Understanding the Doctrine of Patentable Subject Matter

Jing-Yuan Chiou

IMT Lucca, Italy

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Two views on basic inventions

- Basic inventions:

  " principles, laws of nature, mental processes, intellectual concepts, ideas, natural phenomena, mathematical formulae, methods of calculation, fundamental truths, original causes, motives, [and] the Pythagorean theorem. . . ."

- Patent law: Doctrine of Patentable Subject Matter (DPSM)

  "[h]e who discovers a hitherto unknown phenomenon of nature has no claim to a monopoly of it which the law recognizes. If there is to be invention from such a discovery, it must come from the application of the law of nature . . . ."

- Economics: Standing on the shoulder of giants

  ✓ Rewarding early inventions in a cumulative process

Justifying DPSM

- Basic inventions are different in kind
  - ✓ Discovery *vs.* invention
  - ✓ Difficulty in enforcement: e.g., mental steps
- Other patentability requirements: utility, scope, *etc.*
- Incentives?

An incentive theory of DPSM

- Cumulative innovation: 2 stages
  - ✓ Not patent race, but simple search process
  - ✓ 1st stage: one inventor (pioneer, P)
  - ✓ 2nd stage: two inventors (pioneer and follower, F)
  - ✓ At 2nd stage: P moves first
- Asymmetric capacity
  - ✓ At 2nd stage, P and F have different innovation capacity
- When DPSM is optimal: NEC. and SUFF.
  - ✓ Depends on the distribution of downstream capacity

Literature

- Law: ∞
- Cumulative innovation
  - ✓ Green and Scotchmer (1995), Chang (1995), O'Donoghue (1998), Denicoò (2000), *etc.*
  - ✓ Matutes *et al.* (1996), Harhoff *et al.* (2001), Kultti and Mittunen (2008)
  - ✓ Aoki and Nagaoka (2004)
- Design of multi-stage tournaments

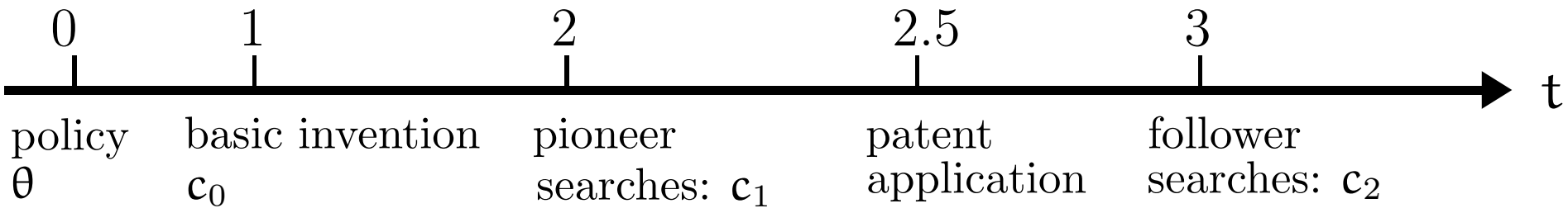
Two-stage innovation

- Innovation activity: search
  - ✓ Spend search cost to find the invention, if exists
- First stage: basic invention/abstract idea
  - ✓ Exists for sure, but no stand-alone value
  - ✓ Patent protection $\theta \in [0, \bar{\theta}]$, $\bar{\theta} < 1$
  - ✓ Stronger protection when θ increases
  - ✓ DPSM: $\theta = 0$
- Second stage: application
  - ✓ Exists with probability $\alpha \in (0, 1]$, value $\pi \Rightarrow \nu \equiv \alpha\pi$
  - ✓ Patentable, but infringes on basic invention (if $\theta > 0$)

Players

- Pioneer (P): Participates in both stages
  - ✓ 1st stage cost $c_0 \sim$ CDF F_0
  - ✓ 2nd stage cost $c_1 \sim$ CDF F_1, searches first
  - ✓ Discloses basic invention if doesn't find application
- Follower (F): Only participates in 2nd stage
  - ✓ Cost $c_2 \sim$ CDF F_2
  - ✓ Searches if application not found yet
  - ✓ Cannot observe c_1 or whether pioneer searches
  - ✓ When finds application, gets $(1-\theta)\pi$
- Assumptions: Limited liability, risk neutrality, and no commitment to search strategy

Timing



Assumptions:

- P protects basic invention with secrecy up to time 2.5
- No licensing (extensions, to be finished)
  - ✓ F's moral hazard if θ too high
  - ✓ P's private, negative information: whether she spent the cost to search

Second stage: F

- Search payoff $(1-\theta)\pi$
- Searches only when no application yet, because
  - ✓ application doesn't exist, with probability $1-\alpha$; or
  - ✓ P does not search
- If believes that P searches for $c_1 \leqslant \tilde{c}_1$, then updated belief

$$\hat{\alpha} = \frac{\alpha[1-F_1(\tilde{c}_1)]}{1-\alpha F_1(\tilde{c}_1)} \leqslant \alpha, \quad \downarrow \text{in } \tilde{c}_1$$

- F searches when $c_2 \leqslant \hat{c}_2 \equiv \hat{\alpha}(1-\theta)\pi$, $\uparrow$ in $\tilde{c}_1$
  - ✓ Cut-off rule

Second stage: P

- If incurs c_1 to search, expected return $\alpha\pi - c_1 = \nu - c_1$
  - ✓ No sale of "negative information"
- If does not search, gets $\theta\pi$ when F finds the application
  - ✓ Basic patent is not used to block
  - ✓ With belief $c_2 \leqslant \tilde{c}_2$, payoff from basic patent $F_2(\tilde{c}_2)\alpha\theta\pi = F_2(\tilde{c}_2)\theta\nu$
- Searches if $c_1 \leqslant \hat{c}_1 \equiv [1 - F_2(\tilde{c}_2)\theta]\nu$, $\downarrow$ in $\tilde{c}_2$
  - ✓ Cut-off rule

Second stage: Search equilibrium

- Rational expectation equilibrium $(\hat{c}_1, \hat{c}_2)$: both guess right
  - ✓ $\hat{F}_1 \equiv F_1(\hat{c}_1)$ and $\hat{F}_2 \equiv F_2(\hat{c}_2)$
- DPSM $(\theta = 0)$: $\hat{c}_1 = \nu \equiv c_1^*$, $\hat{c_2} = \hat{\alpha}(c_1^*)(1-\theta)\pi \equiv c_2^*$
  - ✓ Unique; $F_1^* \equiv F_1(c_1^*)$ and $F_2^* \equiv F_2(c_2^*)$
- $\theta > 0$: $\hat{c}_1 = (1 - \hat{F}_2\theta)\nu$, $\hat{c}_2 = \hat{\alpha}(\hat{c}_1)(1-\theta)\pi$
  - ✓ Strategic substitutes
  - ✓ When $\alpha < 1$, multiple equilibria: $\hat{c}_1 \uparrow \Rightarrow \hat{\alpha} \downarrow \Rightarrow \hat{c}_2 \downarrow \Rightarrow \hat{c}_1 \uparrow$
  - ✓ When $\alpha = 1$, $\hat{\alpha} = \alpha$, unique equilibrium
- Policy effect: $c_1^* > \hat{c}_1$, but $c_2^* \gtrless \hat{c}_2$
  - ✓ $\theta > 0$: direct negative effect + indirect positive effect, via $\hat{\alpha}$
  - ✓ When $\alpha = 1$, $\hat{c}_2 < c_2^*$

Second stage: Performance

$E^* \equiv F_1^* + (1 - F_1^*)F_2^*$ *vs.* $\hat{E} \equiv \hat{F}_1 + (1 - \hat{F}_1)\hat{F}_2$

- ✓ Probability to find application αE^* or $\alpha \hat{E}$

Proposition (Second stage)

When the basic invention becomes patentable, at the 2nd stage,

- P *has lower innovation incentive,* $\hat{c}_1 < c_1^*$;
- *for* $\alpha = 1$, F *has lower incentive, and so* $\hat{E} < E^*$;
- *for* $\alpha < 1$, *ambiguous impact on* F*'s incentive,* $\hat{c}_2 \gtrless c_2^*$, *and* $\hat{E} \gtrless E^*$.

Example: $\alpha < 1$, c_1 and c_2 have two-point distributions

First stage

- Basic invention has no stand-alone value
- P innnovates/searches if $c_0 \leqslant$ payoff from search subgame

$$\left.\begin{array}{rcl} \hat{U}_1 & = & \int_0^{\hat{c}_1}(v-c_1)dF_1 + (1-\hat{F}_1)\hat{F}_2\theta v \\ U_1^* & = & \int_0^{c_1^*}(v-c_1)dF_1 \end{array}\right\} \hat{U}_1 > U_1^*$$

Proposition (First stage)

Patenting basic invention increases the incentive to engage in basic research.

Optimality: Necessary conditions

DPSM is *not* optimal if

- Want to maximize inventors' joint surplus
  - ✓ $S \equiv \int_0^{\hat{U}_1} (\hat{U}_1 - c_0) dF_0 + F_0(\hat{U}_1)(1 - \alpha \hat{F}_1)\hat{U}_2$
  - ✓ $dS/d\theta > 0$ at $\theta = 0$
  - ✓ Use technology progress $F_0 \alpha E$ as policy objective
  - ✓ *Application* has strong positive externality
- $\hat{E} \geqslant E^*$ for some $\theta \in (0, \bar{\theta}]$

Optimality: Sufficient condition

When $0 = \arg\max_\theta F_0(\hat{U}_1)\alpha\hat{E}$?

$$FOC \propto \hat{E} f_0 v \underbrace{\left(\hat{F}_2 + \theta \hat{f}_2 \frac{d\hat{c}_2}{d\theta}\right)}_{\propto\ d\hat{U}_1/d\theta} + F_0(1-\hat{F}_2) \underbrace{\left(\frac{\hat{f}_1}{1-\hat{F}_1}\frac{d\hat{c}_1}{d\theta} + \frac{\hat{f}_2}{1-\hat{F}_2}\frac{d\hat{c}_2}{d\theta}\right)}_{\propto\ d\hat{E}/d\theta}$$

- Trade-offs: θ affects
  - ✓ Incentive at 1st stage: $\hat{U}_1$
  - ✓ New inventor F's incentive $\hat{c}_2$
  - ✓ P's incentive to continue $\hat{c}_1$
- Patenting basic invention is an early reward to P
  - ✓ May not be optimal if needs P's 2nd stage capacity

Optimality: Special case

- $c_0 \sim \text{UNIF}$ and $c_2 \in \{0, K\}$, $K > \nu$ and $\Pr(c_2 = 0) = p_2 \in (0, 1)$
  - ✓ Difficulty of basic invention does not affect optimal policy
  - ✓ F has fixed capacity p_2
- Policy effect: $d\hat{c}_2/d\theta = 0$, $d\hat{c}_1/d\theta = -\nu p_2 < 0$,

$$\frac{d\hat{U}_1}{d\theta} = (1 - \hat{F}_1)p_2\nu > 0 \quad \text{and} \quad \frac{d\hat{E}}{d\theta} = -(1 - p_2)\hat{f}_1 p_2 \nu < 0$$

$$\Rightarrow \qquad \text{FOC} \propto \hat{E}(1 - \hat{F}_1) - \hat{U}_1(1 - p_2)\hat{f}_1$$

- When $c_1 \sim \text{UNIF}[0, \gamma_1 \nu]$, $\gamma_1 > 1$

  $\Rightarrow$ FOC < 0 for all θ when γ_1 and p_2 small enough
  - ✓ $\gamma_1 \downarrow$: P's 2nd stage capacity $\uparrow$

Optimality: NEC and SUFF

Proposition (DPSM)

To promote technology progress, the DPSM

- *(NEC.) is not optimal if it does not improve 2nd stage performance, i.e., if* $\hat{E} \geqslant E^*$ *for some* $\theta > 0$*;*
- *(SUFF.) is optimal if* $c_i \sim \text{UNIF}[0, \gamma_i \nu]$, $\gamma_i > 1$, *and* γ_1 *small enough but* γ_2 *large enough*

Intuition: To preserve P's continuation efforts

$\Rightarrow$ Keep the giant working!

Implications

- Positive: Basic patent may encourage subsequent research
  - ✓ $c_1^* > \hat{c}_1$, but when $\alpha < 1$, may have $c_2^* < \hat{c}_2$ and $E^* < \hat{E}$
  - ✓ may lead to less integrated innovation industry, $(1 - F_1^*)F_2^*/E^* < (1 - \hat{F}_1)\hat{F}_2/\hat{E}$
- Normative: Optimal policy depends on structure of innovation market
  - ✓ Distribution of downstream capacity
- Sources of P's dominance: First-mover advantage
  - ✓ Tacit knowledge that is difficult to transfer, or weak disclosure/best mode requirements
  - ✓ Critical physical assets in application development

Check

- Licensing
  - ✓ Keep (F's) LL, how to induce negative information disclosure
  - ✓ Relax LL, how to design separating contracts
- Multiple applications
  - ✓ May affect the belief-updating process
- Endogenous α: fix ν
  - ✓ $d\hat{U}_1/d\alpha > 0$ and $dU_1^*/d\alpha = 0$, $dE^*/d\alpha = 0$ but $d\hat{E}/d\alpha \gtrless 0$
  - ✓ Social and P's private optimal α may differ
- Endogenous 2nd stage capacity
  - ✓ Difficulty of transferring capacity (tacit knowledge) to F
- Endogenous search order

Future research

- More general SUFF.
- Multiple pioneers
- Other policy instruments