Patent policy, patent pools, and the accumulation of claims in sequential innovation

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Motivation

• **Innovation is cumulative**
  - Issue: how to divide revenues from a chain of inventions among different innovators
  - Patents: transfer from future innovators to current innovators

• **Multiple license fees (patent thickets)**
  - Biomedical research: *MSP1 malaria vaccine* (licenses on 39 patent families)
  - Biotechnology: *β-carotene enriched rice* (40 license fees)
  - Software:
    • Patents may cover algorithms and techniques
    • One program uses thousands of algorithms
    • MPEG2 (DVD): 136 U.S. patents
    • Patent pools
Motivation

- Patent thickets and incentives to innovate

- Previous literature: monopolistic ownership of complementary assets is bad
  - Cournot (1838): perfectly competitive producer of Brass using Copper and Zinc as perfect complement inputs
    - Cost of producing B higher when C and Z are sold by two different monopolist
  - Complementary Monopoly: market outcome gets worse as the number of p.c. inputs increases
  - Patent Pools: concentration of ownership of complementary assets leads to welfare improving outcomes

- Static models: inputs already exist
What we do

- Dynamic model of sequential innovation with endogenous formation of patent thickets

**Questions:**

1. What is the net effect of patents on innovation activity?
2. What is the optimal innovation policy?
3. What is the effect of patent pools in a dynamic setting with endogenous innovation?
Relation with literature

- **Sequential Innovation**
  Scotchmer 1991, 1996; Chang 1995; Green-Scotchmer 1995

- **Complementary Monopoly**
  Cournot 1838; Sonneschein 1968; Bergstrom 1978; Chari-Jones 2000

- **Patent Pools**
  Shapiro 2001; Lerner-Tirole 2004

- **Dynamic Models of Cumulative Innovation**
The Model

- Dynamic model in discrete time
- Potentially infinite periods
- Each period: one potential innovator
  - Sequence of innovations: \( n = 1, 2, 3 \ldots \)
  - Each innovation is based on all previous inventions
  - There may be several trials for each innovation: \( j = 1, 2, 3 \ldots \)
- Deterministic innovation: cost of R&D = \( \varepsilon \)
- **Value of idea** \( n, j = v_{nj} \sim U[0, 1] \). Private information
- Innovators capture full social surplus

**We study:**
- Patents, no-patents and patent pools
- Optimal innovation policy
- Optimal patent length
Innovation with Patents I

- Innovator
  - pays license fees to previous innovators
  - collects license fees from future innovators

- Markov Perfect Equilibrium

\[
\begin{align*}
& \text{At stage } n, j: \\
& 1. \text{ Past innovators set license fees, } \{p_{n,j}^i\}_{i=1}^{n-1}. \\
& 2. \text{ Nature extracts } v_{n,j} \text{ from } U[0,1]. \\
& 3. \text{ Innovator decides to innovate or not.}
\end{align*}
\]

- $\phi$: degree of scarcity of ideas.
Innovation with Patents II

- Revenues of patent holder $i$ at stage $n, j$:
  \[ R_{n,j}^i = Pr_{n,j} (p_{n,j}^i + \beta R_{n+1,1}^i) + (1 - Pr_{n,j}) \phi \beta R_{n,j+1}^i \]

- Innovator will innovate if
  \[ v_{n,j} + \beta R_{n+1,1}^n \geq \varepsilon + \sum_{i=1}^{n-1} p_{n,j}^i \]

- Probability of innovation:
  \[ Pr_{n,j} = \text{Prob} \left( v_{n,j} \geq \varepsilon + \sum_{i=1}^{n-1} p_{n,j}^i - \beta R_{n+1,1}^n \right) \]
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- Solution
  \[ \star \text{Equilibrium: } Pr_{n,j} = Pr_n \ \forall j \]
  \[ \star \text{Resulting probabilities:} \]
  \[ Pr_{n+1}^2 = \frac{1 - \phi \beta}{\beta} \left( Pr_n - \frac{1 - \epsilon}{n} \right) + \frac{n-1}{n} \phi Pr_n^2, \]
  \[ \star \text{Decreasing sequence.} \]
  \[ \star \text{Converges to 0 as } n \to \infty. \]
Innovation without Patents and Innovation with Patent Pool

- **Without Patents:**
  - No license payments.
  - Innovator appropriates $\theta v_n$, with $\theta \in (0, 1)$

- **Patent Pools:**
  - Past innovators form a pool.
  - Pool maximizes joint profits of current members.
  - Pool takes into account cross-price derivatives.
  - New innovators enter the pool after innovating.
Comparison

Figure: Probability of Innovation
Remarks

- Patent Pools are dynamically unstable.

- Patent Pool outcome can be replicated:
  - Innovators sell complete patent rights.
  - Competition between patent holders and original innovators.

- Innovation with patents and pools is higher than in static case.
Proposition 1: Socially Optimal Innovation.

Innovation $n,j$ should be performed if and only if $v_{n,j} \geq v^*$, where

$$v^* = \begin{cases} 
0 & \text{if } \varepsilon \leq \frac{\beta}{2} \frac{1 - \phi}{1 - \gamma \phi}, \\
\frac{\beta - 1 + \sqrt{1 - \beta \phi} \sqrt{1 - 2 \beta (1 - (1 - \phi) \varepsilon - \phi / 2)}}{\beta (1 - \phi)} & \text{if } \varepsilon > \frac{\beta}{2} \frac{1 - \phi}{1 - \gamma \phi}.
\end{cases}$$
Some innovations with value \( v_{n,j} < \varepsilon \) should be performed.

Innovation is suboptimal in the three cases.

No-Patents: dynamic externality.

Patents and Patent Pools: asymmetric information, market power.
Optimal Transfers

- Can reach the first best by decentralizing innovation decision and implementing a tax-subsidy scheme.
- Innovator $n, j$ pays transfer $t_n$ to innovator $n - 1$ if she decides to innovate.
- Gets transfer $t_{n+1}$ from innovator $n + 1$.

**Proposition 2:** Optimal transfer is constant and equal to

$$t^* = \frac{(v^* - \varepsilon)(1 - \phi \beta)}{1 - \beta (1 + \phi - v^*)}.$$  

- Optimal transfer is **always negative** (opposite as patents).
Finite Patents:

- Patents last for $L$ periods.
- $\phi = 0$ (only one trial per innovation) $\beta = 1$.
- Innovator captures $\psi(L) v_n$
- Stationary Equilibrium Probability of Innovation:

$$Pr = \frac{L + 1 - \sqrt{(L - 1)^2 + 4L\varepsilon/\psi(L)}}{2L}.$$
Optimal Patent Length

\[
\psi(L) = 1 - \frac{1 - \psi_0}{(L + 1)^\gamma}
\]

(a) \( \psi_0 = 0.2, \varepsilon = 0.1, \gamma = 1 \)

(b) \( \psi_0 = 0.2, \varepsilon = 0.1, \gamma = 0.1 \)
Conclusions

- With patents, probability of innovation declines fast as the sequence of inventions advances. Theoretical support of anticommons hypothesis.

- Patent pools improve welfare with respect to uncoordinated pricing. Innovation activity is higher than in the static case.

- Innovation is suboptimal under the three regimes because of dynamic externalities, asymmetric information and market power.

- Tax-subsidy scheme can achieve first best

- Optimal patent length: short patents.