How did the *keiretsu* system solve the hold-up problem in the Japanese automobile industry?

by

Sota Ichiba

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Approved by the Thesis Supervisor

Dr. Xiaoting Wang	Date

Approved by the Head of the Department

Dr. Brian VanBlarcom	Date

Approved by the Honours Committee

Dr. Anthony Thompson	Date

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Abstract

The Japanese car industry enjoyed a steady expansion path from 1960, following the *keiretsu* system, the Japanese style of non-vertically integrated system. This is a result of the dissolution of the *zaibatsu* and is characterized by less internalization and flexible contracts. Other characteristics of the *keiretsu* include that the buyer of the product can buy the same product from another different keiretsu company, as seen in the Toyota-Denso relationship. The model proposed by this thesis incorporates these additions to the classical hold-up model, proposed by Grossman and Hart (1986) to examine the efficiency of such system. In particular, the buyer now has an option to partially buy the same product from another company. This introduces implicit competition within the system as seen in the *keiretsu* relationship. Using backward induction to establish a subgame perfect Nash equilibrium, I derive a result indicating that efficiency improves from the classic case of a complete non-vertically integrated system when the buyer has high bargaining power over the share of surplus, and that the magnitude of competition within the *keiretsu* relationship does not affect efficiency, measured by the amount of underinvestment. I also propose a possible extension to the model to further relax the assumption in the model.

1. Introduction

1.1 Statement of the problem

The Japanese economy expanded enormously in the past 50 years. In particular, the automobile industry grew steadily over the past few decades and became one of the biggest in the world. The Japanese car industry has a different structure from its American counterparts. This system, called the *keiretsu* system, is characterized by a non-vertically integrated model with a strong bond among the companies in the supply chain. For example, the part suppliers to Toyota, the largest car company in Japan, openly share any problems in production and try to improve quality collectively even though they are not direct subsidiaries of Toyota. This seems counterintuitive since a non-vertically integrated model is a source of what are called hold-up inefficiencies. However, several assumptions of the hold-up model, such as the absence of other sellers, are not met in the *keiretsu* system.

This thesis attempts to examine the efficiency of the Japanese car industry from the perspective of the hold-up problem by relaxing the assumptions in the original hold-up model, primarily by the introduction of implicit competition among supply firms. This is done by extending the repeated hold-up model by Castaneda (2004) to allow an outside company which supplies the same product to the buyer. The result of a subgame perfect Nash equilibrium in the model suggests that the efficiency of the system is independent from the level of competition as long as there is some, and keiretsu improves efficiency only if the parent company has large bargaining power in the allocation of surplus within the system.

1.2 Introduction of the hold-up problem

The hold-up problem is one of the most heavily studied topics in economics because it connects the study of incentives to the study of the boundaries of firms. It occurs when the seller is protected by an exclusive contract, which ensures that a certain amount of their product is bought by the buyer, and the investment is relation-specific. Relation specific investment (RSI) refers to investment that has no use outside of the relationship. This problem causes inefficiencies from the seller's underinvestment. This inefficiency only happens in a non-vertically integrated system since the downstream firm is able to dictate the upstream firm's action in the case of a vertical integrated system. In his cost-benefit analysis of vertical mergers, Williamson (1979) finds that in a transaction cost economy, the cost of production in a non-vertically integrated model might exceed that of vertically integrated firms because of the associated cooperation cost. Grossman and Hart (1986) took a different approach to this problem by using the idea of an imperfect contract. They stated that in a non-vertically integrated model, it is practically impossible to write a complete contract that protects both firms from all events that would occur in the future. As a result, the upstream firm becomes reluctant to invest in relation-specific assets since the return on such investment is insufficient to justify the optimal investment which maximizes efficiency of the whole system, and the upstream firm is not able to confirm the future commitment from the downstream firm.

1.3 A case study of the hold-up problem: GM-Fisher Body

A consequence of such contracts can be found in the GM-Fisher Body relationship. Fisher Body and GM signed a long term exclusive dealing contract in order to protect their relation-specific assets in 1919. Soon after that, in the early 1920s, Fisher Body started to extort extra investment from GM by refusing to build a new factory near GM's factory. GM had no choice but to agree to this demand because they could not void the contract and they did not have expertise in steel body making. As a result, the cost of producing the body grew substantially. Because of this problem, in 1929, GM bought Fisher Body (Klein 2007). This example illustrates how the upstream firm can hold the downstream up and cause inefficiencies.

1.4 Modifications of the hold-up model

These results seem to indicate that a non-vertically integrated system will never be optimal. However, as Holmstrom and Roberts (1998) suggested, the Japanese system is not fully described by the original hold-up framework because of the restrictions of the model. Several modifications are made to the classic hold up problem in order to relax some assumptions and limitations of the original model. I highlighted some of these studies as they seem to be most relevant to our study of the Japanese system. For example, Lau (2008) extends the model to include asymmetric information. She showed that the introduction of asymmetric information will reduce the hold-up inefficiency. The intuition is that under complete asymmetric information, the investment information is hidden so that the other party's action will not change by the investment amount. As a result, the upstream firm chooses investment level that maximizes its return without considering the upstream firm's reaction, which leads to the optimal level of investment. Castaneda (2004) proved that in a repeated relationship with the possibility of terminating the contract and moving to vertical integration, as the limit of the contract period goes to zero, both parties act optimally and downstream buyer does not choose to integrate its upstream supplier. Intuitively, this model eliminates the inefficiency by giving the downstream company a threat strategy of vertical integration. This forces the upstream company to invest optimally given that the duration of exclusive contract is short. In another study, Schmidt and Nöldeke (1998) showed that the hold-up inefficiencies will be eliminated if the investment is done sequentially. The main assumption of the paper is that the upstream firm's profit depends on how much the downstream values the upstream firm after the first investment by the upstream firm is carried out. Investment now has two types of returns; the return from the lower cost of production, and the return from being valued more by the downstream firm. Consequently, the investment becomes more lucrative to the upstream firm, encouraging them to invest optimally.

The model proposed by this thesis is built to reflect the Japanese *keiretsu* relationship. In particular, implicit competitions within the system as well as repeated game dynamics, which are main characteristics of the Japanese non-vertically integrated system, are incorporated into the model. This model allows us to examine the efficiency of non-vertically integrated firms with various outside options. A subgame perfect Nash equilibrium of the game suggests that the *keiretsu* system improves efficiency from the complete vertically integrated system only when the downstream firm has high bargaining power in splitting the surplus made within the system.

The structure of the Japanese automobile industry is crucial to understand the setup and implications of the model. In the next section, I will discuss the Japanese system in depth. In section 3, the detailed model is discussed. In chapter 4, I propose an extension of the model. Finally, I conclude the paper in chapter 5.

2. Background of the Japanese *keiretsu* system

2.1 History and characteristics of the *keiretsu* system

The expansion of the Japanese automobile industry is a protracted mystery for economists since the industry followed a different direction from its competitors in other parts of the world. Nevertheless, the industry has experienced a huge expansion. Toyota more than tripled its sales from 1960 to 1990 while US car manufacturers, such as Chrysler, reached a plateau in 1960 and did not grow since then (Toyota 2011 and Chrysler 2009). Attempts have been made in order to find a key to growth by gathering differences between the Japanese automobile industry and its US counterparts. Several papers, including the research done by Asanuma (1988) and Ahmadjian and Lincoln (1997) reached a similar conclusion that the Japanese car industry has lower number of suppliers and the buyer-supplier relationship is closer in the Japanese system compared to the United States. This is a result of the *keiretsu* system which can be translated as "series" or "group". The *keiretsu* system is often understood as a type of structure specific to Japan. This is characterized by a loosely tied group of companies. It is common in the automobile industry where relation specific investment is frequently happening and the manufacturer of the final product such as Toyota has to rely on many companies in order to procure numerous parts required for production of car (Ito 2002). This system was formed by a series of policies implemented in the post-war era in Japan.

By the Allied Forces, the country underwent a major economic reform after 1945 in order to demilitarize and recover the country. They called dissolution of *zaibatsu*, a type of conglomerate formed in Japan. *Zaibatsu* is described by a series of vertically integrated firms with a bank on top of the structure. It was believed that by using its capital flow and economic influence to the government, *zaibatsu* indirectly promoted totalitarianism and the war (Noguchi 2008). The *keiretsu* system was born after the dissolution in order to protect formerly the *zaibatsu* subsidiary companies and promote development of these companies as a whole (Kikuchi 2011, Takada 2011). However, several *keiretsu* including the Toyota *keiretsu* do not originate from *zaibatsu*. These are purely made in order to facilitate information flow and production. The *keiretsu* system has similarities to the *zaibatsu* structure as both systems are characterized by a series of related firms albeit these differ in terms of ownership of the whole system. *Zaibatsu* is directly and explicitly owned by a single family whereas *keiretsu* is not. In fact, Nissan, the third largest car manufacturer in Japan (Nissan 2014), used to be a part of a *zaibatsu* structure named Nissan Konzern and later became loosely tied *keiretsu* called Nissan-Hitachi group (Kikuchi 2011). On top of the *keiretsu* system, there is a company called parent company that has its first-tier child companies which in turn oversee companies in the next tier. For example, Toyota has several first-tier companies like Denso and Aishin, supplying car electronics to Toyota and then Denso has several second-tier companies such as Asmo which supplies motors to Denso. However, there is no vertical integration prevalent in the North American automobile industry because child companies are not directly owned by its parent companies. In other words, they are financially independent of each other. Moreover, *keiretsu* is not perfectly competitive as the child companies are willing to share information within the system. For example, they have extensive Supplier Networks and they jointly participate in research and development process (Ku 2011).

2.2 An example of the *keiretsu* relationship: Toyota-Denso

One of the most prominent examples of the *keiretsu* relationship is the Toyota-Denso partnership. Denso (Nihon Denso) is a spin-off company from Toyota founded in 1949. As the translation of the company name suggests, it makes car electronics. It is the largest car parts supplier in Japan and has annual sales revenue of $40 billion (Fortune 2014). In her attempt to find the source of the expansion of the Japanese car industry, Anderson (2003) studied this relationship. She argues that Denso and Toyota are tied by a special personal relationship. Denso originally was a part of Toyota until 1949 when the company became unable to keep some of its direct subsidiary including the car electronics section due to economic situation of the post-war Japan. When Denso was founded, the president of Toyota, Kiichiro Toyoda, personally decided to lend 140 million Japanese Yen (14 million US Dollar) to Denso in hope of revitalizing the struggling company. Denso never forgot this and paid back with their new quality control system which became essential in Toyota's success in the automobile market. The relationship in reality is not as fixed as it seems to be. Denso has an option to sell their product to other car companies. Meanwhile, Toyota can buy from other supplier of the electronic parts. This is an example of hostage model described in Williamson (1983) which promotes efficiency by equalizing the bargaining power among the companies. Nevertheless, this option is not prevalent in the system. For example, only 10% of the parts bought by Nissan were from outside its *keiretsu* relationship (Asanuma 1988). Anderson (2003) concluded that the history of good trust and the threat outside options reduced opportunism and hence made them stick to the cooperative equilibrium outcome of the game.

2.3 Adapting the hold-up model to the *keiretsu* system

By looking at the nature of the relationship, we see how it is different from the previous models in the hold-up literatures. Firstly, the paper by Grossman and Hart (1986) concludes that there is no way to avoid inefficiency if the firms are not vertically integrated. The *keiretsu* system is not vertically integrated yet seems to be efficient. Secondly, the information problem posed by Lau's model (2008) is not applicable to the relationship because the *keiretsu* structure facilitates smooth flow of information by having many technological meetings and joint research and development in order to reduce coordination cost (Ku 2011). The sequential Investment model by Schmidt and Nöldeke (1998) is not at least directly applicable here even though in the Toyota-Denso case, there was an unofficial investment from Toyota since Toyota's investment is not meant to increase Denso's willingness to be vertically integrated as it is assumed in the paper. The repeated hold-up model with an option of vertical integration by Castaneda (2004) provides a model similar to what previous researchers described as the *keiretsu* structure. However, as Anderson (2003) found out in the Toyota-Denso case, there is no option for Toyota to vertically integrate Denso as its subsidiary because of a financial reason. Moreover, production volume is not fixed when these companies sign a contract. These factors were not included in the model of Castaneda (2004).

In order to better examine the efficiency of the Japanese model, this thesis proposes a new model which incorporates the outside option given to the buyer or the parent company as well as repeated nature of the relationship based on Castaneda (2004).

3. The model

3.1 Setup of the game

We consider the simplest case in which there are two players, namely a seller and a buyer. The buyer can buy the seller's product. In period $t \in \mathbb{N}$, the buyer values the seller's product at $v(q_t, \theta_t)$ where q_t is the quantity and θ_t is the state of the world variable, both at time t. The state of the world variable θ takes any uncertainty, such as car demand and financial restriction, into account. To make the problem simpler, θ_t is assumed to be independently and identically distributed for any $t \in \mathbb{N}$.

The cost of producing q_t unit in the state of world θ_t is denoted as $c_1(x, q_t, \theta_t)$ where x is the investment level undertaken by the seller. In accordance to the existing hold-up literatures, the investment is assumed to be completely relation specific. That is, the investment will remain unused outside of the contract relationship. Investment is non-contractible which means the investment amount cannot be specified in contracts. Therefore, the seller determines the investment level so that the payoff for them is maximized.

The buyer has an outside option of purchasing the same product from another inside company. However, the buyer must pay switching cost $m \in \mathbb{R}_+$ in order to do this. It follows that the total cost when the buyer chooses to obtain the product from another company is $c_2(x, q_t, \theta) + m$ where c_2 is the cost structure for the outside company. This is a simplified assumption which allows the buyer to buy the same product from another company.

To proceed, we need the following assumptions about property of the functions;

For any $\theta_t \in \Theta$

1. $v(\cdot, \theta_t): \mathbb{R}_+ \to \mathbb{R}_+$ is continuously differentiable, increasing, and strictly concave.

2. $c_1(\cdot,\cdot,\theta_t): \mathbb{R}_+ \times \mathbb{R}_+ \to \mathbb{R}_+$ is continuously differentiable, decreasing in *x,* increasing in *q,* and strictly convex.

Similarly to the model developed in Castaneda (2004), the game is based on an extensive form. There is a contract period at the beginning followed by the bargaining period. However, a modification is made in order to allow the buyer to procure the product from another company. This indirectly introduces competition to the relationship.

The structure of the game is as follows:

1. Contract Period. The buyer and the seller can bargain over the contract which determines the form of the relationship. After the bargaining, the seller invests *x*.

2. Each period $t \in N$ has 4 sub-periods:

i. The buyer may be able to impose the allocation variable $\lambda \in [0,1]$, the fraction of total demand which she is going to buy from the seller in this period. λ is an exogenous variable determined by factors such as number of other firms supplying the same part to the buyer.

ii. Nature determines the state of the world θ.

iii. The buyer and the seller bargain the price for the trade which takes place in this period. The seller decide the level of output q_t

iv. The seller produces the output and the payoff for the buyer and the seller is realized.

After the state of the world is revealed to both parties, they negotiate over the price and the quantity of the product. This bargaining process has the following assumptions:

1. Efficiency: The bargaining process maximizes the surplus from the trade taking place in the period subject to the earlier actions.

2. Alpha-Bargaining Solution: The result of the bargaining process in period 2-iv always ensures that the buyer gains a fraction $0<\alpha<1$ of the total surplus from the trade.

3. Outside Option: The players always choose the outside option when the payoff within the relationship is less than the outside option.

The parameter α can be thought of as relative bargaining power for the seller. The higher α is, the higher the share of the surplus from the trade the seller gets. It can be influenced by factors such as relative size and the financial situation of the companies. Given the abstract nature of the model, however, this variable is treated as an exogenous constant.

The newly added variable, λ, is meant to relax the model proposed by Castaneda (2004). As we shall see, setting $\lambda = 1$ will duplicate the original model by Grossman (1986) and $\lambda = 0$ corresponds to Castaneda (2004). Figure 1-1 shows visualization of the period 2.

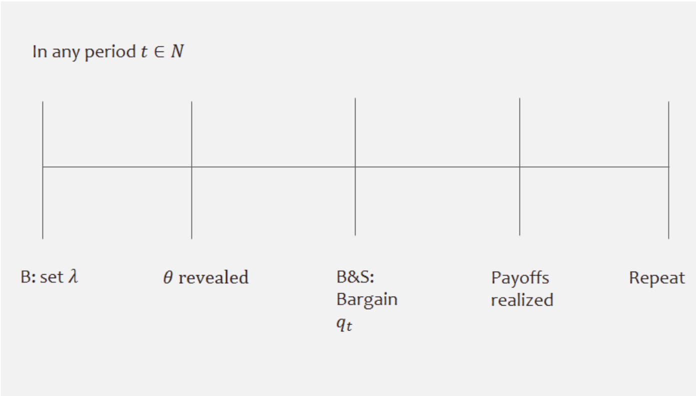

Figure 1 The structure of the subgame

As in Grossman and Hart (1986), we assume that writing a complete contract is impossible in practice, therefore, in this model, the contract $C(T, p)$ consists of only 2 components. Once the parties sign a contract, a transfer which amounts to $\mathrm{T} \in \mathbb{R}^+$ will be made from the buyer to seller in each period. The variable $\mathrm{p} \in \mathbb{R}^+$ determines the period in which the buyer exclusively buys the product from the seller. During the period, the buyer is unable to impose λ therefore the buyer must buy the full amount of the demand from the seller.

Let G(x), the present value of the total surplus within the relationship, be.

$$\mathrm{G(x)} = \sum_{t=0}^{\infty} \delta^t \int_{\theta} v(q^*(x, \theta_t), \theta_t) - c_1(x, q^*(x, \theta_t), \theta_t) dF - x$$

$$\text{where } q^*(x, \theta_t) = \operatorname{argmax} v(q^*, \theta_t) - c_1(x, q^*, \theta_t)$$

This is the present value of the stream of surplus within the system, subtracted by the investment by the seller.

Since c_1 is strictly convex by assumption, by using envelope theorem, the optimal investment level x^* is uniquely determined by the following equation.

$$\sum_{t=0}^{\infty} \delta^t \int_\theta \frac{\delta c_1(x^*, q_t(x^*, \theta_t), \theta_t)}{\delta x} dF = -1 \qquad (1)$$

I examine whether the equilibrium in various setups result in underinvestment for the seller which leads to inefficiency in the system.

3.2 Decentralized equilibrium

Firstly, we examine the case where the buyer and the seller agree to sign an exclusive contract which prohibits the outside option for the seller for the whole game. This case can be expressed as a contract $C(T, \infty)$ for an arbitrary $T \in \mathbb{R}^+$.

Lemma 1

For any contract $C(T,\infty)$, the present value of return for the buyer and the seller in the relationship are

$$\mathrm{U}_i^{\mathrm{B}} = \alpha G(x) + \alpha x - \sum_{t=0}^{\infty} \delta^t T$$
$$\mathrm{U}_i^{\mathrm{S}} = (1-\alpha)G(x) - \alpha x + \sum_{t=0}^{\infty} \delta^t T$$

Proof:

Assuming α-bargaining solution, for each period, the one period surplus for the buyer and the seller are respectively

$$\mathrm{U}_t^{\mathrm{B}} = \alpha[v(q^*(x,\theta_t),\theta_t) - c_1(x,q^*(x,\theta_t),\theta_t)] - \mathrm{T}$$

$$\mathrm{U}_t^{\mathrm{S}} = (1-\alpha)[v(q^*(x,\theta_t),\theta_t) - c_1(x,q^*(x,\theta_t),\theta_t)] + \mathrm{T}$$

Taking the present value of the stream of payoffs, including the cost of the investment gives

$$\mathrm{U}_i^{\mathrm{B}} = \sum_{t=0}^{\infty} \delta^t \int_\theta \mathrm{U}_t^{\mathrm{B}} dF = \alpha G(x) + \alpha x - \sum_{t=0}^{\infty} \delta^t \qquad (2)$$
$$\mathrm{U}_i^{\mathrm{S}} = \sum_{t=0}^{\infty} \delta^t \int_\theta \mathrm{U}_t^{\mathrm{S}} dF = (1-\alpha)G(x) - \alpha x + \sum_{t=0}^{\infty} \delta^t T \qquad (3)$$

as desired. Q.E.D.

3.3 Outside option

Unlike the model by Castaneda (2004), the model proposed in the thesis assumed the imperfect vertical integration outside option in lieu of the perfect vertical integration option. In the *keiretsu* system, the buyer of the product can implicitly introduce competition by exploiting the loose contract system discussed in the paper of Asanuma (1988) and Ahmadjian and Lincoln (1997) even though there is no direct competition in the system. If the seller performs unsatisfactorily, the buyer can penalize such opportunistic behavior by imposing λ in the later period and partly buy the product from another company. Therefore, one can think of the fraction λ as a measure of competition inside the *keiretsu* system. High λ indicates dependence on the seller for the particular product. In the model, we assume λ to be an exogenous variable for simplicity as quantifying this theoretical parameter can be hard. Moreover, to simplify the model, we assume that the competitor company is a direct subsidiary of the buyer and always invests optimally. This assumption might not hold in the actual *keiretsu* relationship. Yet, without the assumption, it is hard to assume another *keiretsu* company which invests optimally without any incentives. I let

$$\mathrm{H(x)} = \sum_{t=0}^{\infty} \delta^t \int_{\theta} v(q_t(x,\theta_t),\theta_t) - c_2(x, q_t(x,\theta_t),\theta_t) dF - x$$

be the total surplus function when the buyer buys the product from the outside company where the cost function for the outside company c_2 shares the same property as c_1. With these assumptions, the payoff for the outside option can be defined.

Lemma 2

For any contract C(T,∞). The present value of return for the buyer and the seller when the outside option was chosen are

$$U_o^B = \lambda\left(\alpha G(x) - \sum_{t=1}^{\infty} \delta^t T\right)(1 + \lambda\alpha - \lambda)x + (1-\lambda)H(x^*) - M$$

$$U_o^S = \lambda\left((1-\alpha)G(x) + \sum_{t=1}^{\infty} \delta^t T\right) - (\lambda - 1 - \lambda\alpha)x$$

Proof:

The one period payoff for the buyer and the seller are

$$\mathrm{U}_{t_o}^{\mathrm{B}} = \lambda \mathrm{U}_i^{\mathrm{B}} + (1-\lambda)H(x^*) - M$$

$$\mathrm{U}_{i_o}^{\mathrm{S}} = \lambda \mathrm{U}_i^{\mathrm{S}}$$

By taking the present value of the sum of the payoff, we obtain the result.

Q.E.D.

The next lemma deals with the equilibrium investment level in a non-vertically integrated model.

Lemma 3

For any contract C(T,∞), the equilibrium level of investment $\underline{x^E}$ is determined uniquely by

$$\sum_{t=0}^{\infty}\delta^t\int_{\theta}\ \frac{\delta c_1(x^*,q_t(x^*,\theta_t),\theta_t)}{\delta x}dF=-1-\frac{\alpha}{1-\alpha} \tag{4}$$

Proof:

Since C(T,∞) is an exclusive contract for any future periods, the seller only needs to maximize its own payoff without any restrictions. By invoking the envelope theorem and differentiating U_i^S in (3), we obtain

$$(1-\alpha)[\sum_{t=0}^{\infty}\delta^t\int_{\theta}\ \frac{\delta c_1(x^*,q_t(x^*,\theta_t),\theta_t)}{\delta x}dF-1]-\alpha=0 \tag{5}$$

as the maximizing condition and the maximizer is unique since $c_1(x,q_t(x,\theta_t),\theta_t)$ is strictly convex in x. Rearranging (5) gives the expression above. Q.E.D.

By contrasting the equilibrium investment level in (4) to the optimal investment level given in (1), we can see that the seller underinvests by $\frac{\alpha}{1-\alpha}$. The alpha-bargaining process of dividing the total surplus distorts the seller's incentive to invest. The seller only obtains the fraction $(1-\alpha)$ of the return of investment compared to what it would have been in the vertically integrated system hence becomes reluctant to invest. The result has exactly the same implication as in the model of Grossman and Hart (1986) and Castaneda (2004).

Whether such an exclusive contract is implemented depends heavily on the outside option for both the buyer and the seller. The contract implements the relationship only if the payoff inside the relationship is larger than the outside option for both the seller and the buyer. Since the model assumed that only the buyer has access to the outside option, we only consider the condition for the buyer.

Proposition 1

There exists a transfer $T \in \mathbb{R}^+$ which implements the relationship if and only if

$$G(x^E) \geq H(x^*) - M$$

Proof:

The following condition must be satisfied in order for the buyer to fully procure the product from the seller.

$$\alpha G(x^E) - (1-\alpha)x^E - \sum_{t=0}^{\infty} \delta^t T \geq +H(x^E) - \frac{M}{1-\bar{q}}$$

$$(1-\alpha)G(x^E) - \alpha x^E + \sum_{t=0}^{\infty} \delta^t T \geq \lambda\left((1-\alpha)G(x^E) + \sum_{t=1}^{\infty} \delta^t T\right) - (\lambda - 1 - \lambda\alpha)x^E$$

The second condition for the seller is always satisfied since $\lambda \in [0,1]$. Therefore, there exists a transfer $T \in \mathbb{R}^+$ if and only if the total surplus for the whole system is larger than that of the outside option case. That is,

$$G(x^E) \geq \lambda G(x^E) + (1-\lambda)H(x^*) - M$$

Rearranging this gives the desired expression. Q.E.D.

3.4 Repeated game equilibrium

Now, I allow p, the number of the exclusive contract period to be different from infinity. The game becomes a repeated game between the seller and buyer. At the end of each contract, the buyer can choose to impose λ on the seller. With this setup, since seller always gets better payoff within the relationship, the seller always wants to maintain the relationship. By using backward induction, we can derive a subgame perfect Nash equilibrium.

Lemma 4

For contracts C(T,k) $k \neq \infty$, there exist a subgame perfect Nash equilibrium in which the investment level, denoted as x^E, is uniquely determined by

$$\sum_{t=0}^{\infty} \delta^t \int_{\theta} \frac{\partial c_1(x, q_t(x^*, \theta_t), \theta_t)}{\partial x} dF = -1 - \frac{\alpha(1-\delta^k) + \delta^k}{1 - \alpha(1-\delta^k)} \quad (\lambda \neq 1) \qquad (6)$$

Proof:

The above analysis shows that in a sub game perfect equilibrium, after the first contract, the buyer has to be indifferent between implementing the relationship and imposing λ. The condition is written as

$$\alpha G(x^E(k)) + \alpha x^E(k) - \sum_{t=k}^{\infty} \delta^{t-k} T_R$$

$$= \lambda\left(\alpha G(x^E(k)) - \sum_{t=k}^{\infty} \delta^{t-k} T_R\right)(1 + \lambda\alpha - \lambda)x^E(k) + (1 - \lambda)H(x^*) - M \quad (7)$$

where T_R is renegotiated transfer after k periods.

The seller maximizes the payoff subject to the condition in (7).

$$\max_x \quad (1-\alpha)G(x) - \alpha x + \sum_{t=0}^{k-1} \delta^t T(k) + \sum_{t=k}^{\infty} \delta T_R$$

Assuming $\lambda \neq 0$, the constraint (7) can be simplified to

$$\alpha G(x^E(k,\lambda)) - (1-\alpha)x^E(k,\lambda) - \sum_{t=k}^{\infty} \delta^{t-k} T_R = H(x^*) - \frac{M}{1-\lambda} \quad (8)$$

Substituting the constraint into the objective function yields

$$\{1 - \alpha(1-\delta^k)\}G(x) - \alpha(1-\delta^k)x - \delta^k x + A \text{ where } A = \sum_{t=0}^{k-1} \delta^t T(k) - \delta^k\{H(x^*) - \frac{M}{1-\lambda}\}$$

Optimizing the above function using envelope theorem leads to the desired expression. Q.E.D.

Lemma 5

For contracts C(k,T) $k \neq \infty$, the subgame perfect Nash equilibrium investment level $x^E(k,\lambda)$ has the following properties;

1, $\dfrac{dx^E(k,\lambda)}{dk} < 0$ (9)

2, $\dfrac{dx^E(k,\lambda)}{d\delta} > 0$ (10)

3, Other than $\lambda = 1$, the value of λ will not change $x^E(k,\lambda)$.

Proof:

By construction, c(x) is strictly increasing and convex. Hence,

$$\frac{dG(x)}{dx} < 0.$$

Therefore,

$$\frac{dx^E(k,\lambda)}{dk} = \frac{\frac{d}{dk}\left[\frac{\alpha(1-\delta^k)+\delta^k}{1-\alpha(1-\delta^k)}\right]}{\frac{dG(x)}{dx}} < 0$$

Similarly,

$$\frac{dx^E(k,\lambda)}{d\delta} > 0 \text{ as } \frac{\partial G}{\partial \delta} > 0$$

During the simplification process from (7) to (8), it was assumed that $\lambda \neq 1$. If $\lambda = 1$, then the solution becomes x^E for any k since there is no option for the buyer to change the allocation. If $\lambda \neq 1$, the equilibrium investment is $x^E(k,\lambda)$. Since $x^E(k,\lambda)$ does not have a term with λ, the investment level is independent of λ.

Q.E.D.

This result of the comparative statics reflects the buyer's penalization strategy. When the contract period is long, one strategy for the seller is to deviate from the optimal investment and let the buyer impose λ or offer lower transfer after k periods. Whether this strategy gives better payoff for the seller depends on k and δ, the discount factor. If discount rate is 0 ($\delta = 1$) or the seller puts equal importance on payoff today and the distant future, and there will not be any incentive for them to deviate because loss from imposing λ or lower transfer will persist throughout the game. When the contract period k is short, even with a positive discount rate, there will be less incentive for the seller to underinvest. The next proposition is about the efficiency of the subgame equilibrium.

Proposition 2

For contracts C(k,T) $k \neq \infty$, the subgame perfect Nash equilibrium investment level $x^E(k,\lambda)$ has the following properties;

1, $x^E(k,\lambda) > \underline{x^E}$ $\quad$ *if and only if* $\alpha > \frac{1}{2}$

2, $x^E(k,\lambda) < x^*$ for any k

Proof:

Using the analysis of the comparative statics in the Lemma 4, $\underline{x^E} < x^E(k,\lambda)$ if and only if

$$\frac{\alpha}{1-\alpha} > \frac{\alpha(1-\delta^k)+\delta^k}{1-\alpha(1-\delta^k)}$$

Solving the above gives the condition in Proposition 2.1.

By (9) in the Lemma 5, the subgame perfect equilibrium investment level $x^E(k,\lambda)$ reaches the maximum when k is approaching to 0. The investment level evaluated at the point is

$$\lim_{k\to 0}\sum_{t=0}^{\infty}\delta^t\int_{\theta}\frac{\partial c_1(x,q_t(x^*,\theta_t),\theta_t)}{\partial x}dF=-1-\frac{\alpha\left(1-\delta^k\right)+\delta^k}{1-\alpha(1-\delta^k)}$$

Comparing this to the social optimal investment, x^*, we have

$$\lim_{k\to 0}\frac{\alpha\left(1-\delta^k\right)+\delta^k}{1-\alpha(1-\delta^k)}=1>0$$

Therefore, $x^E(k,\lambda)<x^*$ for any k. Q.E.D.

The extended model has the same comparative statics as Castaneda (2004). However, the equilibrium result indicates the opposite. In particular, on the contrary to Castaneda (2004), the subgame perfect equilibrium investment level is always less than the social optimal investment regardless of the parameters. Moreover, this implies that the only condition needed for the buyer to ensure the improved investment from the seller over the complete exclusive contract situation is buyer's high bargaining power even though introduction of at least some competition is needed to avoid the case of complete exclusive contract.

The result indicates that the amount of competition does not have any effect on the equilibrium investment despite our intuitive belief that penalizing opportunistic behaviors more enables the buyer to have more bargaining power to make the seller invest optimally. This may be a result of the setup of the model. Since the buyer only has two options, imposing λ or not, and the seller is always worse off if the buyer chooses to impose λ, the seller always tries to avoid such situations. Therefore, the value of λ becomes irrelevant from the seller's perspective.

Nevertheless, the efficiency condition in Proposition 2.1 makes sense in the *keiretsu* relationship since in most of the *keiretsu* relationships, the parent company is larger than the child company. Therefore we expect the parameter α to be large. Furthermore, supply of some car parts is sometimes dominated by a single company. For example, in 1992, about 75% of the demand for electronic control unit (ECU) for fuel injection system by Toyota was supplied only through Denso (Yunokami 2011). Although the share of demand does not directly translate to the parameter λ, we can expect the value to be large.

Technically, the value of λ can be determined through finding a subgame perfect Nash equilibrium for an extension to the 2 players model which introduces the cost difference and internalization of λ. The model will be discussed in the next chapter.

4. Extension to the model

4.1 Setup of the game

The extension to the model internalizes the determination of λ by having two sellers that compete with each other. These companies differ in the cost structure but have the same level of bargaining power over the surplus. The setup relaxes the assumption made in the original model with a hypothetical seller which always invests optimally. Moreover, this model allows the buyer to freely choose λ at the end of each contract period. However, I introduce a switching cost to penalize rapid movements in λ. Because of the nature of multivariate optimization and the lack of functional form assumed in the model, it is hard to obtain the closed form result for the game. Some implication can be drawn from the model. The extended model may also give more implication about λ which had almost no effect on the investment level in the original model.

The cost for the first seller to produce q_{1_t} unit in the state of world θ_t is denoted as $c_1(x_1, q_{1_t}, \theta_t)$ where x_1 is the investment level undertaken by the seller one. Let $c_2(x_2, q_{2_t}, \theta_t)$ be the cost function for the second seller.

Let the surplus function in the relationship between the buyer and seller 1 be

$$\mathrm{G}(\mathrm{x}_1) = \sum_{t=0}^{\infty} \delta^t \int_{\theta} v\big(q_{1_t}(x_1, \theta_t), \theta_t\big) - c_1\big(x_1, q_{1_t}(x_1, \theta_t), \theta_t\big) dF - x_1$$

and the surplus in relation between the buyer and seller 2 be

$$\mathrm{H}(\mathrm{x}_2) = \sum_{t=0}^{\infty} \delta^t \int_{\theta} v\big(q_{2_t}(x_2, \theta_t), \theta_t\big) - c_2\big(x_1, q_{2_t}(x_2, \theta_t), \theta_t\big) dF - x_2$$

We assume the following properties:

For any $\theta_t \in \Theta$

1. $v(\cdot, \theta_t): \mathbb{R}_+ \to \mathbb{R}_+$ is continuously differentiable, increasing, and strictly concave.

2. $c_1(\cdot,\cdot, \theta_t): \mathbb{R}_+ \times \mathbb{R}_+ \to \mathbb{R}_+$ is continuously differentiable, decreasing in x_1, increasing and linear in q_1, and strictly convex in x_1.

3. $c_2(\cdot,\cdot, \theta_t): \mathbb{R}_+ \times \mathbb{R}_+ \to \mathbb{R}_+$ is continuously differentiable, decreasing in x_2, increasing and linear in q_2, and strictly convex in x_2.

The assumption changed from the original model by having linear cost function. The cost function is strictly convex in investment so the optimal investment level is uniquely determined.

The extended model has a similar structure to the original model. However, the buyer now can set the allocation variable λ so that the payoff for the buyer is maximized. Moreover, the buyer only determines total demand for the good instead of individual demand.

The structure of the game is as follows:

1. Contract Period. The buyer and the sellers can bargain over the contract which determines the form of the relationship. After the bargaining, the seller i invests x_i and the buyer determines the initial allocation λ_0.

2. Each period $t \in N$ has 4 sub-periods.

   i. The buyer may change the allocation variable $\lambda \in [0,1]$, the fraction of total demand which she is going to buy from the seller 1 in this period. However, she must incur the cost $M(\Delta\lambda)$ where $\Delta\lambda$ is the change in λ.

   ii. Nature determines the state of the world θ_t.

   iii. The buyer and the sellers bargain the price and quantity for the trade in this period. The buyer decides the total demand Q_t, not the individual demand q_{i_t} The output level for seller 1 q_{I_t} is determined automatically by $q_{1_t} = \lambda Q_t$. Similarly, the output level for the seller 2 is $q_{2_t} = (1-\lambda)Q_t$.

iv. The sellers produce the output and the payoff for the buyer and the sellers are realized.

To define the social optimal investment, I let $K(\lambda)$ be the total surplus in the system. Since $G(x_1)$ and $H(x_2)$ are linear, the function is defined by

$$K(\lambda, x_1, x_2) = \lambda G(x_1) + (1-\lambda)H(x_2)$$

The social optimal investment involves the Pareto optimal allocation and it is obtained by maximizing $K(\lambda, x_1, x_2)$. Due to the complexity of multivariate optimization, the solution may not be a linear combination of (1) similarly to the single seller case and the closed form solution may be hard to obtain. If both sellers have access to the same technology, from a socially optimal perspective, the choice of λ will not matter as products of seller 1 and seller 2 are perfect substitutes. If one dominates the other in terms of the cost structure, the value of λ that the buyer determines favors the seller with better cost structure.

4.2 Equilibrium

Method of backward induction is used to solve for the subgame perfect Nash equilibrium. For the first seller, they want to maximize the payoff

$$\max_{x} \lambda\left((1-\alpha)G(x_i) + \sum_{t=1}^{k-1} \delta^t T_1 + \sum_{t=k}^{\infty} \delta T_{1_R} \right) - (\lambda - 1 - \lambda\alpha)x_1$$

subject to the condition that the buyer will not choose allocation unfavorable to them at the end of the first contract in time k. That is,

$$\alpha K(\lambda_0) + (\lambda_0 - 1 - \lambda_0\alpha)x_1 + (-\lambda_0 - (1-\lambda_0)a)x_2 + \lambda_0 \sum_{t=1}^{k-1} \delta^t T_1 + \lambda_0 \sum_{t=k}^{\infty} \delta^t T_{R_1} + (1-\lambda_0) \sum_{t=0}^{k-1} \delta^t T_2 + (1-\lambda_0) \sum_{t=k}^{\infty} \delta^t T_{R_2}$$

$$= \alpha K(\lambda') + (\lambda' - 1 - \lambda'\alpha)x_1 + (-\lambda' - (1-\lambda')a)x_2 + \lambda_0 \sum_{t=1}^{k-1} \delta^t T_1 + \lambda' \sum_{t=k}^{\infty} \delta^t T_{R_1} + (1-\lambda_0) \sum_{t=1}^{k-1} \delta^t T_2 + (1$$

$$- \lambda') \sum_{t=k}^{\infty} \delta^t T_{R_2} - M(\lambda_0 - \lambda) \;\; for\ any\ \lambda < \lambda_0$$

The coefficients on x_1 and x_2 are derived similarly to the Lemma 1.

Since the buyer's choice of λ depends on the sellers' investment decisions on x_1 and x_2, solving the constrained optimization problems gives a set of best response function, $x_1^*(x_2), x_2^*(x_1)$. Therefore, solving the system of equation gives the equilibrium decision of $x_1, x_2,$ and λ. As the model does not assume any functional form, similarly to the derivation of the social optimal, it is hard to derive a closed-form solution to this. However, if we consider the simplest case where $c_1 = c_2$ and M=0 for any λ, this model becomes similar to the Bertrand model, and the optimal decision for the sellers is to invest optimally since the buyer will always choose $\lambda = 1$ when $x_1 > x_2$ as $c_1(x_1, q) < c_2(x_2, q)$ for any q and vice versa. If we introduce different technology and some switching cost, working through the optimization becomes tedious. Moreover, it is impossible to determine λ unless we assume some decision rule. This extended model adds much more flexibility over the original model. Due to the limitation of my background knowledge as well as the complexity of the model, I will leave the analysis of the extended model in more general cases to future research

5. Conclusion

This thesis attempts to improve the current hold-up models in order to better describe the *keiretsu* system, the Japanese style of non-vertical integrated model. This is done by adding an allocation variable λ to the repeated hold-up model proposed by Castaneda (2004). The additions are meant to capture characteristics of the *keiretsu* relationship, such as loose initial contracts and repeated nature of the relationship, which are left uncaptured by the original hold-up framework by Grossman and Hart (1986).

By solving for a subgame perfect Nash equilibrium for the model, it is shown that the *keiretsu* style relationship is likely to improve efficiency of the whole system, measured by the level of investment, when compared to a complete non-vertical integration system without any outside option. The efficiency condition found in the thesis does not involve the allocation variable λ, which reflects the amount of competitiveness within the system. Contrary to the findings of Castaneda (2004), the investment level is always less than the social optimal level which maximizes the surplus among the upstream firms. The model proposed by this thesis still has its limitations such as the exogeneity of λ and, the hypothetical outside seller which invests optimally without any incentives. To further examine the efficiency of the *keiretsu* system, my future studies will focus on the internalization of the allocation variable, by introducing strategic competition to the upstream sellers.

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