

Research Article

A Consensus Decision-Making Model considering Empathetic Preferences and Power Structure of the Poverty Alleviation E-Commerce Supply Chain

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This article focuses on the conflict consultation process and empathetic decision-making behavior of a poverty alleviation supply chain composed of farmers, retailers, and third-party e-commerce platforms (e-platforms), and proposes an empathetic preference-based consensus decision-making model. The impact of empathetic preferences and power structure on the consensus reaching process are analyzed. The results indicate that consumers' empathy increases the consensus wholesale price and sales price of products, while retailers' and e-platforms' empathy increase the wholesale price and reduce the sales price of products. The empathetic preferences of consumers, retailers, and e-platforms are helpful for increasing the profits of farmers. The retailer's empathetic preference is not beneficial to its own profits and the supply chain, while the e-platform's empathetic preference can help to improve its own income and increase the overall profit of the supply chain at first, before decreasing. Moreover, the power of retailer is positively correlated with the profits of farmers and the retailer, and negatively correlated with the profits of the e-platform and supply chain. The sales price and commission price are negatively correlated with the power of retailer, but the wholesale price is not related to the change in power structure.

1. Introduction

How to improve the sales and circulation of agricultural products is a key problem to promoting the development of rural industry and improve farmers' income [1–3]. With the development of e-commerce technologies, enterprises cooperate with third-party e-commerce platforms (e-platforms), such as Alibaba, JD, and Amazon, forming the e-commerce supply chain (eSC), which has become an important channel to promote the circulation of agricultural products and plays a vital role in poverty alleviation, especially since the outbreak of COVID-19 [4–8]. With the prominent effectiveness of e-platforms on poverty alleviation, the decision-making process of the agricultural supply chain with the participation of e-platforms has attracted scholarly attention, such as the operational and pricing strategies [9], profit distribution mechanism, and conflict

coordination strategies [10–12] of eSC and dual-channel SC. However, the existing research on poverty alleviation eSC (PA-eSC) decision-making is mainly based on game theory for balanced analysis, and rarely analyzes the consensus-reaching process (CRP) of profit conflict within the supply chain.

The CRP is essentially the communication and evolution of preferences or opinions between supply chain subjects, which is very normal in daily life [13, 14]. It was previously assumed that the evolution of preferences is based on individual rationality and self-interest, that is, the hypothesis of “economic man.” With the deepening of behavioral research, the hypothesis of “economic man” falls into theoretical confusion when explaining many phenomena in the real-world [15, 16], that is, when making choices or decisions, people pay attention not only to their own profits or feelings but also to the welfare or emotion of others, and will

incorporate them into their decision goals and therefore adjust their decision [15–17]. In the economics area, individuals’ understanding of others’ emotions and attention to the welfare of others is called empathetic preference [18].

Significantly, when it comes to the poverty alleviation supply chain (PASC), unlike the standard hypothesis that supply chain entities only seek to maximize their own profits, they may care about the profits of farmers and generate empathetic decision-making behavior, which has been proven to be an important basis for social interaction, an important factor in promoting social equity, reducing unfair behavior and altruistic behavior [19–21]. In PASC, consumers may increase their willingness to buy because of their empathy for farmers, and e-platforms may also increase their willingness to participate in the PASC for the same reason. Therefore, taking into account the empathetic preference to explore the CRP of PA-eSC will be more in line with the actual decision-making behavior.

Furthermore, in the real-world situation, it is known that when faced with some strong retail giants (such as Walmart, Jingdong, Suning, and Yonghui), product manufacturers are powerless in the pricing and profit coordination of supply chain, and vice versa, that is, the power of supply chain entities is usually unequal [10–12]. Previous studies have shown that a change in power structure will affect the decision-making and coordination of a supply chain, based on game theory [11, 12, 22, 23]. In practice, when focusing on the PA-eSC, retailers or e-platforms generally occupy a dominant position, have a greater power in supply chain, and usually obtain a larger proportion of supply chain profits. Farmers, on the other hand, have limited sales channels, often passively waiting for retailers’ procurement, with lower pricing power and low profits [24].

In summary, existing research on the PA-eSC is mainly based on the game theory to conduct equilibrium analysis of the supply chain decision-making and coordination strategy, rarely analyzing the decision-making process of supply chain entities from the perspective of consensus negotiation. However, supply chain decision-making is often accompanied by negotiation consensus. Meanwhile, consumers and the main entities of the PA-eSC usually have empathetic preference, which will inevitably affect the CRP of the supply chain, but existing research has not yet considered the existence of empathetic preference. Moreover, some scholars have studied the impact of different power structures on traditional supply chain decision-making and dual-channel supply chain decision-making, but have not yet considered the impact of power structure, especially the “non-dominator-follower” structure on the PA-eSC.

Therefore, this article examines the empathetic preference of consumers and supply chain entities; regards the pricing decision of the PA-eSC as a consensus problem with empathetic preference; and analyzes the influence of empathetic preference and power structure on pricing decisions concerning agricultural products, the income of supply chain entities, and the CRP of supply chain.

The main contributions and innovations of this study are as follows.

Firstly, this article focuses on the empathetic preferences of consumers and supply chain members, and explores the impact of empathetic preferences on decisions and member profits of the PA-eSC. The current literature has not yet considered the empathetic preference in the PA-eSC, nor has it researched the impact of empathetic preferences on the pricing decision and profit of the PA-eSC.

Secondly, the “non-dominator-follower” power structure is considered an important factor of supply chain decision-making, improving the reliability of supply chain decision-making. The current research on power structure is mostly limited to the simple “dominator-follower” structure in traditional offline supply chains and dual-channel supply chains.

Moreover, unlike the game equilibrium analysis of supply chain decision-making in existing research studies, this article researches the decision-making process of supply chain from the perspective of consensus negotiation, and a novel CRP model is proposed.

The rest of this article is organized as follows. Section 2 offers a brief introduction to the research on supply chain decision-making. The description and hypothesis of this study is introduced in Section 3. Section 4 constructs the consensus model of pricing decisions via discussing the empathetic preferences and power distribution of the PA-eSC. In Section 5, we use a case study to analyze the influence of empathetic preferences and the power structure on the CRP of PA-eSC. Finally, our conclusions are set out in Section 6.

2. Literature Review

This section features a brief review of the relevant studies on supply chain decision-making. The existing research related to this study mainly focuses on three aspects: supply chain decision-making under social preference, supply chain decision-making under different power structures, and the decision-making of the PA-eSC.

2.1. Supply Chain Decisions under Social Preference. Many behavioral experiments, such as the ultimatum game experiment and the dictator experiment, have proved that many human behaviors are contrary to the expected behavior based on rational hypothesis [15–17]. Thus, scholars began to try to give up the hypothesis of individual rationality, and the theory of social preference was produced and developed rapidly [16–18]. The basic assumption of social preference is that people care not only about their own benefits but also about the interests of others, and this is also known as “other-regarding preferences,” “pro-social preferences,” or “inter-dependent preferences” [17, 18].

There has been a lot of recent research on the supply chain under social preference, including inequality aversion preference, reciprocity preference, altruism preference, and so on. Ho and Zhang [25] verified the existence of an inequality aversion behavior tendency in the supply chain through empirical methods. Katok et al. [26] found that the weak inequality aversion behavior of members would cause a

loss in efficiency of the supply chain system. Wang et al. [11] studied the decision-making and coordination of a green eSC with manufacturer fairness concerns. Zhang [27] discussed the pricing strategy of supply chain under reciprocity preference, and found that reciprocity preference is beneficial to the income and efficiency of closed-loop supply chain, and an increased reciprocity preference will lead to a decrease in their own income but an increase in others' income. Shi et al. [9] studied the effect of altruism on pricing strategy in two classic dual-channel supply chains using Stackelberg game models, and showed that the altruism preference strongly affects the pricing strategies. Wang et al. [28, 29] studied the impacts of altruistic preference on decisions of retailer-led low-carbon supply chain and e-commerce closed-loop supply chain. Moreover, Sana [30, 31] analyzed the price decision of green products by considering the green preferences of consumers and corporate social responsibility. Nevertheless, when using the theory of social preference to explain individual behavior, one of the major problems encountered is whether the cause of social preference is fairness concerns, reciprocity, or altruism. This problem is often difficult to decompose and test strictly. In fact, the core idea of social preference theory is that people care not only about their own interests but also about the interests of others [15–18]. Psychological research shows that an important factor that leads individuals to pay attention to the interests of others is empathy [19–21].

Empathy is an important inherent ability of human beings to maintain social relations, and it is also an important driving force for people to produce mutual benefit, inequality aversion, and altruistic and other prosocial behavior [18–21]. In the PA-eSC, consumers, e-commerce platforms, and retailers are more likely to empathize with farmers, and may eventually affect supply chain decision-making. Therefore, considering the impact of empathetic preference on supply chain decision-making will be more in line with a realistic decision-making scenario.

2.2. Supply Chain Decision-Making under Different Power Structures. The study of power structure within the supply chain mainly focuses on the discussion of supply chain decision-making under different game power structures, such as retailer dominates, manufacturers dominate, and no one dominates, from a game perspective. Some of the literature discusses the impact of power structure on the traditional supply chain, for example, Gaski and Nevin [32] analyzed the power sources of supply chain members, and discussed the impact of power on supply chain channel decisions. Chen and Wang [33] discovered that power leaders can gain more revenue. Gao et al. [22] found that retailers' profits continued to rise with the increase of their power. Some studies revealed the impact of power on a dual-channel supply chain. Chen et al. [34] studied the influence of power structures on the retailers' dual-channel supply chain. Sun et al. [35] analyzed the influence of power structures on manufacturers' dual-channel supply chain. Cao and Liu [36] compared the optimal strategy and performance of the presale and current sale dual-channel supply

chain under three power structures as described above. Furthermore, some scholars have introduced the power structure of supply chain into research of green supply chain, and studied the impact of power structures on product green degree, wholesale price, retail price, and profit of supply chain [37, 38].

The current research mainly focuses on pricing strategy and profit distribution of supply chain decision-making under the game power structure, that is, "dominator and follower" and "no dominator" structure. However, in the actual decision-making, the power structure between supply chain entities is often not a simple "dominator-follower" or "no dominator" relationship, and the difference in power structure will also play a different role in the decision-making of the supply chain.

2.3. Research on the Decisions of PA-eSC. In recent years, the problem of poverty alleviation has received great attention from scholars, and research hotspots focus on the operation mode of social responsibility, the design of cooperation and coordination mechanism between enterprises and the poor, the creation and distribution of shared value, and so on [1–3]. Previous scholars have studied the way in which government funding promotes agricultural development in the PASC. Besley and Kanbur [39] studied the optimal model of grain subsidy. Yuanchang and Jiyu [40] analyzed the optimal boundary of financial subsidy based on the agricultural insurance welfare loss model. Kang et al. [41] examined the impacts of government subsidies and corporate social responsibility on a PASC, and suggested that the most effective poverty alleviation mechanism in most cases is a combination of government subsidies and market efforts. A few scholars have discussed the decision-making and coordination issues related to the PASC. For example, Kang et al. [24] studied the decision-making and coordination strategy with fairness concerns involved in a PASC, and found that the fairness concerns of the farmer enterprise aggravated the double marginalization within the PASC and reduced the profit of both farmer and core enterprises. Zhou et al. [42] studied the influence of enterprise's poverty alleviation preference on the profits of the supply chain and its members considering consumers' altruistic preferences.

With the popularity of e-commerce, e-platforms give full play to big data advantages and actively invest in poverty alleviation. The decision-making of agricultural product eSC has attracted the attention of scholars. Li et al. [43] analyzed the role of governments in developing rural e-commerce ecosystems and the impact of such ecosystems on poverty alleviation, and elucidated a model of poverty alleviation through e-commerce. Peng et al. [44] confirmed that e-commerce has a significantly positive effect on rural poverty alleviation using empirical evidence. Wan et al. [45, 46] explored the impact of the government financial platform incentive mechanism and consumers' poverty alleviation preference on the decision and coordination strategy of the smart supply chain.

In brief, the research on PA-eSC decision-making has achieved certain research results, but few scholars consider

the impact of consumers' and supply chain entities' empathetic preferences, and the non- "dominator-follower" -type power structure of supply chain on the decision-making of the PA-eSC. Thus, this article studies the pricing decision of the PA-eSC under the empathetic preferences and non- "dominator-follower" power structure, and analyzes the impact of empathetic preferences and power structure on the CRP of PA-eSC, which is closer to the actual decision-making scene, and better to provide scientific suggestions for the supply chain decision-making.

3. Model Description

In this section, the assumptions for this study are presented, and the consensus model of the PA-eSC decision is introduced.

3.1. Description and Assumptions. This article focuses on the CRP of a PS-eSC composed of farmers, retailers, and e-commerce platforms, a three-level supply chain model. In the PA-eSC, similar to the traditional agricultural product supply chain, farmers are often in the position of passively waiting for the retailer to purchase, and have limited alternative sales channels, while the retailer and e-platform have more choice and play a leading role. Simultaneously, the difference of the PA-eSC is that the retailers, e-platforms, and consumers care not only about their own interests but also about the interests of farmers, having empathetic preference, which may affect the CRP of the supply chain. The supply chain network can be described as in Figure 1, and the notations involved in this study are presented in Table 1.

The assumptions of this article are as follows.

Assumption 1. Consumers, retailers, and e-platforms have empathetic preferences for farmers. The higher the consumers' empathy, the more willing consumers are to buy the products. The demand function of agricultural products is $q = d_0(1 + \rho_a) - ap^s$, where $a(a > 0)$ is the price elasticity coefficient of agricultural products, and $\rho_a (0 \leq \rho_a \leq 1)$ is the empathy degree of consumers to farmers

Assumption 2. The empathy degree of consumers for farmers is positively related to the poverty degree of farmers they perceived, which is mainly determined by the service level of the e-platform. As stated in the literature [7], the service level has a linear function of the unit product commission. Therefore, the empathy degree of consumers is set as $\rho_a = 1 - 1/\lambda r$, where λ indicates the sensitivity of consumers to agricultural assistance service level.

Assumption 3. The unit service cost of the e-platform is directly proportional to the service level determined by the service fee. Thus, the unit service cost c_3 is a quadratic function of the unit service fee. With reference to the literature [7], we suppose $c_3 = kr^2/2$, where $k(k > 0)$ is the elasticity coefficient of unit cost, which mainly refers to the funds needed to provide the unit service (marketing promotion service, big data forecast, sales service, logistics service, payment service, and customer service).

Assumption 4. In the PA-eSC, the power of each supply chain entities is different. The power distribution in the supply chain composed of farmers, retailers, and e-platforms is set as (R_1, R_2, R_3) , in which R_1, R_2, R_3 are the power indices of farmers, retailers, and e-platforms, respectively. Farmers are powerless, whereas the retailer and e-platform are powerful, that is, $R_1 \ll R_2, R_3$.

Assumption 5. In the PA-eSC, the government only guides and calls on consumers, retailers, and e-platforms to actively participate in supporting agriculture, without any policy subsidy.

3.2. Consensus Model. In this section, we construct a consensus model of the pricing decisions via discussing the empathetic preferences and power distribution of the PA-eSC.

3.2.1. Basic Models. In the PA-eSC composed of farmers, retailers, and e-platforms, the profit functions of farmers, retailers, and e-platforms are as follows:

$$\begin{aligned} v_1 &= (p^c - c_1)q = (p^c - c_1)(d_0(1 + \rho_a) - ap^s), \\ v_2 &= (p^s - p^c - r - c_2)q \\ &= (p^s - p^c - r - c_2)(d_0(1 + \rho_a) - ap^s), \\ v_3 &= rq - c_3 = r(d_0(1 + \rho_a) - ap^s) - \frac{k}{2}r^2. \end{aligned} \quad (1)$$

The total profit function of the supply chain is

$$\begin{aligned} v &= (p^s - c_1 - c_2)q - c_3 \\ &= (p^s - c_1 - c_2)(d_0(1 + \rho_a) - ap^s) - \frac{k}{2}r^2. \end{aligned} \quad (2)$$

In the PA-eSC, the difference in the power of supply chain entities leads to a different discourse power in the profit distribution of each member. Hence, the profit utility function of each member is also different. Generally, in the supply chain of agricultural products, farmers have the least power, while the retailers and e-platforms have more power. Therefore, the utility function of farmers, retailers, and e-platforms are as follows:

$$\begin{aligned} u_1 &= v_1^\alpha = ((p^c - c_1)(d_0(1 + \rho_a) - ap^s))^\alpha, \\ u_2 &= v_2^\beta = ((p^s - p^c - r - c_2)(d_0(1 + \rho_a) - ap^s))^\beta, \\ u_3 &= v_3^\xi = \left(r(d_0(1 + \rho_a) - ap^s) - \frac{k}{2}r^2 \right)^\xi, \end{aligned} \quad (3)$$

where α, β, ξ determine the concavity and convexity of the utility function of farmers, retailers, and e-platforms, respectively, and they satisfy $1 \geq \alpha, \beta, \xi > 0$ according to the law of diminishing marginal utility. In reality, farmers within the PA-eSC have lower income compared with retailers and e-platforms, and the utility of the same income is necessarily different for farmers, retailers, and e-platforms. Specifically, for the same profits, farmers' utility is the highest, while the

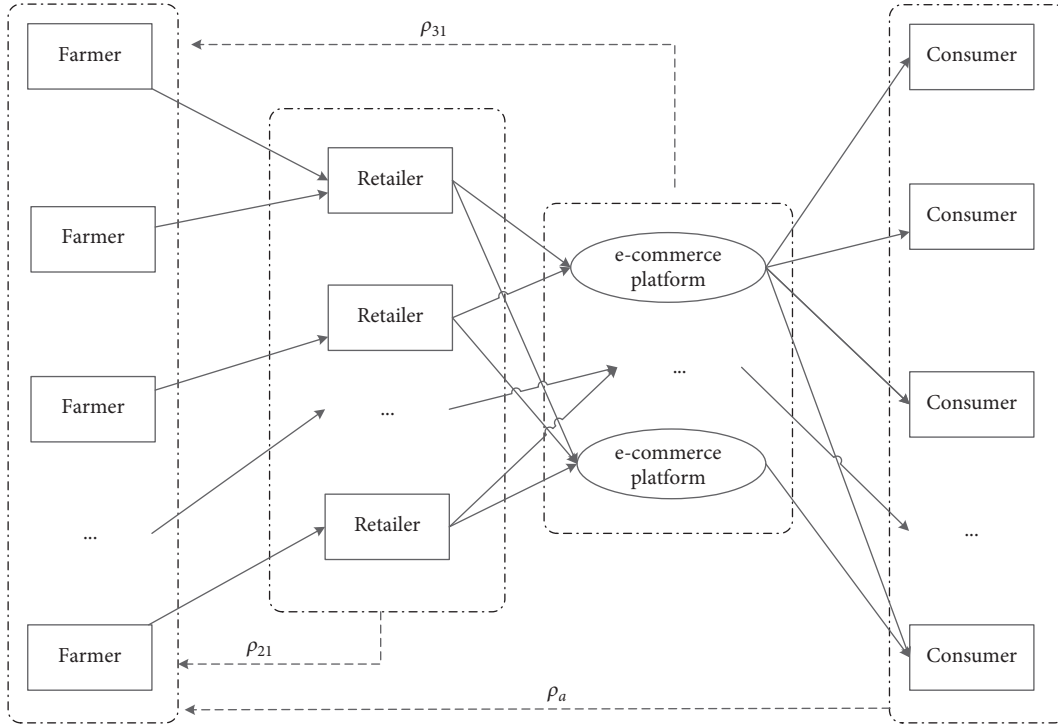


FIGURE 1: The supply chain network of "Farmers + Retailers + e-platforms."

TABLE 1: Notations.

Symbols	Notations
d_0	Market demand for products
p^c	The wholesale price
p_1^c	The wholesale quotation of farmers
p_2^c	The wholesale quotation of retailers
p_3^c	The wholesale quotation expected by e-platforms
p^s	The sales price
p_2^s	The sales quotation of retailers
p_3^s	The sales quotation expected by e-platforms
c_1	The unit production cost of farmers
c_2	The unit production cost of retailers
c_3	The unit service cost of e-platforms
r	The unit service fee paid by retailers to the e-platform (the commission price)
r_2	The commission quotation of retailers
r_3	The commission quotation of e-platforms
ρ_a	The consumers' empathetic preference coefficient, $0 \leq \rho_a \leq 1$
ρ_{21}	The empathetic preference coefficient of retailer to farmers, $0 \leq \rho_{21} \leq 1$
ρ_{31}	The empathetic preference coefficient of platform to farmers, $0 \leq \rho_{31} \leq 1$

retailers and e-platforms have relatively low utility. Therefore, α, β, ξ satisfy $1 \geq \alpha > \beta, \xi > 0$ in the proposed model.

In the PA-eSC, not only do consumers have an empathetic preference for farmers but the retailers and e-platforms also care about the interests of farmers and have empathetic preferences, that is, the utility of each member in the supply chain is not only related to their own profit. Thus, the utility function of farmers, retailers, and e-platforms under empathetic preference conditions can be expressed as follows:

$$\begin{aligned}
 U_1 &= u_1 = (p^c - c_1)(d_0(1 + \rho_a) - ap^s), \\
 U_2 &= u_2 + \rho_{21}u_1 \\
 &= ((p^s - p^c - r - c_2)(d_0(1 + \rho_a) - ap^s))^\beta \\
 &\quad + \rho_{21}((p^c - c_1)(d_0(1 + \rho_a) - ap^s))^\alpha, \\
 U_3 &= u_3 + \rho_{31}u_1 \\
 &= \left(r(d_0(1 + \rho_a) - ap^s) - \frac{k}{2}r^2 \right)^\xi \\
 &\quad + \rho_{31}((p^c - c_1)(d_0(1 + \rho_a) - ap^s))^\alpha.
 \end{aligned} \tag{4}$$

The total utility function of the supply chain is

$$U = U_1 + U_2 + U_3 = (1 + \rho_{21} + \rho_{31})u_1 + u_2 + u_3, \tag{5}$$

where ρ_{21} and ρ_{31} are the retailers' and e-platforms' empathy degree to farmers, respectively.

3.2.2. Consensus Reaching Process. In the following, we consider pricing consensus model with the empathetic preferences, and the consensus reaching process is proposed.

(1) *Initial Pricing Stage.* In the pricing decision of agricultural products supply chain, farmers have the least power to decide the price of agricultural products and are in a follower position. Therefore, the initial pricing process of the PA-eSC can be summarized as follows: First, the wholesale price of agricultural products is determined by the retailer, and farmers can only choose to accept or refuse; next, the retailer

determines the product sales price according to the wholesale price and market demand of agricultural products; then, the e-platform determines the unit service fee according to the product sales price, with some consideration of the profit for farmers.

The retailer and e-platform are two independent economic entities maximizing their own profits. The ideal quotation of the retailer is obtained by the model.

$$\max U_2 = ((p^s - p^c - r - c_2)(d_0(1 + \rho_a) - ap^s))^\beta + \rho_{21}((p^c - c_1)(d_0(1 + \rho_a) - ap^s))^\alpha, \quad (6)$$

$$\text{s.t.} \begin{cases} p^c - c_1 > 0, \\ p^s - p^c - r - c_2 > 0, \\ d_0(1 + \rho_a) - ap^s - \frac{k}{2}r > 0. \end{cases} \quad (7)$$

The optimal quotation of the retailer can be obtained by solving the model equation (6) and model equation (7): wholesale price $p_2^c = p_2^{c*}$, sales price $p_2^s = p_2^{s*}$, and platform commission $r_2 = r_2^*$.

The optimal quotation of the e-platform can be obtained by the model equation (8) and model equation (9).

$$\max U_3 = \left(r(d_0(1 + \rho_a) - ap^s) - \frac{k}{2}r^2 \right)^\xi + \rho_{31}((p^c - c_1)(d_0(1 + \rho_a) - ap^s))^\alpha, \quad (8)$$

$$\text{s.t.} \begin{cases} p^c - c_1 > 0, \\ p^s - p^c - r - c_2 > 0, \\ d_0(1 + \rho_a) - ap^s - \frac{k}{2}r > 0. \end{cases} \quad (9)$$

The optimal quotation of the e-platform can be obtained by the model equation (8) and model equation (9), that is, wholesale price $p_3^c = p_3^{c*}$, sales price $p_3^s = p_3^{s*}$, and platform commission $r_3 = r_3^*$.

According to the model equation (6) and (7) and model equations (8) and (9), if the optimal quotations of the retailer and e-platform are consistent and in line with the expectation of farmers, then a consensus can be reached and the consultation will be concluded; otherwise, the members will negotiate on the basis of the initial prices, that is, the optimal quotations gained and model equations (6) and (7), and model equations (8) and (9), to reach a consensus.

(2) *Consensus Reaching Stage.* The negotiation of the supply chain is conducted through a smart decision-making system (SDMS) which encourages all members to reach a consensus based on the supply chain utility maximization rules and their price expectations.

Suppose that the lowest wholesale price acceptable to farmers is p_1^c , that is, p_1^c satisfies $p_1^c \geq p_1^c$, the highest wholesale price acceptable to the retailer is p_2^c , that is, p_2^c

satisfies $p_2^c \leq p_2^c$, and the lowest wholesale price that the e-platform wants the retailer to give to farmers is p_3^c , that is, p_3^c satisfies $p_3^c \geq p_3^c$; the lowest commission price acceptable for the e-platform is r_3^0 , that is, r_3 satisfies $r_3 \geq r_3^0$.

The above information is the private information provided by each member to the SDMS. Accordingly, the consensus process based on the SDMS is as follows:

(1) *Consensus Information Feedback.* If the optimal wholesale price of farmers, retailer, and e-platform satisfies $p_1^{c*} = p_2^{c*} = p_3^{c*}$, the optimal sales price of retailer and e-platform satisfies $p_2^{s*} = p_3^{s*}$, and the optimal commission price of retailer and e-platform satisfies $r_2^* = r_3^*$, simultaneously, the supply chain reaches a consensus, and we can get consensus prices and consensus profits directly.

If there is no consensus reached among the supply chain members, the SDMS provides feedback consensus information to retailers and offers a suggested quotation to the retailer according to supply chain utility maximization rules, and the provide recommended price to supply chain members based on the following model equations (10) and (11).

$$\max U = U_1^{R_1} + U_2^{R_2} + U_3^{R_3}, \quad (10)$$

$$\text{s.t.} \begin{cases} p_3^{c^0} \leq p^c \leq p_2^{c^0}, \\ p^s - p^c - r - c_2 > 0, \\ d_0(1 + \rho_a) - ap^s - \frac{k}{2}r > 0, \\ r \geq r_3^0. \end{cases} \quad (11)$$

where R_1, R_2, R_3 express the power of farmers, retailer, and e-platform in the supply chain, respectively.

Based on the model equations (10) and (11), the recommended quotation from the SDMS to the retailer can be gained: $p_1^c = \tilde{p}_2^{c*}, p_3^c = \tilde{p}_2^{c*}, r = \tilde{r}_3^*$.

(2) *Price Adjustment.* According to the recommendations of the SDMS, the retailer adjusts its quotation according to the following rules as model equations (12) and (13):

$$\max U_2 = ((p_2^s - p_2^c - r_2 - c_2)(d_0(1 + \rho_a) - ap_2^s))^\beta + \rho_{21}((p_2^c - c_1)(d_0(1 + \rho_a) - ap_2^s))^\alpha, \quad (12)$$

$$\text{s.t.} \begin{cases} \frac{p_2^{c*} + \tilde{p}^{c*}}{2} \leq p_2^c \leq \tilde{p}^{c*}, \text{ if } \tilde{p}^{c*} > p_2^{c*}, \\ p_2^c = \tilde{p}^{c*}, \text{ if } \tilde{p}^{c*} \leq p_2^{c*}, \\ \frac{r_2^* + \tilde{r}^*}{2} \leq r_2 \leq \tilde{r}^*, \text{ if } \tilde{r}^* > r_2^*, \\ r_2 = \tilde{r}^*, \text{ if } \tilde{r}^* \leq r_2^*, \\ p_2^s - p_2^c - r_2 - c_2 > 0, \\ d_0(1 + \rho_a) - ap_2^s - \frac{k}{2}r_2 > 0. \end{cases} \quad (13)$$

The revised quotation given by the retailer according to the model equations (12) and (13) is $\tilde{p}_2^c, \tilde{p}_2^s, \tilde{r}_2$.

Then, the SDMS puts the latest quotation of the retailer $\widehat{p}_2^c, \widehat{p}_2^s, \widehat{r}_2$ feedback to farmers and the e-platform, and they adjust their quotation according to the following model equation (14) and model equations (15) and (16), respectively.

$$\begin{cases} \widehat{p}_1^c = \frac{\widehat{p}_2^c + p_1^{c*}}{2}, & \text{if } \widehat{p}_2^c < p_1^{c*}, \\ \widehat{p}_1^c = \widehat{p}_2^c, & \text{if } \widehat{p}_2^c \geq p_1^{c*}, \end{cases} \quad (14)$$

$$\max U_3 = \left(r_3 (d_0 (1 + \rho_a) - a p_3^s) - \frac{k}{2} r_3^2 \right)^\xi + \rho_{31} ((p_3^c - c_1) (d_0 (1 + \rho_a) - a p_3^s))^\alpha, \quad (15)$$

$$\text{s.t.} \begin{cases} p_1^{c*} \leq p_3^c \leq \max\left(\frac{\widehat{p}_2^c + p_3^{c*}}{2}, \widehat{p}_2^c\right), \\ \min(\widehat{p}_2^s, p_3^{s*}) \leq p_3^s \leq \max(\widehat{p}_2^s, p_3^{s*}), \\ r_3^* \leq r_3 \leq \frac{\widehat{r}_2 + r_3^*}{2}, \text{ if } \widehat{r}_2 < r_3^*, \\ r_3 = \widehat{r}_2, \text{ if } \widehat{r}_2 \geq r_3^*, \\ p_3^s - p_3^c - r_3 - c_2 > 0, \\ d_0 (1 + \rho_a) - a p_3^s - \frac{k}{2} r_3 > 0. \end{cases} \quad (16)$$

According to the model equations (14)–(16), the revised quotation of the e-platform, that is, $\widehat{p}_3^c, \widehat{p}_3^s, \widehat{r}_3$, can be obtained.

(3) *Reach a Consensus.* The consensus process (1) and (2) above are repeated until a consensus is reached among the members of the supply chain, that is, $p_1^{c*} = p_2^{c*} = p_3^{c*}$, $p_2^{s*} = p_3^{s*}$, and $r_2^* = r_3^*$. Then, we can get the consensus wholesale price, sales price, and commission price of the supply chain, and the optional profits of the farmers, retailer, and e-platform, that is, v_1^*, v_2^*, v_3^* .

4. Analysis and Results

In this section, we describe the empirical application of the proposed consensus model, and discuss the influence of the empathetic preferences and the network power index power distribution on the CRP of PA-eSC.

4.1. Setup. It is supposed that the market demand of a certain agricultural product is $d_0 = 500$, and the price elasticity coefficient of agricultural products is $a = 8$. The elasticity coefficient of the service cost of the e-platform is $k = 20$, the cost of processing and selling unit agricultural products (processing, packaging, transportation, storage, and wear and tear,) is $c_2 = 2$, the unit cost of agricultural products for farmers is $c_1 = 5$, the consumer sensitivity to the e-platform services is $\lambda = 2$, and the government does not give any subsidies to the supply chain. The acceptable

wholesale price of farmers satisfies $p_1^c \geq p_1^{c*} = 10$, and farmers' ideal price is $p_1^{c*} = 15$. The acceptable wholesale price of the retailer satisfies $p_2^c \leq p_2^{c*} = 20$. The acceptable commission price for the e-platform satisfies $r_3 \geq r_3^0 = 2$, and the wholesale price that the e-platform wants the retailer to give to the farmer satisfies $p_3^c \geq p_3^{c*} = 15$.

As mentioned in the model equation (3) above, parameters α, β, ξ in the utility functions of farmers, retailers, and e-platforms satisfy $1 \geq \alpha > \beta, \xi > 0$. Although this article pays no more attention to the concave and convexity variation of utility functions, in order to reflect the utility differences of supply chain members and simultaneously not affect the analysis of proposed model, it is assumed that α, β, ξ are known constants and $\alpha = 1, \beta = 0.8, \xi = 0.9$.

In addition, we assume that the empathy degree of the retailer to farmers is $\rho_{21} = 0.1$, and the empathy degree of the e-platform to farmers is $\rho_{31} = 0.2$. We also assume that the power indices of the farmers, retailers, and e-platforms are $R_1 = 0.167, R_2 = 0.5, R_3 = 0.333$, respectively.

4.2. Results and Discussion. We analyze the pricing consensus reaching process using the proposed consensus model equations (1)–(16). The initial quotations and consensus results are shown in Table 2, and the CRP of the PA-eSC is shown in Figure 2.

As shown in Table 2, the optimal quotation agreed upon by the supply chain is $p^{c*} = 19.63, p^{s*} = 68.6, r^* = 7.49$. We can see from Figure 2 that firstly, when the wholesale price given by the retailer is greater than the minimum acceptable price of farmers, they can reach a consensus quickly, while the wholesale price still rises to a certain extent after the consensus has been reached. The main reason for this phenomenon is that the e-platform is concerned about the profits of farmers and tends to urge the retailer to give farmers higher prices. Secondly, the sales price is determined by the retailer based on its own utility maximization, and the sales price rises with the increase of the wholesale price. Moreover, in terms of the platform commission price, it is related to the service level of the platform, which is also an important factor that affects the empathy degree of consumers, and the higher the empathy degree of consumers, the stronger the willingness to buy products. Therefore, the retailer pays more attention to the service level and commission price that maximize their utility, and the consensus process of commission price in Figure 2 verifies this point: the retailer is less able to compromise on commission price.

In order to reach consensus, supply chain members may need to make a compromise, which may harm their own profits. Figure 3 shows the changes in the expected profits of the members during the CRP of supply chain. It can be seen that the expected profits of farmers gradually increased, while the profits of the retailer and the e-platform gradually decreased. This result is consistent with the empathetic preference of the retailer and the e-platform: they are concerned about the interests of farmers, and will make a compromise for farmers to obtain higher profits.

TABLE 2: Price quotes of farmers, retailers, and e-commerce platforms.

Members	Wholesale price p^{c*}	Sales price p^{s*}	Commission fee r^*
Farmers' initial quotation	15		
Retailer's initial quotation	6	66.04	5.59
E-commerce platform's initial quotation	42.09	58.41	14.32
SDMS' suggested quotation	20	63.1	7.47
Consensus quotation	19.63	68.6	7.49

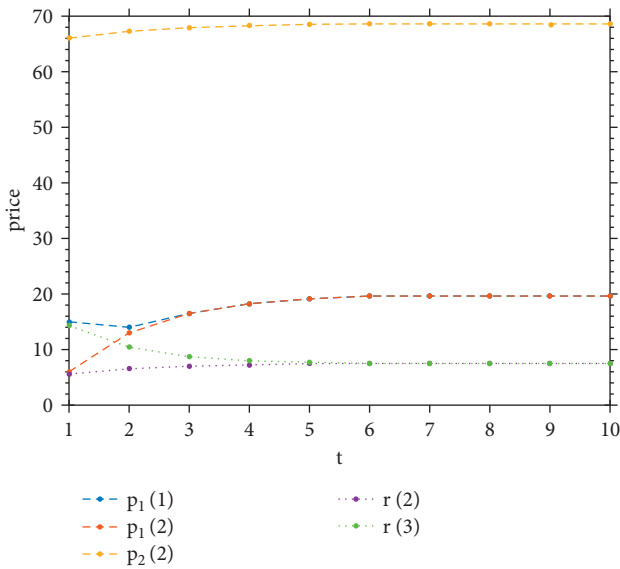


FIGURE 2: The consensus process of supply chain on sales price, wholesale price, and platform commission. $p_1(1)$ is the optimal wholesale price expected by farmers, $p_1(2)$ represents the wholesale price given by the retailer, $p_2(2)$ is the optimal sales price of the retailer, $r(2)$ is the commission price given by the retailer, $r(3)$ represents the optimal commission price of the platform, and t refers to the number of consultations.

It can be known from the proposed consensus model that empathetic preference and power structure have an important impact on the pricing decisions of the consumers, retailers, and e-platforms. On the one hand, the empathy degree of consumers stimulated by e-platform services level will affect the market demand of products, and thus may affect the pricing strategy of the retailer in relation to wholesale price and sales prices. The empathetic preference of the retailer and e-platform will also affect their pricing decisions based on the utility of farmers. On the other hand, in the CRP, the power structure of supply chain is an important factor affecting profit distribution. In order to make the supply chain reach a consensus as quickly as possible, the SDMS will feedback the optimal quotation according to the power of each member, and thus may affect the pricing strategy of the supply chain. To further understand the

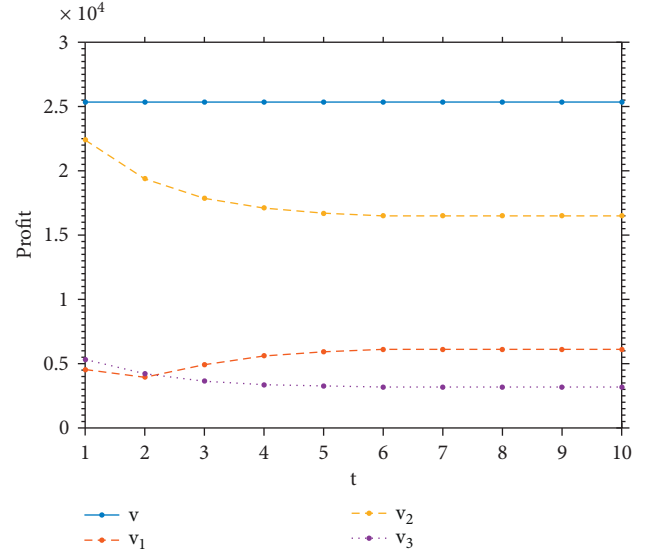


FIGURE 3: Changes in expected profits in the CRP of PA-eSC. v represents the maximum profit of the supply chain, v_1 is the maximum profit of farmers, v_2 is the maximum profit of the retailer, and v_3 is the maximum profit of the e-commerce platform.

influence of empathetic preferences and power structure on the consensus process, the simulation analysis is conducted as follows.

4.2.1. *The Influence of Consumers' Empathy on the CRP of the PA-eSC.* The impact of consumers' empathy on the CRP of supply chain is shown in Figure 4.

As shown in Figure 4, with the increase of consumers' sensitivity to the level of the e-platform service, consumers' empathy degree is also increasing. The higher the sensitivity of consumers to the service level, the more the empathy degree of consumers can be stimulated, the higher the wholesale price and the sales price, and the greater the profits that the farmers and retailers receive. On the contrary, the more sensitive consumers are to the service level, the lower the commission price, and the lower the profit earned by the e-platform. At the same time, an improvement in consumers' empathy degree will promote an increase in the overall profit of the supply chain. This shows that the more the e-platform can stimulate the consumers' empathetic preference, the more it will benefit the farmers and retailers.

4.2.2. *The Influence of Empathetic Preferences of the Retailer and E-Platform.* Figures 5 and 6 show the impact of empathetic preferences of the retailer and e-platform on supply chain consensus.

Firstly, it can be seen from Figure 5 that with the increase of empathy degree of the retailer and the e-platform, the wholesale price obtained by farmers gradually rises until the highest acceptable value of the retailer, and the sales price set by retailer gradually decreases. The commission price of the e-platform increases with the improvement

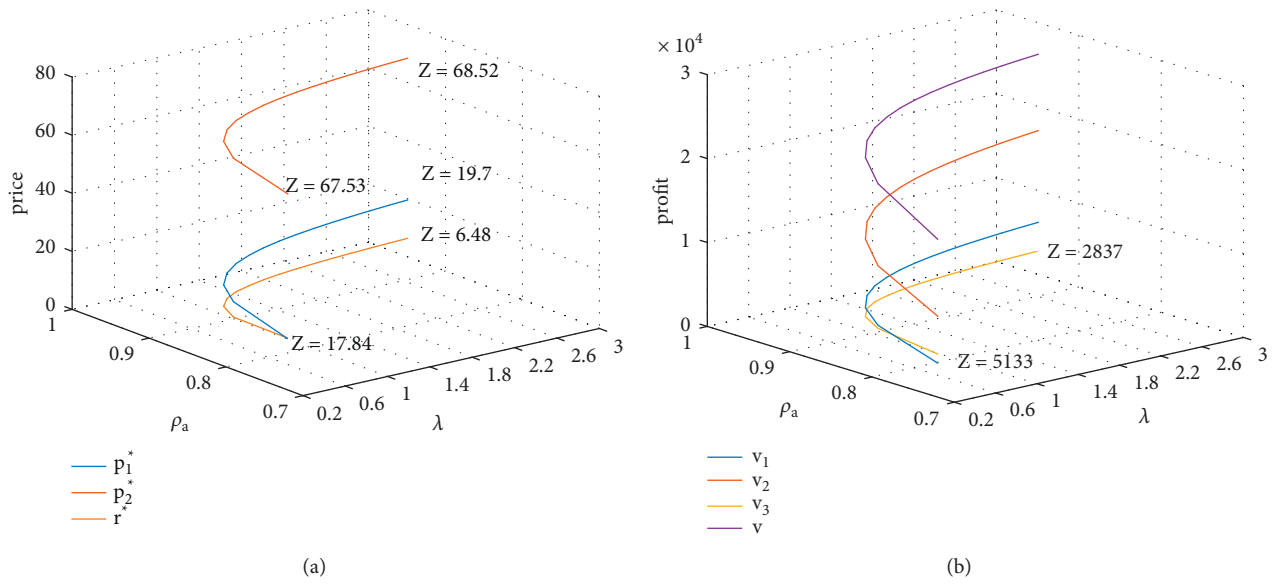


FIGURE 4: The influence of consumers' empathy on supply chain consensus. (a) The effect of empathetic preferences on the consensus prices; (b) the effect of empathetic preferences on the profits of supply chain. λ is the consumers' sensitivity coefficient of services. ρ_a is the consumers' empathy degree to farmers. p_1^*, p_2^*, r^* are the consensus wholesale prices, consensus sales price, and consensus commission price of the supply chain, respectively. v, v_1, v_2, v_3 are the total profits, farmers' profits, retailer's profits, and e-platform's profits when the supply chain reaches a consensus, respectively.

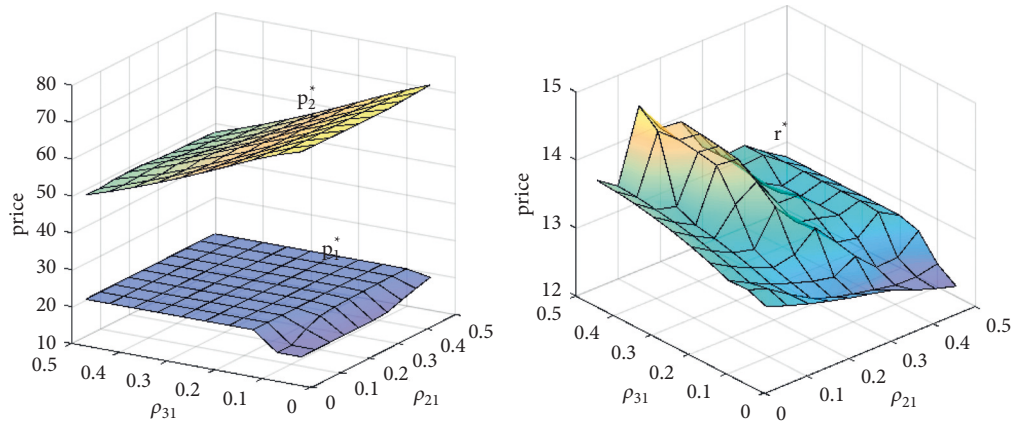


FIGURE 5: The influence of empathetic preference of retailer and e-platform on the prices. (a) The influence on wholesale price and sales price; (b) the influence on commission price. ρ_{21}, ρ_{31} are the empathy degrees of retailers and e-platforms to the farmers, respectively.

of its empathy degree, and it shows a fluctuating decrease trend with the improvement of retailer's empathy degree. Secondly, in terms of profits, as shown in Figure 6, with the improvement of the empathy of retailer and e-platform toward farmers, the farmers' profits gradually rise and the retailer's profit gradually decrease. The profit of the e-platform increases with the improvement of its empathy degree, and decrease with the improvement of the retailer's empathy degree. This shows that the empathetic preferences of the retailer and the e-platform are helpful to the promotion of the farmers' interests. Meanwhile, the retailer's empathetic preference will reduce its own benefits, and the empathetic preference of the e-platform will help to

improve its own benefits. However, in the supply chain where the retailer has a higher power, with the improvement of retailer's empathy degree, the retailer not only cares about the farmers' profits, but also tries maximizing their own benefits, causing them to control the commission price to reduce costs, which may reduce the profit of the e-platform.

Furthermore, it can be seen in Figure 7 that the improvement of retailer's empathy degree will reduce the overall profit of the supply chain, and the overall profit of the supply chain will initially increase and then decrease with the increase of the e-platform's empathy degree toward farmers. This is because when the e-platform's empathy degree toward farmers is high, the supervision intensity of the e-platforms for the

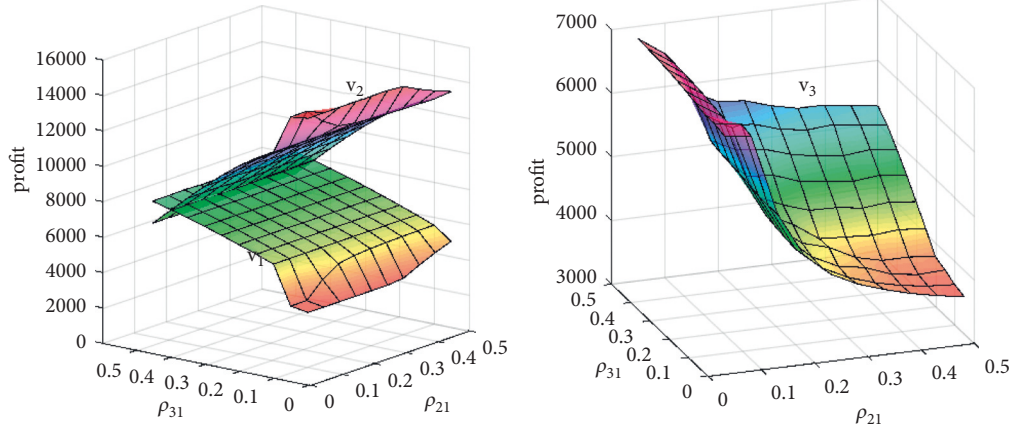


FIGURE 6: The influence of empathetic preferences of retailer and e-platform on the profits. (a) The impact on the profits of the farmers and the retailer; (b) the impact on the profits of e-commerce platform.

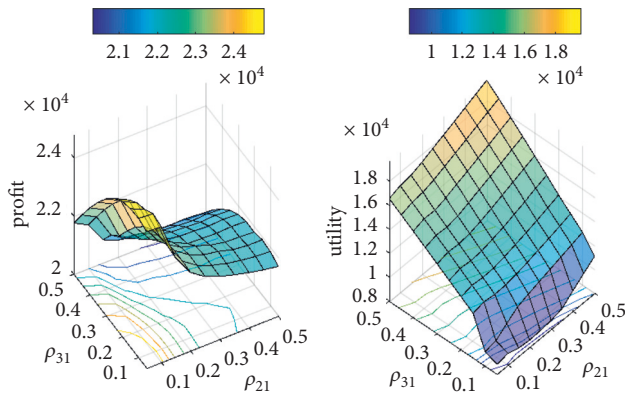


FIGURE 7: The influence of empathetic preferences of the retailer and the e-platform on the total profits and utility of supply chain. (a) The influence on the total profits; (b) the influence on the utility of supply chain.

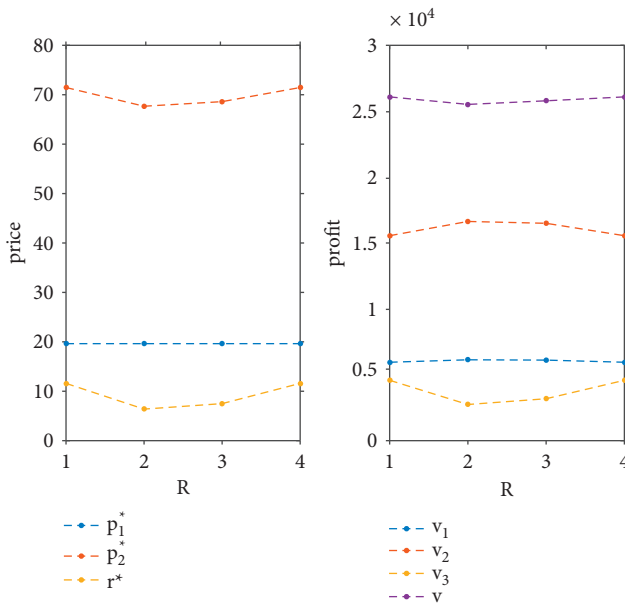


FIGURE 8: The influence of power structure on the supply chain pricing and profit disposition. (a) The influence on the prices; (b) the influence on the profits.

retailer is at a high level. With the increase in supervision intensity of the e-platform, the interests of farmers and e-platform is lower than the reduced interests of the retailer, resulting in a decreasing trend of the total profit of the supply chain.

4.2.3. *The Influence of the Power Structure within Supply Chain on the CRP.* Figure 8 shows the impact of power structure within the supply chain on pricing strategy and profit disposition, where horizontal coordinate R represents the power distribution in the supply chain, the four points represent $R = (0.05, 0.35, 0.6)$, $R = (0.05, 0.6, 0.35)$, $R = (0.167, 0.5, 0.333)$, and $R = (0.5, 0.3, 0.2)$, respectively.

The analysis results in Figure 8 show that the change in power distribution will not affect the wholesale price, but has a great impact on the sales price and the commission price of the e-platforms. The sales price and commission price are negatively correlated with the power of the retailer. The greater the power of the retailer, the lower the sales price and commission price of the product. The power of the retailer is positively correlated with the profits of farmers and retailers, and negatively correlated with the profit of e-platform. At the same time, the total profit of the supply chain is negatively correlated with the power of the retailer, and decreases with the growth in power of the retailer.

5. Conclusions

This article proposed a consensus model of the PA-eSC considering the empathetic preference and power structure, and analyzed the influence of empathetic preference and power structure on pricing decisions concerning agricultural products, the income of supply chain entities, and the CRP. The major findings are as follows.

Firstly, consumers' empathy increases the wholesale price and sales price of products. Consumers' empathy has a positive impact on the demand for products, and increases the profits of farmers, retailers, and the supply chain.

Secondly, the wholesale price increases with the improvement of retailers' and e-platforms' empathy to

farmers, but the sales price is the opposite, and commission prices rise with an increase in the e-platforms' empathy. The empathetic preference of retailers will reduce their own profit and the overall profit of the supply chain, while the empathetic preference of e-platforms will help to improve their own profit, and will increase the overall profit of the supply chain at first, before decreasing.

Moreover, the sales price and commission price are negatively correlated with the power of retailer, but the wholesale price is not related to the change in power distribution. The power of retailers is positively correlated with the profits of farmers and retailers, and negatively correlated with the profits of e-platforms and the supply chain.

The conclusions bring various managerial insights to the PA-eSC stakeholders. Firstly, a straightforward managerial insight is that empathetic preferences of consumers have positive impacts on improving the supply chain profits and system efficiency. Therefore, farmers, retailers, and e-platforms should pay attention to the marketing planning and service levels, and improve consumers' empathy for all aspects. In doing this, consumers' purchasing desires can be enhanced, and the profits of supply chain can be increased. Secondly, e-platforms that sell agricultural products should improve the quality of online sales services, strengthen cooperation with retailers and pay appropriate attention to the profits of farmers, but not apply too much interest concessions pressure to retailers because of the empathy to farmers. In this way, it is possible to stabilise and expand the market, and realize the promotion of the overall profit of the supply chain. Moreover, retailers should properly respect the voice of e-platforms and farmers in order to achieve the overall profit growth of the supply chain in the actual supply chain management.

This study has several limitations. First, this research model only considers retailers' and e-platforms' empathy toward farmers, but there is also empathy between retailers and e-platforms in practice, so the empathetic preferences for the supply chain needs further exploration. Moreover, this study only considers the e-commerce supply chain. Further exploration of empathetic preferences in dual-channel supply chains will make the research conclusions on the empathetic preferences more realistic and meaningful.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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