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# Pricing Strategy for Resalable Intellectual Properties: A Game Theoretic Approach

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論 文 要 旨

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（論文題名）

Pricing Strategy for Resalable Intellectual Properties:
A Game Theoretic Approach

（内容の要旨）

The aim of our research is to estimate the maximum amount of revenue that a firm can gain from trading its resalable intellectual property as a stable negotiation outcome of sequential trades of the information comparing to an initial state where there is only one firm which has the information, and we discuss conditions that how many players the firm should sell the information to.

Resalable intellectual property is defined as expertise that is not be protected as a patent such as trade secrets, methodological know-how, and personal insights that is not known publicly.

As a result of our research, we show that: 1) the diffusion process stops at some points where any informed player does not have incentive to sell the information even at the highest price that all uninformed players can offer; 2) if the initial owner of information has an incentive to sell the information to some players at which maximizes the player's payoff, the player should sell the information to them; and 3) if the initial owner cannot maximize its payoff even though the player sells the information to some players and obtains some profits of the trade, the player should keep the information in secret.

Though intellectual property is a source of business activity, once it is publicly known, its right will no longer be protected, and thus a firm needs to consider how to handle intellectual property carefully how much the value and the price will be and how much a firm eventually obtains as a consequence of trading. Our research shows that if an overall profit of the trade surpasses a profit obtained by monopoly trade, a firm should sell the information. In contrast, if a firm cannot maximize its profit by the trade, the information should be kept within the firm.

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# 1. Introduction

The aim of this research is to estimate the maximum amount of revenue that a firm can gain from trading its resalable intellectual property as a stable negotiation outcome of sequential trades of the information.

According to the Intellectual Property Basic Act[1], the term "intellectual property" shall mean inventions, devices, new varieties of plants, designs, works and other property that is produced through creative activities by human beings, trademarks, trade names and other marks that are used to indicate goods or services in business activities, and trade secrets and other technical or business information that is useful for business activities. According to the paragraph 6 in Article 2 of the Unfair Competition Prevention Act[2], the term "trade secret" shall mean a production method, sales method, or any other technical or operational information useful for business activities that is controlled as a secret and is not publicly known, and thus publicly known trade secrets will no longer be the intellectual property.

If intellectual property cannot be protected when its know-how is publicly known, a firm has to control their trade secrets in their business activities otherwise the intellectual property right will no longer be applicable. Hence the value of the intellectual property that a firm has developed for years needs to be estimated and priced before it is sold to others to capture the maximum value.

Even though we make a non-disclosure agreement with customers, we cannot

1 See Intellectual Property Basic Act in Japan
http://www.japaneselawtranslation.go.jp/law/detail_main?vm=&id=129
2 See Unfair Competition Prevention Act in Japan
http://www.japaneselawtranslation.go.jp/law/detail_main?id=83&vm=4&re=

monitor all the activities whether the customers keep the firm's intellectual property. However, we assumed that if we properly manage a price of the intellectual property, we can both control its diffusion in order to keep it in secret and maximize its profit. This assumption is the background of our research and we can show that if we set a price of an intellectual property at an optimal level and sell the information to only limited number of people as an optimal solution obtained in our model, we can prevent further diffusion while maximize profit.

Since our model is a versatile model which is applicable to various industries, we can use this model in many service industries such as interpretation, translation, preparatory school, consulting, or investment bank, where their source of profit depends on their intellectual properties. Albeit many researchers try to find out how to plan a pricing strategy to determine a price of a product or a service, it was quite difficult to estimate the customer's true willingness to pay which even the customer has not perceived yet. Hence, our research helps managers plan a pricing strategy.

In prior research, there are some models that incorporated a trade of intellectual property formalized by Muto (1986), Nakayama et al. (1991), and Muto and Nakayama (1992). There are several characteristics of the information trade: 1) free replication; 2) indivisibility; 3) irreversibility; and 4) negative external effect (Muto 1986). When the diffusion of the information stops based on their profits where the payoff of informed player decreases when the number of informed player increases (Muto, 1989; Muto and Nakayama, 1988). Nakayama et al. (1991) showed that oligopolistic players can exploit all the profits in a resale-proof trade, a trade such that no buyer has an incentive to resell the information after acquiring it even when a resale is freely allowed, pointing that this self-binding trade is indispensable especially in the case of a technical know-how. In the previous assumption, the technology information, whose demanders are geographically separated and thereby its external effects are negligibly small (Muto 1986). In terms of profits, they assumed that a profit for uninformed players is zero, meaning there is no negative externality of the information, which is a process where those who do not possess a certain type of information incur the more loss than those who have the information. This loss occurs due to the increase of competition and the loss of customers. That is why we took into account the negative externality of information influencing uninformed agents (Watanabe 2018) in order to incorporate the loss of profit by doing nothing or staying the same.

In this paper, we assume that the maximum payoff of the initial owner of information at a maximum price of the information as a solution of a bargaining set. We also consider several decision making processes whether any of the players purchases or sells the information to increase the player's payoff. Then, with backward induction, a process of reasoning from the end of a situation to determine a sequence of optimal actions, a firm can expect a most preferable outcome before selling the information.

As a result of our research, we show that: 1) the diffusion process stops at some points where any informed player does not have incentive to sell the information even at the highest price that all uninformed players can offer; 2) if the initial owner of information has an incentive to sell the information to some players at which maximizes the player's payoff, the player should sell the information to them; and 3) if the initial owner cannot maximize its payoff even though the player sold the information to some players and obtains some profits of the trade, the player should monopolize the information.

The advantages of this strategy have two-folds. First, a firm can control a diffusion process by themselves. Second, a firm can capture a value of the information internally. Given that a proper pricing strategy prevents further diffusion of the information, our research paves a new way to protect intellectual property while the owner can maximize its payoff. Hence, this approach can be a standard practice in service industry where its business mainly relies on intellectual property such as interpreting agents, preparatory schools, or consulting firms.

The outline of this paper is as follows. The model, key ideas, and formal definitions are explained in Chapter 2 and two propositions are shown in Chapter 3, including several examples with different profits. Concluding remarks and issues for further research have been described in Chapter 4. General information regarding both interpretation, translation industry and other similar service industry is summarized in the Appendix.

# 2. Model

The model described here is formalized by Watanabe (2018). Let $N = \{1,2,\dots,n\}$ be the finite set of agents (players), where player 1 is an initial owner of information, and player 2, ..., and player $n$ are its potential demanders.

In our model, there are several key assumptions as follows:

1) Profits that players can gain by utilizing the information depend only on the number of informed players.
2) The value of information to each informed player never increases.
3) A negative externality to each uninformed player increases as the

information further diffuses.

4) For every player m, the values of $W(m)$ and $L(m)$ are commonly known to all the players.
5) Resales are freely allowed.
6) A player's payoff does not increase when others resell the information

Let $W(m)$ denote the profits to each informed player and $L(m)$ denote the one to each uninformed player when the information is shared by m players;

$$W(1) \geq W(2) \geq \cdots, \geq W(n) > L(1) \geq L(2) \geq \cdots, L(n-1) \geq 0.$$[3]

$L(n-1)$ represents that if all players obtain the information, there is no $L(n)$, and thus the maximum number of uninformed player is $L(n-1)$. In addition, it is greater or equal to zero, meaning even uninformed player can obtain profit to some extent in this model.

## Key Idea

Consider the beginning of trades, only one informed player, player 1, gains $W(1)$ and the other players gain $L(1)$. This is called the initial state and denoted by $[\{1\}; x^0]$,

[3] This means for all players, payoff increases when they have the information but the benefit of the information differs respectively. In addition, even though a player did not have the information, the player will not incur the loss by the definition.

where $x_0 = (x_i^0)_{i \in N}$ is a vector of payoffs given by

$$x_i^0 = \begin{cases} W(1) & \text{for } i = 1; \\ L\,(1) & \text{for } i \neq 1 \end{cases}$$

Suppose a group of players $\{1\} \cup \mathrm{S}$, where $\mathrm{S} \subseteq \mathrm{N} \setminus \{1\}$, starts negotiations on how to share the total profit produced by sharing player 1's information within $\{1\} \cup \mathrm{S}$. Let $y = (y_{i \in \{1\} \cup S})$ be a vector of payoffs in $\{1\} \cup \mathrm{S}$, where

$$y_i = W(1+s) + p_i$$

for all $i \in S$ where $p_i$ denotes the amount of money that player *i* gains from or pays to members of $\{1\} \cup \mathrm{S}$ and $\mathrm{s} = |\mathrm{S}|$. We say that a vector $y$ of payoffs is an $\{1\} \cup \mathrm{S}$-imputation at the initial state $[\{1\}; x^0]$ if the following conditions are satisfied[4];

$$\textstyle\sum_{i \in \{1\} \cup S} p_i = 0 \text{ (balancedness in } \{1\} \cup \mathrm{S})$$

and

$$\mathrm{y}_i \geq x_i^0 \text{ for all } i \in \{1\} \cup S \text{ (individual rationality of } i \in \{1\} \cup \mathrm{S}.$$

Suppose that members in $\{1\} \cup \mathrm{S}$ reach a particular $\{1\} \cup \mathrm{S}$-imputation $\mathrm{y}^*$ in

4 This means that total amount of the money that players earned or payed equals to zero. In addition, since there is no trade yet, nobody gains nothing. Furthermore, it is rational that nobody purchases the information unless it is worthwhile of buying. In other words, any trade for any player makes more money than the previous status; otherwise the player refuses to purchase it.

negotiations and they share the information as a result. Otherwise, for all $i \in S$, in case of $y_i < x_i^0$, the $i$ does not disclose the information as a result. Then, we have a new state $[\{1\} \cup S;\ x^1]$, where $\{1\} \cup S$ is the set of informed players and $x^1 = (x_i^1)_{i \in N}$ is the vector of payoffs given by

$$x_i^1 = \begin{cases} y_i^* = W(1+s) + p_i^* & \text{for any } i \in \{1\} \cup S; \\ L(1+s) & \text{for any } i \notin \{1\} \cup S. \end{cases}$$

The interpretation of $L(1+s)$ is that as the number of informed player increases, the payoff for those who does not possess the information decreases.

If $\{1\} \cup S = N$, then trading is over since all players have obtained the information. Otherwise, there exists a possibility of the second resale by a member of $\{1\} \cup S$, and thus trade may continue in a similar way as above.

Suppose, at the state $[\{1\} \cup S;\ x^1]$, a group of players $Q$ consisting of both informed and uninformed players, i.e., $Q \cap (\{1\} \cup S) \neq \emptyset$ and $Q \cap (N \setminus (\{1\} \cup S)) \neq \emptyset$, starts negotiation on a resale. Let $T = Q \cap (\{1\} \cup S)$ denote the set of informed players in $Q$, and let $R = Q \cap (N \setminus (\{1\} \cup S))$ denote the set of uninformed players in $Q$.

Let $y = (y_i)_{i \in Q}$ be a payoff vector in $Q$ which is given by

$$y_i = \begin{cases} W(1+s+r) + p_i^* + q_i & \text{for any } i \in T; \\ W(1+s+r) + q_i & \text{for any } i \in R, \end{cases}$$

where $s = |S|$, $r = |R|$, and $q_i$ is the amount of money that player $i$ gains from or pays to members of $Q$. We say a payoff vector $y$ is a Q-imputation at the state $[\{1\} \cup S;\ x^1]$, if it satisfies the balancedness in Q and individual rationality of $i \in Q$;

$$\sum_{i \in Q} q_i = 0 \ \ and\ y_i \geq \ x_i^1 \text{ for all } i \in Q.$$

Suppose that members in $Q$ agree upon a particular Q-imputation $y^*$; and they share the information. Then, we reach another state $[\{1\} \cup S \cup R;\ x^2]$, where $x^2 = (x_i^2)_{i \in N}$ is the payoff vector given by

$$x_i^1 = \begin{cases} y_i^* = W(1+s+r) + p_i^* + q_i^* & \text{for any } i \in T; \\ y_i^* = W(1+s+r) + q_i^* & \text{for any } i \in R \\ W(1+s+r) + p_i^* & \text{for any } i \in (\{1\} \cup S \setminus T; \\ L(1+s+r) & \text{for any } \ i \in \big(N \setminus (\{1\} \cup S)\big) \setminus R. \end{cases}$$

If $\{1\} \cup S \cup R = N$ then trading is over. Otherwise, trading may continue because of a possibility of further resales. Suppose, on the other hand, that members in Q cannot agree upon a particular Q-imputation $y^*$. Then, reselling the information will stop and the state $[\{1\} \cup \mathrm{S};\ x^1]$, where $x^1 = (x_i^1)_{i \in N}$ is the outcome of this sequential trades.

To analyze this situation, we consider whether a state $[M; x]$, where $M = \{1\} \cup S$, is stable in the sense that for any objection of an arbitrary player $i \in Q$ against another player $j \in Q \setminus \{i\}$ in $x$ there exists a counter objection of $j$ against $i$.[5]

[5] This stability notion is called a bargaining set (Aumann and Maschler, 1963).

## Formal Definitions

Suppose that all players have obtained player 1's information. Let $x = (x_i)_{i \in N}$ be a payoff vector associated with *n* where $x_i = W(n) + p_i$ and $p_i$ denotes the net amount of money that player *i* has gained or paid up to that time. We say a payoff vector $x$ is balanced in $N$ if

$$\sum_{i \in N} p_i = 0$$

i.e., $\sum_{i \in N} x_i = nW(n)$. We call a pair of the set of informed players $N$ and an associated balanced payoff vector $x$, a state, and denote it by $[N; x]$. If all players obtained the information and further an associated payoff vector is balanced, this state will last. Thus, we say that the state $[N; x]$ is stationary for each balanced payoff vector $x$ associated with $N$.

When some players do not have the information, we hereafter denote a state by $[M;\ x]$. $M$ is a set of informed players, and $x$ is a vector of payoffs given by

$$x_i = \begin{cases} W(m) + p_i & \text{for all } i \in M; \\ L(m) & for\ all\ i \in N \setminus M, \end{cases} \tag{1}$$

which meets the balancedness in $M$: $\sum_{i \in M} p_i = 0$ or $\sum_{i \in M} x_i = mW(m)$. Here, $m = |M|$, and $p_i$, is the net amount of money that $i$ gained or paid before the state is reached.

Let $\Delta(M) = \{q \subseteq N : Q \cap M \neq \emptyset \ and \ Q \cap (N \setminus M) \neq \emptyset\}$. For each $Q \in \Delta(M)$, let

$$Q^M = Q \cap M \text{ and } Q^{-M} = Q \cap (N \setminus M),$$

And let $y^Q$ be a vector of payoffs in $Q$ given by

$$y_i = \begin{cases} W(m + q^{-M}) + p_i + p_i^Q & \text{for all } i \in Q^M; \\ W(m + q^{-M}) + p_i^Q & \text{for all } i \in Q^{-M}, \end{cases}$$

Where $q^{-M} = |Q^{-M}|$ and $p_i^Q$ is the amount of money that $i$ gains from or pays to the members in $Q$. We say that a vector of payoffs $y^Q$ is a Q-imputation in $[M, x]$ if $\sum_{i \in Q} p_i^Q = 0$ and $y_i^Q \geq x_i$ for all $i \in Q$.

For each $Q \in \Delta(M)$, if all members of $Q$ agree upon a Q-imputation $y^Q$ and resale is carried out, then the information is shared by members of $M \cup Q^{-M}$ and a new vector of payoffs $z = (z_i)_{i \in N}$ is given by

$$z_i = \begin{cases} W(m + q^{-M}) + p_i + p_i^Q & \text{for any } i \in Q^M; \\ W(m + q^{-M}) + q_i^Q & \text{for any } i \in Q^{-M}; \\ W(m + q^{-M}) + p_i & \text{for any } i \in M \setminus Q^M; \\ L(m + q^{-M}) & \text{for any } i \in (N \setminus M) \setminus Q^M. \end{cases}$$

Since $\sum_{i \in M} p_i = 0$ and $\sum_{i \in Q} p_i^Q = 0$, z is a vector of payoffs that is balanced in $M \cup Q^{-M}$. Thus, we have a new state $[M \cup Q^{-M}, z]$.

For each $Q \in \Delta(\mathrm{M})$, we say that a Q-imputation $\mathrm{y}^Q$ in $[M\,; x]$ is valid if a new state $[M \cup Q^{-M}, z]$ included by $y^Q$ is stationary. Take a valid Q-imputation $y^Q$ and take two members $i$ and $j$ of $Q$ arbitrarily. We say that $i$ has an objection $(K, y^K)$ against $j$ in $y^Q$, if there exists a set $K \in \Delta(M)$ with $i \in K$ and $j \notin K$ and a valid $K$-imputation $y_i^Q$ such that

$$y_i^K > y_i^Q,$$

$$y_j^K > y_j^Q \text{ for all } i \in K \cap (Q \setminus \{i\}).$$

For this objection, we say that $j$ has a counter objection $(L, y^L)$against $i$, if there exists a set $L \in \Delta(M)$ with $L \in \Delta(M)$ $i \notin L$ and $j \in L$ and a valid L-imputation $y^L$ such that

$$y_i^L > y_i^K \text{ for all } i \in K \cap L,$$

$$y_j^L > y_j^Q \text{ for all } j \in (L \setminus K) \cap Q.$$

A valid Q-imputation $y^Q$ is stable, if for each $i,\ j \in Q(i \neq j)$ and each objection of $i$ against $j$ in $y^Q$ there exists a counter objection of $j$ against $i$. A state $[M\,; x]$ is called stationary, if no set $Q \in \Delta(M)$ has a stable Q-imputation in $[M\,; x]$. We complete the definitions of our solution concept hereby.

# 3. Results

For simplicity, the price of the information is the highest possible one in the case of resale. Let $m(0) = n$. Then, let $m(1)$ be the largest integer m that satisfies $2 \leq m \leq$

$m(0) - 1$ and

$$\mathrm{W(m) \geq W(n) + (m(0) - m)\big(W(n) - L(m)\big),} \tag{2}$$

and let m(2) be the largest integer that satisfies $\mathrm{2 \leq m \leq m(1) - 1}$ and

$$\mathrm{W(m) \geq W(m(1)) + (m(1) - m)\big(W(m(1)) - L(m)\big),}$$

i.e.,

$$W(m) - L(m) \geq (m(1) - m + 1)(W\big(m(1)\big) - L(m))$$

Define $m(2), m(3)$, ..., in a similar manner. In general, $m(r)$ is defined as the largest integer that satisfies $2 \leq m(r) \leq m(r-1) - 1$ and

$$W(m) - L(m) \geq (m(r-1) - m + 1)(W(m(r-1)) - L(m)). \tag{3}$$

For all $m = 1, \dots, n$, let $E(m) = W(m) - L(m)$, where $E(n) = W(n)$

By the definition, $m(1)$ is the largest integer that satisfies $2 \leq m \leq n - 1$ and (1). No resale will carried out when $m = m(1)$. When $m(r) > m(1)$, the seller's payoff increases by reselling it to all remaining uninformed players, and thus resale will be carried out. In general, if the information is shared by more than $m(r)$ players, say $m(r) + k\big(< m(r-1)\big)$ with $k \geq 1$, the seller's payoff increases by reselling it to $m(r-1) - k$ uninformed players, and thus resale will be carried out.

Let $m(r^*)$ be the minimum integer of $m(r)$ defined in such a way that described above. Note that if $E(m) < (n-m+1)E(n)$ for all $m$ with $1 \leq m \leq n-1$, then $m(r^*) = n = m(0)$. It is now ready to state our main propositions. See Watanabe (2018) for the proofs.

**Proposition 1**

*Suppose that* $E(1) \geq E(2) \geq \cdots E(n)$. *Then, for any state* $[M, x]$, *where* $\{1\} \subset M \subseteq N$ *and* $x$ *is a vector of payoffs that is balanced in* $M$, *if* $|M| = m(r)$ *for some* $r = 1, \ldots, r^*$, *then* $[M, x]$ *is stationary; otherwise, not.*

This proposition explains that every player *m* does not have any incentive to diffuse the information unless that the player can increase its payoff by selling the information to others. Moreover, when the total number of informed player is $m(r)$, the diffusion process stops at $m(r)$. Thus, the state $[M, x]$ becomes stationary.

**Proposition 2**

*(1) Suppose that* $E(1) \geq E(2) \geq \cdots E(n)$ *and* $E(1) < m(r^*)E(m(r^*))$. *If* $m(r^*) = n$, *then the information will be eventually shared by all players, i.e.,* $[N, x^N]$ *is the only stationary state, where* $x^N$ *is an arbitrary N-imputation in* $[N, x^N]$. *If* $m(r^*) < n$, *then the information will be shared by* $m(r^*)$ *players, i.e.,* $[M, y]$ *is the stationary state, where* $|M| = m(r^*)$ *and y which gives the highest possible payoff for player 1 is as follows;*

$$y_i = \begin{cases} m(r^*)(W(m(r^*)) - L(m(r^*)) & \text{for } i = 1; \\ L(m(r^*)) & \text{for any } i \in N \setminus \{1\}. \end{cases}$$

*(2) Suppose that* $E(1) \geq E(2) \geq \cdots E(n)$ *and* $E(1) \geq m(r^*)E(m(r^*))$*. Then, the information will be kept by player 1. Namely, the initial state* $[\{1\}, x^0]$ *is stationary.*

The interpretation of $m(r^*)(W(m(r^*)) - L(m(r^*)))$ is that for any uninformed player m, the current payoff is $L(m)$ but if the player could manage to obtain the information, the payoff will eventually become $W(m)$. That means the difference between $W(m) - L(m)$ is the value of the information. In other words, the willingness to pay of the information for player $m$ can be shown $W(m) - L(m) = E(m)$. This is applicable to all the players instead of player 1. Since player 1 does not disclose the information as many players as $|M| = m(r)$, the total value that player 1 capture is $m(r^*) \times E(m(r^*))$. If $E(1) \geq m(r^*)E(m(r^*))$, which means the player 1 is in the situation where the player 1 cannot increase the payoff even after the trade of the information, the player 1's optimal behavior is not to share the information to other players at all shown in (2). If $E(1) < m(r^*)E(m(r^*))$, the player 1 can increase its payoff by sharing and selling the information as many as $m(r^*)$ players and obtains $m(r^*)E(m(r^*))$ in total.

## Example 1

In order to maximize the player 1's payoff, we compute the optimal reaction with an example. The benefit of this example enables us to comprehend the managerial decision making process with backward induction used in game theory more clearly. Suppose we estimated the following profits, which is based on the introduced model where each profit decreases when the information diffuses and those who do not possess the information have lower profit due to the negative externality of the information as mentioned in the introduction.

$$W(1) = 150, \quad W(2) = 120, \quad W(3) = 100, \quad W(4) = 80, \quad W(5) = 60$$
$$L(1) = 50, \quad L(2) = 40, \quad L(3) = 20, \quad L(4) = 10, \quad L(5) = 0$$

Let $m(0) = 5$. Find the largest integer $m$ such that $2 \leq m \leq m(0) - 1$ and

$$W(m) \geq W(5) + (5 - m)(W(5) - L(m))$$

which was defined as (1).

When $m = 4$, $W(4) = 80$ but $W(5) + (5 - 4)(W(5) - L(4)) = 110$, and thus (1) does not hold. When $m = 3$, $W(3) = 100$ but $W(5) + (5 - 3)(W(5) - L(3)) = 140$, and thus (1) does not hold also with m=3. When $m = 2$, $W(2) = 120$ and $W(5) + (5 - 2)(W(5)) - L(2)) = 120$, and thus $m(1) = 2$. Therefore, $m(r^*) = 2$ and the initially informed player 1 eventually obtains $\mathrm{m}(r^*)W(m(r^*)) - L(m(r^*)) = 2(W(2) - L(2)) = 160$ at most, which is more than the amount player 1 would obtain at $m = 1$. Note that the total sum of profits (producer surplus) is maximized at $m = 1$, which is $W(1) + 4L(1) = 150 + 4 * 50 = 350$. In this example, the producer surplus is not maximized by resale of the information.

As such, the initial owner of the information can maximize its payoff by sharing the intellectual property to two demanders and obtain 160 in maximum profit.

## Example 2

As an example of a situation in which the initial owner of the information should not disclose the information to maximize its payoff, let the profit be as following:

$$W(1) = 110, \quad W(2) = 100, \quad W(3) = 90, \quad W(4) = 80, \quad W(5) = 70$$
$$L(1) = 60, \quad L(2) = 50, \quad L(3) = 40, \quad L(4) = 30, \quad L(5) = 0$$

Let $m(0) = 5$. Find the largest integer m such that m satisfies the following conditions.

$$2 \leq m \leq m(0) - 1 \text{ and}$$
$$W(m) \geq W(n) + (m(0) - m)(W(n) - L(m))$$

which was defined as (1).

When $m = 4$, $W(4) = 80$ but $W(5) + (5 - 4)\big(W(5) - L(4)\big) = 110$, and thus (1) does not hold. When $m = 3$, $W(3) = 90$ but $W(5) + (5 - 3)\big(W(5) - L(3)\big) = 130$, and thus (1) does not hold. When $m = 2$, $W(2) = 100$ but $W(5) + (5 - 2)\big(W(5) - L(2)\big) = 130$, and thus (1) does not hold. Since $2 \leq m$, there is no $m$ that satisfies the condition. Hence, the agent 1 can maximize its profit by keeping it in secret.

Even though resale is freely allowed, it is not a good strategy for player 1 to sell the information to other players in order to maximize its payoff. Another solution is that based on the estimation, the player 1 should offer to make a contract with a condition not to sell the information to other players. By the contract, the diffusion of the information can be stopped. Other than that, the player 1 can add the expected profit that other players can obtain by selling the information during a trade in advance with backward induction. Hence, player 1 should take any of these measurements to maximize its payoff.

# 4. Concluding Remarks

This paper studied the maximum amount of revenue that an initial owner of an intellectual property can gain as a consequence of trading. We showed that the diffusion process stops at certain points called $m(r)$ where no one makes a deal for the information due to the lack of incentive in either way. Especially, when there are informed players as many as $\mathrm{m}(r^*)$, a minimum integer of $m(r)$, the payoff of the initial owner of the information maximizes. If the initial owner of information can increase its profit by selling it and when the number of informed player is as many as the total number of players, the information will be eventually shared by all players and when the informed player is less than the total number of players, the information will be shared by $m(r^*)$ players. In Contrast, if the initial owner of information cannot increase its profit by selling it, the information will be kept by the initial owner of information and thus there will be no trade at all.

One of the advantages of this model is that this model can cope with irreversibility of an information trade. In terms of traditional pricing strategy model, a firm sets different prices and analyzes the results, finding out an equilibrium where the firm can maximize its profit. In this case, there is a risk of diffusion of the information once the firm sells the good. However, our model can prevents the deterioration of the value of the intellectual property in a decision making process. That is why this model is very practical.

Although this model is versatile, there are some limitations. First, we have not computed the minimum profit yet. If we could compute the minimum payoff based on accounting data, we can seek a possibility to increase a price of a good. Second, we have not developed a model how to estimate the profit of $W(m)$ and $L(m)$ yet. If we could include at least some major factors that affect to the revenue or the profit, we can show a detail model applicable in a certain industry such as interpretation industry that the author belongs to. Last but not least, we have not assumed different types of orders of profit. If we could change the order of profits, the initial owner of an intellectual property should always sell it.[6] In other words, if we cannot increase a value of an intellectual property unless some other players use it, the owner of the information may diffuse the information to some extent. These new assumptions might change the results. These limitations could be potential themes for further research.

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[6] For instance, suppose $N = 1,2, \ldots, s, \ldots n$ and there is a peak of the payoff such that $W(s)$ between $W(1)$ and $W(5)$, conditions and results may differ. e.g. $W(1) < W(2) < W(s) > \cdots \geq W(n) > L(1) \geq L(2) \geq \cdots \geq L(n-1) \geq 0$.

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