Endogenous Coalition of Intellectual Properties: A Three-Patent Story

Chen Qu
Department of Economics, BI Norwegian Business School, Norway

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Background

- Cooperation among intellectual property owners (e.g., patent pools) is often observed in a variety of industries.
- Patent pool: an agreement by multiple patentholders to license a portfolio of patents as a package to outsiders (or to share intellectual property among themselves) (*New Palgrave*)
- In 2001, sales of devices wholly or partly based on pooled patents exceeded $100 billion.
- Third Generation Patent Platform Partnership (3G3P): 5 independent PlatformCos (platform companies), each consisting of patents essential to one 3G radio interface technology.

Research questions

- The purpose of this paper is to investigate the endogenous coalition formation among intellectual property owners in a 3-patent setting:
  - fragmented pool structure [® | ® | ®]
  - incomplete pool structure [® | ® ®]
  - complete pool [® ® ®]

- 4 questions:
  - (Q1) What are the profits of patent pools in equilibrium under different pool structures?
  - (Q2) Under what circumstances is the (in)complete pool the stable pool structure?
  - (Q3) Is a market structure of fragmented patents a possible outcome?
  - (Q4) What is the welfare effect of a stable pool structure?

Theoretical resources and contributions

- Lerner & Tirole (2004, AER): a tractable model of patent pools.
  - Non-essential cumulative patents ($\surd$)
  - Stand-alone patents vs. one complete pool ($\times$)
- Ray & Vohra (1997, JET): equilibrium binding agreements (EBA).
  - The protocol of endogenous pool formation.
  - Incomplete pool may form.
- Contributions:
  1. A full picture of endogenous coalitional behaviors of IP owners; particularly, the relationship between pool structure outcome and value accumulation from increasing patents.
  2. An application of theory of coalition formation (in a symmetric and asymmetric case).
- Other related literature: Quint (2014), Aoki & Nagaoka (2006), Brenner (2009)

Plan of the paper

- The model and preliminaries
- Building block: equilibrium profits under different pool structures (Q1)
- Stable pool structure: symmetric profits (Q2, Q4)
- Stable pool structure: asymmetric profits (Q2, Q3, Q4)
- Discussions
  1. Alternative protocol: sequential bargaining
  2. *n*-patent case (marginal contribution, homogeneous licensees)

Timeline of game

- *Stage 1.* n owners form a pool structure C (a partition of n patents).
- *Stage 2.* Prices are set by simultaneous Nash-like play by the pools. The profit is divided equally within a pool. Asymmetric equilibria are allowed.

Licensees distributed over $[\overline{\theta} - \Delta, \overline{\theta}]$. Licensee θ's valuation: $\theta + V(k)$, k: # of patents θ access, $V(k) \nearrow$ in k.

- *Stage 3.* Each licensee selects the basket B s.t. $\max_{B \subseteq C} \{V(\sharp B) - \mathbf{P}_B\}$. (not user-specific)
- *Stage 4.* Licensee θ adopts the technology iff $\theta + V(\sharp B) \geq \mathbf{P}_B$. (user-specific)

Equilibrium of subgame: stages 2-4

Lerner and Tirole (2004):

- All pools are in the equilibrium basket.
- In equilibrium each pool charges min {competition margin, demand margin}.
  - *Competition margin*: the highest price a pool can charge without being excluded from the basket.
  - *Demand margin*: the optimal price in the absence of co. margin.
- $\exists$ some pool, s.t. all bigger pools charge same de. margin, and the rest charge co. margin.

3-patent case: profits

- 3 feasible pool structures:
  $\{1,1,1\}$ (fragmented); $\{1,2\}$ (incomplete); $\{3\}$ (complete).
- Notations: $v_1 \equiv V(1) + \overline{\theta}$, $v_2 \equiv V(2) + \overline{\theta}$ and $v_3 \equiv V(3) + \overline{\theta}$.
- Assume licensees *uniformly* distributed.

- Per-owner profit $\pi(\{3\}) = \frac{1}{12} v_3^2$.

- **Prop 1**.

	$\pi(\{1,2\})$
(a)	$\left(\frac{1}{9} v_3^2, \frac{1}{18} v_3^2\right)$
(b)	$\left(\frac{1}{2} v_2 (v_3 - v_2), \frac{1}{8} v_2^2\right)$
(c)	$\left((v_1 + v_2 - v_3)(v_3 - v_2), \frac{1}{2}(v_1 + v_2 - v_3)(v_3 - v_1)\right)$

(a) $v_3 \geq \frac{3}{2} v_2$ (b) $v_1 + \frac{1}{2} v_2 \leq v_3 < \frac{3}{2} v_2$ (c) $v_3 < v_1 + \frac{1}{2} v_2$

3-patent case: profits cont.

- **Prop 2**.

	$\pi\left(\{1,1,1\}\right)$
(d+f)	$\left(\frac{1}{16}v_3^2\right)_3$
(concavity+g)	$\left((3v_2-2v_3)(v_3-v_2)\right)_3$
(e+convexity)	$(v_1-z)\left(z,z,v_3-v_1-z\right)$ with $z\in\left[v_2-v_1,\frac{v_3-v_1}{2}\right]$

<u>(d)</u> $v_3>2v_1$	<u>(f)</u> $v_3\geq\frac{4}{3}v_2$	<u>(concavity)</u> $v_3<2v_2-v_1$
<u>(e)</u> $v_3\leq 2v_1$	<u>(g)</u> $v_3<\frac{4}{3}v_2$	<u>(convexity)</u> $v_3\geq 2v_2-v_1$

In (e+convexity),

- z: degree of symmetry. When $z=\frac{v_3-v_1}{2}$, symmetric.
- Infinite number of asymmetric equilibria: owner 3 earns high profit and the other two the same low profit.

Equilibrium binding agreements (symmetric profits)

- A pool structure is called an *equilibrium pool structure (EPS)* if, under this structure, no owners, individually or as a group, have incentive to break away from the current pool by EBA:
  1. Only internal deviations of a subset of an existing pool are allowed: $\{3\} \to \{1,2\} \to \{1,1,1\}$;
  2. Owners are farsighted: $\{3\} \to \{1,2\} \overset{?}{\dashrightarrow} \{1,1,1\}$;
- The coarsest EPS is the stable pool structure.

- Example: (a+d+f)

$\pi(\{3\})$	$\pi(\{1,2\})$	$\pi(\{1,1,1\})$
$\frac{1}{12}v_3^2$	$\left(\frac{1}{9}v_3^2, \frac{1}{18}v_3^2\right)$	$\left(\frac{1}{16}v_3^2\right)_3$

  - $\{1,1,1\}$ is EPS; $\{1,2\}$ is *not* EPS ($\{1,1,1\}$ *blocks* $\{1,2\}$);
  - $\{3\}$, comparing $\pi(\{3\})$ with $\pi(\{1,1,1\})$, is (coarsest, stable) EPS.
- A simple algorithm:
  - *Step I*: Is $\{1,2\}$ EPS?
  - If NO, $\hookrightarrow$*Step II*: $\{3\}$ is stable PS. Done.
  - If YES, $\hookrightarrow$*Step III*: Is $\{3\}$ EPS? (Compare $\pi(\{3\})$ with $\pi(\{1,2\})$)

Stable pool structure (symmetric profits)

- **Props 3-5**.

stable PS:	$\{3\}$?	$\{1,2\}$?	$\{1,2\}$ EPS?	Who defects?
a+d+f	Always		Never	
b+d+f	$v_3 > x_1$	$v_3 \leq x_1$	$v_3 \leq x_1$	$\{1\}$
b+concavity+g	$v_3 \in [x_2, x_3]$	$v_3 \notin [x_2, x_3]$	Always	$\{2\}$ [/] $\{1\}$
c+concavity+g	$v_3 \notin (x_4, x_5)$	$v_3 \in (x_4, x_5)$	Always	/ $(\{2\})$ /
a/c+e+convexity	Always		Never	
b+e+convexity	$v_3 \notin (x_3, x_6]$	$v_3 \in (x_3, x_6]$	$v_3 \leq x_6$	/ $(\{1\}]$

$$x_1 \equiv \sqrt{2} v_2.$$

$$x_2 \equiv \sqrt{\tfrac{3}{2}} v_2;\ x_3 \equiv \left(3 - \sqrt{3}\right) v_2.$$

$$x_4\ (x_5) \equiv \tfrac{1}{7}\left(6v_1 + 3v_2 - (+)\sqrt{3\delta}\right),\ \delta \equiv 3v_2^2 - 2v_1 v_2 - 2v_1^2 \text{ if } \delta \geq 0.$$

$$x_6 \equiv 2v_1 - \tfrac{\sqrt{2}}{2}\sqrt{2v_1^2 - v_2^2},\ \text{if } 2v_1^2 - v_2^2 > 0.$$

Stable pool structure (symmetric profits) cont.

stable PS:	$\{3\}$?	$\{1,2\}$?	$\{1,2\}$ EPS?	Who defects?
a+d+f	Always		Never	
b+d+f	$v_3 > x_1$	$v_3 \leq x_1$	$v_3 \leq x_1$	$\{1\}$
b+concavity+g	$v_3 \in [x_2, x_3]$	$v_3 \notin [x_2, x_3]$	Always	$\{2\}$ [/] $\{1\}$
c+concavity+g	$v_3 \notin (x_4, x_5)$	$v_3 \in (x_4, x_5)$	Always	/ ($\{2\}$) /
a/c+e+convexity	Always		Never	
b+e+convexity	$v_3 \notin (x_3, x_6]$	$v_3 \in (x_3, x_6]$	$v_3 \leq x_6$	/ ($\{1\}$]

- **Eg**. (a+d+f) $V(1) \approx V(2) \approx 0$, $V(3) \gg 0 \Rightarrow$stable $\{3\}$.
- **Eg**. (b+d+f) (linear) $V(k) = Ak$, A constant, $k = 1, 2, 3$. $v_3 > x_1 \Rightarrow$stable $\{3\}$.
- **Eg**. (b+concavity+g) $V(1) \approx 0$, $V(2) \approx V(3) \gg 0$. $v_3 < x_2 \Rightarrow$ stable $\{1, 2\}$.
- **Eg**. (c+e+convexity) $V(1) \approx V(2) \approx V(3) \gg 0 \Rightarrow$stable $\{3\}$.
- **Prop 6.** Stable PS is $\{3\}$ if $v_3 \geq \frac{3}{2} v_2$ or $v_2 < \frac{\sqrt{7}+1}{3} v_1$. (The latter is irrespective of v_3.)

Welfare analysis (symmetric profits)

- We say the stable PS *increases welfare* if the total price under it $<$ that under $\{1, 1, 1\}$.
- **Prop 7**.

	When the coarsest EPS $\nearrow$ welfare?
a/b+d+f	always
b+concavity+g	$v_3 \geq \sqrt{3/2}v_2$
c+concavity+g	always $\searrow$ welfare (except if $v_2 > \frac{5}{4}v_1$ and $v_3 \geq x_5$)
a/b+e+convexity	always
c+e+convexity	$v_3 > \frac{3}{2}v_1$

Except (c+concavity+g) with restrictive v_3, the stable PS (almost) always increases welfare.

Stable pool structure (asymmetric profits)

- 4 feasible PSs: $\{aaA\} \to \begin{matrix} \{a, aA\} \\ \{A, aa\} \end{matrix} \to \{a, a, A\}$.
- Subtleties arise of the algorithm of finding the stable PS.
- **Prop 8.** (Polar asym.) When $z = v_2 - v_1$, $\{A, aa\}$ (always EPS) can be stable in all the cases with (e+convexity).
  $\Rightarrow \{a, a, A\}$ is never stable.
  (In (c+e+convexity), $\{a, a, A\}$ is never stable for *any* z.)

- Can $\{a, a, A\}$ be stable? YES!
- **Prop 9.** In (a+e+convexity), $\exists \left(\underline{z}, \overline{z}\right) \subset \left[v_2 - v_1, \frac{v_3 - v_1}{2}\right]$ s.t.

z	$\left[v_2 - v_1, \underline{z}\right]$	$\left(\underline{z}, \overline{z}\right)$	$\left[\overline{z}, \frac{v_3 - v_1}{2}\right]$
stable PS	$\{A, aa\}$	$\{a, a, A\}$	$\{aaA\}$

- Modest asymmetry $\Rightarrow$ finest market structure. Why?
  - High asymmetry $\not\Rightarrow \pi\left(a \middle| A, aa\right) < \pi\left(a \middle| a, a, A\right)$
  - High symmetry $\not\Rightarrow \pi\left(A \middle| aaA\right) < \pi\left(A \middle| a, a, A\right)$

Welfare implication (asymmetric profits)

- By Prop 9, in (a+e+convexity),

z	$[v_2 - v_1, \underline{z}]$	$(\underline{z}, \overline{z})$	$[\overline{z}, \frac{v_3 - v_1}{2}]$
stable PS	$\{A, aa\}$	$\{a, a, A\}$	$\{aaA\}$
total price	$\frac{2}{3} v_3$	$v_3 - v_1 + z$	$\frac{1}{2} v_3$

- **Prop 10**. In (a+e+convexity), when $v_3 < \frac{18}{11} v_1$, $\exists z^* \in (\underline{z}, \overline{z})$ s.t. $z \in (\underline{z}, z^*)$ leads to a lower total price than the one charged by $\{aaA\}$; when $v_3 \geq \frac{18}{11} v_1$, any $z \in (\underline{z}, \overline{z})$ leads to a higher total price.

Discussions

- Alternative protocol: infinite-horizon unanimity bargaining ($\Leftrightarrow$ sequential game of choosing pool size)
- 3 symmetric patents: stable PS = SPE of game above.

- Marginal contribution of Δk patents to a size-k pool: $w(k, \Delta k) \equiv V(k) - V(k - \Delta k)$.
- **Prop A2**. Consider equilibrium $\mathbf{p}$. Then $\underline{\text{co. margin}_i = w(n, n_i)}$ iff

$$C \backslash n_i \in \arg\max_{J \subseteq C \backslash n_i} \{V(\sharp J) - \mathbf{P}_J\}.$$

  This holds if $V(\cdot)$ satisfies $w(n, \Delta k) \leq w(k, \Delta k)$ for any $k \leq n$ and any $\Delta k < k$. (weaker than concavity of $V(\cdot)$).
  Eg. $V(1) = 1$, $V(2) = 2$, $V(3) = 5$, $V(4) = 6$.

Discussions cont.

- Homogeneous licensees (same θ), no externalities (using Prop.12) $\Rightarrow$ Per-owner profit of a size-t pool is $\frac{w(n,t)}{t}$.
- **Eg**.

t	1	2	3	4	5	6
$V(t)$	11.5	14	36	46	53	54
$w(n,t)/t$	1	4	6	10	8.5	9

  Multiple stable PS with no stand-alone patents: $\{2,4\}$, $\{3,3\}$. (EPS $\{1,1,4\}$ blocks $\{1,5\}$. $\{2,4\}$ blocks $\{6\}$.)

- Possible refinement $\Rightarrow$ $\{4,2\}$ the only outcome:
  - The coarsest EPS should block some coarser structure;
  - Alternative protocol of sequential bargaining.

Conclusions

- Varieties of equilibrium profits under different structures.
- NO straightforward prediction on stable PS!
- Symmetric profits: either complete pool or incomplete PS is stable.
- Asymmetric profits: fragmented PS can be stable.
- Stable PS tends to increase welfare with large $V(3)$; fragmented PS may increase welfare.

- Future research:
  1. Up-front fees, per-unit royalties, and combinations of the two.
  2. "Weak" patent: patent litigation, spillovers.
  3. Full characterization of n-patent case.

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Thank you ^O^