Patent Licensing : A Game Theoretic Analysis

Shigeo MUTO
(Tokyo Institute of Technology, Japan)

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Overview

A patent holder → Firms

New technology
- cost-reducing
- new product

Inside or Outside
- the product market

Licensing

Fee (lump-sum)
Royalty (per unit production)
Auction

Open trading (take-it or leave-it)
Negotiation

Strategic interaction in licensing

Oligopoly (duopoly)
- Cournot (quantity-setting)
- Bertrand (price-setting)

Homogeneous goods
Differentiated products

Strategic interaction in the product market

Game Theory

Outline of the Talk

Duopoly market

Licensing

- Outside patent holder (e.g. Research lab.)
- Cournot
  - Fee
  - Open trading (non-cooperative game)
  - Negotiation (cooperative game)

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Duopoly Market

$N = \{1, 2\}$: firms produce homogeneous goods

firm 1's cost function

cx_1 (x_1 : firm 1's production level)

firm 2's cost function

cx_2 (x_2 : firm 2's production level)

(inverse) demand function

price of the product

$$p = \max (a - (x_1 + x_2),\ 0)$$

(a : constant, $a > c$)

Cost-reducing Technology

patent holder 0

new technology $c \rightarrow c - \varepsilon$

licensee

$\rightarrow c - \varepsilon$,

non-licensee

$\rightarrow c$

Cournot Duopoly Market

Both firms hold a license (cost: $c-\varepsilon$)

Each firm's production $(a-c+\varepsilon)/3$; profit $\underline{(a-c+\varepsilon)^2/9}$

$W(2)$

One firm holds a license (cost: licensee $c-\varepsilon$, non-licensee c)

$\varepsilon \le a-c$:

Licensee's production $(a-c+2\varepsilon)/3$, profit $\underline{(a-c+2\varepsilon)^2/9}$

Non-licensee's production $(a-c-\varepsilon)/3$, profit $\underline{(a-c-\varepsilon)^2/9}$

$\varepsilon > a-c$: (drastic innovation, monopoly by licensee)

Licensee's production $(a-c+\varepsilon)/2$, profit $\underline{(a-c+\varepsilon)^2/4}$

Non-licensee's production 0, profit $\underline{0}$

licensee's profit $W(1)$, non-licensee $L(1)$

Neither firm holds a license (cost: c)

Each firm's production $(a-c)/3$; profit $\underline{(a-c)^2/9}$ $L(0)$

Note: $W(1) > W(2) > L(0) > L(1) \ge 0$

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Survey

Open trading (take-it or leave-it) : non-cooperative game

Kamien-Tauman (84,86)

Negotiation : cooperative game

Watanabe-Tauman (07)

Watanabe-Muto (07)

Kishimoto-Watanabe-Muto (08)

Open Trading (Take-it or leave-it): Non-cooperative Game Analysis (Kamien & Tauman etc.)

Procedure :

1 Patent holder announces
fee p for licensing a patent

2 Each firm decides whether to buy the patent.
If a firm buys the patent,
→ pay p and get the patent: cost $c-\varepsilon$
If a firm does not buy the patent
→ pay nothing: cost c

3 Each firm determines its production level.

$\exists$ uniuque subgame perfect equilibrium

Problems: Optimal licensing for the patent holder ?
→ diffusion of the patent, etc. ?

2nd stage: whether to buy or not

Two firms buy: firm 1: $W(2) - p$, firm 2: $W(2) - p$

firm 1 buys if $W(2) - p \geq L(1)$

$\rightarrow \quad p \leq W(2) - L(1)$

firm 2 : same

max. fee $= W(2) - L(1)$

Patent holder's max profit : $2\,(W(2) - L(1))$

fee $= W(2) - L(1)$

firms (licensees): $L(1)$, $L(1)$

2nd stage: whether to buy or not

One firm buys: licensee : $W(1)$, non-licensee : $L(1)$

licensee buys if $W(1) - p \geq L(0)$

non-licensee does not buy if $L(1) \geq W(2) - p$

$\rightarrow \quad W(2) - L(1) \leq p \leq W(1) - L(0)$

(Note : $W(2) - L(1) < W(1) - L(0)$)

max fee = $W(1) - L(0)$

Patent holder's max profit : $W(1) - L(0)$

fee = $W(1) - L(0)$

firms : licensee $L(0)$

non-licensee $L(1)$

2nd stage: whether to buy or not

Neither firm buys: firm 1: $L(0)$, firm 2: $L(0)$

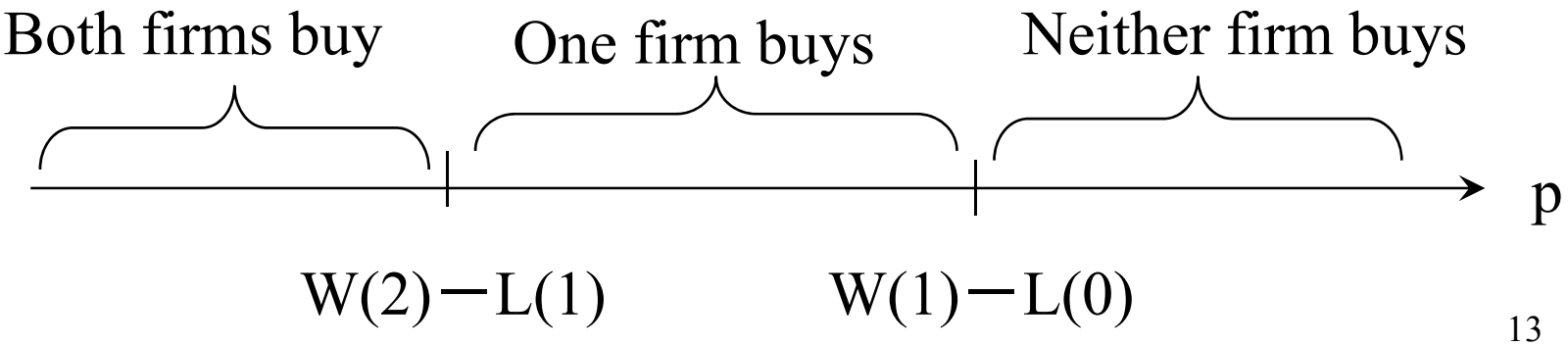
firm 1 does not buy if $L(0) \geq W(1) - p$

$\rightarrow \quad p \geq W(1) - L(0)$

firm 2 : same

Patent holder gains nothing.

$W(1) - L(0) > W(2) - L(1)$ holds



1st stage : optimal fee for patent holder

Two firms buy : Patent holder's max : $\underline{2\,(W(2) - L(1)),}$

firms (licensees) : L(1), L(1)

One firm buys : Patent holder's max : $\underline{W(1) - L(0),}$

firms : licensee L(0), non-licensee L(1)

Note : $\underline{2\,(W(2) - L(1)) \geq W(1) - L(0)} \quad \Leftrightarrow \quad \varepsilon \leq a - c$

Equilibrium :

$\varepsilon \leq a - c \quad \rightarrow$ fee = $W(2) - L(1)$ two firms buy

pat. holder $2\,(W(2) - L(1))$

firms (licensees) : L(1), L(1)

$\varepsilon > a - c \quad \rightarrow$ fee = $W(1) - L(0)$ one firm buys

pat. holder $W(1) - L(0)$

firms : licensee L(0), non-licensee L(1)

Open Trading (oligopoly n firms)

s^* maximizes $s\,(W(s) - L(s-1))$

$\varepsilon \leq a - c$

$\rightarrow$ # of lecensees : $s^* \downarrow$ as $\varepsilon \uparrow$

fee : $W(s^*) - L(s^*-1)$

pat. holder's profit :

$s^*\,(W(s^*) - L(s^*-1)) \uparrow$ as $\varepsilon \uparrow$

licensee : $L(s^*-1)$, non-licensee : $L(s^*)$

$\varepsilon > a - c$ (drastic innovation)

$\rightarrow$ # of lecensees : 1 (monopoly by licensee)

fee : $W(1) - L(0)$

pat. holder's profit: $W(1) - L(0)$

licensee : $L(0)$, non-licensee : 0

Fee vs. Royalty : Cournot

Royalty : <u>All firms</u> buy the license

royalty ε if non-drastic

$(a-c+\varepsilon)/2$ if drastic

Patent holder : Fee > Royalty

Consumers: Fee > Royalty

Firms: Royalty $\geq$ L(0) $\geq$ Fee

$\varepsilon \leq a-c$ Fee, Royalty

# of firms $n \to \infty$

$\Rightarrow$ patent holder's profit $\to \varepsilon(a-c)$

$a-c$: competitive output under old technology

$\varepsilon > a-c$ (drastic innovation) Fee, Royalty

# of firms $n \to \infty$

$\Rightarrow$ patent holder's profit $\to (a-c+\varepsilon)^2/4$

Fee vs. Royalty

Patent holder's profit

Cournot : Fee > Royalty

Bertrand : Fee = Royalty

Royalty often observed; why ?

Differentiated goods

Inside patent holder Royalty > Fee

Muto(1993), Wang(1998)

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Tauman-Watanabe

Negotiation in licensing

→ Characteristic function form game (N, v)

N : set of players, v(S) : worth of $S \subseteq N$

Procedure:

1. Patent holder and all firms get together.
2. Firms maximize their total profit. → monopoly
3. Discuss how to share the profit based on v(S).

descriptive viewpoint, normative viewpoint

Tauman and Watanabe assume:

<u>negotiation in licensing & cooperation in production</u>

TU-game formulation

- assume fee & side-payments among firms

Solution: Shapley value - normative

Tauman-Watanabe

v : $\{0,1,2\}$ 1, 2 maximize their joint profit with cost $c-\varepsilon$

$v(\{0,1,2\}) = (a-c+\varepsilon)^2/4$

$\{0,1\}$ 1 with $c-\varepsilon$ and 2 with c maximize their own profits

$v(\{0,1\}) = (a-c+2\varepsilon)^2/9$, $v(\{2\}) = (a-c-\varepsilon)^2/9$

similarly $v(\{0,2\}) = (a-c+2\varepsilon)^2/9$, $v(\{1\}) = (a-c-\varepsilon)^2/9$

$\{1,2\}$ 1, 2 maximize their joint profit with cost c

$v(\{1,2\}) = (a-c)^2/4$

$\{0\}$ $v(\{0\}) = 0$

Shaplev value of (N, v)

# of firms $\rightarrow \infty$

$\Rightarrow$ Patent holder's payoff $\rightarrow \varepsilon(a-c)$

Same payoff as in open trading

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Watanabe-Muto, Kishimoto-Watanabe-Muto

Negotiation only in licensing stage

(cooperation in production stage often prohibited)

→ Characteristic function form game with coalition structures

Procedure:

1. Patent holder selects some firms and invite them to the negotiation on licensing issues. Any other firm cannot participate in the negotiation.
2. If the patent holder and the firms reach an agreement on the amount of fee, then the patent holder licenses the firms to use the new technology.
3. Every firm (licensee, non-licensee) determines its production Level.

Watanabe-Muto, Kishimoto-Watanabe-Muto

Kishimoto, Watanabe and Muto assume:

1. negotiation only in licensing

   firms act independently in production stage

2. TU-game formulation - assume fee & side-payments

   coalition structure :

   patent holder + firms invited to negotiation

   other firms (singletons)

3. Solution:

   core, bargaining set,

   Shapley value (Auman-Dreze value)

Watanabe-Muto : abstract model

Kishimoto-Watanabe-Muto : Cournot oligopoly

Watanabe-Muto, Kishimoto-Watanabe-Muto

{0,1,2} 1, 2 independently maximize their profits with cost $c-\varepsilon$

$\underline{v(\{0,1,2\}) = 2(a-c+\varepsilon)^2/9}$

0, 1 and 2 participate in negotiation.

coalition structure $\{\{0,1,2\}\}$

{0,1} 1 with $c-\varepsilon$ and 2 with c maximize their own profits

$v(\{0,1\}) = (a-c+2\varepsilon)^2/9$, $v(\{2\}) = (a-c-\varepsilon)^2/9$

0 and 1 negotiate. 2 does not join.

coalition structure : $\{\{0,1\},\{2\}\}$

{0,2} similar coalition structure $\{\{0,2\},\{1\}\}$

{1,2} 1, 2 independently maximize their profits with cost c

$v(\{1,2\}) = 2(a-c)^2/9$

Side-payments between 1 and 2 are allowed.

{0} $v(\{0\}) = 0$

Watanabe-Muto, Kishimoto-Watanabe-Muto

Coalition structure $(\{0\}\cup S, \{\{i\}\}_{i\in N-S})$

Core = $\varnothing$ for all coalition structures

Bargaining sets $\neq \varnothing$ for all coalition structures

s** maximizes $s\,(W(s) - L(0))$

In the bargaining sets,

patent holder's maximum payoff = $s^{**}(W(s^{**}) - L(0))$

Watanabe-Muto, Kishimoto-Watanabe-Muto

Comparison with open trading

Suppose patent holder invites s** firms to negotiation.

1. For large innovations,

   # of licensees : same

   patent holder's max profit : open trading > negotiation

   firms' profits : licensee open trading < negotiation

   non-licensee same

   (Drastic innovations: all are same)

2. Small innovations

   # of licensees : open trading > negotiation

   patent holder's profit : open trading >< negotiation

   firms' profits : licensee open trading < negotiation

   non-licensee open trading < negotiation

Watanabe-Muto, Kishimoto-Watanabe-Muto

Comparison with open trading

Suppose patent holder invites s** firms to negotiation.

# of firms $\rightarrow \infty$

1. Patent holder's profits in the bargaining set $\rightarrow \varepsilon(a-c)$
2. Patent holder's profit in the Shapley value (Aumann-Dreze value)
   $\rightarrow \varepsilon(a-c)/2$

Remarks

Negotiation:

Royalty → NTU-games (games without side-payments)

Bertrand-type oligopoly

inside patent holder

comparison with open trading case

Production of new technology

Research joint venture

Katz, M.L. and Shapiro, C. (1986), How to license intangible property, Quart. J. of Econ. Vol.101, 567-589, etc.

cooperative game theoretic approach

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