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Research Article

Bargaining Power Choices with Moral Hazard in a Supply Chain

Hongmei Guo,[1] Shuiliang Gu ,[2] and Yingsheng Su [3]

[1] *Business School, Sichuan University, Chengdu 610064, China*
[2] *College of Nuclear Technology and Automation Engineering, Chengdu University of Technology, Chengdu 610059, China*
[3] *Statistics School, Southwestern University of Finance and Economics, Chengdu 611130, China*

Correspondence should be addressed to Yingsheng Su; suys@swufe.edu.cn

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A supply chain contract is established using a dynamic, Nash bargaining game which determines the optimal bargaining power allocation for the manufacturer, retailer, and society in an environment affected by moral hazard and irreversible investment. The results found that the manufacturer's choice was to hold all bargaining power; however, due to the remaining information problem, the retailer still had a profit; in contrast, the retailer was only willing to give up bargaining power if the manufacturer's profit was reserved. The optimal bargaining power allocation was found to be strongly related to the ability to convert and monitor technology, with the bargaining power gradually shifting to the manufacturer as the technology improved. A numerical simulation is given to examine the theoretical results.

1. Introduction

Information plays an important role in the formulation of corporate strategies in the competitive business environment of the twenty-first century. As the entities in a supply chain are usually from different firms and often have conflicting objectives and private information, system-wide optimal solutions are not possible unless the incentive problems resulting private information can be eliminated in the system.

Principal-agent models that assume that the principal offers a "take-it-or-leave-it" contract [1] have been developed in an effort to resolve such information incentive problems [2]. However, for most real-world problems, this approach is generally inappropriate as many supply chain situations tend to be determined through some form of bargaining between the manufacturers and retailers, in which both parties hold some bargaining power. Therefore, as "take-it-or-leave-it" contracts could be seen to be unduly restrictive when seeking to comprehensively model real life supply chain problems, introducing bargaining power could bring these models closer to reality, primarily because bargaining power affects supply chain profit and the profit allocation between retailers and manufacturers.

Demougin and Helm [3] introduced bargaining power into a moral hazard framework using three different approaches, a standard P-A framework which varied the agent's outside opportunities, an alternating offer game which varied the participants' discount factors, and a generalized Nash bargaining game which varied the participants' bargaining power, and found that all approaches led to the same set of contracts. Bental and Demougin [4] modelled a design for labor market institutions in a Nash bargaining game and derived the optimal bargaining power with moral hazard and irreversible investment from the firms', workers', and social planning viewpoints. They also examined the impact of improved monitoring and investigated the implication on labor share, effort, and investment. Demougin and Helm (2011) [5] used a Nash bargaining solution in a job matching model with moral hazards. In the labor market, Dittrich and Städter [6] analyzed bargaining for an incentive compatible contract within a moral hazard framework. Whether the worker's effort was higher in the solution depended on the agents' bargaining power. Social planners can mitigate the inefficiencies arising from moral hazards and even achieve a first-best outcome by correctly allocating an agent's bargaining power.

Ma [7] analyzed renegotiation in a moral hazard model when the agent, rather than the principal, had proposed the renegotiation contract, and found that the bargaining power allocation was different to when the principal offered a renegotiation. With adverse selection, Inderst [8] explored a model which allowed for a continuous shift in bargaining power between two parties and found that giving the informed side more bargaining power gradually reduced contract distortions.

Some research has examined bargaining power problems when there is asymmetric information in the supply chain. Within a vertical cooperative advertising program framework, Aust and Buscher [9] considered four possible relationships between channel members and found that the highest total profit was gained when both players cooperated and negotiated the allocation, which gave customers a better position because it resulted in the lowest retail prices and the highest advertising expenditures compared to other configurations. Papers [10–12] also discussed advertising models in the supply chain using different game configurations.

Sheu and Gao [13] investigated how bargaining power affected negotiations between manufacturers and reverse logistics providers in reverse supply chains. Feng and Lu [14] contrasted the contract outcome of a Stackelberg game in which the manufacturers offered take-it-or-leave-it contracts to the retailers with a bargaining game in which the firms bilaterally negotiated contract terms using an alternating offers and found that the manufacturers in the Stackelberg game had a Stackelberg-leader advantage as the retailers were unable to make any counteroffers, thus suggesting that this advantage for manufacturers depended on the contractual forms. Bedrey [15] developed a sequential bilateral negotiation framework between two competing retailers and a manufacturer. Unfortunately, none of the models reviewed above considered the impact of private information.

A report prepared for the European Commission suggested that when faced with powerful buyers, suppliers may "reduce investment in new products or product improvements, advertising and brand building" [16]. Nair et al. [17] considered a scenario in which the buyer and supplier invested in strategic capabilities to increase their relative bargaining power.

Because manufacturing investment, retailer effort, and the respective bargaining powers affect supply chain operations and the development of optimal contracts, in this paper, the choice of bargaining power is examined in consideration of moral hazards and irreversible investments in the supply chain.

The remainder of this paper is structured as follows. In Section 2, the assumptions and notations are presented. In Section 3, the dynamic game between the manufacturer and retailer is analyzed using backward induction, three bargaining power choices are characterized, and the main results are derived. Section 4 gives a numerical simulation to examine the theoretical results and Section 5 gives the conclusion and directions for future research.

2. Assumptions and Notations

This paper considers a supply chain with two risk-neutral firms, a manufacturer and a retailer, in a perfectly competitive market. The "products" provided by the supply chain are produced in two stages. The first involves manufacturer investment in which the manufacturer invests in k units, including plant, equipment, and raw materials, to produce the goods. The second stage involves retailer effort, in which the retailer exerts effort e, including logistics and after-sales service, to sell goods to the consumers at a fixed price p. The supply chain-specific demand curve is considered to be horizontal, meaning that the supply chain can sell as much as it wants at the market price. Therefore, consumer demand is the supply chain output, which is related to the manufacturer's investment, the retailer's effort, and other random factors.

Consumer demand, therefore, is indicated using $D(k,e,\varepsilon) = e^{\nu} f(k) + \varepsilon$, in which k is manufacturer investment, e is retailer effort, ν is a technical parameter (exogenous common knowledge which depends on the nature of industry), and ε represents random factors, where e and $\nu \in [0,1]$, and $E[\varepsilon] = 0$. It is assumed that $f(\cdot)$ is an increasing concave function, with $f(0) = 0$. Effort and investment can be converted into output using the technical parameter ν and function $f(\cdot)$; a decrease in ν is interpreted as an improvement in the technology, with $\nu = 0$ representing the most developed technology.

Clearly, $D(k,e,\varepsilon) \cdot p$ is the gain for the supply chain. Let $F(k,e,\varepsilon) \triangleq D(k,e,\varepsilon) \cdot p$, so

$$F(k,e,\varepsilon) = pe^{\nu} f(k) + p\varepsilon. \tag{1}$$

It is further assumed that effort e is not contractible. Instead, the manufacturer is assumed to observe a contractible measure for the retailer's effort, $s \in \{0,1\}$, for which $s = 1$ is considered a favorable signal [18]. The probability of observing the favorable signal depends on retailer effort and the precision of the underlying monitoring technology. It is supposed that the probability [4] is

$$\sigma(e) = e^{\theta}, \tag{2}$$

where $\theta \in [0,1]$ reflects monitoring technology precision, the exogenous common knowledge. An increase in θ, therefore, is an improvement in the monitoring technology, with $\theta = 1$ indicating the most advanced technology; this is equivalent to directly observing the level of effort. At the other extreme, when $\theta = 0$, $e^{\theta} = 1$; in other words, a favorable signal is observed with a probability of 1 no matter the effort level, so the signal is useless. Retailer never exerts effort. In addition, given θ, σ is increasing in e.

As exerting effort is costly to the retailer, this cost can be specified in its monetary equivalent as [2]

$$c(e) = \frac{\beta}{2} e^2. \tag{3}$$

Suppose that if all the gain generated by the supply chain belongs to manufacturer and that the manufacturer transfers T to the retailer only when a favorable signal is observed, the expected compensation to a retailer who exerts effort e is $T\sigma(e)$.

The game between the manufacturer and retailer is assumed to have the following timing (Figure 1).

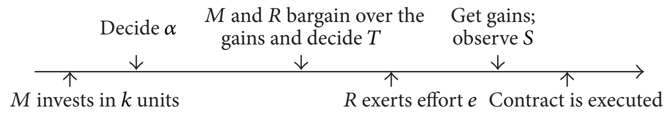

Figure 1: Timeline of events.

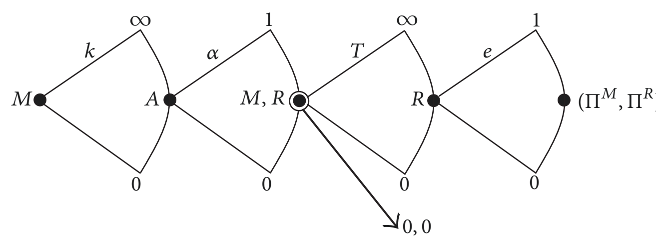

Figure 2: Dynamic game between manufacturer and retailer.

(1) The manufacturer invests in k units at the rental rate r, which is induced by alternative production technology. This investment is irreversible and is taken as a fixed cost that the retailer is able to observe.

(2) Choice of bargaining power: assume that α represents the bargaining power of the retailer. To find the optimal bargaining power and reveal the conflicts between the two parties, three situations are considered: the manufacturer makes the choice; the retailer makes the choice; or society makes the choice.

(3) With the bargaining power decided in step (2), the manufacturer and retailer bargain over the supply chain gain and decide on the transfer payment T, with different bargaining powers leading to different transfer payments. If the supply chain cannot be formed, the game ends and both parties receive zero.

(4) The retailer selects the non-contractible effort level e, which affects the probability of observing a favorable signal.

(5) Gain is realized and signal s is observed.

(6) The contract is executed. The manufacturer transfers T to retailer when a favorable signal is observed.

3. Contract

The interaction between the manufacturer and the retailer is analyzed as a dynamic game (Figure 2). In Figure 2, the double circles represent the joint-decision node; that is, the manufacturer and retailer negotiate and establish a contract. The solid circles represent the individual nodes; that is, the manufacturer or the retailer makes the decision. The nodes are labeled with the manufacturer's or retailer's initial, which signifies the move at that node. Note that "A" represents the manufacturer, the retailer, and the society. The terminal node is labeled with profit vector (Π^M, Π^R), one for manufacturer and one for retailer.

The backward induction is applied starting with the retailer's effort decision. Then, the next move is the bargaining stage, where the choice of bargaining power is selected; the manufacturer makes the choice, the retailer makes the choice, or society makes the choice. Finally, the manufacturer's decision regarding investment is examined.

3.1. Retailer's Decisions. At this stage, the investment, bargaining power, and transfer payments are already determined. The retailer then selects an effort level to maximize profit:

$$\Pi^R = T\sigma(e) - c(e). \tag{4}$$

The effort level affects profit in two opposing ways; as increasing the effort level improves the probability of getting a transfer payment but also raises the effort cost, a trade-off becomes necessary.

Using (2) and (3), there is

$$\Pi^R = Te^{\theta} - \frac{\beta}{2}e^2. \tag{5}$$

Clearly, the retailer's profit is a convex function with respect to effort level. The first-order condition in (5) yields the retailer effort selection as a function of the transfer payment:

$$e^{\circ} = T^{1/(2-\theta)}\lambda^{1/(2-\theta)}, \tag{6}$$

where $\lambda = \theta/\beta$.

Because $e \in [0, 1]$, we have

$$e^{*} = \min\{e^{\circ}, 1\}. \tag{7}$$

Equations (6) and (7) reflect the incentive effect of the transfer payment on effort. The effort level e increases along with transfer payment T until it reaches 1. In addition, we have

$$e^{*} = \begin{cases} 1 & T \geq \dfrac{1}{\lambda} \\ e^{\circ} & T < \dfrac{1}{\lambda}. \end{cases} \tag{8}$$

Further, the effort is positively affected by the monitoring technology θ. In particular, when $\theta = 1$, $e^{*} = \min\{T/\beta, 1\}$, so the retailer exerts maximum effort because of the good monitoring technology. If $\theta = 0$, $e = 0$; that is, there is no effort for the retailer because there is no monitoring.

Clearly, effort is negatively affected by parameter β as bigger β indicates a greater effort cost.

3.2. Bargaining Stage. At the bargaining stage, the manufacturer and retailer negotiate a transfer payment based on the anticipated effort (see (6)). At this stage, the investment has already been determined and is irreversible, with both the manufacturer and retailer having this knowledge. Therefore, they negotiate the transfer payment to maximize the Nash product, so we get

$$\max_T \Pi = \max_T E\left[F(e,k,\varepsilon) - T\sigma(e)\right]^{1-\alpha}\left[T\sigma(e) - c(e)\right]^{\alpha}. \tag{9}$$

Using $E[\varepsilon] = 0$, (1), (2), (3), and (6), the Nash bargaining problem is reformulated in terms of T:

$$\max_T \left[p\lambda^{\nu/(2-\theta)} T^{\nu/(2-\theta)} f(k) - T^{2/(2-\theta)}\lambda^{\theta/(2-\theta)}\right]^{1-\alpha} \cdot \left[\left(1-\frac{\theta}{2}\right)T^{2/(2-\theta)}\lambda^{\theta/(2-\theta)}\right]^{\alpha}. \tag{10}$$

For the first-order condition, the transfer payment is obtained:

$$T^{\circ} = \left\{p\left[\frac{\nu}{2}(1-\alpha)+\alpha\right]f(k)\right\}^{(2-\theta)/(2-\nu)}\lambda^{(\nu-\theta)/(2-\nu)}. \tag{11}$$

$T > 1/\lambda$ is not necessary because $e^* = 1$ with $T \geq 1/\lambda$, so we have

$$T^* = \min\left\{T^{\circ}, \frac{1}{\lambda}\right\}. \tag{12}$$

It can be clearly seen that the bargaining power increases the transfer payment. Intuitively, the greater the bargaining power for the retailer (measured by α), the greater the share the retailer can get from the supply chain gain.

The transfer payment is also positively affected by the investment; the greater the manufacturer investment (measured by k), the greater the supply chain gain; that is, as there is a bigger pie because of the greater level of investment, the retailer should gain a greater transfer payment.

Substituting (11) into (6) and (7), the effort is determined:

$$e^* = \min\left\{\left[p\left[\frac{\nu}{2}(1-\alpha)+\alpha\right]f(k)\lambda\right]^{1/(2-\nu)}, 1\right\}. \tag{13}$$

Therefore, the investment positively affects the effort level by increasing the transfer payment.

3.3. Choice of Bargaining Power. In reality, the manufacturers (retailers) can select different retailers (manufacturers) for the supply chain; however, different selections change the bargaining power each side has. Further, as shown above, the type of bargaining power affects "the size of the pie" and "the share of the pie" as it influences both retailer effort and the size of the transfer payment.

At this stage, as outlined above, the investment has already been determined. Therefore, for the game timing, to find the optimal bargaining power and to reveal the conflicting interests between the two parties, the three bargaining situations are now discussed: the manufacturer makes the choice; the retailer makes the choice; or society makes the choice. First, how manufacturers and retailers individually want to allocate the bargaining power is examined, and then the respective preferred allocation is compared to the societal optimum.

3.3.1. Manufacturer Makes the Choice. Assume that the manufacturer can determine the bargaining power allocation. Increasing the bargaining power of the retailer increases the retailer's output share but gives higher incentives to the retailer; therefore, there are two conflicting effects on profit, which the manufacturer seeks to balance. Assuming that the manufacturer can anticipate the contract negotiation outcome and the impact of the retailer's effort, the manufacturer's profit is obtained, as follows:

$$\Pi^M = E\left[F(e,k,\varepsilon) - T\sigma(e) - rk\right] \tag{14}$$

$$= \Phi(\alpha)\, p^{2/(2-\nu)} f(k)^{2/(2-\nu)} - rk, \tag{15}$$

where $\Phi(\alpha) = (1-\alpha)(1-\nu/2)[(\nu/2)(1-\alpha)+\alpha]^{\nu/(2-\nu)}\lambda^{\nu/(2-\nu)}$.

Taking the derivative of the manufacturer's profit with respect to α, we have

$$\frac{\partial \Pi^M}{\partial \alpha} = p^{2/(2-\nu)}\Phi'_{\alpha} f(k)^{2/(2-\nu)} < 0, \tag{16}$$

where $\Phi'_{\alpha} = -\alpha(1-\nu/2)[(\nu/2)(1-\alpha)+\alpha]^{(\nu/(2-\nu))-1}\lambda^{\nu/(2-\nu)} < 0$. Denoting the manufacturer's preferred level of bargaining power by α^M, the following result is obtained.

Result 1. The manufacturer's choice is to set the bargaining power at $\alpha = \alpha^M = 0$.

This result indicates that manufacturer would rather give up the incentive to the retailer than raise the retailer's share; therefore, the optimal effort is distorted and the best supply chain outcome is not achieved; when $\alpha^M = 0$, the retailer still has profit because of the remaining information problem.

3.3.2. Retailer Makes the Choice. Assume that retailer can determine the allocation of bargaining power. In this case, the increase in the retailer's bargaining power can be decomposed into three separate effects: (1) the retailer's output share increases; (2) the retailer is induced to exert greater effort in the negotiation stage; and (3) the manufacturer investment decreases.

Using (5), (11), and (13), we have

$$\Pi^R = \Omega(\alpha)\, p^{2/(2-\nu)} f(k)^{2/(2-\nu)}, \tag{17}$$

where $\Omega(\alpha) = (1-\theta/2)[(\nu/2)(1-\alpha)+\alpha]^{2/(2-\nu)}\lambda^{\nu/(2-\nu)}$

$$\frac{\partial \Pi^R}{\partial \alpha} = \Omega'_{\alpha} p^{2/(2-\nu)} f(k)^{2/(2-\nu)}, \tag{18}$$

where $\Omega'_{\alpha} = (1-\theta/2)\lambda^{\nu/(2-\nu)}[(\nu/2)(1-\alpha)+\alpha]^{\nu/(2-\nu)} > 0$, so $\partial\Pi^R/\partial\alpha > 0$.

For the retailer, the greater the bargaining power, the more the retailer receives. However, when $\alpha = 1$, $\Pi^M = -rk < 0$, which is less attractive than the outside option for the manufacturer. From (16), the manufacturer's profit is a monotonic decreasing function of α, meaning that, with greater α, the retailer can select α^R that ensures $\Pi^M(\alpha^R) = 0$.

Using (15), α^R must satisfy the following equation:

$$\Phi\left(\alpha^R\right) p^{2/(2-\nu)} f(k)^{2/(2-\nu)} = rk. \tag{19}$$

Therefore, $0 < \alpha^R < 1$, from which we have the following result.

Result 2. The retailer's choice is to set bargaining power $\alpha = \alpha^R < 1$ which satisfies (19).

3.3.3. Society Makes the Choice. Societal welfare is the sum of the manufacturer's and retailer's profits; therefore, we have

$$\Pi = \Pi^M + \Pi^R \tag{20}$$

$$= \left[\Phi(\alpha)(pf(k))^{2/(2-\nu)} - rk\right] + \left[\Omega(\alpha)(pf(k))^{2/(2-\nu)}\right]. \tag{21}$$

From (21), it can be seen that a regulator is needed to balance the conflicting interests of the two parties. Taking the derivative of (21) with respect to α, we get

$$\Pi'_\alpha = \left\{\frac{\nu}{2} - \frac{\theta}{2}\left[\frac{\nu}{2}(1-\alpha)+\alpha\right]\right\} \cdot \left[\frac{\nu}{2}(1-\alpha)+\alpha\right]^{\nu/(2-\nu)-1} \cdot \lambda^{\nu/(2-\nu)}(pf(k))^{2/(2-\nu)}. \tag{22}$$

Taking a second derivative with respect to α, we have

$$\Pi''_\alpha = X\frac{\nu}{2}\left[\frac{\nu}{2}(1-\alpha)+\alpha\right]^{\nu/(2-\nu)-2} \cdot \lambda^{\nu/(2-\nu)}(pf(k))^{2/(2-\nu)}, \tag{23}$$

where $X = (\nu-1)-(\theta/2)[(\nu/2)(1-\alpha)+\alpha] < 0$, so $\Pi''_\alpha < 0$, and societal welfare is a concave function of α; thus, α° ensures $\Pi'_\alpha = 0$

$$\alpha^\circ = \frac{(2-\theta)\nu}{(2-\nu)\theta}. \tag{24}$$

Obviously, α° is increasing in ν and decreasing in θ. Because $\alpha \in [0,1]$, we have

$$\alpha^* = \min\{\alpha^\circ, 1\}. \tag{25}$$

If $\nu \geq \theta$, $\alpha^\circ \geq 1$, so $\alpha^* = 1$; that is, all bargaining power is given to the retailer to achieve the highest possible societal welfare. Putting $\alpha^* = 1$ into (15) and (17), we have

$$\Pi^M(1) = -rk \leq 0, \tag{26}$$

$$\Pi^R(1) = \left(1-\frac{\theta}{2}\right)\lambda^{\nu/(2-\nu)}(pf(k))^{2/(2-\nu)} > 0 \tag{27}$$

which indicates that the retailer achieves the best profit for $\partial\Pi^R/\partial\alpha > 0$; however, as the manufacturer receives negative profit, the regulator needs to reallocate the societal welfare so that the manufacturer accepts the bargaining power allocation.

If $\nu < \theta$, $\alpha^\circ < 1$, so $\alpha^* = \alpha^\circ < 1$; we have

$$\begin{aligned}\Pi^M(\alpha^\circ) &= \left(1-\frac{\nu}{\theta}\right)\left(\frac{\nu}{\theta}\right)^{\nu/(2-\nu)}\lambda^{\nu/(2-\nu)}(pf(k))^{2/(2-\nu)} - rk,\\ \Pi^R(\alpha^\circ) &= \left(1-\frac{\theta}{2}\right)\left(\frac{\nu}{\theta}\right)^{2/(2-\nu)}\lambda^{\nu/(2-\nu)}(pf(k))^{2/(2-\nu)} > 0.\end{aligned} \tag{28}$$

The sign for $\Pi^M(\alpha^\circ)$ depends on the relationship between α° and α^R; if $\alpha^\circ > \alpha^R$, $\Pi^M(\alpha^\circ) < 0$. Compensate for the manufacturer's loss. If $\alpha^\circ \leq \alpha^R$, $\Pi^M(\alpha^\circ) > 0$.

Consequently, we get the following result.

Result 3. The regulator's optimal bargaining power α^* is determined by the technological parameters ν and θ. If ν is equal to or greater than θ, $\alpha^* = 1$; if ν is less than θ, $\alpha^* = \alpha^\circ = (2-\theta)\nu/(2-\nu)\theta < 1$.

From the assumptions, greater ν and smaller θ are interpreted as lower conversion and monitoring technologies. With a lower technology, the retailer's effort needs to be incentivized by a larger bargaining power, so we have $\alpha^* = 1$. On the other hand, smaller ν and greater θ are interpreted as superior conversion and monitoring technologies, which means that there is no need to incentivize the retailer to exert greater effort using a larger bargaining power, so we have $\alpha^* = \alpha^\circ = (2-\theta)\nu/(2-\nu)\theta < 1$. Therefore, the higher the technologies, the less the bargaining power available to the retailer.

From the discussion on these three situations, it is known that α^* is the best choice for the supply chain. In the following, only α^* is analyzed in relation to the manufacturer's choice.

3.4. Manufacturer's Decision. In the first state, the manufacturer decides on the investment level, which then incentivizes the retailer's effort, and increases the supply chain gain. However, the manufacturer's investment transfers a greater share to the retailer, even though the manufacturer has to bear all the costs. Therefore, the manufacturer needs to find a way to trade off these opposite effects.

Suppose that the manufacturer is able to anticipate the outcome of the latter stages and is able to determine the optimal bargaining power α^*. Therefore, in the following, two situations are examined: when the manufacturer's investment is $\alpha^* = 1$ and when $\alpha^* = \alpha^\circ$.

If $\alpha^* = 1$, the retailer holds all bargaining power and the manufacturer has a negative profit; therefore, the manufacturer needs to be compensated for the loss $-rk$. As k depends on the retailer's profit only, $\widehat{k}$ can be determined by maximizing the following formula:

$$\max_k \left(1-\frac{\theta}{2}\right)\lambda^{\nu/(2-\nu)}p^{2/(2-\nu)}f(k)^{2/(2-\nu)} - rk. \tag{29}$$

The first-order derivative equal to zero in (30) with respect to k leads to the following equation. $\widehat{k}$ satisfies this equation; that is,

$$\left(1-\frac{\theta}{2}\right)\frac{2}{2-\nu}\lambda^{\nu/(2-\nu)}p^{2/(2-\nu)}f\left(\widehat{k}\right)^{\nu/(2-\nu)}f'\left(\widehat{k}\right)=r. \quad (30)$$

If $1 > \alpha^* = \alpha^\circ > \alpha^R$, it is similar to $\alpha^* = 1$, where k depends on the retailer's profit. Therefore, $\hat{k}$ satisfies the following equation:

$$\left(1-\frac{\theta}{2}\right)\left(\frac{\nu}{\theta}\right)^{2/(2-\nu)}\frac{2}{2-\nu}\lambda^{\nu/(2-\nu)}p^{2/(2-\nu)}f\left(\hat{k}\right)^{\nu/(2-\nu)} \cdot f'\left(\hat{k}\right)=r. \quad (31)$$

If $\alpha^* = \alpha^\circ \le \alpha^R < 1$, from (15) and (25), the first-order condition for k is

$$\left(1-\frac{\nu}{\theta}\right)\left(\frac{\nu}{\theta}\right)^{\nu/(2-\nu)}\frac{2}{2-\nu}\lambda^{\nu/(2-\nu)}p^{2/(2-\nu)}f(k)^{\nu/(2-\nu)} \cdot f'(k)=r. \quad (32)$$

This defines the optimal $\tilde{k}$ in $\alpha^* = \alpha^\circ$ case. Using (31), (32), and (33), the following result is determined.

Result 4. If $\alpha^* = 1$, $k^* = \widehat{k}$. If $1 > \alpha^* = \alpha^\circ > \alpha^R$, $k^* = \hat{k}$. If $\alpha^* = \alpha^\circ < \alpha^R < 1$, $k^* = \tilde{k}$. In addition, $\widehat{k}$, $\hat{k}$, and $\tilde{k}$ satisfy (31), (32), and (33), respectively.

Bringing α^* and k^* into (11) and (13), the transfer payment T^* and effort level e^* can be calculated

$$T^* = \begin{cases} \min\left\{p^{(2-\theta)/(2-\nu)}\lambda^{(\nu-\theta)/(2-\nu)}f\left(\widehat{k}\right)^{(2-\theta)/(2-\nu)}, \dfrac{1}{\lambda}\right\} & \alpha^* = 1 \\ \min\left\{\left(\dfrac{\nu}{\theta}\right)^{(2-\theta)/(2-\nu)} p^{(2-\theta)/(2-\nu)}\lambda^{(\nu-\theta)/(2-\nu)}f\left(\hat{k}\right)^{(2-\theta)/(2-\nu)}, \dfrac{1}{\lambda}\right\} & \alpha^* > \alpha^R \\ \min\left\{\left(\dfrac{\nu}{\theta}\right)^{(2-\theta)/(2-\nu)} p^{(2-\theta)/(2-\nu)}\lambda^{(\nu-\theta)/(2-\nu)}f\left(\tilde{k}\right)^{(2-\theta)/(2-\nu)}, \dfrac{1}{\lambda}\right\} & \alpha^* \le \alpha^R, \end{cases} \quad (33)$$

$$e^* = \begin{cases} \min\left\{\left(p\lambda f\left(\widehat{k}\right)\right)^{1/(2-\nu)}, 1\right\} & \alpha^* = 1 \\ \min\left\{\left(\dfrac{\nu}{\theta}\right)^{1/(2-\nu)}\left(p\lambda f\left(\hat{k}\right)\right)^{1/(2-\nu)}, 1\right\} & \alpha^* > \alpha^R \\ \min\left\{\left(\dfrac{\nu}{\theta}\right)^{1/(2-\nu)}\left(p\lambda f\left(\tilde{k}\right)\right)^{1/(2-\nu)}, 1\right\} & \alpha^* \le \alpha^R. \end{cases} \quad (34)$$

4. Numerical Simulation

Because the optimal bargaining power allocation was obtained from the societal perspective, in this section, a numerical example is provided with the corresponding game and results to better explain how the negotiation and execution of the contracts operate. To attain the specific expressions and results, first the specific parameters and functions are outlined.

Suppose that $f(k) = k^\gamma$, $p = 10$, $\beta = 20$, $r = 1.1$, and $\gamma = 0.5$, and parameters ν and θ are random variables that follow a uniform distribution on $[0, 1]$. From (26), it is known that different combinations of ν and θ result in different α^*. Therefore, in this example, a series of random combinations which satisfied $\nu < \theta$ are given. Applying Matlab and the results derived from the theoretical discussion, α^*, k^*, e^*, and T^* were determined for each random combination. Part of the data used for the calculations in Matlab is listed in Table 1.

As the technical parameters ν and θ for the supply chain are assumed to be known by the manufacturer and retailer, the optimal bargaining power allocation (the third row) can be calculated. Correspondingly, the manufacturer can determine their optimal investment (the fourth row) and the retailer can determine the optimal effort (the fifth row). Also, the optimal transfer payment from the manufacturer to the retailer can be negotiated (the sixth row).

Taking the last column as an example, here, the random technical parameters are 0.25 and 0.54. According to the game timing (Figure 1), the manufacturer invests 5.67 units and the regular decides on the optimal bargaining power allocation; in this case, retailer's bargaining power is 0.38. Then, the manufacturer and the retailer negotiate and decide on a transfer payment of 13.30. After the negotiation, the retailer exerts an effort of 0.5. Both effort and investment lead to supply chain gain; the manufacturer holds all the gain. Next, the signal, which depends on effort, is observed (favorable or not). Finally, if the manufacturer observes a favorable gain, he transfers 13.30 to the retailer.

To understand the results completely and intuitively, the figures (Figures 3, 4, 5, and 6) are given. Each figure includes one 3D relationship graph and one contour map. From the contour map, the change in the value in 3D relationship graph can be easily examined.

Figure 3 shows the change of retailer's bargaining power α^* with the technical parameters ν and θ. This change also can be described by using the data in Table 1 (the data in the third row and the first two rows). Decreasing ν and increasing θ mean the improvement of converting and monitoring

Table 1

v	0.09	0.22	0.03	0.68	0.48	0.72	0.10	0.53	0.69	0.25
θ	0.20	0.27	0.07	0.84	0.61	0.84	0.19	0.83	0.73	0.54
α^*	0.39	0.80	0.41	0.72	0.73	0.77	0.51	0.51	0.93	0.38
k^*	6.19	0.43	6.53	0.26	0.50	0.09	3.93	2.75	0.00	5.67
e^*	0.31	0.23	0.19	0.27	0.31	0.17	0.30	0.57	0.03	0.50
T^*	12.02	5.76	11.43	5.13	6.51	3.10	11.74	12.54	0.33	13.30

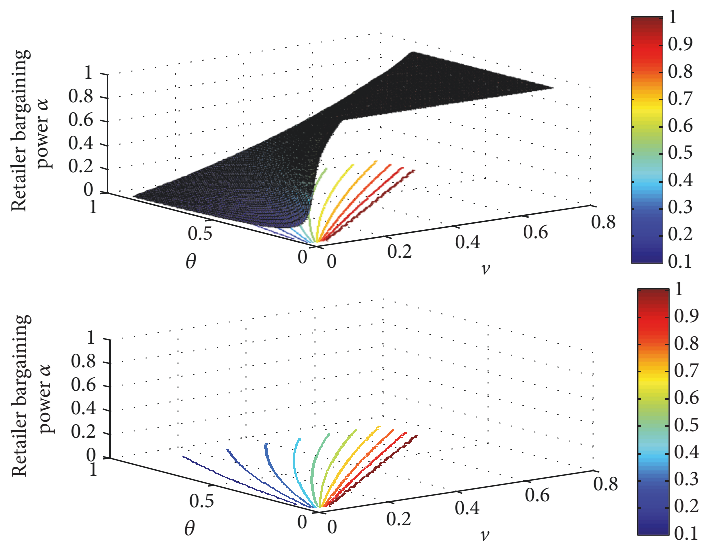

Figure 3: Relationship between the retailer's bargaining power and the technical parameters.

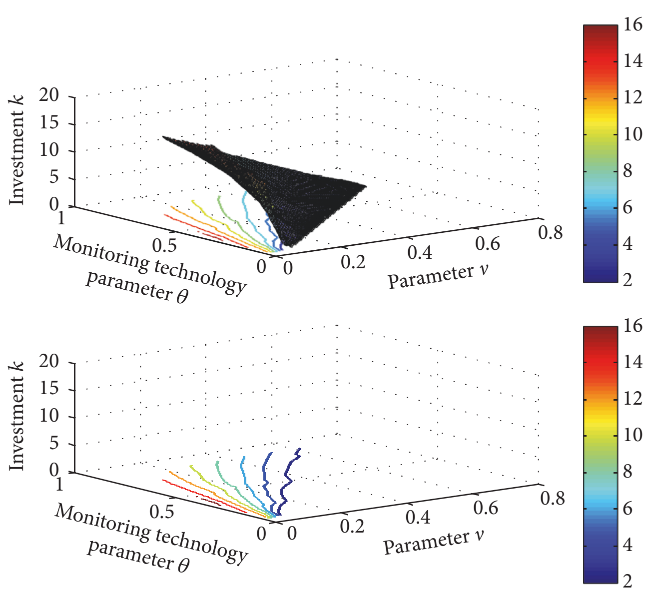

Figure 4: Relationship between the investment and the technical parameters.

technologies. In Figure 3, the bargaining power of retailer is weakening as technologies improve. This coincides with Result 3.

In Figure 4, we can get the relationship between the optimal investment k^* and the technical parameters v and θ (the relationship between the fourth row and the first two rows in Table 1). In this figure, smaller v and greater θ imply higher investment because of superior conversion and monitoring technologies. In fact, the bargaining power gradually shifts to the manufacturer as the technology improves.

Figure 5 describes the relationship between the optimal effort e^* and the technical parameters v and θ. Given monitoring technology parameter θ, there is no monotonic relation between effort and converting technology parameter v. Given converting technology parameter v, effort is an increasing function of monitoring technology parameter θ.

Last, we get the relationship between the transfer payment and the technical parameters in Figure 6. Given monitoring technology parameter θ, there is still no monotonic relation between transfer payment and converting technology parameter v. This is similar to the relationship between effort and converting technology parameter in Figure 5.

5. Conclusions

In this paper, the choice of bargaining power was analyzed from the manufacturer, retailer, and societal perspectives in a moral hazard framework. The manufacturer seeks to hold all the bargaining power to decrease the retailer's share, distorting the retailer's effort but still returning a positive

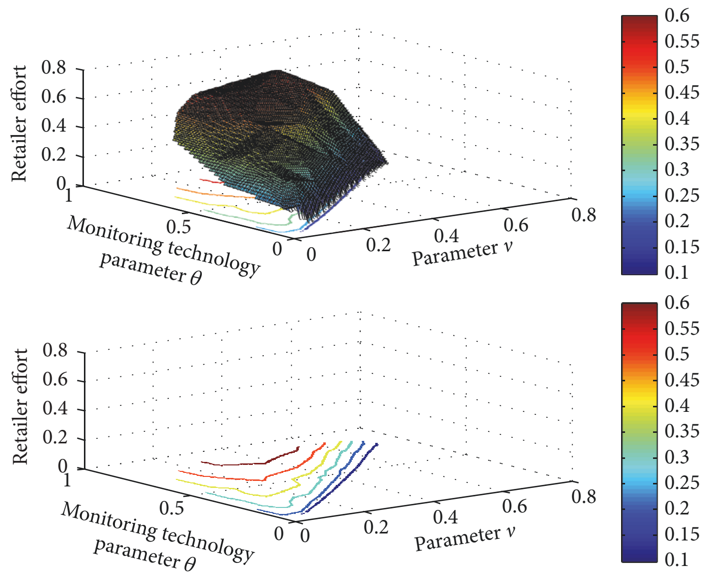

Figure 5: Relationship between the retailer's effort and the technical parameters.

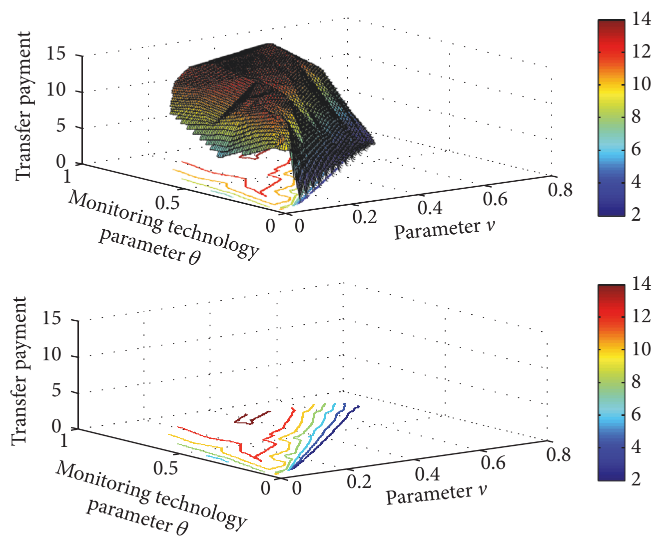

Figure 6: Relationship between the transfer payment and the technical parameters.

profit due to the remaining information problem. The retailer only wishes to have enough bargaining power to keep the manufacturer's reserved profit. From the societal perspective, the optimal bargaining power allocation is related to the conversion and monitoring technologies, with the bargaining power gradually shifting to the manufacturer as the technology improves.

In practice, the choice of bargaining power can be interpreted as the choice of partners. From the point of view of society, firms in different industries have different optimal partner selections when developing their supply chains. The optimal partner selections are related to the conversion and monitoring technologies in the particular industry.

This paper supposes that both manufacturer and retailer are risk-neutral. However, in reality, both manufacturer and retailer are possibly risk-averse for some cases. This is our future research. In addition, we only consider moral hazard caused by ex post asymmetric information; there is no adverse selection caused by ex ante asymmetric information.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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