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Research Article

The Impact of Social Preferences on Supply Chain Performance: An Application of the Game Theory Model

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Traditional supply chain literature on contracting only considers agents' economic motivation. Nowadays, with the development of behavioral economics, social preference theory has been widely used in supply chain research. These social preferences are distinct from economic motivation and will influence agents' behaviors in the supply chain. Agents will make decisions based on not only self-interests but also the interests of others, reciprocity, and fairness. This paper introduces the relationship and status preferences in the utility function. We aim to analyze the impact of social preference on individual competition intensity in the supply chain. A Stackelberg game model (tacit collusion) is used as the theoretical framework of the choice behavior between competition and cooperation. The theoretical results and numerical simulation analysis show that under some conditions, suppliers and retailers who take the social preference factors into account can realize multiple-stage channel coordination through revenue sharing. Moreover, social preference factors will influence the choice behavior of agents in competition and cooperation. Specifically, the relationship preference promotes close cooperation among enterprises and significantly improves the supply chain and individual performance. Status preference causes fierce competition among enterprises and adversely affects supply chain performance and individual performance, making it more unstable. These findings can provide useful insights for supply chain coordination.

1. Introduction

Traditional economics takes self-interest and rationality as the precondition of the hypothesis. Under this assumption, agents in a supply chain will make decisions according to their interests [1]. Usually, these decisions are suboptimal concerning the whole system because of double marginal problems. Thus, many researchers on the supply chain proposed coordinating contracts to obtain optimal decisions in a whole system. A series of coordination contracts, such as buyback, quantity discounts, and other contracts based on the assumption precondition, has been designed [2–4]. A supply chain coordinating contract expects to achieve the overall effectiveness of the whole system through specific economic incentives, namely, channel coordination [5]. The sense of cooperation between employees is not only due to material incentives but also to social preference factors: individuals are not only concerned about their interests but also about the interests of others [6]. Still, it is shown in many recent results of experimental research on contract theory that there is a distinct difference between the behaviors of supply chain competitors and the prediction of contract theory [7]. A series of contracts, such as pricing and quantity discount contracts, buyback, revenue sharing, and other coordination mechanisms, can't help to realize supply chain coordination [8, 9].

Motivated by research in behavioral economics, social preference theory has been introduced into the supply chain coordinating study area. Behavioral economics holds that people are concerned about not only their economic

interests but also the interests of others, reciprocity, and fairness [10]. When the team members take self-interest behavior, there will be the so-called social dilemma. That is, the interests of individual team members are less than the benefits of not taking self-interest behavior. Social dilemmas often occur in teams and other operation management processes, such as new product development and total quality management (Loch and Wu [11]). Thus, social preference is an essential reference factor for agents' decision-making. A growing number of convincing research results to deal with actual economic problems have been achieved. Supply chain contracting models can achieve full system efficiency and channel coordination by considering social preference [12]. Social preferences may mitigate the double marginal problems [13, 14]. Therefore, this study aims to examine the influence of social preference in a supply chain framework and how social preference would change the cooperation and competition of agents in the supply chain. Specifically, we consider two types of preferences: relationship and status. By solving this, we could obtain insights into agents' strategies in a supply chain.

To address this question, in this paper, we consider the role of social preference in the utility function. Relationships and status preferences are two common kinds of social preferences. Status preference makes the competition between team members more intense, and the construction of good relationships can help team members sincerely cooperate. Agents in a market of cooperation and competition will make decisions to optimize their profits. We analyze the influence of relationships and status preference on competitive intensity. Through the game theoretic model, we examine the performance of the overall supply chain system and the individual agents. Furthermore, we utilize a numerical simulation to study the variation trend of the critical discount factor on the performance of the supply chain. The framework of the study is shown in Figure 1.

Our research has contributed to the existing studies on the channel coordination contract in supply chain management. First and foremost, according to the authors best knowledge, this study is the first to consider relationship preference and status preference in the competition and cooperation of agents in a supply chain, which contributes to the operational management literature. Second, we examine their effects on the competitive intensity in the supply chain through game theoretical models. We find that the relationship preference promotes close cooperation between enterprises and significantly improves the performance of the supply chain system and individuals. Besides, the status preference leads to intensified competition between enterprises and damages the performance of the supply chain system and individuals making it more unstable.

The rest of this study is structured as follows. In Section 2, we review the relevant literature. In Section 3, we build models of agents' behavior in cooperation and competition cases. Section 4 studies the effect of social preference on supply chain performance, including relationship preference and status preference. In Section 5, utilize a numerical simulation for future analysis of the model. Conclusions are presented in Section 6.

2. Literature Review

This study relates to several distinct strands of operations management literature. We can divide the most related studies into three streams: the failure of channel coordination, social preference theory, and their usage in supply chain studies. The details are presented in the following subsections.

2.1. The Failure of Channel Coordination. There is a rich body of research studying coordinating contracts in supply chains. Theoretically, coordination contracts can achieve supply chain coordination and overall profit optimization. Nevertheless, in the experimental environment, the actual results and the standard theory of predictions have shown a systematic deviation. Specifically, the efficiency of coordination contracts is less than 100%, about 80% [8]. Standard theory cannot predict whether the supply chain coordination contract will be rejected.

Many researchers have studied the reasons for the failure of channel coordination. The refusal has become the most important reason for the inefficient performance of supply chain contracts in the experimental environment. For example, Katok and Wu [15] found that buyback and revenue sharing contracts failed to fully realize supply chain coordination based on the experimental background with a two-stage supply chain structure consisting of a supplier and a newsboy. They pointed out that the channel coordination contract is a hotspot in supply chain management. Still, the latest research shows that part of the coordination mechanism in the experimental environment did not achieve the purpose of channel coordination. Besides, the ineffectiveness of the coordination contract may be due to the participant's unilateral denial of the supply chain coordination contract. For example, Katok and Pavlov [16] used the experimental economics method to systematically study the effects of unbalanced aversion, limited rationality, and imperfect information on supply chain channels. The results showed that three factors affect the behavior of participants. Unbalanced aversion has the most substantial explanatory effect on retailers' behavior. The imperfect information about the degree of a retailer's unbalanced aversion is the most explanatory of supplier behavior. The limited rationality affects suppliers and retailers but is weaker than the previous two factors.

Furthermore, Pavlov et al. [4] proposed an analytical model based on fair and bounded rationality to explain why supply chain contracts were rejected. The study shows that fairness and bounded rationality are important reasons for the failure of coordination contracts and the inefficiency of supply chain coordination. In theory, it is possible to achieve a coordinated form of contract that may not coordinate supply chain channels even without considering bounded rationality. The reason for coordination failure is information incompleteness in the process game. And if the

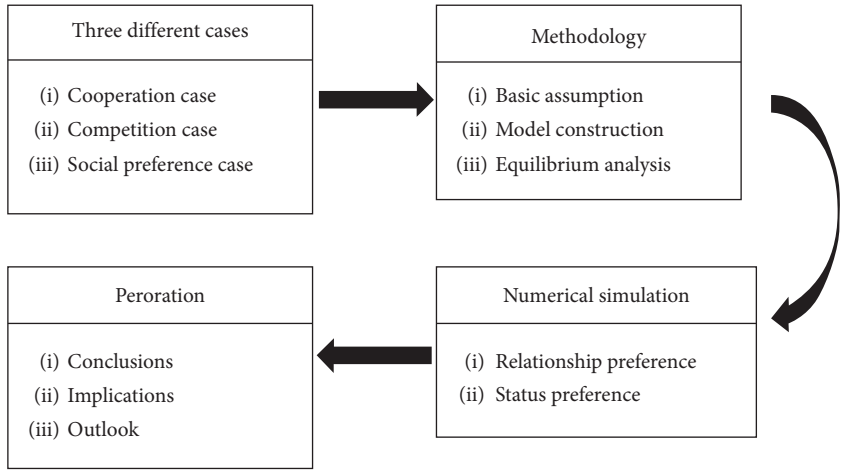

Figure 1: The framework of this research.

retailer's fair preference is public information, suppliers can design an appropriate coordination contract to ensure the retailers' acceptance. But if retailers' fairness preferences are private information, suppliers' contracts may encounter retailers' unilateral rejection.

2.2. Social Preference Theory. Previous psychology and sociology literature focused on social preferences found that the competition participants were also concerned about economic interests, reciprocity, fairness, status, and other social preference factors [6, 17, 18]. The traditional analytical coordination model assumes that the channel members are only concerned with their economic interests and have come up with many conclusions. For example, there are double marginal problems in the two-stage supply chain channel. Jeuland and Shugan [19] proposed a quantitative discount contract to revise the double marginalization problem in the two-stage supply chain channel, the other two-stage pricing contracts, and other nonlinear pricing mechanisms. Different from the traditional principal-agent theory, which is based on the complete rational hypothesis, it does not consider the sociality of the individual, such as fairness preferences.

Social preference believes that individuals are concerned not only about their economic interests but also about income fairness. Therefore, many scholars have proposed that the social preference factors could explain the reasons for the supply chain contracts with economic rationality as its hypothesis precondition failing to work on the individual competition participants with social attributes. The vast majority of supply chain contract models are based on the hypothesis of self-interested and rational economic agents and ignore the prosocial behavior of human beings (Espinosa and Kovářík [20]), such as reciprocity, status, and team spirit. Charness and Rabin [17] classified social preferences as one that cares about final disposition and another about reciprocity behind intentions. But it is unclear whether these contractual mechanisms are still applicable when the supply chain members consider the economic benefits and social factors.

2.3. Social Preference Factors in the Supply Chain Studies. Many studies have investigated the influence of social preference factors on the supply chain. Loch and Wu [11] introduced the relationship and status preference into the decision model to construct a new utility function and researched the two-stage supply chain consisting of the supplier and retailer. The research result showed that social preference had a systematic influence on the decision-making behavior in the supply chain transaction. Relationship preference improved the cooperation between the supplier and the retailer to achieve higher supply chain performance. In contrast, status preference intensified the competition and lowered the performance of the supply chain and individual competitors. They then emphatically analyzed the relationship and status preference compatibility. The result shows that relationship and status preference are mutually exclusive, and the decrease in status preference originates from the cooperation of good relations and strengthens the individual's consciousness. It is hard to motivate teams to pursue both the position and a harmonious atmosphere when a social dilemma exists. Subsequently, Caliskan–Demirag et al. [21] further demonstrated the role of a simple whole pricing contract in realizing coordination in the nonlinear demand hypothesis. They reached a similar conclusion and, to some extent, explained why the simple wholesale pricing mechanism could last long and be adopted by the market participants. Different from experimental economics adopted by Loch and Wu [11] as the main research method, this paper introduces the relationship and status preference into the decision model assumes tacit collusion as the theoretical framework of the choice behavior between corporation and competition, and tries to conduct rigorous mathematical analysis on the action mechanism of such social preference factors over the choice behavior of supply chain enterprises between competition and corporation through using the game theory as the main analysis tool.

Concerning the agents' fairness preferences, scholars found that fairness preferences have changed some of the conclusions of the traditional principal-agent theory and produced a new incentive mechanism and a new form of

remuneration structure [22]. Haitao Cui et al. [23] introduced fairness preference into the decision model to construct a new utility function. They discussed whether the simple whole pricing contract could realize the coordination of the two-stage supply chain consisting of a supplier and retailer through the game theory. This research showed that when the retailer or supplier and retailer have a fairness preference, the simple whole pricing contract could realize a supply chain coordination. Loch and Wu [11] systematically summarized the research outcomes by analyzing human social attributes in experimental economics. A game analysis based on the assumption of fairness and mutual benefit assumes that experimental economics is contrary to the traditional prediction theory. Furthermore, Cachon and Zipkin [24] studied the optimal inventory level and wholesale price in the two-stage supply chain when considering the fairness preferences in the stochastic demand environment. The Saranga and Moser [25] introduced fairness preferences into the quality optimization of the engineering supply chain and pointed out that fairness preferences harm the incentive effect of one-to-many owners on the contractor's group structure. Recently, many studies have also considered fairness in supply chain studies. Jian et al. [26] introduced fairness preferences into the operation analysis of supply chain behavior. They concluded that the fairness preference would not change the coordination effect of the wholesale price contracts, the repurchase contracts, and the revenue sharing contracts. Specifically, simple wholesale pricing in the stochastic demand state cannot achieve the coordination of the supply chain while the repurchase contracts and benefit-sharing contracts work. Han et al. [22] introduced fairness into a revenue sharing problem of the three-stage supply chain, focusing on the coordination ability of revenue sharing contracts when the distributors and retailers consider fairness preferences. They pointed out that cultivating and shaping the correct fairness view and minimizing blind comparisons and jealousy among team members can help build a standardized team, while introducing fairness preferences cannot change the coefficients of revenue sharing contracts and the coordination of the supply chain system. Liu et al. [27] introduced retailers' fairness concerns and manufacturers' attitudes into a two-echelon circular supply chain model. They indicated that agents could achieve a win-win situation when the manufacturer considers retailers' fairness concerns during the decision-making process. Zhang et al. [28] studied the social impact of individual behavior on the level of revenue sharing and the retail sales efforts by the Stackelberg game with fairness preferences in the two-level supply chain. They introduced fairness preferences into the research topic of project management. They pointed out that cross-organizational bi-directional incentives contribute to the project's value proposition when project-oriented organizations are introduced into fairness preferences. Liu et al. [29] built a three-party sustainable supply chain model considering fairness. Zheng et al. [30] integrated willingness to cede behavior into the sustainable supply chain models. They found leaders are less likely to cede profits when the competition is fierce.

Extant literature has demonstrated the role of social preference in supply chain modeling. However, separately considering the role of relationships and status preferences of social preference in the utility function and their influence on competitive intensity have not been well investigated in the existing literature, although these issues are close to reality. In this study, we aim to fill the gap in the existing theoretical research.

3. Model of Cooperation-Competition Behavior

3.1. Description of the Problem and the Basic Hypothesis. Similar to the research of Loch and Wu [11], this paper also researches a two-stage supply chain consisting of suppliers and retailers. In the game process, the supplier first determines his marginal revenue, and the retailer determines his marginal revenue after knowing the marginal quotation of the supplier. The quotes of both the supplier and retailer determine the market price. Since the supply chain is in line with the nature of a simple linear demand function in the face of market demand, as is assumed in prior studies such as Loch and Wu [11]. The research of this paper is based on revenue management, so the costs are normalized to be zero, thereby easily finding out that the profits of the supplier and retailer are as follows:

$$\begin{aligned} \pi_1 &= p_1 (d - p_1 - p_2), \\ \pi_2 &= p_2 (d - p_1 - p_2). \end{aligned} \tag{1}$$

To facilitate the discussion and logical-mathematical reasoning in the paper, we propose the following two assumptions:

(1) Assume that relationship, status, fairness, and other social preferences have timeliness; that is to say, the same social preference factors have different influences on utility at different times.

(2) Assume that the measure coefficients of social preference factors range from −1 to 1: $a_i, b_i \in [-1, 1], i = 1, 2$.

a or $b = 1$ indicates complete social preference and a or $b = 0$ indicates no specific social preference; plus or minus sign represents the positive or negative correlation. The above two assumptions have been widely used in the operational management literature [11–13]. All parameters' notations are summarized and shown in Table 1.

3.2. A Basic Model of Cooperation Competition. This paper takes tacit collusion as the theoretical framework of cooperation competitive choice behavior. Namely, suppose the retailer chooses to cooperate with the supplier. In that case, he will form tacit collusion with the supplier and can obtain part of the proceeds from the profit maximization of the supply chain system. Suppose the retailer chooses to cheat (the speculative behavior of a self-interested man) at a certain stage after cooperating with the supplier to get more revenue. In that case, he will later get caught in the infinite times of the Stackelberg game with the supplier [31].

Table 1: Notation glossary.

Parameters used	Description of the parameter
p	The selling price
d	Demand
π_s	Profit
a	The degree of relationship preference
b	The degree of status preference
δ	The discount factor
r	The profit-sharing factor
U	The utility
m	The subscript for the cooperation case
s	The subscript for the Stackelberg competition case
d	The subscript for cheating case

Through the present value calculation of the future earnings indefinitely in both cases mentioned above, it can be determined when the retailer will choose to cooperate or compete with the supplier and the dominant relation of the market oriented interest rate, and the choice behavior can be established. In later research, we will link the market oriented interest rate with the measurement coefficients of relationship and status preference to deduce a certain kind of mathematical correlation between such social preference coefficients and the choice behavior of the retailer between competition and cooperation, thus explaining some of the economic phenomena [11]. The following part will discuss the tacit collusion of suppliers and retailers, gaming, and cheating in this order.

3.2.1. Basic Model of Cooperation. If the supplier and retailer make tacit collusion, the decision objectives of the tacit collusion group could be obtained as follows:

$$\begin{aligned}\pi_m &= \max_{p_1,p_2} \frac{1}{2}(\pi_1 + \pi_2) \\ &= \max_{p_1,p_2} \frac{1}{2}(p_1 + p_2)(d - p_1 - p_2).\end{aligned} \tag{2}$$

Solving the optimized quotation of the supplier and the retailer during the tacit collusion process is as follows:

$$\begin{cases} \dfrac{\partial \pi_m}{\partial p_1} = \dfrac{1}{2}(d - 2p_1 - 2p_2) = 0, \\ \dfrac{\partial \pi_m}{\partial p_2} = \dfrac{1}{2}(d - 2p_1 - 2p_2) = 0. \end{cases} \tag{3}$$

Combining the equations, it can obtain that $p^* = p_1^* + p_2^* = d/2$, so the profits from the tacit collusion between the supplier and retailer in the tacit collusion process are $\pi_m = d^2/8$.

3.2.2. Basic Model of Competition. If the supplier and retailer conduct the Stackelberg game, then the results will be as follows through adopting adverse selection:

$$\begin{aligned}\frac{\partial \pi_2}{\partial p_2} &= \frac{1}{2}(d - 2p_1 - 2p_2) \\ &= 0.\end{aligned} \tag{4}$$

The optimum reaction curve of the retailer's quotation provided for the supplier during the game is $p_2 = 1/2(d - p_1)$, so the above reaction curve is substituted into the decision function of the supplier to obtain the optimal quote:

$$\begin{aligned}\frac{d\pi_1}{dp_1} &= \frac{\partial \pi_1}{\partial p_1} + \frac{\partial \pi_1}{\partial p_2}\frac{dp_2}{dp_1} \\ &= \frac{d}{dp_1} p_1(d - p_1 - p_2(p_1)) \\ &= \frac{1}{2}d - p_1 \\ &= 0.\end{aligned} \tag{5}$$

It can be obtained $p_1^* = d/2, p_2^* = d/4$ from the above equation, so the respective profits of the supplier and retailer during the game shall be $\pi_1^* = d^2/8, \pi_2^* = d^2/16$, and the game profits are $\pi_s = d^2/16$.

Based on the Stackelberg game, the supplier has a first-mover advantage compared with the retailer. Still, in terms of tacit collusion, this advantage turns out to be a disadvantage. Under the circumstance that the supplier and retailer quote in order, the retailer is likely to cheat in tacit collusion, thus damaging the supplier's interests. Although the retailer knows that once they cheat, he will get caught in the punishment of the Stackelberg game with the supplier on a perpetual basis, and the retailer is still likely to do so. The following part is the analysis of this cheating in tacit collusion:

Under the agreement of tacit collusion, the supplier will first quote $p_1^* = d/4$ following the decision value during the maximization of tacit collusion revenues. The supplier realizes that the retailer might commit cheating to damage their interests after he quotes such prices. As we mentioned before, this first-mover advantage might become a disadvantage. Still, to realize the potential interests from the tacit collusion and set contract spirit and seek effective regulatory measures to prevent the cheating of the retailer, we first assume that such a quotation premise exists. After the quotation by the supplier, the retailer determines his new quotation p2 based on the new profit function $\pi_2 = p_2(d - d/4 - p_2)$ in his decision to cheat:

$$\begin{aligned}\frac{d\pi_2}{dp_2} &= \frac{d}{dp_2} p_2\left(\frac{3}{4}d - p_2\right) \\ &= \frac{3}{4}d - 2p_2 \\ &= 0.\end{aligned} \tag{6}$$

At this point $p_2^* = 3/8d, \pi_2 = 9/64d^2 > 1/8d^2$, namely, in terms of a single game, the profits from cheating are more than the ones from tacit collusion, so the temptation to cheat exists, and the cheat profits are $\pi_d = 9/64d^2$.

At this point, the decision-making process of the regulation measure against cheating in tacit collusion, namely, the choice decision of the retailer between competition and cooperation, is as follows:

$$\pi_m + \delta\pi_m + \delta^2\pi_m + \delta^3\pi_m + \cdots + \delta^n\pi_m > \pi_d + \delta\pi_s + \delta^2\pi_s + \delta^3\pi_s + \cdots + \delta^n\pi_s + \cdots. \tag{7}$$

where $\delta \in [0, 1]$, it can be obtained that:

$$\pi_m \lim_{n \longrightarrow \infty} \frac{(1-\delta^n)}{1-\delta} > \pi_d + \pi_s \lim_{n \longrightarrow \infty} \frac{\delta(1-\delta^n)}{1-\delta},$$

$$\frac{\pi_m}{1-\delta} > \pi_d + \frac{\delta\pi_s}{1-\delta} \Rightarrow \pi_m > (1-\delta)\pi_d + \delta\pi_s. \tag{8}$$

Because $\pi_d > \pi_m > \pi_s$, then, it can be obtained that

$$\begin{aligned} \delta \geq \delta^* &= \frac{\pi_d - \pi_m}{\pi_d - \pi_s} \\ &= \frac{9d^2/64 - 8d^2/64}{9d^2/64 - 4d^2/64} \\ &= \frac{1}{5} > 0. \end{aligned} \tag{9}$$

Following the hypothesis of the punishment strategy, when the discount factor satisfies the above conditions, the tacit collusion group is stable and unlikely to collapse. The above results will be corrected to some extent in the following part, for the gross profits of the tacit collusion group are equally divided between the two subjects participating in the tacit collusion through the punishment strategy of the tacit collusion. Although equal division seems fair, it is not always valid, for some people focus on relative value, while others pay more attention to absolute value. Therefore, we correct the hypothesis to make it more consistent with the general sense. It is assumed that the two subjects participating in the tacit collusion share the profits of tacit collusion by a certain proportion (r_1, r_2) and satisfaction $r_1 + r_2 = 1$. We expect to find a suitable proportion (r_1^*, r_2^*) to distribute the profits from the tacit collusion group or centralized decision-making and maintain the tacit collusion supported by the restrictive constraints of the critical discount factor (market oriented interest rate) $\delta \geq \delta^*$. It is essentially equivalent to finding a coordination contract combination $(r_1^*, r_2^*, \delta \geq \delta^*)$ to achieve coordination of the supply chain, maximizing the profits of the overall system.

Because the collective profit of tacit collusion is $\pi^* = d^2/4$, the profit from tacit collusion obtained by the retailer shall be $\pi_m = r_2 d^2/4, r_2 \in [0, 1]$, then

$$\begin{aligned} \delta \geq \delta^* &= \frac{\pi_d - \pi_m}{\pi_d - \pi_s} \\ &= \frac{9d^2/64 - 8d^2/64}{9d^2/64 - 4d^2/64} \\ &= \frac{9}{5} - \frac{16}{5}r^2. \end{aligned} \tag{10}$$

Based on this $\delta \in [0, 1]$, it can be obtained that $0 \leq 9/5 - 16/5r_2 \leq 1$, so $4/16 \leq r_2 \leq 9/16$. Therefore, it is easy to obtain the following proposition:

Proposition 1. *Suppliers and retailers can realize multiple-stage channel coordination through revenue sharing. If a combination contract $(r_1^*, r_2^*, \delta \geq \delta^*)$ formed by the revenue sharing factor and the discount factor converted based on the market oriented interest rate satisfies the following conditions:*

$$\begin{cases} \delta \geq \delta^* = \dfrac{9}{5} - \dfrac{16}{5}r^2, \\ r_2^* \in \left[\dfrac{4}{16}, \dfrac{9}{16}\right], \delta \in [0, 1], \\ r_1^* + r_2^* = 1. \end{cases} \tag{11}$$

Proposition 1 shows that suppliers and retailers can realize multiple-stage channel coordination through revenue sharing under some conditions. The above combination is referred to as one of the contract combination forms. Based on the following considerations, in terms of the Stackelberg game in the two-stage supply chain, the leader can be the supplier or the retailer. When the supplier acts as the leader, it will be essential within the scope of price leadership. When the retailer acts as the leader, it will be essential within the scope of production leadership, especially when the supplier acts as a leader and hopes to establish a strategic partnership with the downstream enterprises in the supply chain and even vertical integration, namely, the forward integration. He can choose the abovementioned contract as the necessary regulatory measure to prevent cheating of the downstream enterprises in the supply chain. As Varian [32] mentioned in his book Intermediate Microeconomics, when the long-term Stackelberg game can act as a kind of punishment and "Threat" to cheating in the tacit collusion, the above regulation measures can be proved to be effective.

Furthermore, it is easy to draw the below inference based on the above conclusion.

Corollary 1. *If the profit r_2^* given to the retailer is more than 9/16, then the profit obtained from the tacit collusion is more than the profit gained from gaming and the profit from cheating. If the supplier can achieve his own vertical (forward) integration strategy, then he needs not to add the restrictive constraints of the critical discount factor (market oriented interest rate) to the profit-sharing factor; if the profit r_2^* given to the retailer is less than 4/16, then the profit obtained by the retailer from the tacit collusion is not only less than the profit*

gained from cheating, but also less than the profit from gaming and the retailer apparently will not accept such result; Corollary 1 shows that only if $r_2^* \in [1/16, 9/16]$*, then,* $\pi_d > \pi_m > \pi_s$ *established. To maintain the tacit collusion stable, it only needs to add the regulation measure* $\delta \geq \delta^* = 9/5 - 16/5r^2$*. It can be seen that if* δ^* *changes from 0 to 1, the lower limit of the value range of* r_2^* *will be gradually reduced to* 4/16*. At this point, if the supplier acquires the vast majority of profit from tacit collusion, it shows that the increase in the critical discount factor (marketoriented interest rate) is more favorable to the supplier. From another point of view, based on* $\delta^* = 9/5 - 16/5r^2 \Longrightarrow r_2^* = 9/16 - 5/16\delta^*$*, since the regulatory effectiveness also depends on the value of market discount factor, they need to satisfy* $\delta \geq \delta^*$*, then it can obtain that* $r_2^* \geq 9/16 - 5/16\delta$*. Namely, when the market discount factor is* δ*, to make such regulation measure effective, it shall satisfy* $r_2^* \in [9/16 - 5/16\delta, 1]$*. To implement the vertical (forward) integration strategy or establish a strategic partnership with the downstream enterprises in the supply chain, the supplier can provide the downstream enterprises in the supply chain with a profit-sharing factor in accordance with the decision of the above equation.*

4. Effect of Social Preference on the Supply Chain Performance

In this part, we mainly consider two kinds of social preference factors: relationship preference and status preference. When these two social preference factors are substituted into the general utility function of the supplier and retailer, we can obtain the following revised utility function:

$$\begin{aligned} U_1 &= \pi_1 + a_1\pi_2 + b_1(\pi_1 - \pi_2), \\ U_2 &= \pi_2 + a_2\pi_1 + b_2(\pi_2 - \pi_1). \end{aligned} \tag{12}$$

Such formulations are widely used in social preference studies; see Loch & Wu [11], where $a_i\,(i = 1, 2)$ indicates the degree of relationship preference works as the influence coefficient of the other party's profit on the utility of one party while $b_i\,(i = 1, 2)$ showing the degree of status preference works as the influence coefficient of the profit difference between the supplier and retailer on the utility of one party. To facilitate the following analysis, let us assume $a_i, b_i \in [-1, 1], i = 1, 2$.

$$\begin{aligned} v_1 &= \frac{a_1 - b_1}{1 + b_1}, \\ v_2 &= \frac{a_2 - b_2}{1 + b_2}; \end{aligned} \tag{13}$$

then,

$$\begin{aligned} U_1 &= (1 + b_1)(p_1 + v_1 p_1)(d - p_1 - p_2), \\ U_2 &= (1 + b_2)(p_2 + v_2 p_1)(d - p_1 - p_2). \end{aligned} \tag{14}$$

Thus, in the tacit collusion of the supplier and retailer, the decision is as follows:

$$U = \max_{p_1, p_2} \{U_1 + U_2\}. \tag{15}$$

It can be obtained from this

$$\frac{\partial U}{\partial p_i} = \left[1 + b_i + v_j\left(1 + b_j\right)\right]d - 2\left[1 + b_i + v_j\left(1 + b_j\right)\right]p_i - \left[2 + b_i + b_j + v_i(1 + b_i) + v_j\left(1 + b_j\right)\right]p_j = 0; i, j = 1, 2 \& i \neq j. \tag{16}$$

It can be obtained from the simultaneous equations:

$$\begin{cases} p_1 + \dfrac{2 + b_1 + b_2 + v_1(1 + b_1) + v_2(1 + b_2)}{2\left[1 + b_1 + v_2(1 + b_2)\right]}, & p_2 = \dfrac{1 + b_1 + v_2(1 + b_2)}{2\left[1 + b_1 + v_2(1 + b_2)\right]}d, \\ p_1 + \dfrac{2\left[1 + b_2 + v_1(1 + b_1)\right]}{2 + b_1 + b_2 + v_1(1 + b_1) + v_2(1 + b_2)\right]}, & p_2 = \dfrac{1 + b_2 + v_1(1 + b_1)}{2 + b_1 + b_2 + v_1(1 + b_1) + v_2(1 + b_2)\right]}d. \end{cases} \tag{17}$$

To simplify the solving process, we set $B_1 = 1 + b_1 + v_2(1 + b_2)], B_2 = 1 + b_2 + v_1(1 + b_1)]$, and then we can obtain the simplified simultaneous equations:

$$\begin{cases} p_1 + \dfrac{B_1 + B_2}{2B_1}, \quad p_2 = \dfrac{1}{2}d, \\ \\ p_1 + \dfrac{2B_2}{B_1 + B_2}, \quad p_2 = \dfrac{B_2}{B_1 + B_2}d. \end{cases} \tag{18}$$

Through solving the above equation, we can obtain the optical quotations of the supplier and retailer in tacit collusion, which are, respectively:

$$\begin{cases} p_1^* = \dfrac{{B_2}^2 - 3B_1B_2}{2(B_1 - B_2)^2}d, \\ \\ p_2^* = \dfrac{{B_1}^2}{(B_1 - B_2)^2}d. \end{cases} \tag{19}$$

It is easy to obtain the maximum utility in tacit collusion, which is

$$\begin{aligned} U^* &= (B_1p_1^* + B_2p_2^*)(d - p_1^* - p_2^*) \\ &= \frac{B_1B_2^2}{4(B_1 - B_2)^2}d^2. \end{aligned} \tag{20}$$

According to the agreement $r_1 + r_2 = 1$ by the supplier and the retailer about sharing the profit of tacit collusion, the retailer's tacit collusion utility is as follows:

$$\begin{aligned} U_m &= r_2, \\ U^* &= \frac{r_2B_1B_2^2}{4(B_1 - B_2)^2}d^2. \end{aligned} \tag{21}$$

In this part, we still assume the Stackelberg game as the gaming method, so it is the same as the above: we only need to research the retailer's attempt to cheat. The retailer can easily determine his price by observing whether the supplier is still quoting according to the optimized quotation decision in the tacit collusion, so $p_1^* = B_2^2 - 3B_1B_2/2(B_1 - B_2)^2d$. At this point, the retailer's maximum utility decision becomes

$$\begin{aligned} &\frac{dU_2}{dp_2} = (1 + b_2)[d - (1 + v_2)p_1 - 2p_2] = 0, \\ &\Longrightarrow p_2 = f(p_1) \\ &\quad = \frac{1}{2}[d - (1 + v_2)p_1], \\ &p_2^* = \frac{1}{2}[d - (1 + v_2)p_1^*] \\ &\quad = \frac{2(B_1 - B_2)^2 - (1 + v_2)(B_2^2 - 3B_1B_2)}{4(B_1 - B_2)^2}d. \end{aligned} \tag{22}$$

Now, if the quotations of the supplier and retailer are substituted into the retailer's utility function, the cheating utility of the retailer can be obtained as follows:

$$\begin{aligned} U_d &= (1 + b_2)(p_2^* + v_2p_1^*)(d - p_1^* - p_2^*) \\ &= (1 + b_2)\left(\frac{2(B_1 - B_2)^2 - (1 + v_2)(B_2^2 - 3B_1B_2)}{4(B_1 - B_2)^2}\right)^2 d^2. \end{aligned} \tag{23}$$

In the following part, the adverse selection will be adopted to solve the retailer's utility during the Stackelberg game. The retailer's optical reaction $p_2 = f(p_1) = 1/2[d - (1 + v_2)p_1]$ with self-interest as his objective towards the quotation of the supplier will be substituted into the utility function of the supplier, so the optical quotation of the supplier during the game can be obtained as follows:

namely,

$$\begin{aligned} &U_1 = (1 + b_1)(p_1 + v_1f(p_1))(d - p_1 - f(p_1)), \\ &\frac{dU_1}{dp_1} = \frac{\partial U_1}{\partial p_1} + \frac{\partial U_1}{\partial p_2}\frac{dp_2}{dp_1} = (1 + b_1)\left(\frac{2 - v_1(1 + v_2) - v_1(1 - v_2)}{4}d - \frac{2(1 - v_2) - v_1(1 - v_2)^2}{2}p_1\right) \\ &\quad = 0 \Rightarrow p_1^* = \frac{1 - v_1}{(1 - v_1)(2 - v_1(1 + v_2))}d. \end{aligned} \tag{24}$$

After substituting the optimal quotation of the supplier into the optical reaction curve of the retailer, we can obtain the optimal quotation of the retailer as follows:

$$p_2^* = \frac{(1 + v_2)(1 - v_1)}{2(1 - v_2)(2 - v_1(1 + v_2))}d. \tag{25}$$

It is easy to obtain the optical utility of the retailer during gaming from the above result of the optical quotation, which is as follows:

$$\begin{aligned} U_s &= (1+b_2)\left(p_2^* + v_2 p_1^*\right)\left(d - p_1^* - p_2^*\right) \\ &= (1+b_2)\frac{(1-v_1v_2)^2}{4(2-v_1(1+v_2)^2}d^2. \end{aligned} \tag{26}$$

According to the definition of the critical discount factor (market oriented interest rate) in the punishment strategy against cheating in tacit collusion, it can be obtained:

$$\delta \geq \delta^* = \frac{U_d - U_m}{U_d - U_s} = \frac{\widetilde{B}^2 - 4r_2 B_1 {B_2}^2 (B_1 - B_2)^2/1 + b_2}{\widetilde{B}^2 - \left(2(B_1 - B_2)(1 - v_1v_2)/2 - v_1(1+v_2)\right)^2}, \tag{27}$$

where $\widetilde{B}^2 = 2(B_1 - B_2)^2 - (1 - v_2)(B_2^2 - 3B_1B_2)$. The contract combination form, which takes social preference into account, can be obtained following the solution of the combination contract. If the critical discount factor (market oriented interest rate) is marked as $\delta^*(r_2)$, it is easy to learn that:

$$D\left(r_2^*\right) = \arg_{r_2} \delta^*(r_2) \in [0,1], \tag{28}$$

where $D(r_2^*)$ represents the feasible region of r_2^*.

Proposition 2. *The supplier and the retailer who take the social preference factors into account can realize the multiple-stage channel coordination through revenue sharing. If the combination contract $(r_1^*, r_2^*, \delta \geq \delta^*)$ formed by the revenue sharing factor and the discount factor converted based on the market oriented interest rate satisfies the following conditions:*

$$\begin{cases} \delta \geq \delta^*, \\ r_2^* \in D\left(r_2^*\right) = \arg_{r_2}\{\delta^*(r_2) \in [0,1]\}, \\ r_1^* + r_2^* = 1, \delta \in [0,1]. \end{cases} \tag{29}$$

Proposition 2 shows that multiple-stage channel coordination through revenue sharing could be obtained when the combination contract satisfies some conditions. The critical discount factor (market-oriented interest rate) is influenced by the proportion of profit sharing and is sensitive to the value of every social preference factor to some extent. Thus, retailers and suppliers should consider the value of social preference and profit-sharing proportion in decision-making. To study the influence of social preference factors on the stability of tacit collusion, it is necessary to analyze the expression formula of the critical discount factor (market oriented interest rate) on the social preference factor mainly through derivation and computation and the research on the variation trend of the curve. Considering the complexity of the critical discount factor (market oriented interest rate) expression formula, a mathematical analysis will be adopted to research the variation trend in the following part.

5. Model Analysis and Numerical Simulation

In order to explain the influence of social preference factors on the choice behavior of competition and cooperation, it is only needed to study the variation trend of the critical discount factor (market oriented interest rate) of every social preference factor during the change. Our research is to, respectively, study the influence of relationship preference and status preference on the critical discount factor (market oriented interest rate).

First, the paper studies the influence of relationship preference. The measurement coefficient of status is set to be $b_i (i = 1, 2) = 0$, and the value of the profit-sharing factor is set to be 0.5, for the value will not affect the variation trend of the discount factor relative to the relationship preference measurement coefficient. The simplified critical discount factor (market oriented interest rate) is as follows:

$$\begin{aligned} \delta^*(a_1, a_2) &= \frac{U_d - U_m}{U_d - U_s} \\ &= \frac{\widetilde{A}^2 - 2(1+a_2)(1+a_1)^2(a_2 - a_1)^2}{\widetilde{A}^2 - \left(2(a_2 - a_1)(1 - a_1a_2)/2 - a_1(1+a_2)\right)^2}, \\ \widetilde{A} &= 2(a_2 - a_1)^2 - (1 - a_2)\left(a_1^2 - a_1 - 2 - 3a_2 - 3a_1a_2\right), \\ & a_i \in [-1,1], i = 1,2. \end{aligned} \tag{30}$$

The trend of the critical discount factor (market oriented interest rate) varying with the two relationship preference measurement coefficients is shown in detail in the Table 2 in the following part. Therefore, the following inference can be obtained:

Table 2: The critical discount varies with relationship preference.

a_2	Theta	a_1									
	−1	−0.8	−0.6	−0.4	−0.2	0	0.2	0.4	0.6	0.8	1
−1	1.003	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002
−0.8	1.001	1.001	1.001	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002
−0.6	0.999	1.000	1.000	1.001	1.001	1.001	1.001	1.001	1.001	1.001	1.001
−0.4	0.997	0.998	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
−0.2	0.993	0.995	0.996	0.998	0.999	0.999	1.000	1.000	1.000	1.000	0.999
0	0.987	0.991	0.993	0.995	0.997	0.998	0.999	0.999	0.999	0.999	0.998
0.2	0.977	0.983	0.988	0.992	0.995	0.997	0.998	0.999	0.999	0.999	0.998
0.4	0.955	0.968	0.978	0.986	0.992	0.996	0.999	1.001	1.001	1.000	0.998
0.6	0.897	0.929	0.954	0.974	0.989	1.000	1.008	1.012	1.013	1.010	1.004
0.8	0.573	0.716	0.834	0.929	1.004	1.061	1.099	1.120	1.124	1.110	1.079
1	2.531	1.938	1.438	1.023	0.691	0.439	0.267	0.173	0.159	0.224	0.368

Corollary 2. *The relationship between the critical discount factor (market oriented interest rate) and the relationship preference measurement coefficients of the supplier and retailer can be summarized as follows:*

$$\frac{\partial \delta^* (a_1, a_2)}{\partial a_2} \leq 0, \quad \frac{\partial \delta^* (a_1, a_2)}{\partial a_1} = 0. \tag{31}$$

Corollary 2 illustrates that the greater the retailer's preference for the relationship, the more friendly the retailer is toward the supplier. The smaller the critical discount factor (the market interest rate) δ^* becomes, the higher the stability of the tacit collusion becomes. It is consistent with the actual situation and the existing O.M. literature, such as Jeuland and Shugan [19] and Loch and Wu [11]. When the relationship between the two parties is better, they will be more likely to cooperate and maintain stability. In order to keep this relationship, they need to cooperate the sincerity. When the supplier's preference for relationship increases, the critical discount factor (market oriented interest rate) has no obvious change. Because the critical discount factor (market oriented interest rate) in the context of the Stackelberg game is not very sensitive to the supplier's relationship preference.

Then, the paper studies the influence of the status preference measurement coefficient on the critical discount factor (market-oriented interest rate) through the same numerical simulation. Given that the relationship preference measurement coefficient is $a_i (i = 1, 2) = 0$, the value of the profit-sharing factor r_2 is set to be 0.5, for the value will not affect the variation trend of the discount factor relative to the relationship preference measurement coefficient. Figure 2 displays their relationships, as shown in Table 2. The trend of the critical discount factor (market oriented interest rate) varying with the two status preference measurement coefficients is shown in detail in Table 3 in the following part. Therefore, the following inference can be obtained:

Corollary 3. *The relationship between the critical discount factor (market-oriented interest rate) and the status preference measurement coefficients of the supplier and retailer can be summarized as follows:*

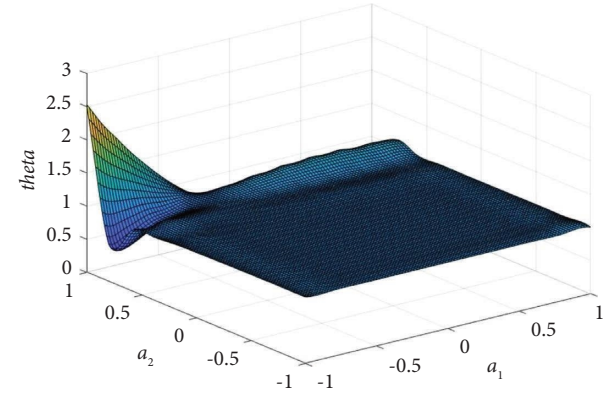

Figure 2: The critical discount varies with relationship preference.

$$\begin{cases} \dfrac{\partial \delta^* (b_1, b_2)}{\partial b_2} \leq 0, b_2 \leq -0.5, \\ \dfrac{\partial \delta^* (b_1, b_2)}{\partial b_2} \geq 0, b_2 > -0.5, \\ \dfrac{\partial \delta^* (b_1, b_2)}{\partial b_1} > 0. \end{cases} \tag{32}$$

Corollary 3 shows that when the given relationship preference measurement coefficient is 0, the retailer's utility function is $U_2 = \pi_2 + b_2(\pi_2 - \pi_1) = (1 + b_2)\pi_2 - b_2\pi_1$. When $b_2 \leq -0.5$, then $1 + b_2 < -b_2$, which means that the supplier's profit size has a greater influence on the retailer's utility than the retailer's profit. In other words, the retailer attaches more importance to the supplier's profit than his profit (a little similar to the situation of relationship preference). At this point, the retailer is in a dilemma, for, on the one hand, he has a stronger preference for the prominent status; on one hand, the high profit of the supplier is more favorable to the overall utility. After weighing the two aspects, it shows within the scope. With the increase in status preference, the critical

Table 3: The critical discount varies with the status preference.

b_2	Theta	b_1									
	−0.9	−0.7	−0.5	−0.3	−0.1	0	0.1	0.3	0.5	0.7	0.9
−0.9	−0.03	−1.320	2.740	1.471	1.230	1.174	1.135	1.086	1.057	1.039	1.026
−0.7	−1.42	0.559	0.760	0.829	0.860	0.870	0.878	0.890	0.897	0.903	0.907
−0.5	0.203	0.233	0.296	0.379	0.479	0.535	0.596	0.730	0.880	0.105	0.123
−0.3	0.216	0.786	0.880	0.915	0.931	0.936	0.940	0.946	0.950	0.953	0.955
−0.1	0.953	0.986	0.990	0.993	0.994	0.994	0.995	0.995	0.995	0.995	0.996
0	1.035	1.007	1.000	1.001	1.000	1.000	1.000	1.000	1.000	0.999	0.999
0.1	1.081	1.019	1.000	1.005	1.003	1.003	1.002	1.002	1.002	1.001	1.001
0.3	1.131	1.030	1.010	1.009	1.006	1.005	1.005	1.004	1.003	1.003	1.003
0.5	1.161	1.036	1.010	1.010	1.007	1.006	1.006	1.005	1.004	1.004	1.003
0.7	1.183	1.041	1.010	1.011	1.008	1.007	1.006	1.005	1.004	1.004	1.003
0.9	1.201	1.044	1.020	1.012	1.008	1.007	1.006	1.005	1.004	1.004	1.003

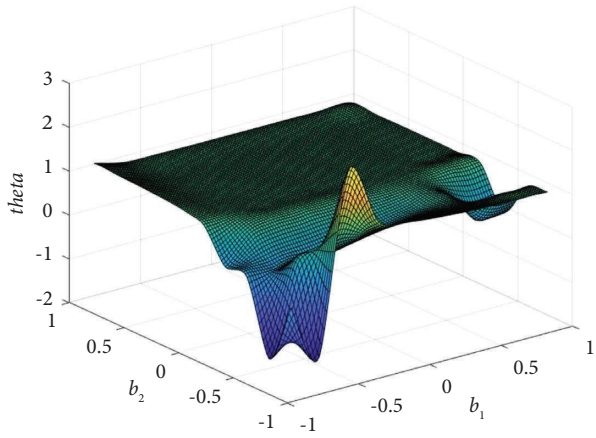

Figure 3: The critical discount varies with the status preference.

discount factor (market interest rate) decreases gradually, namely, the stability of tacit collusion gradually increases. When $b_2 > -0.5$, then $1 + b_2 > -b_1$. When the retailer attaches more importance to his profit, he successfully eliminates the dilemma. The critical discount factor (market interest rate) increases with the increase in the status preference measurement coefficient, and the stability of tacit collusion decreases. The retailer attempts to obtain more profit through cheating to enlarge the profit gap between himself and the supplier and satisfy his pursuit of prominent status. When the supplier's status preference measurement coefficient increases, the supplier wants to widen the profit gap between himself and the retailer. Then, the retailer will be dissatisfied. At this point, the decrease in the stability of the tacit collusion is represented by the gradual increase in the critical discount factor (market interest rate). These results are consistent with recent literature such as Haitao Cui et al. [23], Cachon and Zipkin [24], and Saranga and Moser [25]. Figure 3 shows the graphical representation of Table 3 results.

6. Conclusion

Social preference factors, such as relationship, status, and team spirit, are the focus of the research and discussions in social science. Some social science, psychology, and economics scholars believe that human beings demand for social preference constitutes the ultimate demand. Just as Maslow's hierarchy of needs theory advocates that people's social needs are higher than physiological needs, safety needs, and other needs related to economic aspects. We found that most supply chain contracting studies only consider self-interested agents and ignore their social preferences.

The theoretical contribution of this study is twofold. First, this paper innovatively substitutes the relationship and status preference into the utility function and adopts tacit collusion as the theoretical framework of choice behavior between cooperation and competition. Second, we aim to discuss and analyze the influence of social preference on the competitive intensity between individuals in the supply chain through the strict mathematical logic of the game theory. After theoretical analysis and numerical simulation, we find that the relationship preference promotes close cooperation between enterprises and significant improvement in the performance of the supply chain system and individuals. On the other hand, status preference leads to intensified competition between enterprises and damages the performance of the supply chain system and individuals making it more unstable.

Our results also have several managerial implications. First, like economic incentives, social preference can also incentivize human behaviors, so the standard incentive theory (bonus, research, revenue sharing, and so on) may be incomplete without considering social preference factors. In addition to economic incentives, the relationship can be used to enhance the cooperation of enterprises, and a good enterprise relationship (even an employment relationship) can improve the performance of the supply chain system. Second, too much emphasis on the status and other similar factors among the supply chain enterprises may threaten the stability of the supply chain system and is not conducive to establishing strategic cooperative partnerships and improving supply chain performance.

While this study makes several contributions to the literature by considering social preferences in agents' utility functions, it still has some limitations. Further research may consider how networks between agents affect the performance of the whole supply chain. In addition, it will be interesting to investigate and empirically verify this study's results. Last but not least, social preferences across different

cultures might vary; thus, it would be important to put this analysis in a global context, and more profound insights may be obtained.

Data Availability

All the data are available on the mentioned resources in the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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