Pricing Decision for Fresh Food Produce in Dual-Channel Supply Chain Considering Corporate Social Responsibility and Preservation Effort

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Abstract. This paper investigates the fresh food firms' corporate social responsibility (CSR) in the dual-channel supply chain in terms of freshness preservation efforts and pricing. By examining the influence of CSR on preservation effort, profit, pricing, and comparative analysis, the study concludes that CSR may always raise the freshness effort put into a product, reduce price, boost demand, and increase consumer surplus and social welfare. When a provider of the fresh product performs CSR on his own, he frequently sacrifices his profit for the sake of consumers.

Keywords: Dual-channel supply chain system; Freshness effort; Corporate social responsibility; Stackelberg game

1 Introduction

As the internet keeps growing, the proportion of products purchased online continues to increase. The fresh produce e-commerce industry is developing quickly. According to statistics [1], the size of the fresh produce e-commerce industry reached 458.5 billion yuan in 2020, an increase of 64.0% over 2019, and the size of the fresh produce e-commerce industry is expected to exceed a trillion by 2023. However, while the industry is developing, many fresh food companies are pursuing profit maximization, and corporate social responsibility is seriously lacking, causing many problems such as: "Dingdong " sold dead fish as live fish and was investigated for being substandard; "Missfresh" was repeatedly complained about by consumers due to food quality.

To address this issue, the State Council first upgraded CSR to the level of national strategy as early as 2014 and issued the Guide to Social Responsibility in 2015, both of which have clear requirements for enterprises to fulfil their social responsibility. Therefore, to be more sustainable and respond to the national policy, corporate social responsibility practices have been carried out: “Freshippo” launched the " compensation for bad fruit" service and "compensation for seafood not living."

From a supply chain system research perspective [2-4], there are two main strands in which scholars have approached theoretical modelling studies of CSR. Some scholars viewed CSR as an internal variable and focusing on the CSR input decisions of com-

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panies. Hsueh [5] finds that CSR can increase the profitability of the supply chain system and that revenue-sharing contracts can coordinate the supply chain and increase the level of social responsibility. Raza [6] and others use a supply chain consisting of a manufacturer and a retailer to develop deterministic and stochastic demand models related to price and CSR investment, respectively, and obtain optimal joint pricing, inventory, and CSR investment decisions.

Other scholars have portrayed CSR as the extent to which a firm care about its stakeholders, expressed as external variables in the model. Panda [7-9] describes CSR as a supply chain member's concern for consumer surplus. He looked at how manufacturers or retailers take on CSR and how it affects decisions in the supply chain. Modak et al. [10] find that fulfilment of social responsibility enhances supply chain profits and share residual profits using a Nash bargaining scheme.

Based on those discoveries, adopting mathematical modelling, we take a representative dual-channel supply chain, composed of a single retailer and a single supplier as our object, and consider CSR and preservation effort into this supply chain. we Integrate social welfare responsibility into the supply chain and establish three models: no CSR by the supply chain, CSR by the retailer, and CSR by the supplier. Then, we employ game theory to study different models, by doing so, getting the parameters under various models. We can discuss the impact of CSR and preservation effort on the members' decision variables and profits.

2 Questions and assumptions

This paper makes a structure for a two-channel supply chain with a supplier O and a retailer S. The supplier puts in some freshness technology just once. There are two ways to sell fresh food: 1) take to the retailer and sold to the market through the retailer. The supplier sells the fresh products to the retailer in bulk for price w. The retailer then sells it to the consumer at price p_2 and $p_2 > w$; 2) sold directly to the market online at price p_1. The unit cost of making a fresh product is C, and the prices at which it is sold online and in stores will affect channel demand. Figure 1 shows the supply chain system consisted of the supplier O and the retailer S and their business relationship.

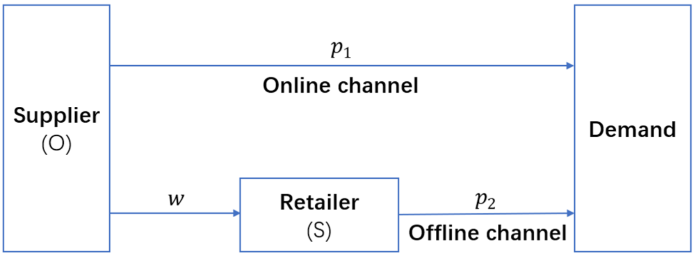

Fig. 1. Supply chain system.

In association with existing scholarly research, this paper makes the following assumptions:

1. To increase the company's market share and satisfy consumer demand for freshness, the supplier will invest in research and development in fresh produce preservation technology. Assume that the effort it invests is y.

2.Throughout the supply chain cycle, the supplier bears the cost of freshness. The impact factor of the preservation effort input on the cost is $v_1(v_1 > \frac{(3+2\beta)\gamma^2}{2(1-\beta)\beta})$. For the convenience of the subsequent study. The freshness cost function is [11]

$$C(y) = \frac{1}{2}v_1 y^2. \quad (1)$$

3.To simplify the analysis, the supplier and the retailer sell the same product to the same market in this dual-channel supply chain. The market demand is mainly determined by the price and freshness of the product. The demand D_1 for the online channel O and the demand D_2 function for the offline channel S can be represented by

$$D_1 = a - p_1 + \beta p_2 + \gamma y. \quad (2)$$

$$D_2 = a - p_2 + \beta p_1 + \gamma y. \quad (3)$$

where a is the potential market demand for online O and offline S, β is the cross-price elasticity coefficient (0<β<1). p_1 is the selling price of online channel O and p_2 is the selling price of offline channel S. γ is expressed as the consumer's freshness sensitivity factor (γ>0). y is the supplier's input of freshness effort, and the effect of this quantity on demand is γy. A larger γ indicates a greater increase in demand per unit of the preservation effort.

4.Taking CSR behavior as an external variable, supply chain members take on social responsibility and take consumer surplus into account in their own profit function. Combining the definitions, consumer surplus is understood to be the difference between the price that consumers pay and the most they are willing to pay. So, the consumer surplus [8] is

$$CS = \int_{p}^{p_{max}} D dp = \frac{D^2}{2}. \quad (4)$$

The supplier's online channel consumer surplus is

$$CS_{D_1} = \int_{p_1}^{p_{1max}} D_1 d\, p_1 = \int_{p_1}^{p_2\beta+y\gamma+a} (a - p_1 + \beta p_2 + \gamma y) d\, p_1 = \frac{(a-p_1+\beta p_2+\gamma y)^2}{2}. \quad (5)$$

The retailer's offline channel consumer surplus is

$$CS_{D_2} = \int_{p_2}^{p_{2max}} D_2 d\, p_2 = \int_{p_2}^{a+p_1\beta+y\gamma} (a - p_2 + \beta p_1 + \gamma y) d\, p_2 = \frac{(a-p_2+\beta p_1+\gamma y)^2}{2} \quad (6)$$

Where p_{max} is found by making D_i=0, it is easy to learn from Eq (2-3) that the size of the CS is related to the price of the sale as well as the preservation effort.

Assume that R ($0 \leq R \leq 1$) is the amount of consumer surplus that the supplier considers in the utility function. More consumer surplus is considered, and more social responsibility is assumed when R is larger.

This section begins with the construction of the Stackelberg game for the three scenarios described above. In this case, the fresh produce supplier acts as the leader. Firstly, the supplier decides on the wholesale price w and y preservation effort level of the fresh produce and price p_1.Secondly, based on the wholesale price w and y preservation effort level of the fresh produce and price p_1, the fresh produce e-commerce company decides the price p_2.The main variables are shown in Table 1.

Table 1. Main variables and meanings.

variables	meanings
a	Potential market demand
D_1	Online channel demand
D_2	Demand from retailer channel
p_1	Online channel sales price
p_2	Retailer channel sales price
w	Supplier wholesale price
C	Unit cost
y	Preservation effort input
v_1	Cost impact factor for preservation effort inputs
β	Inter-channel cross-price elasticity factor
γ	Consumer sensitivity factor for freshness
C(y)	Cost of preservation efforts
Π	Profits
U	Social utility welfare function
Π_{OS}	Overall supply chain profit
M_1	The supply chain does not undertake CSR
M_2	Retailer undertakes CSR alone
M_3	The supplier undertakes CSR alone
O	Supplier
S	Retailer
R	Percentage of CSR undertaken

3 Model construction and analysis of equilibrium results

3.1 No CSR taken by supply chain(M_1)

In the supply chain, the supplier acts as a leader. The decision sequence of the model is as follows: first, the supplier decides the wholesale price w, the input y for preservation effort and price p_1 of the product to maximize his profit; then, the retailer decides the selling price p_2 of the product to maximize his profit based on the supplier's decision.

The profit function of the supplier under model M_1 is

$$\Pi_O^{M_1}=(p_1 - C)D_1+(w - C)D_2 - \mathrm{C(y)}. \tag{7}$$

The profit function of the retailer under model M_1 is

$$\Pi_S^{M_1}= (p_2 - w)D_2. \tag{8}$$

The total profit function of the supply chain under the M_1 model is

$$\Pi_{OS}^{M_1} = \Pi_O^{M_1} + \Pi_S^{M_1}. \tag{9}$$

According to the inverse method, we can get the optimal decisions as shown in Table 2.

Table 2. The optimal solutions when Supply chain does not undertake CSR.

$\mathrm{p}_1^{M_1} = \frac{-2v_1(a+c-c\beta)+c(3+\beta)\gamma^2}{4v_1(-1+\beta)+(3+\beta)\gamma^2}$,	$\Pi_O^{M_1} = -\frac{v_1(a+c(-1+\beta))^2(3+\beta)}{8v_1(-1+\beta)+2(3+\beta)\gamma^2}$,
$\mathrm{p}_1^{M_2} = \frac{av_1(-3+\beta)+cv_1(-1+\beta^2)+c(3+\beta)\gamma^2}{4v_1(-1+\beta)+(3+\beta)\gamma^2}$,	$\Pi_S^{M_1} = \frac{{v_1}^2(a+c(-1+\beta))^2(-1+\beta)^2}{(4v_1(-1+\beta)+(3+\beta)\gamma^2)^2}$,
$w^{M_1} = \frac{-2v_1(a+c-c\beta)+c(3+\beta)\gamma^2}{4v_1(-1+\beta)+(3+\beta)\gamma^2}$,	$\Pi_{OS}^{M_1} = -\frac{v_1(a+c(-1+\beta))^2(2v_1(-1+\beta)(7+\beta)+(3+\beta)^2\gamma^2)}{2(4v_1(-1+\beta)+(3+\beta)\gamma^2)^2}$,
${D_1}^{M_1} = \frac{v_1(a+c(-1+\beta))(-2+\beta+\beta^2)}{4v_1(-1+\beta)+(3+\beta)\gamma^2}$,	$y^{M_1} = -\frac{(a+c(-1+\beta))(3+\beta)\gamma}{4v_1(-1+\beta)+(3+\beta)\gamma^2}$,
${D_2}^{M_1} = \frac{v_1(a+c(-1+\beta))(-1+\beta)}{4v_1(-1+\beta)+(3+\beta)\gamma^2}$.	

3.2 Retailer undertakes CSR alone (M_2)

The supply chain decision sequence is the same as M_1 ,but the retailer considers maximize its social utility welfare function.

The social utility welfare function of the retailer under model M_2 is

$$\mathrm{U}_S^{M_2} =(w - C)D_2 - \mathrm{C(y)}+ \frac{R({D_2}^2)}{2}. \tag{10}$$

The profit function for a retailer under the M_2 model is

$$\Pi_S^{M_2}= (p_2 - w)D_2. \tag{11}$$

The profit function for a supplier under the M_2 model is

$$\Pi_O^{M_2}=(p_1 - C)D_1+(w - C)D_2 - \mathrm{C(y)}. \tag{12}$$

The total profit function of the supply chain under the M_2 model is

$$\mathit{\Pi}_{SO}^{M_2} = \Pi_S^{M_2} + \Pi_O^{M_2}. \tag{13}$$

Similarly, we can get the optimal decisions as shown in Table 3.

Table 3. The optimal solutions when retailer undertakes CSR alone.

$\mathrm{p}_1^{M_2} = \frac{-((-2+\mathrm{R})v_1(a+c-c\beta))+c(-3+\mathrm{R}+(-1+\mathrm{R})\beta)\gamma^2}{2(-2+\mathrm{R})v_1(-1+\beta)+(-3+\mathrm{R}+(-1+\mathrm{R})\beta)\gamma^2}$,	$\Pi_O^{M_2} = \frac{-v_1(a+c(-1+\beta))^2(-3+\mathrm{R}+(-1+\mathrm{R})\beta)}{4(-2+\mathrm{R})v_1(-1+\beta)+2(-3+\mathrm{R}+(-1+\mathrm{R})\beta)\gamma^2}$,
$\mathrm{p}_2^{M_2} = \frac{av_1(3+\mathrm{R}(-2+\beta)-\beta)+cv_1(-1+\beta)(-1+(-1+\mathrm{R})\beta)+c(-3+\mathrm{R}+(-1+\mathrm{R})\beta)\gamma^2}{2(-2+\mathrm{R})v_1(-1+\beta)+(-3+\mathrm{R}+(-1+\mathrm{R})\beta)\gamma^2}$,	$\Pi_S^{M_2} = -\frac{(-1+\mathrm{R})v_1{}^2(a+c(-1+\beta))^2(-1+\beta)^2}{(2(-2+\mathrm{R})v_1(-1+\beta)+(-3+\mathrm{R}+(-1+\mathrm{R})\beta)\gamma^2)^2}$,
$\Pi_{OS}^{M_2} = -\frac{v_1(a+c(-1+\beta))^2(2v_1(-1+\beta)(7+\beta+\mathrm{R}(-6+\mathrm{R}+(-2+\mathrm{R})\beta))+(-3+\mathrm{R}+(-1+\mathrm{R})\beta)^2\gamma^2)}{2(2(-2+\mathrm{R})v_1(-1+\beta)+(-3+\mathrm{R}+(-1+\mathrm{R})\beta)\gamma^2)^2}$,	
${D_1}^{M_2} = \frac{v_1(a+c(-1+\beta))(-1+\beta)(-2+\mathrm{R}+(-1+\mathrm{R})\beta)}{2(-2+\mathrm{R})v_1(-1+\beta)+(-3+\mathrm{R}+(-1+\mathrm{R})\beta)\gamma^2}$,	
${D_2}^{M_2} = \frac{-v_1(a+c(-1+\beta))(-1+\beta)}{2(-2+\mathrm{R})\mathrm{v1}(-1+\beta)+(-3+\mathrm{R}+(-1+\mathrm{R})\beta)\gamma^2}$,	$\mathrm{U}_S^{M_2} = -\frac{(-2+\mathrm{R})v_1{}^2(a+c(-1+\beta))^2(-1+\beta)^2}{2(2(-2+\mathrm{R})v_1(-1+\beta)+(-3+\mathrm{R}+(-1+\mathrm{R})\beta)\gamma^2)^2}$,
$w^{M_2} = \frac{-((-2+\mathrm{R})v_1(a+c-c\beta))+c(-3+\mathrm{R}+(-1+\mathrm{R})\beta)\gamma^2}{2(-2+\mathrm{R})v_1(-1+\beta)+(-3+\mathrm{R}+(-1+\mathrm{R})\beta)\gamma^2}$,	$CS_{D_2} = \frac{v_1{}^2(a+c(-1+\beta))^2(-1+\beta)^2}{2(2(-2+\mathrm{R})v_1(-1+\beta)+(-3+\mathrm{R}+(-1+\mathrm{R})\beta)\gamma^2)^2}$,
$y^{M_2} = -\frac{(a+c(-1+\beta))(-3+\mathrm{R}+(-1+\mathrm{R})\beta)\gamma}{2(-2+\mathrm{R})v_1(-1+\beta)+(-3+\mathrm{R}+(-1+\mathrm{R})\beta)\gamma^2}$.	

3.3 Supplier undertakes CSR alone (M_3)

The supply chain decision sequence is the same as M_1 ,but the supplier considers maximize its social utility welfare function.

The social utility welfare function of the supplier under model M_3 is

$$\mathrm{U}_O^{M_3} = (p_1 - C)D_1+(w - C)D_2 - \mathrm{C(y)}+ \frac{R({D_1}^2)}{2}. \tag{14}$$

The profit function for a supplier under the M_3 model is

$$\Pi_O^{M_3}=(p_1 - C)D_1+(w - C)D_2 - C(\mathrm{y}). \tag{15}$$

The profit function for a retailer under the M_3 model is

$$\Pi_S^{M_3}= (p_2 - w)D_2. \tag{16}$$

The total profit function of the supply chain under the M_3 model is

$$\mathit{\Pi}_{SO}^{M_3} = \Pi_S^{M_3} + \Pi_O^{M_3}. \tag{17}$$

Similarly, we can get the optimal decisions as shown in Table 4.

Table 4. The optimal solutions when supplier undertakes CSR alone.

$$p_1^{M_3}=\frac{-((cv_1(-1+\beta)(-4+R\beta)+av_1(4+R(-4+\beta+2\beta^2))+c(-6+R+(-2+R)\beta)\gamma^2)}{(2v_1(-1+\beta)(4+R(-2+\beta^2))-(-6+R+(-2+R)\beta)\gamma^2))},$$

$$p_2^{M_3}=\frac{(cv_1(-1+\beta)(2-R+2\beta)+av_1(-6+3R+2\beta-2R\beta^2)-c(-6+R+(-2+R)\beta)\gamma^2)}{(2v_1(-1+\beta)(4+R(-2+\beta^2))-(-6+R+(-2+R)\beta)\gamma^2)},$$

$$w^{M_3}=\frac{-((v_1(a+c-c\beta)(4+R(-2+\beta^2))+c(-6+R+(-2+R)\beta)\gamma^2)}{(2v_1(-1+\beta)(4+R(-2+\beta^2))-(-6+R+(-2+R)\beta)\gamma^2))},$$

$$y^{M_3}=\frac{((a+c(-1+\beta))(-6+R+(-2+R)\beta)\gamma)}{(2v_1(-1+\beta)(4+R(-2+\beta^2))-(-6+R+(-2+R)\beta)\gamma^2)},$$

$${D_1}^{M_3}=\frac{2v_1(a+c(-1+\beta))(-2+\beta+\beta^2)}{2v_1(-1+\beta)(4+R(-2+\beta^2))-(-6+R+(-2+R)\beta)\gamma^2},$$

$${D_2}^{M_3}=-\frac{v_1(a+c(-1+\beta))(-1+\beta)(-2+R+R\beta)}{2v_1(-1+\beta)(4+R(-2+\beta^2))-(-6+R+(-2+R)\beta)\gamma^2},$$

$$U_O^{M_3}=\frac{v_1(a+c(-1+\beta))^2(-6+R+(-2+R)\beta)}{4v_1(-1+\beta)(4+R(-2+\beta^2))-2(-6+R+(-2+R)\beta)\gamma^2},$$

$$CS_{D_1}=\frac{2{v_1}^2(a+c(-1+\beta))^2(-2+\beta+\beta^2)^2}{(2v_1(-1+\beta)(4+R(-2+\beta^2))-(-6+R+(-2+R)\beta)\gamma^2)^2},$$

$$\Pi_S^{M_3}=\frac{{v_1}^2(a+c(-1+\beta))^2(-1+\beta)^2(-2+R+R\beta)^2}{(-2v_1(-1+\beta)(4+R(-2+\beta^2))+(-6+R+(-2+R)\beta)\gamma^2)^2},$$

$$\Pi_{SO}^{M_3}=\frac{(v_1(a+c(-1+\beta))^2(2v_1(-1+\beta)(-4(7+\beta)+R(28+R(1+\beta)(-3+2\beta^2)-4\beta(-2+\beta(4+\beta))))-(-6+R+(-2+R)\beta)^2\gamma^2))}{(2(-2v_1(-1+\beta)(4+R(-2+\beta^2))+(-6+R+(-2+R)\beta)\gamma^2)^2)},$$

$$\Pi_O^{M_3}=\frac{(v_1(a+c(-1+\beta))^2(2v_1(-1+\beta)(-8(3+\beta)+R(-12+R+(-4+R)\beta)(-2+\beta^2))-(-6+R+(-2+R)\beta)^2\gamma^2))}{(2(-2v_1(-1+\beta)(4+R(-2+\beta^2))+(-6+R+(-2+R)\beta)\gamma^2)^2)}.$$

3.4 Analysis of equilibrium results

Proposition 1: $\frac{\partial p_1^{M_2}}{\partial R}>0$, $\frac{\partial {D_2}^{M_2}}{\partial R}>0$, $\frac{\partial w^{M_2}}{\partial R}>0$, $\frac{\partial \Pi_O^{M_2}}{\partial R}>0$, $\frac{\partial U_{OS}^{M_2}}{\partial R}>0$, $\frac{\partial \Pi_{OS}^{M_2}}{\partial R}>0$, $\frac{\partial y^{M_2}}{\partial R}>0$, $\frac{\partial p_2^{M_2}}{\partial R}<0$, $\frac{\partial {D_1}^{M_2}}{\partial R}<0$, $\frac{\partial \Pi_S^{M_2}}{\partial R}<0$.

Proposition 1 indicates that: In this supply chain, supplier dominates, and retailer considers CSR. As retailer's CSR levels increase, supplier's sale price and wholesale price increase, investment in preservation efforts increases, supplier's profit increases, and the effect of the social welfare function increases, but retailer's sale prices, market demand on supplier's lines and retailer's profits are all declining, as the retailer's CSR level rises.

Proposition 2: $\frac{\partial p_2^{M_3}}{\partial R}>0$, $\frac{\partial {D_1}^{M_3}}{\partial R}>0$, $\frac{\partial w^{M_3}}{\partial R}>0$, $\frac{\partial y^{M_3}}{\partial R}>0$, $\frac{\partial U_{OS}^{M_3}}{\partial R}>0$, $\frac{\partial \Pi_O^{M_3}}{\partial R}<0$, $\frac{\partial \Pi_{OS}^{M_3}}{\partial R}<0$, $\frac{\partial p_1^{M_3}}{\partial R}<0$, $\frac{\partial {D_2}^{M_3}}{\partial R}<0$, $\frac{\partial \Pi_S^{M_3}}{\partial R}<0$.

Proposition 2 suggests that: in the supply chain, the supplier dominates and considers CSR, and the retailer considers maximizing his own profit. As the supplier's level of CSR increases, the supplier's sale price decreases, the supplier's preservation effort increases, market demand expands, wholesale prices increase, his own profit decreases, the social utility welfare function increases, and the overall profit of the supply chain decreases. The retailer's sale price increases, the market demand decreases, and his own profit decreases.

Proposition 3: (1) $p_1^{M_2} > p_1^{M_1} > p_1^{M_3}, p_2^{M_1} > p_2^{M_3} > p_2^{M_2}$; (2) $w^{M_2} > w^{M_3} > w^{M_1}, y^{M_3} > y^{M_2} > y^{M_1}$; (3)${D_1}^{M_3} > {D_1}^{M_1} > {D_1}^{M_2}, {D_2}^{M_2} > {D_2}^{M_1} > {D_2}^{M_3}$.

Proposition 3 suggests that: Comparing the three models, the M_2 model has the lowest online price from the supplier and the most market demand from the retailer, followed by the M_1 model and the M_3 model. The M_2model has the highest wholesale price, followed by the M_3 model and the M_1 model. The M_1 model has the highest retail price, followed by the M_3model, and then the M_2model. The M_3 model has the highest input of supplier preservation efforts, followed by the M_2 model and the M_1 model. The M_3 model, followed by the M_1 and finally the M_2 model, has the highest demand for supplier's online market.

Proposition 4: $\Pi_O^{M_3} < \Pi_O^{M_1} < \Pi_O^{M_2}$, When 0<R<$\bar{R}$, $\Pi_S^{M_1} > \Pi_S^{M_2} > \Pi_S^{M_3}$. When $\bar{R} < R < 1$, $\Pi_S^{M_1} > \Pi_S^{M_3} > \Pi_S^{M_2}$. Where $\bar{R}$ is $\Pi_S^{M_3} = \Pi_S^{M_2}$ obtained. $\bar{R}$ is too complex to show.

Proposition 4 suggests that: In all three models, the supplier's profit is greatest in the M_2 model, followed by M_1 model and finally M_3 model. The amount of profit a retailer makes depends on the level of CSR commitment. When R is within a certain level, M_1 mode is the largest, followed by M_2 mode and then M_3 mode. When R exceeds this level, M_1 mode remains the largest, and M_3 mode is larger than M_2 mode.

4 Numerical Examples and Analysis

To make the expression of major propositions in the article clear and to further investigate the impact of the CSR level of the supply chain on the balanced results under the three modes in the article, this section will build on the initial analysis. Assume that all members are economically rational: $p \geq w \geq c$. Based on the model established in the previous section, data assignments were made with reference to the literature [11], and reasonable changes were made to suit the actual situation in the paper. This paper assumes that: $v_1 = 33$,$\beta = 0.4$,$c = 20$,R=0.5,$a = 100$,$\gamma = 0.5$.When a certain parameter is analyzed, the preset value will be changed.

Figures 2 - 4 collectively reveal the impact of undertaking CSR levels on profits. Firstly, about the supplier. In the M_2 model, as the level of CSR undertaken rises, so make the profits. Yet, in the M_3 model, the supplier's profits decline, primarily because of the model's CSR initiatives, which sacrifice the supplier's profits to create customer benefits.

Figure 3 demonstrates that the rate of drop at the start of the period is slower for the M_2 mode than for the M_3 mode. However, at "R=0.4" and beyond, the rate of decline accelerates abruptly. At "R=0.85", it is the same as the profit in the M_3 model, after which it decreases until it reaches zero.

Finally, we examine the overall supply chain's profit. Only the M_2 model demonstrates an increase in total supply chain profitability among the three models. In the M_3 model, the whole supply chain profit is drastically reduced.

In the M_3 model, when the supplier commits to CSR, it sacrifices its own profit for the consumer's sake to maximize the social welfare utility, resulting in a reduced total profit. Similarly, it demonstrates the significance of the supplier's profit to the total supply chain profit.

It is easy to see that when a supplier undertakes CSR investment in preservation efforts are all far greater than in other models with increasing levels of CSR undertaken. Yet, the combination of Figures 2 to 5 demonstrates that the supplier's sacrifice of its own earnings to obtain these results is the reason for achieving such excellent results.

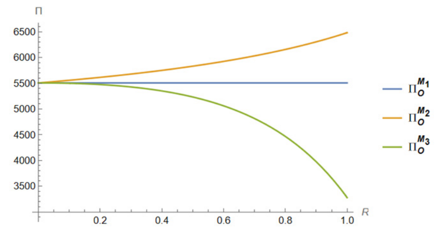

Fig. 2. The impact of the proportion of CSR undertaken on supplier profitability.

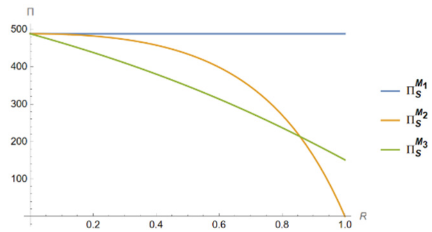

Fig. 3. The impact of the proportion of CSR undertaken on retailer profitability.

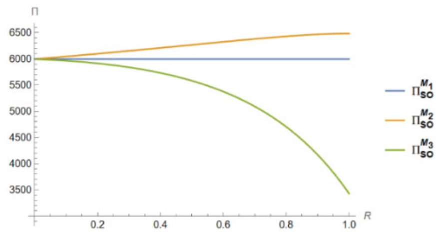

Fig. 4. The impact of the proportion of CSR undertaken on the overall profitability of the supply chain.

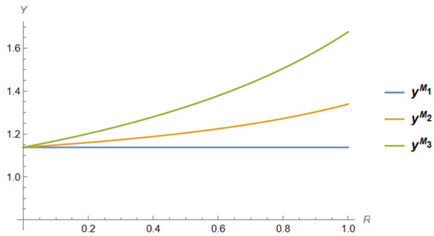

Fig. 5. The impact of the proportion of CSR undertaken on preservation efforts.

5 Conclusions

This article analyses the effect of corporate social responsibility on preservation effort, profit, and price, and by doing a comparative analysis, arrives at the following key conclusions:

1.Regardless of the CSR model, when the amount of CSR commitment rises, it leads not only to reduced selling prices and greater market demand for fresh products but also to greater preservation efforts and bigger consumer surplus.

2.When a member of the supply chain undertakes CSR, the social utility welfare function grows proportionally to the level of CSR committed; nevertheless, supply chain members frequently sacrifice their own profits for the consumer's welfare.

3. If we pursue a higher degree of preservation effort and a lower market price to drive demand, we might consider having the supplier of fresh food undertake CSR, namely M_3 mode.

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