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GAME THEORETIC APPROACH FOR COORDINATION OF TELECOMMUNICATION SUPPLY CHAIN UNDER NETWORK EXTERNALITY

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Abstract. *In view of the booming of telecom industry, we study the coordination issues in a telecom service supply chain with network externality. First, a mathematical model of the business model in a telecom supply chain is established for one mobile provider and one service provider. Second, pricing and profit sharing mechanism between telecom operators and service providers in the perspective of non-cooperative game and cooperative game are analysed respectively. Finally, numerical examples are given to support our model. Some good insights are presented for both agents in the telecom service chain. The effects of system parameters on the pricing strategy and the profit allocation mechanism are also given.*
Keywords: Telecom supply chain, Network externality, Cooperative game

1. **Introduction.** In recent years, service plays a growing important role in both economy and employment. The world economy has been grown to be service oriented. Service science and service management attracted much attention in both manufacturing companies and service industries. Service related issues have been a hot topic in operations research, management science and operations management. Taking supply chain for example, more attention has been paid to service operations and the traditional supply chain system has evolved to be service supply chain system. There are a lot of definitions and clarifications of service supply chain. Interested readers are suggested to refer to the excellent review by Wang et al. (2015) [27]. In our paper, we follow their definition of service only supply chain, where the products are pure service and physical products do not play a role. It can be found in industries such as telecommunication (telecom), finance, and mobile Internet. As a typical service industry, telecom industry plays an important role in the national economy. Due to a data of China, the total number of Chinese mobile Internet users reached 838 million, accounting for 67.8% of mobile phone users up to January 2014. Hui Dian Market Research also reported that, the mobile Internet industry obtained more than 900 billion RMB, accounting for 1.8% of China's GDP in 2013. Meanwhile, there are some structural reforms in China telecom industry in

recent years. On December 4, 2013, the ministry of industry and information technology telecommunication issued 4G licenses to China Mobile, China Unicom and China Telecom. On December 26, virtual operator licenses are firstly issued to 11 companies. All these show a new age for the mobile Internet industry in China.

Another feature in telecom industry is the network externality. Network externality is a concept that new subscribers/consumers joining a network will increase the utility of current subscribers/consumers. It has been observed by a wide range of industries both in physical and service. In particular, service industries related to Information and Communication Technology (ICT) show a strong characteristic of network externality. Interested readers should refer to Conner (1995) [5]. Recently, with the development of mobile Internet technology, more and more industry has the characteristics of network externality such as mobile map service, mobile communication tool, and instant messaging services. When users utilize a mobile service more, the more other users will utilize it. Therefore, the total utility of the network members is improved. An excellent example is about the development of the Coloring Ring Back Tone (CRBT). In the early stage, due to the limited variety, CRBT does not attract much attraction. Only with the increasingly rich product/service style, more and more users begin to accept CRBT. This in turn greatly enhanced the enthusiasm of the service providers, who provide all kinds of CRBT service. Finally, CRBT has a rapid growth in the market. It shows an obvious network externality. In view of the network externality, service providers deem it an important strategy for promotion. Due to a strong network externality of telecom service, the growth of users always shows an increasingly high rate. Thus, it is very necessary to study telecom supply chain issues with network externality. In this paper, we study the coordination issues in a telecom service supply chain with network externality. We analyze the pricing and profit sharing mechanism between telecom operators and service providers in both non-cooperative game and cooperative game. What we are targeting at is to present the effect of network externality on the pricing strategy and profit allocation mechanism in such a telecom supply chain.

Our contribution of the paper is summarized as follows. We have presented a mathematic model for telecom supply chain with network externality. The coordination strategies for mobile provider (MP) and service provider (SP) with both non-cooperative game and cooperative game are analyzed. The results show that cooperative game is better than non-cooperative game and the network externality has a positive influence on the total profit of the supply chain.

The paper is organized into the following sections. Section 2 introduces literature reviews. Section 3 states model development. The main results are stated in Section 4. Numerical results are provided in Section 5. Section 6 concludes this study.

2. Literature Review.

In the following, we review three streams of literature which are related to our research, respectively. The first is telecom supply chain management, then network externality, and the last is cooperative game theory.

2.1. Telecom supply chain.

Supply chain management has been deemed to be the key to competitive advantage since its birth in the middle of 1980s. With the booming of service industry, supply chain management is adopted as a new significant tool in many service-oriented firms. One of these applications is telecom supply chain management. In recent years, some scholars have already begun to study telecom supply chain by using a supply chain model such as contract, information, and outsourcing. There are tons of literature on supply chain management; in the following, we only present some most related to telecom supply chain.

Gruber and Hoenicke (1999) [15] described a mobile telephone network, which was composed of the physical components such as handset, base station, and mobile service switching station required to connect users. A call made from a handset is transmitted to a base station and then to a mobile service switching station. El-Azouzi et al. (2003) [12] studied a telecom service chain model which was composed of multiple telecom service providers and analyzed the service providers' optimal pricing strategy and optimal service quality level. They proved the existence and uniqueness of the Nash equilibrium. Agrell et al. (2004) [1] studied a telecom supply chain in a perspective of risk, information and incentives. In their paper, they firstly presented a three-level telecom supply chain including a tire supplier, an EMS (e.g., Flextronics or Solectron) and an OEM (e.g., Nokia, Ericsson). Problems such as information sharing, specific investment problem were addressed by using a two-period investment production game. Zheng and Da (2005) [32] investigated the supply chain cooperation mechanism of mobile Internet with the background of multimedia messaging service. They found that supply chain profit can be maximized and coordination of a mobile Internet can be realized by using revenue sharing contract. Wu et al. (2009) [28] formulated a model with one service provider and one mobile provider in the Chinese telecom industry, where the mobile provider is the leader of the chain. They studied the cooperation mechanism between the service provider and the mobile provider. Cricelli et al. (2011) [6] studied a telecom supply chain model into different components of value chain based on on-net call and off-net call. A competition model following the framework proposed by Laffont et al. (1998) [19], Carter and Wright (2003) [3] is well addressed. Chakravart and Werner (2011) [4] studied a mobile commerce value chain which consisted of a mobile network operator and multiple service providers using the game theory. They further analyzed the optimal pricing strategy and the profit distribution plan with different cooperation mechanisms. A formal structured managerial approach for organizations to help evaluate the influence relationships among green supplier development programs is introduced by Fu et al. (2012) [14]. They acquired multi-functional managerial inputs within a telecommunication systems provider to evaluate the green supplier development programs by using their new approach. Xu and Yang (2015) [29] studied a telecom value-added service chain with two service providers and one mobile provider with advertisers implanted. Some numerical results were presented for supporting optimal decision in telecom operations.

2.2. **Network externality.** Network externality has been first studied by Rohlfs (1974) [23], he has found that a user's utility gained from the communication service increases with the number of users joining the system. Katz and Shapiro (1985) [17] developed a simple, static model of oligopoly to analyze markets in which network externality was present. They studied the effect of network externality on competition and the form of the market equilibrium. They confirmed the importance of consumers' expectation in markets where network externality was present. Dhebar and Oren (1985) [7] discussed a monopoly manufacturer which provides products with network externality how to determine the optimal price dynamically to make the profit maximization in the network expansion. Farrel and Saloner (1986) [13] mainly studied the influence of network externality on technology selection. They found that the existence of network externality will not affect the technology progress if the companies have complete information. However, if the information is incomplete, they may all use the old technology, that is non-optimal social technology. Economides and Himmelberg (1995) [11] found that network externality will lead to self propelling or endogenous network growth. They suggested that current subscription was positively influenced by previous subscribers. Conner (1995) [5] proved that consumers value a product more, the more other consumers use it. It had been observed by a wide range of industries both in physical and service. Economides (1996) [9,10] explained why an exclusive holder of a technology wants to share it with competitors in a market with network externality.

2.3. **Cooperative game.** Cooperative game has been first presented by Von Neumann and Morgenstern (1944) [26]. Since then, cooperative game has developed rapidly. An important application of cooperative game is a profit distribution or cost allocation. According to the ideas of expected marginal revenue, Shapley and Shubik (1972) [24] put forward Shapley value. This is the start of exploring the problems of the income distribution with quantitative methods. Mariotti (1996) [20] discussed how enterprise's revenue increased the mode and the meaning of revenue distribution. Burrows and Black (1998) [2] studied the firms mode of operation and analyzed the influence of revenue allocation on the union members. They obtained the revenue distribution method based on fuzzy theory. Duca and VanHoose (1998) [8] designed a set of theoretical models to deal with the problem of revenue distribution in the competitive market. Their studies showed that because of the increasingly fierce market competition, more and more enterprises were forced to restrain the behavior of each other by making league contract to achieve the goal of increasing revenue. Nagarajan and Sosic (2008) [21] presented an excellent review of game theoretic analysis of cooperation among supply chain agents. Nishi et al. (2008) [22] addressed a collaborative production planning for supply chains with multiple companies. They placed a special emphasis on profit allocation and stability in cooperative games; they first described the construction of the set of feasible outcomes and then used cooperative bargaining models to find allocations of the profit pie between supply chain partners. Tominaga et al. (2008) [25] studied the effects of bullwhip in the cooperative supply chain under demand uncertainty. Yin et al. (2014) [30] addressed an optimal quantity discount coordination by cooperation among single manufacturer and multiple suppliers in a supply chain. Yin et al. (2015) [31] presented a game theoretic model for supply chain coordination with quality variations under demand uncertainty.

2.4. **Discussion.** In telecom industry, the network externality of information service products is often obvious because such products need to interconnect with each other. People produce and consume them in order to collect information and communication better, so it is closely related to the network size. As the previous literature finds that Information and Communication Technology (ICT) related industry shows a strong characteristic of network externality. Most of the previous studies on supply chain focus on issues such as pricing, risk, and coordination. Supply chain with network externality is seldom mentioned in literature. Motivated by this, in this paper, we study a telecom supply chain with network externality. We simplify the telecom supply chain as a two level supply chain composed of one service provider and one mobile provider. We study some key issues such as pricing, profit allocation and coordination of telecom supply chain under network externality. The differences between this paper and the previous literature are given as follows. First, we introduce network externality into the consumer's utility function of telecom service supply chain and transfer it into demand function. Second, we use two cooperation pricing strategy, linear and nonlinear cooperation pricing model and compare them with the non-cooperative case; third, we analyze the impact of external strength on telecom supply chain.

3. **Model.** In this paper, we consider a telecom supply chain with two participants, i.e., service provider (SP) and mobile provider (MP). As far as we have known, this model is firstly presented by Zheng and Da (2005) [32] based on China telecom industry operations and followed by many researchers. Among them, Wu et al. (2009) [28] study

the cooperation mechanism by using a non-cooperative game and present some numerical results with a widely accepted allocation rate. Our paper is mostly related to the above two but with major differences. First, we include the key factor of telecom supply chain, i.e., network externality in such a model. Second, we analyse this model both in non-cooperative game and cooperative game for a comparison. Last, the objective function used in this paper is utility maximization but not profit maximization. In such a model, SP provides service and MP sells the service to customers. The information revenue from consumers is shared between SP and MP. Potential customers choose whether to buy this product according to their net utility. The structure of the model in this paper is shown in Figure 1. SP and MP provide service to MP and user, respectively. User pays information fee p_0 and communication fee to MP. MP pays $(1-\varphi)p_1$ to SP where φ is a cooperative parameter.

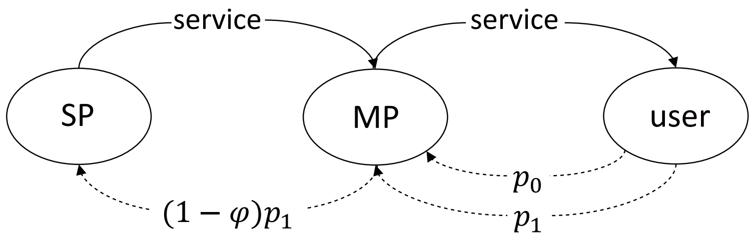

FIGURE 1. Structure of telecom service supply chain

3.1. **Assumptions.** In this paper, based on the above analysis, we assume that MP dominates the market price, SP provides one single value-added service in one specified period to telecom consumers and they only share the information fee.

We also follow the assumption that the potential demand is a constant D, and each potential customer purchases one product at most. Potential consumers can not only get basic utility u from the product but also get some network utility related to network size. Kim (2000) [18] has proposed the famous Hotelling model, the consumer's utility observed from network externality is αQ, α represents the intensity of network externality, Q represents the number of users who really buy the products, and the net utility is $U=u-p+\alpha Q$. To facilitate the analysis, we suppose u is subject to uniform distribution in $[0,A]$, and A is deemed as the highest degree of satisfaction. Potential consumers would buy the product when U is nonnegative; otherwise, they will not buy it. Only when $U=u-p+\alpha Q\geq 0$, i.e., $u\geq p-\alpha Q$, the potential consumer really buys the product. It is assumed that θ is the proportion of purchasing customer, then the purchasing proportion is $\theta=(A-p+\alpha Q)/A=(A-p+\alpha\theta D)/A$ since $Q=\theta D$. We can obtain that $\theta=(A-p)/(A-\alpha D)$, so the actual sales $Q=(A-p)D/(A-\alpha D)$. To ensure the actual sales $Q>0$, we suppose that $A>p$, $A>\alpha D$.

3.2. **Analysis.** Let p_0 be communication fee, p_1 be information fee, and then the selling price to the consumer should be $p=p_0+p_1$. Let c_{m0} be MP's fixed cost and c_{s0} be SP's fixed cost. Let $\varphi(0<\varphi<1)$ be cooperation parameter, i.e., share of information revenue per unit. Let Π_{MP} be MP's profit. It includes three parts: information fee sharing with SP, communication fee and fixed costs, namely

$$\Pi_{MP}=\varphi p_1 Q+p_0 Q-c_{m0}=(\varphi p_1+p_0)(A-p_1-p_0)D/(A-\alpha D)-c_{m0}. \quad (1)$$

Let Π_{SP} be SP's profit. It includes two parts: information fee sharing with MP and fixed costs, namely

$$\Pi_{SP}=(1-\varphi)p_1 Q-c_{s0}=(1-\varphi)p_1(A-p_1-p_0)D/(A-\alpha D)-c_{s0}. \quad (2)$$

Let Π be telecom service supply chain's total profit, namely

$$\Pi = (p_1 + p_0)(A - p_1 - p_0)D/(A - \alpha D) - c_{m0} - c_{s0}. \tag{3}$$

3.3. **Non-cooperative case.** In this model, SP is responsible for the production of products, MP sells the service to consumers and shares the revenue with SP, and potential customers choose whether to buy this product according to their net utility. The decision making process of MP and SP is: under the Stackelberg game decision-making framework, MP first determines p_0 according to the reaction function of SP, and then SP determines information fee p_1 according to MP's decision.

The Stackelberg model is as follows:

$$\Pi_{MP} = \max_{p_0}(\varphi p_1 + p_0)(A - p_1 - p_0)D/(A - \alpha D) - c_{m0},$$
$$\text{s.t. } \begin{cases} p_1 \in \max(\Pi_{SP}) \\ \Pi_{SP} = (1-\varphi)p_1(A - p_1 - p_0)D/(A - \alpha D) - c_{s0} \end{cases}. \tag{4}$$

We use backward induction to analyze the model, and SP's decision behavior comes first. Take partial derivative of p_1, and we achieve the optimal first-order condition as follows,

$$p_1{}^*(p_0) = \frac{A - p_0}{2}, \tag{5}$$

where * represents the optimal solution, we find that $\frac{\partial^2 \Pi_{SP}}{\partial p_1{}^2} = -\frac{2(1-\varphi)D}{A - D\alpha} < 0$, so SP's profit function is strictly concave.

Taking $p_1{}^*(p_0)$ into Equation (1), and we obtain MP's optimal first-order conditions as follows,

$$p_0^{ST} = \frac{A(1-\varphi)}{(2-\varphi)}, \tag{6}$$

we find that $\partial^2 \prod_{MP}/\partial p_0{}^2 = -\frac{D(2-\varphi)}{2(A-D\alpha)} < 0$, so MP's profit function is strictly concave.

Taking p_0^{ST} into Equation (5), we have

$$p_1^{ST} = \frac{A}{4 - 2\varphi}. \tag{7}$$

Taking p_0^{ST}, p_1^{ST} into Equations (1)-(3), we have

$$\Pi_{MP}^{ST} = -\frac{A^2 D + 4Ac_{m0}(2-\varphi) - 4c_{m0}D\alpha(2-\varphi)}{4(A - D\alpha)(2-\varphi)}, \tag{8}$$

$$\Pi_{SP}^{ST} = \frac{-4Ac_{s0}(2-\varphi)^2 + 4c_{s0}D\alpha(2-\varphi)^2 + A^2(D - D\varphi)}{4(A - D\alpha)(2-\varphi)^2}, \tag{9}$$

$$\Pi^{ST} = \frac{A^2 D(3 - 2\varphi)}{4(A - D\alpha)(2-\varphi)^2} - (c_{m0} + c_{s0}), \tag{10}$$

where ST represents the equilibrium solution of Stackelberg game.

3.4. **Cooperative game case.** In this section we estimate pricing strategy under cooperative decision-making. We have the total revenue given as follows

$$\Pi = p\,(A - p)\,D/\,(A - \alpha D) - c_{m0} - c_{s0}.$$

According to optimal first-order conditions $\partial\Pi/\partial p = 0$, we have

$$p^* = \frac{A}{2}, \tag{11}$$

then we have

$$\Pi^* = \frac{A^2 D}{4(A - D\alpha)} - (c_{m0} + c_{s0}). \tag{12}$$

In the following, we provide two cooperative strategies targeting at increasing the overall revenue of telecom service supply chain. In other words, we should determine the information fee p_1 and communication fee p_0 to let Π approach to Π^* and make a Pareto improvement of Π_{MP} and Π_{SP}. The starting points of the two cooperative strategies are what obtained in the non-cooperative game.

Case 1. A linear case

Under the cooperative strategy, we have $p^* = A/2$. In order to make Pareto improvement of both players' gains under Stackelberg equilibrium solution, $\Pi_{MP} \geq \Pi_{MP}^{ST}$ and $\Pi_{SP} \geq \Pi_{SP}^{ST}$ should be satisfied, expressed as

$$\begin{cases} (\varphi p_1 + p^* - p_1)(A - p^*)D/(A - \alpha D) - c_{m0} \geq \Pi_{MP}^{ST} \\ (1 - \varphi p_1)(A - p^*)D/(A - \alpha D) - c_{s0} \geq \Pi_{SP}^{ST}. \end{cases}$$

Then we find $p_1 \in [p_{1\min}, p_{1\max}]$,

$$p_{1\max} = \frac{A}{4 - 2\varphi}, \tag{13}$$

$$p_{1\min} = \frac{A}{2(2 - \varphi)^2}. \tag{14}$$

Obviously, MP hopes to reach $p_1 \to p_{1\min}$ while SP wants $p_1 \to p_{1\max}$ on the other hand. Suppose that p_1^L represents the information fee of SP based on liner pricing strategy, λ and $1-\lambda$ represent the bargaining power of MP and SP respectively. When $\lambda \in (0, 1)$, the information fee can be expressed as follows,

$$p_1^L = \lambda p_{1\min} + (1 - \lambda) p_{1\max} = \frac{A(2 - \lambda + \lambda\varphi - \varphi)}{2(2 - \varphi)^2}. \tag{15}$$

Case 2. A nonlinear case

For multiplayer consultations, Nash has discussed multiplayer negotiations, and proposed the famous Nash bargaining solutions; Harsanyi and Selten (1988) [16] worked on the basis of Nash's research and figured out non-optimal Nash bargaining solutions,

$$\begin{aligned} &(u_1(x^*), \cdots, u_n(x^*)) = \arg\max \prod_{i=1}^{n} (u_i(x) - d_i)^{\lambda_i}, \\ &\text{s.t.} \begin{cases} (u_1(x^*), \cdots, u_n(x^*)) \geq (d_1, \cdots, d_n) \\ (u_1(x^*), \cdots, u_n(x^*)) \in S \end{cases}. \end{aligned} \tag{16}$$

where $u_i(x)$ is the utility function of decision-maker i, d_i represents the starting points of negotiation (the profit obtained in the non-cooperative case), S represents the negotiation domain, and λ_i represents the negotiation capability of decision-maker i, $\sum_{i=1}^{n} \lambda_i = 1$. In this model, both MP and SP are thought risk-neutral. On the basis of non-optimal Nash bargaining solutions, we post the objective function of the nonlinear coordination pricing model

$$\begin{aligned} E(p_1) &= \left(\Pi_{MP} - \Pi_{MP}^{ST}\right)^{\lambda} \left(\Pi_{SP} - \Pi_{SP}^{ST}\right)^{1-\lambda} \\ &= \left(\frac{((1-\varphi)p_1 + p^* - p_1)(A - p^*)D}{A - \alpha D} - c_{m0} - \Pi_{MP}^{ST}\right)^{\lambda} \\ &\quad \left(\frac{(p_1 - \varphi p_1)(A - p^*)D}{A - \alpha D} - c_{s0} - \Pi_{SP}^{ST}\right)^{1-\lambda}. \end{aligned} \tag{17}$$

When $\partial E(p_1)/\partial p_1 = 0$, the function can be arranged as

$$p_1^{NL} = \frac{A(2-\lambda+\lambda\varphi-\varphi)}{2(2-\varphi)^2}. \tag{18}$$

4. Analytic Results.

Theorem 4.1. *In non-cooperative game, with the rise of the highest satisfaction A, p_0 and p_1 will have a growth accordingly, and with the rise of cooperation parameter φ, p_0 will have a growth accordingly and p_1 will have a decline.*

Proof: We investigate the relationship between p_0, p_1 and A, φ through partial derivative.

$$\frac{\partial p_0}{\partial A} = \frac{\varphi-1}{\varphi-2} > 0, \quad \frac{\partial p_1}{\partial A} = \frac{1}{4-2\varphi} > 0,$$
$$\frac{\partial p_0}{\partial \varphi} = -\frac{A}{(\varphi-2)^2} < 0, \quad \frac{\partial p_1}{\partial \varphi} = \frac{A}{2(\varphi-2)^2} > 0.$$

With the improvement of consumers' satisfaction, single information service fee and the single communication fee will increase accordingly. That is to say if SP can provide better information goods and MP can provide better services, customers' satisfaction will improve, MP and SP's pricing can be appropriately raised and also can get higher profits. With the rise of cooperation parameter φ, on the one hand, SP's single information revenue $(1-\varphi)p_1$ will decrease. In order to improve his own profit, SP will increase his decision variable p_1, so p_1 is an increasing function of φ. On the other hand, MP's single information revenue φp_1 will increase; from the perspective of the whole supply chain coordination, MP will decrease his decision variable p_0, namely p_0 is a decreasing function of φ.

Theorem 4.2. *With the rise of cooperation parameter φ, the equilibrium profit Π_{MP}^{ST} will have a growth and Π_{SP}^{ST} will have a decline accordingly under Stackelberg game. With the rise of the intensity of network externality, the equilibrium profit Π_{MP}^{ST} and Π_{SP}^{ST} will have a growth accordingly under Stackelberg game.*

Proof: The above results can be obtained directly from the partial derivative.

$$\frac{\partial \Pi_{MP}^{ST}}{\partial \varphi} = \frac{A^2 D}{4(A-\alpha D)(2-\varphi)^2} > 0, \quad \frac{\partial \Pi_{MP}^{ST}}{\partial \varphi} = -\frac{A^2 D\varphi}{4(A-\alpha D)(2-\varphi)^3} < 0,$$
$$\frac{\partial \Pi_{MP}^{ST}}{\partial \alpha} = \frac{A^2 D^2}{4(A-\alpha D)^2(2-\varphi)} > 0, \quad \frac{\partial \Pi_{MP}^{ST}}{\partial \alpha} = \frac{A^2 D^2(1-\varphi)}{4(A-\alpha D)^2(2-\varphi)^2} > 0.$$

Cooperation parameter φ shows a different cooperation degree between MP and SP, which can be divided into ordinary, half close and close cooperation. With the rise of contribution to the cooperation, the revenue sharing ratio φ will increase, so Π_{MP}^{ST} is an increasing function of φ. The more SP contributes to the cooperation, the less MP's revenue sharing ratio φ and the more SP's profit will be, so Π_{SP}^{ST} is a decreasing function of φ.

With the strength of network externalities, consumers' net utility gained from the information service product will increase; under the same price the more consumers would be willing to buy the product, MP and SP's profit will increase accordingly.

Theorem 4.3. *The optimal price under cooperative game is less than that under Stackelberg game, and the total profit is more than that under Stackelberg game. In addition, the total profit has nothing to do with φ under cooperative game.*

Proof: We can prove the theorem through partial derivative.

$$p_0^{ST} + p_1^{ST} = \frac{A(1-\varphi)}{(2-\varphi)} + \frac{A}{4-2\varphi} = \frac{A(3-2\varphi)}{2(2-\varphi)} > \frac{A}{2} = p^*,$$

$$\frac{3-2\varphi}{(2-\varphi)^2} < 1,$$

$$\Pi^{ST} = \frac{A^2D(3-2\varphi)}{4(A-D\alpha)(2-\varphi)^2} - (c_{m0}+c_{s0}) < \frac{A^2D}{4(A-D\alpha)} - (c_{m0}+c_{s0}) = \Pi^*.$$

Centralized decision can not only make the whole supply chain's profit maximum, and it is also good for consumers. Consumers need to pay less than that in the Stackelberg model for per unit product; according to the demand function, the sales will increase. Combined with the existence of a positive feedback effect of price, sales and consumer's net utility is generated by network externalities, and the whole supply chain will be more effective operation.

Theorem 4.4. *When the consumers' basic utility is subject to uniform distribution, MP and SP's profit sharing are the same in the two different pricing strategies under cooperative game.*

Proof:

$$p_1^L = p_1^{NL} = \frac{A(2-\lambda+\lambda\varphi-\varphi)}{2(2-\varphi)^2}.$$

So MP and SP's profit sharing are the same in linear pricing and nonlinear pricing strategy expressed as follows

$$\Pi_{MP}^* = \frac{A^2D(2+\lambda(1-\varphi)^2-\varphi) - 4(A-D\alpha)(2-\varphi)^2 c_{m0}}{4(A-D\alpha)(2-\varphi)^2}, \tag{19}$$

$$\Pi_{SP}^* = \frac{A^2D(2-\lambda(1-\varphi)-\varphi)(1-\varphi) - 4(A-D\alpha)(2-\varphi)^2 c_{s0}}{4(A-D\alpha)(2-\varphi)^2}. \tag{20}$$

The above gives a special case when the basic utility-density function $f(u)$ follows uniform distribution, which shows some interesting results different from the general case. In general, the cooperative prices in linear and nonlinear cases are different. However, when consumers' basic utility follows uniform distribution, we can get the same pricing strategy and the profit sharing mechanism.

5. **Numerical Results.** In this section we will use four sets of numerical examples to give a straightforward idea of the above problem, demonstrating the impact of intensity of network externality α, revenue sharing ratio φ and barging power λ on all kinds of gains of telecom service supply chain on the basis of Stackelberg game and the above coordination strategy separately.

Example 5.1. *Suppose that $A = 3$, $D = 1$, $c_{m0} = 0.2$, $c_{s0} = 0.1$, $\varphi = 0.5$, $\lambda = 0.5$. Figures 2(a) and 2(b) illustrate the changes of the revenue of both members and the whole telecom service supply chain based on Stackelberg and cooperative game when α is in the range of 0 to 1. Figure 2 shows that $\Pi_{MP}^* \geq \Pi_{MP}^{ST}$, $\Pi_{SP}^* \geq \Pi_{SP}^{ST}$, $\Pi^* \geq \Pi^{ST}$ and with the growth of λ, MP, SP and the whole supply chain's profit will all increase.*

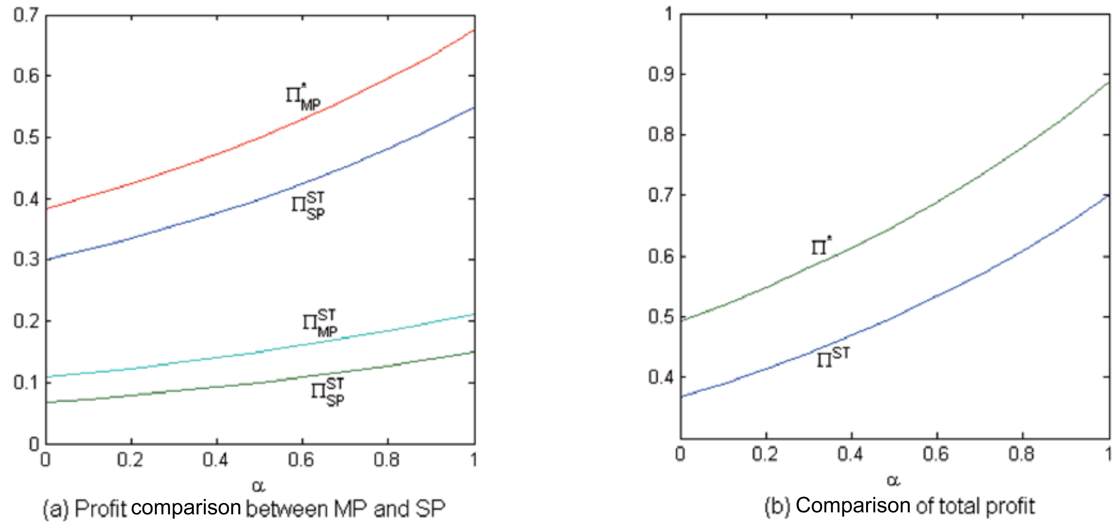

FIGURE 2. Relationship of α and profit of the telecom service

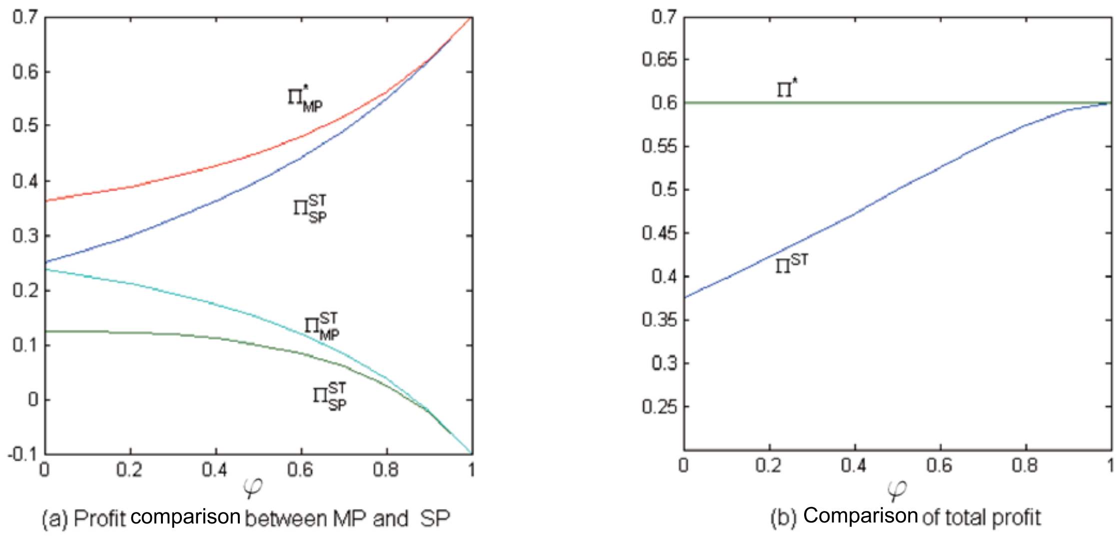

FIGURE 3. Relationship of φ and profit of the telecom service

Example 5.2. *Suppose that* $A = 3$, $D = 1$, $c_{m0} = 0.2$, $c_{s0} = 0.1$, $\alpha = 0.5$, $\lambda = 0.5$. *Figures 3(a) and 3(b) illustrate the changes of the revenue of both members and the whole telecom service supply chain based on Stackelberg and cooperative game when* φ *is in the range of 0 to 1.*

Figure 3(a) shows that with the growth of φ, *MP's profit* Π^{ST}_{MP}, Π^*_{MP} *will increase and SP's profit* Π^{ST}_{SP}, Π^*_{SP} *will decrease; when* $\varphi = 1$, $\Pi^{ST}_{MP} = \Pi^*_{MP}$ *and* $\Pi^{ST}_{SP} = \Pi^*_{SP}$.

Figure 3(b) shows that $\Pi^* \geq \Pi^{ST}$ *and with the growth of* φ, Π^* *will increase but* Π^{ST} *remains the same.*

Example 5.3. *Suppose that* $A = 3$, $D = 1$, $c_{m0} = 0.2$, $c_{s0} = 0.1$, $\alpha = 0.5$, $\varphi = 0.5$. *Figure 4 illustrates the changes of the revenue of both members and the whole telecom service supply chain based on cooperative game when* λ *is in the range of 0 to 1.*

Figure 4 shows that with the growth of λ, *MP's profit* Π^*_{MP} *will increase and SP's profit* Π^*_{SP} *will decrease, but the total profit of the supply chain* Π^* *remains the same.*

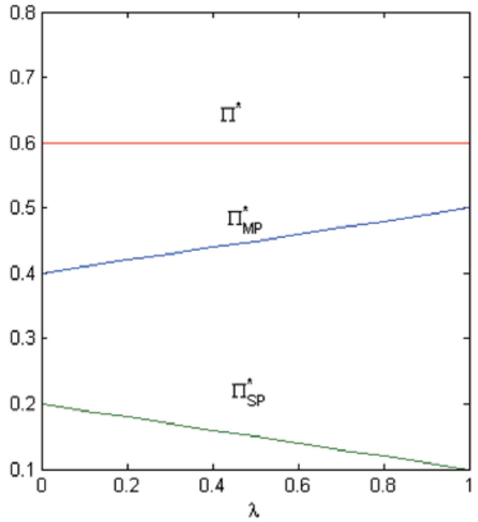

FIGURE 4. Relationship of λ and profit in cooperative game

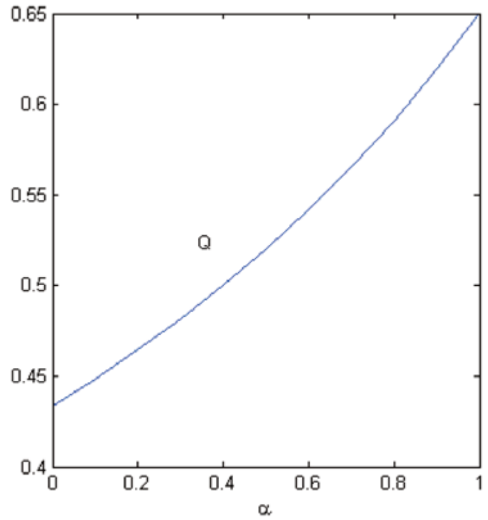

FIGURE 5. Relationship of α and actual sales in cooperative game

Example 5.4. *Suppose that* $A = 3$, $D = 1$, $c_{m0} = 0.2$, $c_{s0} = 0.1$, $p = A/2$ *(under cooperative game),* $\varphi = 0.5$, $\lambda = 0.5$. *Figure 5 illustrates the changes of actual sales when* α *is in the range of 0 to 1.*

Figure 5 shows that with the growth of α, the actual sales will increase.

It means that the network externality contributes to the sales volume, which is helpful insights for marketing. Different from the previous literature, we analyze the telecom supply chain by using cooperative game. We also compare the cooperative case with non-cooperative case and find that both MP and SP can benefit from the cooperative case. Thus, we present a possible cooperative model for the telecom industry in real-world practice. Besides this, we also analyze the network externality in this supply chain model, which is a key feature in the telecom industry. We also find that network externality is an obvious factor that influences the revenue.

In summary, we can obtain from the above results that both MP and SP can benefit from the cooperative game, and therefore it is a more effective cooperative mode than a Stackelberg game. And the stronger the network externalities is, the better the entire telecom service supply chain will be.

6. **Conclusions.** We established a telecom service supply chain that consisted of one MP and one SP based on network externalities and studied coordination of the supply chain through Stackelberg and cooperative game model. We found that cooperative game is a better mode than a Stackelberg game for MP, SP and the whole telecom service supply chain. We analyzed the impact of some parameters in the model on MP and SP's optimal pricing, equilibrium profit and actual sales of the supply chain. Results have shown that network externalities have a positive influence to the supply chain's profit and the more MP contributes to the cooperation, the better the entire supply chain will be.

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