Contract Design, Relationship-Specific Investment and Renegotiation

Wenmin Peng

***Abstract*—This paper focuses on the contract design in which the buyer offers a price-quantity contract and the seller makes a relationship-specific investment. We introduce the regulating mechanism between the price and trade level into the setting of buyer's optimal contract that can maximize her payoff taking into account the seller's investment incentive. The result shows that renegotiation can enhance the cooperation efficiency by mitigating the problem of underinvestment. But the asymmetric information of outside option reduces the efficiency of ex-ante contract.**

***Index Terms*—Hold-up, outside option, renegotiation, relationship-specific investment.**

I. Introduction

Many trades are formed with relationship specific investment, which is undertaken in support of the particular transaction. Considering a cooperative investment, investor may be held up by another party. This result of this problem is underinvestment. A verifiable ex-ante contract is required for investor to ensure his benefits. General Motors and Fisher Body is a classic case of hold-up problem. The transistors of this case had a contract including the pricing mechanisms and exclusive dealing clause to prevent General Motors from appropriating the quasi-rent of Fisher's investment [1], [2]. Thus the contract solution is important for the hold-up problem. This article is concerned primarily with the buyer's contract problem to induce the seller to make the relationship-specific investment.

Relationship-specific investment has attracted much attention [1]-[6]. The studies have proved that it is possible to write a simple contract to induce efficient investment. It is generally impossible to implement the first-best relationship-specific investment even a long-term contract that can stipulate a sophisticated revelation mechanism to reverse the terms of trade [7]. For improving the parties' investment incentive, the research designs a simple option contracts that can achieve the efficient investment without renegotiation [8]. The further study shows the first best can be achieved with a simple contract and renegotiation, even if the parties' valuations are their private information [9].

The theoretical analysis of contract design is closely related to the mechanism design. However, the research has shown the efficient investment can't realize when seller makes a hidden investment that influences the buyer's hidden valuation, and the budget-balanced trading mechanisms implement both first-best efficient investment and efficient trade [10]. The trading mechanism under two-sided incomplete information about the cost and benefit is further distorted in order to provide investment incentives [11]. The present articles emphasize the mechanism design by solving an optimal contract, which specifies the terms to maximize the joint surplus of trade.

More recently, several papers have argued the contracting problem that maximizes the contractor's expected payoff considering the investor's constraint of individual rationality and incentive compatibility under the situation of renegotiation. The optimal contract model with unobservable relationship-specific investment and renegotiation assumes that the ex-ante contract can transmit information; at the renegotiation stage, the uninformed party can make a price-quantity menu to the informed party. The result shows that a partial-disclosure contract may be optimal [12]. Considering asymmetric information, the result show there is a conflict between efficiency of investment and the contractual signaling to extract the surplus [13]. Our study considers a model of hold-up to characterize the design of optimal price-quantity contract, in which the trading level is depend on the price. More precisely, our model focus on the buyer's design of contract with the following two features: first, the buyer offers a price to maximize her payoff; second, this price should take into account the seller's investment incentive.

In the renegotiation stage, the parties out option is very important, in order to discuss the signal effect between outside level and investment choice, the research has introduced an outside option signaling model to discuss the investment choice when both parties can't sign an ex-ante contract. It is obvious that the seller only can obtain a payoff which is equivalent to the value trading with external party [14]. So it is necessary to write a contract specifying the trading terms to ensure the seller's investment incentive. The buyer offers a contract to the seller; then the seller makes a cooperative investment to supply a good specialized to the buyer. We first consider the case when the buyer knows the seller's outside option at the contracting stage. The result shows that a price-quantity contract can relieve the problem of underinvestment. The optimal contract offered by buyer is depend on the seller's level of outside option. The buyer sets a high price for high type seller; and the high type seller prefers to invest more. Then we discuss the buyer's decision mechanism when seller's outside option level is his private information. The asymmetric information makes the buyer in a bad situation if she offers a different price with the seller's type. In this case, the buyer makes the offer according to her prior belief, once this probability is greater than the critical value, she will choose a high price.

Our study attempts to discuss the contracting problem

Manuscript received November 12, 2016; revised January 15, 2017.
Wenmin Peng is with the Southwest Jiaotong University, China (e-mail: wenminpeng@163.com).

doi: 10.18178/ijimt.2017.8.2.711

with renegotiation, and the disagreement payoff is equivalent to the value specified in initial contract minus the sunk cost. The trade level in the case with renegotiation is increased. Simultaneously, the optimal price and investment are higher than the case without renegotiation; so the renegotiation can enhance the cooperation efficiency of the parties. The pooling of types is the result of asymmetric information, in this case the low type seller pretends a high type, but its bargaining power will decrease after the nature state realized. The optimal contract of low type investment depends on the degree of asymmetric information.

II. The Model

This article considers a bilateral trade model where only the seller makes the investment. The model describes the relationship between a buyer B and a seller S , for convenience, B and S will be referred to as "she" and "he" respectively. Buyer offers a contract c for the terms of trading, if the seller accepts it, he supply an intermediate good or service to buyer according the contracted terms, otherwise she rejects it and trades with another party.

We also consider the case that a cooperative investment i is taken by seller [15]. The sequence of events taking place is demonstrated in the timeline below

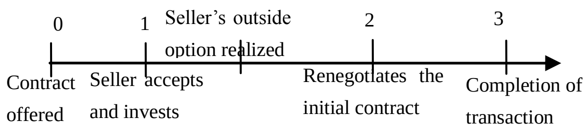

Fig. 1. The timeline.

Buyer offers a contract at $t=0$, then the seller makes a decision about this contract at $t=1$. If the seller accepts it, he will make an investment i. Then the uncertainty about seller's outside option is resolved. If the initial contract specified an inefficient trade level, the parties have to make a renegotiation about the trading terms at $t=2$. Both sides complete the collaboration at $t=3$.

Let $v(i)$ denote the total trading value when the buyer and seller agree on the transaction. We assume that $v(i)$ is twice differentiable and has the following properties:
$v'(i)>0, v''(i)<0, v(0)=0; and \lim_{i\to 0} v'(i)=\infty, \lim_{i\to\infty} v'(i)=0$.

The payoff seller can get without the buyer is $\theta v(i)$. The value of θ indicates the level of seller's outside option, which is a proportion of the total benefits, and $\theta\in[0,1]$; $\theta=1$ means a general investment. Buyer obtains a zero payoff when the seller rejects the contract or takes outside option. We first describe the case of non-contractible investment, and then introduce the discussion of buyer's contracting behavior and seller's investment decision.

If the parties can't sign an ex-ante contract, seller will accept an offer of θ once the specific investment is sunk. The seller's payoff is $u_S^n(\theta,i)=\theta v(i)-i$.

In this case, the seller's optimal investment level i_0 is characterized by the first order condition, it means $\theta v'(i_0)=1$. The seller's payoff is equivalent to his outside option that is independent of parties' particular trading relationship. Ultimately, the result is the lack of relationship-specific investment. But it is important to enhance product competitiveness, so parties attempt to improve investment incentive in their ex-ante contract. Our paper mainly consider the case that $u_S^n(\theta,i)>0$, so the seller's outside option is always binding.

The contracting problem can be perceived as a standard mechanism-design problem. In standard models, the under-investment result of hold-up problem can be solved by carefully setting the contract terms including the transfer and quantity traded. This paper consider a class of simplified contract whose terms only specify the price and quantity. Before the seller makes a specific investment, the buyer offers a contract including the trading price λ, expressed as a proportion to share the surplus $v(i)$. Our theoretical is closely related to mechanism design, quantity denotes the trade level, which means the probability that the buyer and seller must trade. In this article, let the probability that the seller accepts the trading price specified in the contract denotes the trade level. The payoff of both sides depend on the contracted price λ, $q(\lambda)$ denotes the trade level, where $q(\lambda)\in[0,1]$. Many models in the mechanism-design and contract-theory literature implicitly associate verifiability with forcing contracts. Our setting assumes the contract assigned between two parties can be verified by a third party. The seller only needs to make a decision about the buyer's offer. The payoffs of both sides are given by the following when seller accepts it:

$$u_S=\lambda q(\lambda)v(i)-i \text{ and } u_B=(1-\lambda)q(\lambda)v(i); \quad (1)$$

otherwise,

$$u_S=\theta v(i)-i \text{ and } u_B=0. \quad (2)$$

Note from (1), (2), the payoff of the buyer and seller are respectively denoted by

$$u_S(i,\lambda,\theta)=\lambda q(\lambda)v(i)+[1-q(\lambda)]\theta v(i)-i; \quad (3)$$

$$u_B(i,\lambda,\theta)=(1-\lambda)q(\lambda)v(i). \quad (4)$$

It follows from the observation of (3) and (4), we can obtain the efficient total surplus is given by $s(i,\lambda,\theta)=[\theta+(1-\theta)q(\lambda)]v(i)-i$.

Comparing with the case without an initial contract, we conclude that the price specified in the contract must satisfy $\lambda>\theta$. For all $\theta\in(0,1)$, $\forall\ \lambda\in(\theta,1)$, there is no doubt that $u_S(i,\lambda,\theta)>u_S^n(i,\theta)$. We can conclude that the seller's payoff is greater than the case without commitment, so an initial price-quantity contract is efficient to incentive more relationship-specific investment.

III. The Benchmark Case

A. Contracting and Relationship-Specific Investment

This section considers the design of optimal contract with complete information. Before we delve into this issue, it is indispensable to discuss the seller's investment decision. Given a trading price, the seller will chose the investment to maximize his payoff. It is defined by the following first-order condition:

$$\left\{\lambda q(\lambda)+\left[1-q(\lambda)\right]\theta\right\}v'(i)=1. \tag{5}$$

The seller's optimal investment satisfies equation (5), its value depends on the mathematical relationship between the total value and investment. In conclusion, the seller's optimal investment level is given by $\tilde{i}(\lambda)$, which is a function of the contracted price λ, and the function relationship is effected by his outside option level θ.

Suppose information is symmetric, both the seller and the buyer know the outside option and total surplus before trading. We start with the relationship between the buyer's price and quantity traded. Considering the seller's participation constraints, it is obvious that any share less than θ is sure to be rejected by seller, and the price $\lambda=1$ must be rejected by buyer. We assume that the fair price can realize the maximum quantity. So we obtain $q(\theta)=0, q(1)=0$ and $q(\lambda_0)=1$, where λ_0 stands for the fair price. The quantity of trading increases with the price, but presents a downward trend after the fair price. Then consider the characteristics of seller's investment decision. Equation (5) implies the seller's investment decision is increasing with outside option level θ and contracted price λ.

Next, we attempt to discuss whether the buyer can induce the seller to choose the first best level of investment by setting an appropriate contract. It requires $q(\lambda)=(1-\theta)/(\lambda-\theta)$, if it is true, there is a contradiction with $q(\theta)=0$. Thus, in our setting, the first best level of investment can't be realized except the seller receives the total surplus.

Comparing the various investment levels, it is clear that $i_0<\tilde{i}(\lambda)<\hat{i}$. Hence, there is a problem of underinvestment comparing with the first best investment level, and a price-quantity contract can relieve it.

Now we begin to discuss the contracting problem. In our setting, it means that the buyer has to choose a price to maximize her payoff taking into account the seller's investment decision. This problem can be explained as follow:

$$\begin{aligned}&\max_{\lambda} u_B(i,\lambda,\theta)\\&s.t.\ i\in\arg\max_{\tilde{i}(\lambda)} u_S\left(\tilde{i}(\lambda),\lambda,\theta\right)\end{aligned}. \tag{6}$$

The problem of finding the optimal contract can be divided into three steps. First, we assume that it is possible to induce seller to make an optimal investment level with a given contract, and it is determined by equation (5). Then the seller proposes a price specified in the contract to maximize her payoff specified in this contract. Finally, we can obtain the optimal investment level.

If the buyer perfectly knows the seller's outside option, she would design the trading mechanism to ensure the success of cooperation. In this model, this mechanism can realize by the setting of price for its restriction relationship with quantity. For a given price λ, the seller choose the optimal investment level $\tilde{i}(\lambda)$ to maximize his payoff. Then the buyer sets the price to solve the problem $\max_{\lambda} u_B$, which is as follows:

$$\max_{\lambda}(1-\lambda)q(\lambda)v\left(\tilde{i}(\lambda)\right). \tag{7}$$

Note that $v(i)$ is increasing and strictly concave, and both $q(\lambda)$ and $v\left(\tilde{i}(\lambda)\right)$ depend on λ. We can obtain the buyer's optimal price by differentiating (7) with respect to λ. The solution satisfies the first-order condition: $\frac{\partial u_B(i,\lambda,\theta)}{\partial\lambda}=0$. For future convenience, let $\tilde{i}'$ denote $\frac{\partial\tilde{i}(\lambda)}{\partial\lambda}$. Substituting $v'(\tilde{i})$ into first-order condition, we can obtain the buyer's optimal price $\tilde{\lambda}$ satisfies

$$\begin{aligned}&\tilde{\lambda}\left[q'(\tilde{\lambda})\left(1-q(\tilde{\lambda})\right)\theta v(\tilde{i}(\lambda))\right]+\tilde{\lambda}^2 q'(\tilde{\lambda})q(\tilde{\lambda})v(\tilde{i}(\lambda))\\&-\tilde{\lambda}\left[q(\tilde{\lambda})\left(q'(\tilde{\lambda})-q(\tilde{\lambda})\right)v(\tilde{i}(\lambda))-\left(1-q(\tilde{\lambda})\right)\tilde{i}'\right]\\&=\left(1-q(\tilde{\lambda})\right)\left(q'(\tilde{\lambda})-q(\tilde{\lambda})\right)\theta v\left(\tilde{i}(\lambda)\right)\end{aligned}. \tag{8}$$

The result specified in (8) can answer the question what contract designed by the buyer is optimal, and it also induces the seller to make the first best investment level. Finally, we can get the value of seller's best investment level $\tilde{i}(\tilde{\lambda})$. This result can be explained as follows. The buyer offers a contract $\left(\tilde{\lambda},\ q(\tilde{\lambda})\right)$ that can maximize her expected payoff. The optimal contract induce an investment level $\tilde{i}(\tilde{\lambda})$ that satisfies the condition specified in equation (5) to ensure the seller's optimal decision based on the price $\tilde{\lambda}$. The seller's investment level can be indirectly specified by the ex-ante contract. The outcome of this game implies that it is possible to mitigate the hold-up effect on investment when the investor's outside option is binding. Next, we will introduce a special case to illustrate our results.

Now we provide a simple example. Consider a special case that the total value of the investment is defined by $v(i)=\sqrt{i}$. In order to utilize the result specified in equation (8), we must determine the expression of quantity, which is the probability that the seller accepts the buyer's price. We have known $q(\lambda_0)=1$, so it is important to identify the value of fair price. Some researches show that the equal split to be the fair outcome. But psychologists have examined that sunk costs greatly affect peoples' notion about fair outcome. In our setting, the seller can obtain $\theta v(i)$ from external buyer. So the seller's fair price satisfies $\lambda_0=\theta+(1-\theta)/2=(1+\theta)/2$. Thinking about the properties of quantity, we can obtain a specification about $q(\lambda)$, which is given by $q(\lambda)=-4(\lambda-1)(\lambda-\theta)/(1\text{-}\theta)^2$. In this situation, we can get the numerical solution of problem (7), Table 1 shows these results with respect to different types. The buyer sets a high price for high type seller; and the seller's investment is increasing in θ. For all $\theta \in (0,1)$, the trade level $q(\tilde{\lambda})$ is almost equal.

TABLE I: THE OPTIMAL CONTRACT AND INVESTMENT LEVEL

θ	$\tilde{\lambda}$	$q(\tilde{\lambda})$	$\tilde{i}(\tilde{\lambda})$
0.1	0.4149	0.6998	0.0257
0.2	0.4797	0.6992	0.0391
0.3	0.5446	0.6989	0.0554
0.4	0.6096	0.6987	0.0746
0.5	0.6746	0.6984	0.0967
0.6	0.7396	0.6980	0.1216
0.7	0.8047	0.6980	0.1494
0.8	0.8698	0.6980	0.1801
0.9	0.9349	0.6980	0.2136

We also can obtain the payoff of both sides in the speical case, as dispalyed in Fig 2. The critical outside option level occurs at $\theta^c \approx 0.35$, and the seller's payoff is higher than the buyer for $\theta > \theta^c$. Moreover, u_S is increasing in θ; u_B is weakly increasing when $\theta \in [0.1, 0.3]$, but decreasing on $[0,3, 0.9]$.

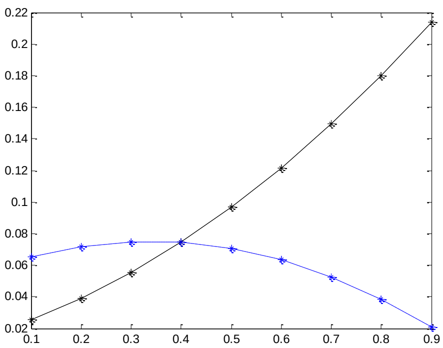

Fig. 2. The payoff of both sides.

B. Contract and Asymmetric Information

This section considers the case that the seller has private information about his outside option level. Suppose that there are only two types of the outside option level, $j \in \{l, h\}$ *and* $0 < \theta_l < \theta_h < 1$. The buyer only knows the type $j = h$ occurs with the probability π, and the probability of low type case is $1-\pi$. For each type j, let $\tilde{\lambda}_j$ respectively denote the buyer's price by solving problem (7), and $\tilde{i}_j$ denote the seller's investment decision based on the this contracted price. Under this condition, the payoff of buyer and the seller is given by u_j^B, u_j^S. The example indicates u_S increase with his outside option level. Conversely, the buyer's payoff decrease with θ on $\theta \in [0,3, 0,9]$. The discussion of asymmetric information in this article mainly focuses on the situation that $u_h^S > u_l^S, u_h^B < u_l^B$.

When buyer makes a high price, the low type seller's payoff is $u_{lh}^S = \lambda_h q(\lambda_h) v(i_h) + [1 - q(\lambda_h)] \theta_l v(i_h) - i_h$. As argued in the last section, it is obvious that $u_l^S < u_{lh}^S$. And the high type seller's payoff under low contracted price is $u_{hl}^S = \lambda_l q(\lambda_l) v(i_l) + [1 - q(\lambda_l)] \theta_h v(i_l) - i_l$. It is clear that $u_l^S < u_{hl}^S$, but the size relationship between u_{hl}^S and u_h^S is uncertain. If $u_{hl}^S > u_h^S$, the seller's decision is irrelevant to the buyer's contract. Then we can conclude $u_h^B = u_l^B$, which is a contradiction as the assumption specifies that $u_h^B < u_l^B$, therefore, $u_{hl}^S < u_h^S$. Undoubtedly, in this case the low type seller will accept the high price, but the high type seller will reject the low price. Then we can obtain the buyer's prior belief $\bar{\pi}$ is such that to make the buyer is indifferent between the high contracted price and low contracted price. This probability satisfies $\bar{\pi} = \frac{u_h^B - u_l^B}{u_l^B}$. If the buyer's prior belief $\pi > \bar{\pi}$, she will make a contract to specify a high trading price λ_h.

IV. CONTRACT SOLUTION AND RENEGOTIATION

In this section, we consider the contracting problem in the case of renegotiation. Our setting assumes that the initial contract can be verified, if parties do not reach a renegotiation agreement, the initial contract is executed. So the buyer's disagreement payoff is equivalent to the value of u_B, and the seller' disagreement payoff is $u_B + i$.[4] The renegotiation surplus is the difference between the surplus and the sum of disagreement payoff.

The relationship specific investment is undertaken for a particular transaction, its value is very low trading with external party. After the investment is sunk, it will have little influence on the profit allocation. We ignore investment cost in the acquisition process of disagreement payoff.

Observe that the renegotiation surplus is equivalent to the seller's payoff trading with external buyer, and it can be denoted by $R = [1 - q(\lambda_l)](1-\theta) v(i)$. In the renegotiation stage, we assume that both sides have the equal bargaining power, each one receive half of the renegotiation surplus plus their disagreement payoff.

Similarly, suppose that there are only two types of the outside option level, $j \in \{l, h\}$. We first consider the problem of contract design with complete information. Is this case, the renegotiation payoff of the seller and the buyer is respectively denoted by

$$U_j^S(i, \lambda) = \lambda_j q(\lambda_j) v(i) + \frac{(1+\theta_j)[1 - q(\lambda_j)]}{2} v(i_j) - i_j. \quad (9)$$

$$U_j^B(i, \lambda) = \left[\frac{1 - \theta_j + q(\lambda_j)(1+\theta_j)}{2} - \lambda_j q(\lambda_j) \right] v(i_j). \quad (10)$$

From (9) and (10), we can obtain the efficient total surplus of renegotiation, which is denoted by $S(i,\lambda)=U_j^S+U_j^B$. Clearly, $S(i,\lambda)=v(i_j)-i_j$, which is equivalent to the net surplus of the trading. Because $\theta\in(0,1), q(\lambda)\in[0,1]$, for all i and $\lambda\in\mathrm{R}^+, j\in\{h,l\}$, the seller and buyer's payoff and the joint surplus are obviously higher than in the case without renegotiation. So the renegotiation can improve the trading efficiency.

The process of optimal contract design is in accordance with the problem without renegotiation. The seller choose his optimal investment $i_j^r(\lambda,\theta)$ by optimizing $U_j^S(i,\lambda)$, it satisfies

$$\left[\lambda_j q(\lambda_j)+\frac{(1-q(\lambda_j))(1+\theta_j)}{2}\right]v'\left(i^r(\lambda_j,\theta_j)\right)=1, \quad (11)$$

as $\tilde{i}_j^r(\lambda,\theta)>\tilde{i}_j(\lambda,\theta)$, it is obvious that renegotiation can increase the seller's incentive to invest. Then the buyer's contracting problem can is represented by

$$\begin{aligned}&\max_{\lambda} U_j^B(i,\lambda)\\ &s.t.\ i\in\underset{\tilde{i}_j^r(\lambda_j,\theta_j)}{\arg\max}\, U_j^S\left(\tilde{i}_j^r(\lambda_j,\theta_j),\lambda\right)\end{aligned}. \quad (12)$$

Similarly, problem (11) can be solved by the same way in the part *A* of section Ⅲ, the buyer's optimal price with renegotiation is denoted by $\tilde{\lambda}_j^r$, which satisfies

$$\begin{aligned}&\frac{1-\theta_j+q(\tilde{\lambda}_j^r)(1+\theta_j)-2\theta_j q(\tilde{\lambda}_j^r)}{2\theta_j q(\tilde{\lambda}_j^r)+\left[1-q(\tilde{\lambda}_j^r)\right](1+\theta_j)}\tilde{i}'(\tilde{\lambda}_j^r,\theta_j)=\\ &\left[q(\tilde{\lambda}_j^r)+q'(\tilde{\lambda}_j^r)\tilde{\lambda}_j^r-\frac{q'(\tilde{\lambda}_j^r)(1+\theta_j)}{2}\right]v\left(\tilde{i}^r(\tilde{\lambda}_j^r,\theta_j)\right)\end{aligned}. \quad (13)$$

Consider the special case and investment type presented in the part *A* of section Ⅲ, we also can obtain the numerical value satisfying condition (13). The optimal contract $\left(\tilde{\lambda}^r, q(\tilde{\lambda}^r)\right)$ and investment $\tilde{i}(\tilde{\lambda}^r)$ under the case of renegotiation is specified in Table II.

TABLE II: THE OPTIMAL CONTRACT AND INVESTMENT DECISION WITH RENEGOTIATION

θ	$\tilde{\lambda}^r$	$q(\tilde{\lambda}^r)$	$\tilde{i}(\tilde{\lambda}^r)$
0.1	0.4133	0.6962	0.0253
0.2	0.4888	0.7220	0.0417
0.3	0.5596	0.7417	0.0607
0.4	0.6259	0.7530	0.0813
0.5	0.6888	0.7552	0.1032
0.6	0.7495	0.7475	0.1266
0.7	0.8095	0.7300	0.1521
0.8	0.8704	0.7040	0.1804
0.9	0.9336	0.6720	0.2128

In this case, the trade level displays a more obvious difference. Comparing with the case without renegotiation, the optimal price and investment level are improved.

V. CONCLUSION

This paper considers the case that the unilateral investment has a cooperative effect on both sides. We focus on the contractual solution to the hold-up problem for relationship-specific investment. The investment level depends on the price-quantity pair specified in the contract. The quantity of trading increases with the price, but presents a downward trend after the fair price. The analysis shows that an initial price-quantity contract is efficient to incentive more relationship-specific investment. The buyer can offer a price to maximize her payoff while it ensures the seller's investment satisfying his first-order condition. The results of the special case show that the optimal price and investment increases with seller's outside option level. When the seller's type is his private information the buyer offers the contract according to her prior belief about the seller's type. If $\pi>\bar{\pi}$, she will make a contract to specify a high trading price. The optimal contract and investment level is higher than the case without renegotiation. It is impossible that the renegotiation can mitigate the problem of underinvestment. In the contract design with asymmetric information, the buyer has the opportunity to renegotiate with seller. In this case, the price of high type is equal to $\tilde{\lambda}_h^r$. But the optimal contract of low type investment depends on the degree of asymmetric information between the parties.

Our results on the optimal contracts rely on the assumption that initial price-quantity contract can be verified by third party. If this condition is slackening, the optimal contract is more complex and interesting. Our possible extension for future research focuses on the renegotiation contract design with asymmetric information. The degree of asymmetric information still has a great influence on bargaining power.

REFERENCES

[1] B. Klein, R. G. Crawford, A. Alchian, "Vertical integration, appropriable rents and the competitive contracting process," *Journal of Law and Economics*, vol. 21, pp. 297-326, October 1978.

[2] B. Klein, "Why hold- ups occur: The self-enforcing range of contractual relationships," *Economic Inquiry*, vol. 34, pp. 444-463, July 1996.

[3] O. E. Williamson, *Markets and hierarchies: Analysis and antitrust implications*. New York: Free Press, 1975.

[4] O. E. Williamson, "Transaction-cost economics: The governance of contractual relations," *Journal of Law and Economics*, vol. 22, pp. 233-261, Oct 1979.

[5] P. A. Grout, "Investment and wages in the absence of binding contracts: A Nash bargaining approach," *Econometrica*, vol.52, pp. 449-460, March 1984.

[6] O. E. Williamson, *The Economic Institutions of Capitalism*, New York: Free Press, 1985.

[7] O. Hart and J. Moore, "Incomplete contracts and renegotiation," *Econometrica*, vol. 56, pp. 755-785, July 1988.

[8] G. Nöldeke and K. M. Schmidt, "Option contracts and renegotiation: a solution to the hold-up problem," *The RAND Journal of Economics*, vol. 26, pp. 163-179, Summer, 1995.

[9] P. W. Schmitz, "Simple contracts, renegotiation under asymmetric information, and the hold-up problem," *European Economic Review*, vol. 46, pp.169-188, Jan 2002.

[10] R. R. Zhao, "Rigidity in bilateral trade with holdup," *Theoretical Economics*, vol. 3, pp. 85-121, Mar 2008.

[11] S. Lau, "Investment incentives in bilateral trading," *Games and Economic Behavior*, vol. 73, pp. 538-552, Nov 2011.

[12] M. Goltsman, "Optimal information transmission in a holdup problem," *The RAND Journal of Economics*, vol. 42, pp. 495-526, Sep 2011.
[13] L. Vasconcelos, "Contractual signaling, relationship-specific investment and exclusive agreements," *Games and Economic Behavior*, vol. 87, pp. 19-33, Sep 2014.
[14] S. Goldlücke, P. W. Schmitz, "Investments as signals of outside options," *Journal of Economic Theory*, vol. 150, pp. 683-708, Mar *2014.*
[15] P. W. Schmitz, "Information gathering, transaction costs and the property rights approach," *American Economic Review*, vol. 96, pp. 422-34, Mar 2006.

Wenmin Peng was born in Wanyuan, Sichuan province, China. She is a Ph.D. candidate studying in Southwest Jiaotong University. Her major field of study is investment management under incomplete contract.