\alpha C_m^1 + 1\right)\right) \tag{3.22}$$

$$\frac{\partial \prod_S}{\partial t} = -\eta t + p_a\left(-\alpha C_m^1 \beta\gamma + \beta\left(c_m^q \beta\gamma - c_m^q \alpha a C_m^1 \beta\gamma + \gamma\right)\right) \tag{3.23}$$

let $C_s^p = -\alpha\left(-\alpha C_m^1 + 1\right) - \alpha\beta c_m^q\left(-\alpha C_m^1 + 1\right), C_s^t = -\alpha C_m^1 \beta\gamma + \beta\left(c_m^q \beta\gamma - c_m^q \alpha a C_m^1 \beta\gamma + \gamma\right).$

Then equations (3.22) and (3.23) can be simplified as

$$\frac{\partial \prod_S}{\partial p_a} = D + p_a C_s^p \tag{3.24}$$

$$\frac{\partial \prod_S}{\partial t} = p_a C_s^t - \eta t. \tag{3.25}$$

So it can be deduced the optimal packaging investment for retailer is

$$t = \frac{p_a C_s^t}{\eta}\cdot \tag{3.26}$$

The retailer optimal gross profit is

$$p_a = \frac{\alpha}{C} p_m - \frac{\beta\gamma}{C} q - \frac{a}{C} \tag{3.27}$$

where $C = C_s^p - \alpha + \beta\gamma\frac{C_s^t}{\eta}$.

Combine equations (3.16), (3.17), (3.20), (3.21), (3.26) and (3.27) together to get the following equation set

$$\begin{cases} Q = a - \alpha(p_m + p_a) + \beta(q + \gamma t) \\ Q = \alpha(p_m - k_1 q - k_2) \\ c_m^u Q = vq \\ \eta t = p_a C_s^t \\ Cp_a = \alpha p_m - \beta\gamma q - a \end{cases}. \tag{3.28}$$

The Proposition 3.2 can be obtained by solving equation (3.28).

Proposition 3.2. *Product gross profit, product quality and packaging investment are proportional to each other.*

Since the optimal gross profit for retailer is

$$p_a = -\frac{\gamma}{C_s^p C_m^u} q.$$

The optimal packaging investment for retailer is

$$t = \frac{p_a C_s^t}{\eta} = \frac{-C_s^t \gamma}{\eta C_s^p C_m^u} q$$

when retailer entrusts manufacturer to produce its PB product, although retailer is in the dominant position in supply chain, the product quality also affects market demand. Consumers cannot ignore product quality simply due to low sales price or exquisite packaging from retailer, and *vice versa*. The specific results are shown in Appendix B.

4. Experimental results

Since there are many parameters in this paper, in order to vividly show the impact of above two situations on manufacturer decision and retailer decision, a series of values is set and cases by simulation is analyzed. It is assumed that market demand base $a = 500$, cost coefficient of package invested by retailer $\eta = 1$, coefficient of linear relationship between unit production cost and quality $k_1 = 1$ and $k_2 = 1$, and cost coefficient of product quality invested by manufacturer $v = 1$. The simulations are done with Matlab.

The impact of perception coefficient on optimal product pricing, quality and packaging investment based on consumer preferences is studied in Table 2. α is price coefficient reflecting the impact of product price on consumer demand, $\alpha \in (0, 1)$. β is quality factor reflecting the impact of consumer perceived quality on consumer demand $\beta \in (0, 1)$. γ is packaging investment coefficient reflecting the impact of marketing investment on consumer demand [4, 11]. During the numerical experiment, this study classifies consumes into 4 types and consider each type of consumers in our numerical experiments. For the consumers with and without price sensitiveness, our solutions are similar to many previous studies with classic Stackelberg game models [1,4,7,26]. For the consumers whose perception quality is (and is not) affected by product package, there few studies focus on the relation between perception quality and product package. The parameter values respecting to four types of consumers are presented by Table 3.

4.1. Case I. Manufacturer product sold through retailer

According to Section 3.2, it is obtained that the optimal D_b, p_m, p_s, q, t when manufacturer product is sold through retailer channel. These variables are related to consumer preference parameter value α, β, γ. The relationship between these variables and parameters in cases is analyzed.

TABLE 1. Main notations.

	Manufacturer	Retailer	Market demand
Basic information	C fixed cost ($/unit); v cost coefficient of product quality invested, $\nu \in (0,1]$	η cost coefficient in packaging invested, $\eta \in (0,1]$	a market demand base (units)
Decision variable	q product quality, $q \in (0,1)$; p_m manufacturer wholesale price ($/unit); p_c cost of manufacturer product ($/unit)	p_s retail price ($/unit); t packaging investment ($/unit); Q retailer order quantity (units)	α price coefficient, $\alpha \in (0,1)$; β quality coefficient, $\beta \in (0,1)$; γ packaging investment coefficient, $\gamma \in (0,1)$
Objective function	$\prod_M (p_m, q, Q)$ manufacturer's profits	$\prod_S (p_s, p_m, t)$ retailer's profits	D product demand

TABLE 2. Summary of existing studies.

Author(s)	Consider product quality	Consider product packaging	Demand function	Decision-making model	Research method
Soberman and Parker [26]	Yes	No	Linear	Decentralized	Game model
Amrouche and Zaccour [1]	Yes	No	Linear	Decentralized	Game model
Gurnani et al. [7]	Yse	No	Linear	Centralized + Decentralized	Game model
Chen *et al.* [4]	Yse	No	Linear	Centralized + Decentralized	Game model
Prakash and Pathak [18]	No	Yes	Not Applicable	Not Applicable	Structural equation model
Yan *et al.* [34]	Yes	Yes	Not Applicable	Not Applicable	Empirical study
Magnier *et al.* [13]	Yes	Yes	Not Applicable	Not Applicable	Empirical study
Nigel *et al.* [17]	No	Yes	Not Applicable	Not Applicable	Empirical study
Sarkar *et al.* [20]	No	Yes	Nonlinear	Centralized	Multi-objective optimization
This paper	Yes	Yes	Linear	Centralized + Decentralized	Game model

TABLE 3. Parameter values for four types of consumers.

Four types of consumers	α	β	γ
Type 1. Consumers whose willingness-to-pay is affected by product package	–	–	1
Type 2. Consumer whose willingness-to-pay is not affected by product package	–	–	0.5
Type 3. Consumer whose willingness-to-pay is affected by product price	1	–	–
Type 4. Consumer whose willingness-to-pay is affected by product price	0.5	–	–

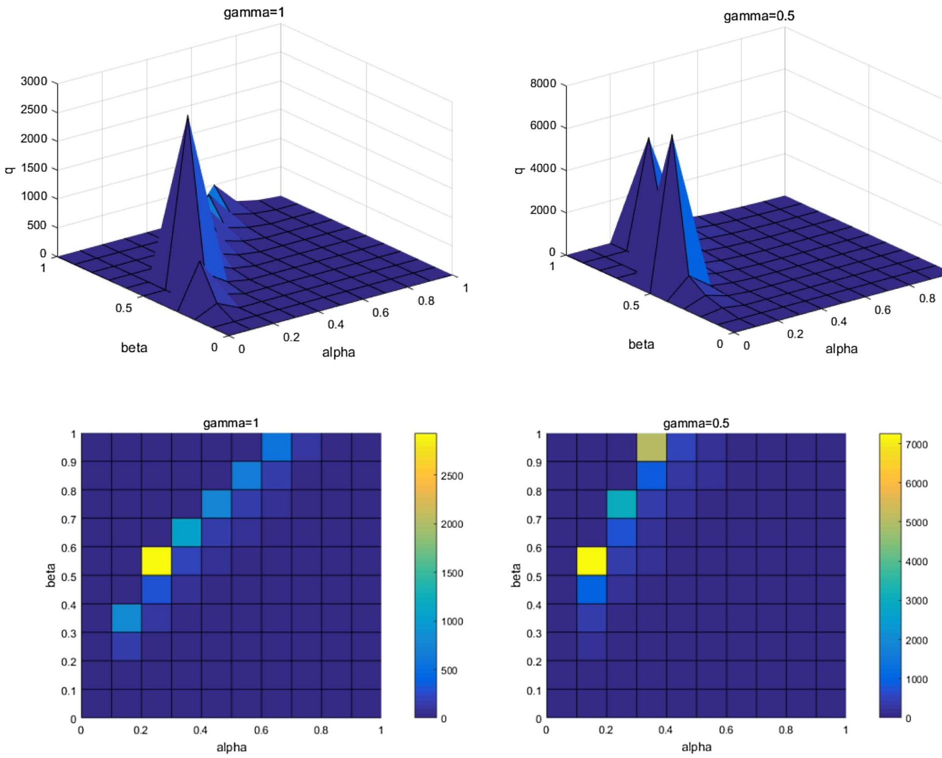

FIGURE 2. Relationship between q and α, β in manufacturer domination.

4.1.1. Relationship between price coefficient, quality coefficient and optimal product quality

It can be seen from Figure 2 that when manufacturer sells through traditional retailer channels, the manufacturer product quality is higher than when $\lambda = 0.5$ than when $\lambda = 1$. It shows that when consumers do not have high demand on product packaging, the demand on product quality is higher. When $\alpha < 0.5$, $\beta > 0.5$, it is easier for manufacturer product quality to reach its maximum value. This shows that when manufacturer product has brand effect, consumer is not price sensitive, more product quality sensitive, and not sensitive to packaging investment of retailer.

4.1.2. Relationship between quality coefficient, packaging investment coefficient and optimal product quality

According to Section 4.1.1 it is assumed that $\alpha = 0.2$. It can be seen from Figure 3 that when β approaches 1, γ approaches 0.1, manufacturer product quality reaches the maximum. That is, when manufacturer sells through traditional retailer channel, consumers are more product quality sensitive and not sensitive to the packaging investment, so this is her best strategy to reach maximum product quality. This shows that manufacturer will look for traditional retail channel to sell product and put into the market after simple packaging in order to pursue the optimal strategy so as to take the initiative and gain more revenue.

4.1.3. Relationship between quality coefficient, packaging investment coefficient and optimal packaging investment

According to Section 4.1.1 it is assumed that $\alpha = 0.2$. It can be seen from Figure 4 that when β approaches 1, γ approaches 0.1, the retailer packaging investment for product reaches the maximum. It shows that when manufacturer product is sold through traditional retailer channel, its price has small impact on market demand.

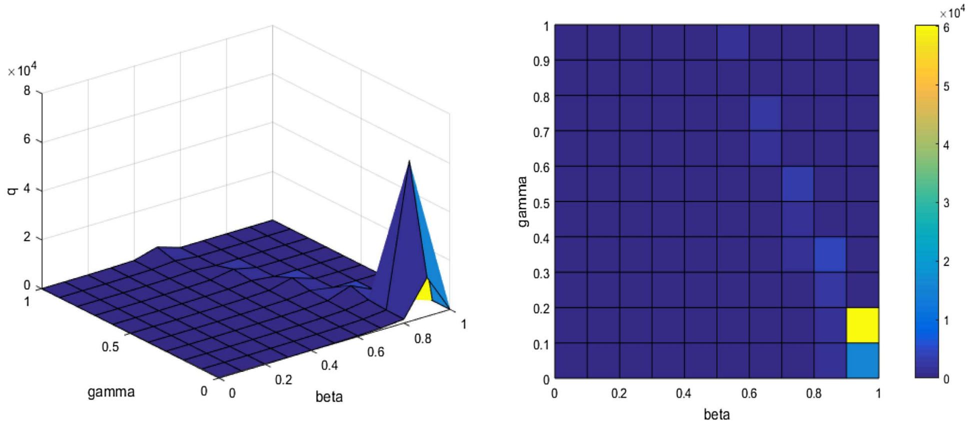

FIGURE 3. Relationship between q and β, γ in manufacturer domination.

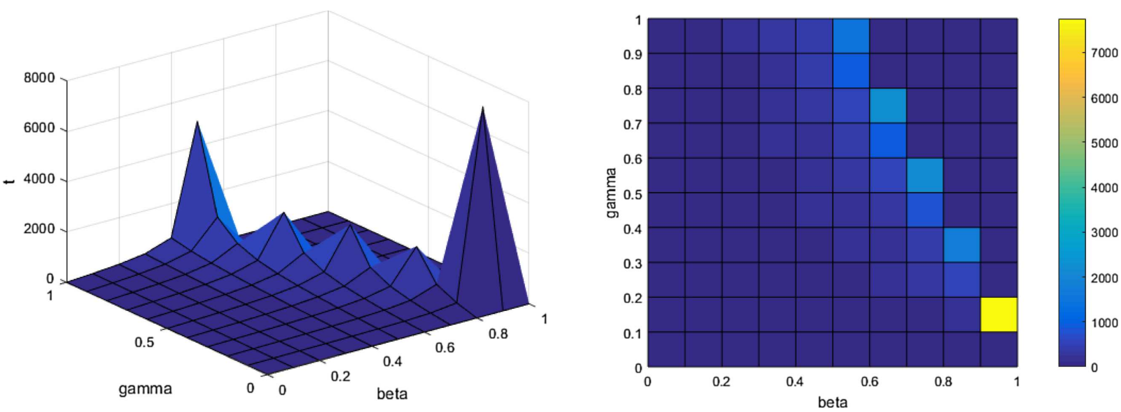

FIGURE 4. Relationship between t and β, γ in manufacturer domination.

The key lies in that manufacturers need to improve product quality in order to win consumers' favor. Then manufacturer needs to look for retailer providing better packaging level. This is because even though manufacturer dominates the supply chain, retailer is closer to the market and easier to influence consumer demand for product.

In reality, if its product is of high quality, a strong manufacturer takes the lion's share of retailer profits and it has pricing power in the supply chain. Conversely, retailer also hopes to sell some manufacturer product with high quality even if the profits are minor but they can have a good promotion effect. For example, Costco sells Moutai and Louis Vuitton in low price without packaging and often sells them directly.

4.2. Case II: Retailer entrusts manufacturer to produce PB product

In Section 3.3, the optimal Q, p_m, p_s, q, t, p_a in retailer domination is obtained. These variables are related to parameter values of consumer preference α, β, γ. The relationship between these variables and parameters in cases is analyzed.

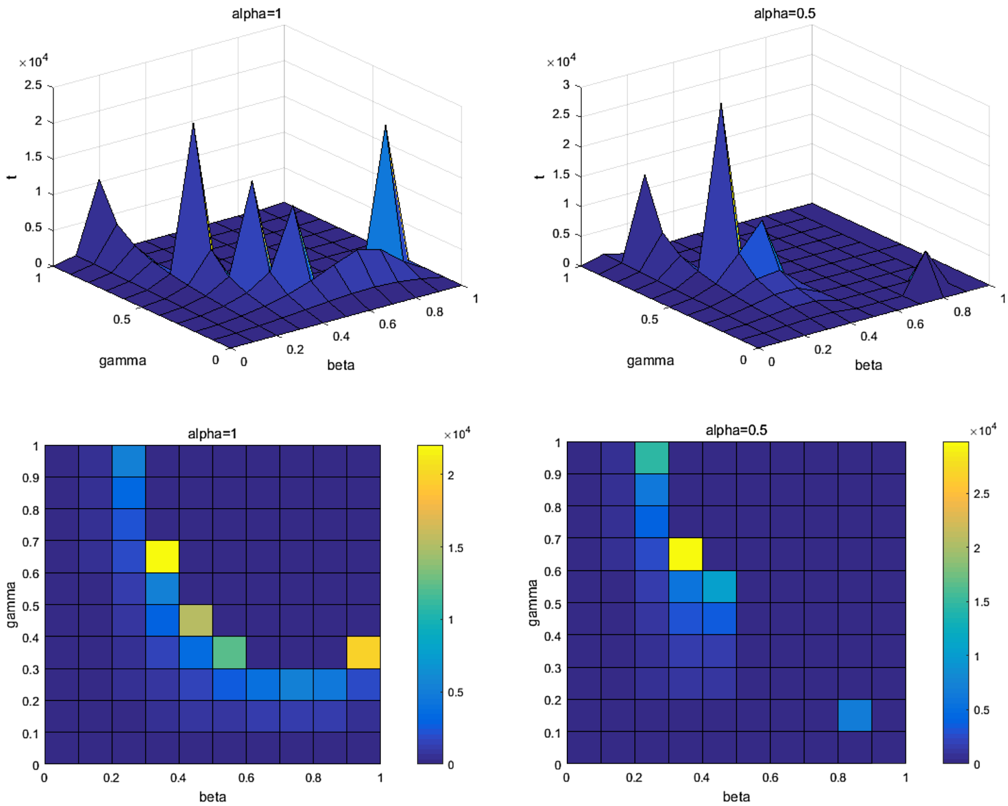

FIGURE 5. Relationship between t and β, γ in retailer domination.

4.2.1. Relationship between quality coefficient, packaging investment coefficient and optimal packaging investment

It can be seen from Figure 5 that when $\beta \in (0.3, 0.4)\gamma \in (0.6, 0.7)$, retailer packaging investment can reach the maximum whether consumer is price sensitive or not. When $\alpha = 1$, $\beta \in (0.9, 1)\gamma \in (0.3, 0.4)$, consumers are price and product quality sensitive while not packaging investment sensitive, retailer packaging investment can also reach the maximum. When $\alpha = 0.5$, $\beta < 0.5$, $\lambda > 0.5$, consumers are not price and product quality sensitive while packaging investment sensitive, retailer packaging investment is generally improved. It shows that when retailer sells PB products, consumers are more sensitive to product packaging than quality, especially when consumers are not price sensitive, they hope to get better package experience from retailer. For those consumers who are price sensitive, they hope that product quality could be correspondingly better.

4.2.2. Relationship between price coefficient, quality coefficient and optimal gross profit

According to Section 4.2.1 it is assumed that $\gamma = 0.65$. It can be seen from Figure 6 that in area where $\alpha > 0.1$, $\beta < 0.3$ and $\alpha/\beta = 1$, retailer earns more gross profit. Among them, when $\alpha \in (0.4, 0.5)$, $\beta \in (0.3, 0.4)$, retailer gets the most gross profit. It shows that when consumers are equally sensitive to product price and quality, consumers are more sensitive to the product packaging. If retailer at this time invests more in packaging of its PB product, it can maximize gross profit and earn more profits.

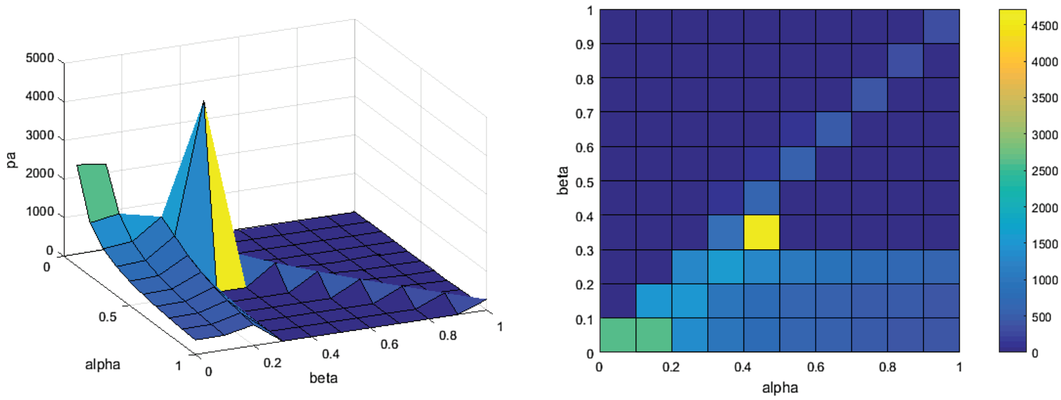

FIGURE 6. Relationship between p_a and α, β in retailer domination.

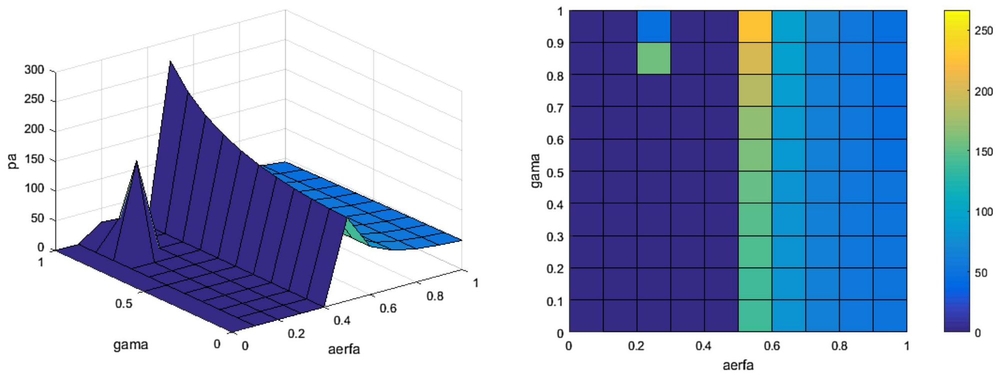

FIGURE 7. Relationship between p_a and α, γ in retailer domination.

4.2.3. Relationship between price coefficient, packaging investment coefficient and optimal gross profit

According to Section 4.2.1 it is assumed that $\beta = 0.35$. It can be seen from Figure 7 that when $\alpha \in (0.5, 0.6)$, γ approaches 1, retailer gross profit reaches the maximum. When $\alpha > 0.6$, gross profits will decrease. It shows that when consumers are not product quality sensitive, if consumers are not price sensitive, retailer can only make profits from consumers who are more sensitive to product packaging. Conversely, if consumers are price sensitive, it will be difficult for retailer to make more profit.

In reality, retailers tend to choose some less well-known manufacturer to occupy the dominant position in supply chain so as to control pricing power and earn more revenue. For example, WalMart's PB product, Great Value, is about 30% cheaper than counterpart products, but regardless of price sensitive or insensitive consumers, Great Value can still make more sales volume and profits by improving its product packaging appearance.

5. CONCLUSION

In the context of manufacturer provide products for retailer private brands, this paper, by building a three-tier supply chain model among manufacturer, retailer and consumer, studies the impact of consumer perception on manufacturer product quality, retailer packaging investment and pricing decision. When manufacturer product is sold in retailer channel, even if manufacturer is in dominant position, retailer has great impact on market demand. The lower the product retail price, the greater the market demand. The product packaging investment is directly proportional to market demand. When retailer entrusts manufacturer to produce PB products, product gross profit, product quality, and packaging investment are proportional to each other. At this time, the retailer occupies the dominant position, but manufacturer product quality also affects market demand and consumer will not ignore product quality simply due to retailer low sales price or high packaging investment. This all verify the rationality of the model design in this paper.

Since many parameters are involved in this model, different consumer preferences through examples through simulation experiment is analyzed. When consumers are less sensitive to retailer's price and packaging but more sensitive to manufacturers' product quality, the retailer's strategy is to sell some high-quality manufacturer brand product to attract consumers even if the profit is minor. For manufacturer, her strategy is to improve product quality and gain more market demand. In addition, she is more willing to cooperate with traditional retailer with ordinary packaging so as to take the initiative in supply chain and gain more profits. When consumers are not sensitive to product price, but more sensitive to product packaging than its quality, this means that consumers want to get better package service from the retailer. If the retailer invests more in the packaging of its PB product in circulation processing, advertising promoting and after-sales service, he is likely to maximize the gross profit. When other price sensitive consumers who hope that the retailer's PB product could have lower price and higher quality, the retailer's strategy is to choose some less well-known manufacturer, occupy the dominant position in supply chain, try to improve quality and gain more profits in low cost strategy.

The supply chain decisions with different supply chain power structures are examined in this study, but the limitations of the study enriches more extending studies in future. Because BP products are becoming more popular in recent years, it is worthwhile to provides more research directions. Consumers' perceptions of product quality is affected by many determinants, *e.g.*, retailer and manufacturer's reputations, recommendations from others, price of congeneric products, it is worthwhile to explore how impacts from the determinants. Meanwhile, supply chain partners' inventory level and time in transportations affect supply chain decisions, inventory and transportation time can be considered in extending studies.

Appendix A.

Combine equations (3.6), (3.7), (3.8), (3.13) and (3.14) to obtain the following equation set

$$\begin{cases} D_b = a - \alpha p_m + \beta q \\ D_b = xt \\ \beta\gamma p_s = \beta\gamma p_m + \eta t \\ q = Q_t t \\ Q_{\Delta p_m} p_m = (Q_{\Delta p_m} k_1 Q_t - D_e)t + k_2 Q_{\Delta p_m} \end{cases}.$$

Its coefficient matrix is

$$A = \begin{bmatrix} 1 & \alpha & 0 & -\beta & 0 \\ 1 & 0 & 0 & 0 & -x \\ 0 & 1 & -1 & 0 & \frac{\eta}{\beta\gamma} \\ 0 & 0 & 0 & 1 & -Q_t \\ 0 & 1 & 0 & 0 & \frac{D_e}{Q_{\Delta p_m}} - k_1 Q_t \end{bmatrix}.$$

Then A can be transformed into

$$A^* \begin{bmatrix} D_b \\ p_m \\ p_s \\ q \\ t \end{bmatrix} = \begin{bmatrix} a \\ 0 \\ 0 \\ 0 \\ k_2 \end{bmatrix}. \tag{A.1}$$

After calculation it can be obtained

$$|A| = -x - \alpha k_1 Q_t + \alpha \frac{D_e}{Q_{\Delta p_m}} + \beta Q_t = 2\beta\gamma - 4\frac{\alpha\eta}{\beta\gamma} + \frac{(k_1\alpha)^2\eta}{v\beta\gamma} + \frac{\beta\eta}{v\gamma} - \frac{2\alpha\eta k_1}{v\gamma}$$

when $|A| \neq 0$ solve equation (A.1), it can be obtained

$$
\begin{aligned}
D_b &= \frac{\beta^2\gamma^2 av - 2\alpha\eta av + \beta^2\gamma^2\alpha k_2 v + 2\alpha^2\eta k_2 v}{2\beta^2\gamma^2 v - 4\alpha\eta v + \alpha^2 k_1^2\eta + \beta^2\eta - 2\alpha\beta\eta k_1} \\
p_m &= \frac{\beta^2\gamma^2 v k_2\alpha - 2\alpha^2\eta k_2 v - \beta k_2\alpha^2\eta k_1 + \eta\beta^2 k_2\alpha + a\alpha^2\eta k_1^2 - ak_1\alpha\beta\eta - 2a\alpha\eta^2 + a\beta^2\gamma^2 v}{2\beta^2\gamma^2 v\alpha - 4\alpha^2\eta v + \alpha^3 k_1^2\eta + \alpha\beta^2\eta - 2\alpha^2\beta\eta k_1} \\
p_s &= \frac{\beta^2\gamma^2 v k_2\alpha - \alpha^2\eta k_2 v - 3a\eta v\alpha + a\beta^2\gamma^2 v - \beta a\alpha\eta k_1 + a\alpha^2\eta k_1^2 + k_2\alpha\beta^2\eta - \beta\alpha^2\eta k_1 k_2}{2\beta^2\gamma^2 v\alpha - 4\alpha^2\eta v + \alpha^3 k_1^2\eta + \alpha\beta^2\eta - 2\alpha^2\beta\eta k_1} \\
q &= \frac{a\alpha\eta k_1 - \alpha^2\eta k_1 k_2 + \beta\alpha k_2\eta - \beta a\eta}{2\beta^2\gamma^2 v - 4\alpha\eta v + k_1^2\alpha^2\eta + \beta^2\eta - 2\alpha^2\beta\eta k_1} \\
t &= \frac{\alpha k_2\beta\gamma v - a\beta\gamma v}{2\beta^2\gamma^2 v - 4\alpha\eta v + k_1^2\alpha^2\eta + \beta^2\eta - 2\alpha^2\beta\eta k_1}.
\end{aligned}
$$

Appendix B.

Combine equations (3.16), (3.17), (3.21), (3.26) and (3.27) to obtain the following equation set

$$
\begin{cases}
Q = a - \alpha\left(p_m + p_a\right) + \beta(q + \gamma t) \\
Q = \alpha\left(p_m - k_1 q - k_2\right) \\
c_m^u Q = vq \\
\eta t = p_a C_s^t \\
C p_a = \alpha p_m - \beta\gamma q - a
\end{cases}.
$$

Its coefficient matrix is

$$
A = \begin{bmatrix}
1 & -\alpha & 0 & \alpha k_1 & 0 \\
1 & \alpha & \alpha & -\beta & -\beta\gamma \\
c_m^u & 0 & 0 & -v & 0 \\
0 & 0 & C_s^t & 0 & -\eta \\
0 & \alpha & -C & -\beta\gamma & 0
\end{bmatrix}.
$$

Then equation (3.28) can be transformed into

$$
A^* \begin{bmatrix} Q \\ p_m \\ p_a \\ q \\ t \end{bmatrix} = \begin{bmatrix} -\alpha k_2 \\ a \\ 0 \\ 0 \\ a \end{bmatrix}. \tag{B.1}
$$

After calculation it can be obtained

$$
|A| = -2\alpha\eta Cv - \alpha^2\eta v + \alpha\beta\gamma v C_s^t - \alpha\beta^2\gamma^2 c_m^u C_s^t + \alpha^2\beta\gamma\eta c_m^u + \alpha\beta C\eta c_m^u + \alpha^2\beta\gamma k_1 c_m^u C_s^t - \alpha^3\eta k_1 c_m^u - \alpha^2\eta C k_1 c_m^u
$$

when $|A| \neq 0$ solve equation (B.1), it can be obtained

$$
\begin{aligned}
Q &= \frac{\alpha^2 k_2 v\eta C + \alpha^3 k_2 v\eta - \alpha^2 k_2 v\beta\gamma C_s^t - av\alpha\eta C + av\alpha\beta\gamma C_s^t - av\alpha^2\eta}{-2\alpha\eta Cv - \alpha^2\eta v + \alpha\beta\gamma v C_s^t - \alpha\beta^2\gamma^2 c_m^u C_s^t + \alpha^2\beta\gamma\eta c_m^u + \alpha\beta C\eta c_m^u + \alpha^2\beta\gamma k_1 c_m^u C_s^t - \alpha^3\eta k_1 c_m^u - \alpha^2\eta C k_1 c_m^u} \\
p_m &= \frac{\beta\gamma C_s^t\left(av - c_m^u\beta\gamma\alpha k_2 + c_m^u a\alpha k_1\right) + \eta c_m^u\left(\alpha^2 k_2\beta\gamma + \alpha k_2\beta C - \alpha k_1 aC - \alpha^2 k_1 a\right) - nv\left(aC + a\alpha + \alpha k_2 C\right)}{-2\alpha\eta Cv - \alpha^2\eta v + \alpha\beta\gamma v C_s^t - \alpha\beta^2\gamma^2 c_m^u C_s^t + \alpha^2\beta\gamma\eta c_m^u + \alpha\beta C\eta c_m^u + \alpha^2\beta\gamma k_1 c_m^u C_s^t - \alpha^3\eta k_1 c_m^u - \alpha^2\eta C k_1 c_m^u} \\
p_a &= \frac{\eta c_m^u\left(\alpha a\beta\gamma - a\alpha\beta - \alpha^2\beta\gamma k_2 + \alpha^2 k_1 a + \alpha^2 k_2\beta - ak_1\alpha^2\right) + nv\left(a\alpha - \alpha^2 k_2\right)}{-2\alpha\eta Cv - \alpha^2\eta v + \alpha\beta\gamma v C_s^t - \alpha\beta^2\gamma^2 c_m^u C_s^t + \alpha^2\beta\gamma\eta c_m^u + \alpha\beta C\eta c_m^u + \alpha^2\beta\gamma k_1 c_m^u C_s^t - \alpha^3\eta k_1 c_m^u - \alpha^2\eta C k_1 c_m^u}
\end{aligned}
$$

$$q = \frac{c_m^u \alpha a \beta \gamma C_s^t - \alpha^2 \beta \gamma k_2 c_m^u C_s^t - c_m^u \eta a \alpha^2 - c_m^u \eta \alpha a C + c_m^u \eta k_2 \alpha^2 C + c_m^u \eta k_2 \alpha^3}{-2\alpha\eta C v - \alpha^2 \eta v + \alpha\beta\gamma v C_s^t - \alpha\beta^2\gamma^2 c_m^u C_s^t + \alpha^2\beta\gamma\eta c_m^u + \alpha\beta C\eta c_m^u + \alpha^2\beta\gamma k_1 c_m^u C_s^t - \alpha^3\eta k_1 c_m^u - \alpha^2\eta C k_1 c_m^u}$$

$$t = \frac{C_s^t v\left(a\alpha + k_2\alpha^2\right) - C_s^t c_m^u\left(a\alpha\beta - a\alpha\beta\gamma - a\alpha^2 k_1 - \alpha^2\beta\gamma k_2 + a k_1 \alpha^2 + \beta k_2 \alpha^2\right)}{-2\alpha\eta C v - \alpha^2 \eta v + \alpha\beta\gamma v C_s^t - \alpha\beta^2\gamma^2 c_m^u C_s^t + \alpha^2\beta\gamma\eta c_m^u + \alpha\beta C\eta c_m^u + \alpha^2\beta\gamma k_1 c_m^u C_s^t - \alpha^3\eta k_1 c_m^u - \alpha^2\eta C k_1 c_m^u}.$$

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