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:**
  i. What is the net effect of patents on innovation activity?
  ii. What is the optimal innovation policy?
  iii. What is the effect of patent pools in a dynamic setting with endogenous innovation?

Relation with literature

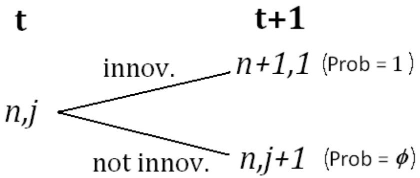
- Sequential Innovation
  Scotchmer 1991, 1996; Chang 1995; Green-Scotchmer 1995
- Complementary Monopoly
  Cournot 1838; Sonneschein 1968; Bergstrom 1978; Chari-Jones 2000
- Patent Pools
  Shapiro 2001; Lerner-Tirole 2004
- Dynamic Models of Cumulative Innovation
  O'Donoghue, Scotchmer and Thisse 1998; Hopenhayn, Llobet and Mitchell 2006

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 = ε
- **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***



- At stage n, j:
  1. Past innovators set license fees, $\{p^i_{n,j}\}_{i=1}^{n-1}$.
  2. Nature extracts $v_{n,j}$ from $U[0,1]$.
  3. Innovator decides to innovate or not.
- ϕ: degree of scarcity of ideas.

Innovation with Patents II

- Revenues of patent holder i at stage n, j:

$$R^i_{n,j} = Pr_{n,j}\,(p^i_{n,j} + \beta\, R^i_{n+1,1}) + (1 - Pr_{n,j})\,\phi\,\beta\, R^i_{n,j+1}$$

- Innovator will innovate if

$$v_{n,j} + \beta\, R^n_{n+1,1} \geq \varepsilon + \sum_{i=1}^{n-1} p^i_{n,j}$$

- Probability of innovation:

$$Pr_{n,j} = Prob\left(v_{n,j} \;\geq\; \varepsilon + \sum_{i=1}^{n-1} p^i_{n,j} - \beta\, R^n_{n+1,1}\right)$$

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- Solution
  - ⋆ Equilibrium: $Pr_{n,j} = Pr_n \quad \forall\, j$
  - ⋆ Resulting probabilities:

$$Pr^2_{n+1} = \frac{1 - \phi\beta}{\beta}\left(Pr_n - \frac{1 - \varepsilon}{n} \right) + \frac{n-1}{n}\,\phi\, Pr^2_n,$$

  - ⋆ Decreasing sequence.
  - ⋆ 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

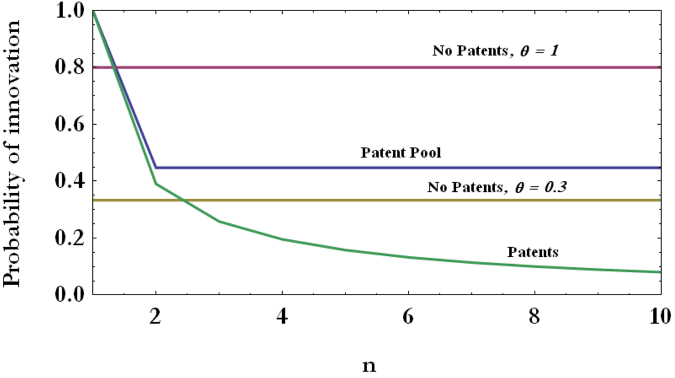


Figure: Probability of Innovation

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.

Optimal Innovation I

Proposition 1: Socially Optimal Innovation.

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

$$\underline{v}^* = \begin{cases} 0 & \text{if } \varepsilon \leq \frac{\beta}{2}\,\frac{1-\phi}{1-\beta\,\phi}, \\ \frac{\beta-1+\sqrt{1-\beta\,\phi}\,\sqrt{1-2\,\beta\,(1-(1-\phi)\,\varepsilon-\phi/2)}}{\beta\,(1-\phi)} & \text{if } \varepsilon > \frac{\beta}{2}\,\frac{1-\phi}{1-\beta\,\phi}. \end{cases}$$

Optimal Innovation II

- 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

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

- Optimal transfer is **always negative** (opposite as patents)

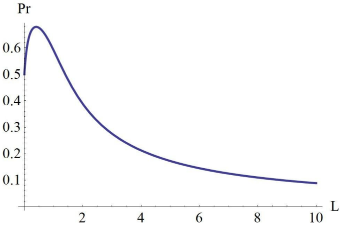
Optimal Patent Length

Finite Patents:

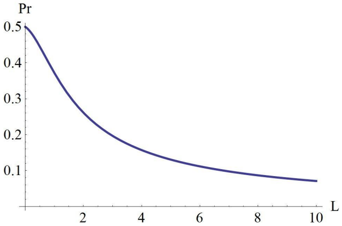
- Patents last for L periods.
- $\phi = 0$ (only one trial per innovation) $\beta = 1$.
- Innovator captures $\psi(L)\, v_n$
- Stationary Equilibrium Probability of Innovation:

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

Optimal Patent Length



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



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

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

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.