Errors in the Patent Office and Collusion in Innovation

Preliminary

Nisvan Erkal[1] Simona Fabrizi[2] Steffen Lippert[3]

[1]University of Melbourne

[2]Massey University

[3]University of Auckland

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Acquisitions and Innovation

- We investigate strategic elimination of potential competition between rivals in the innovation process.
- Elimination of competition in the product market attracts a lot of attention from competition authorities.
  - Presumption: greater competition $\rightarrow$ enhanced market performance and consumer welfare (lower prices, higher quality, higher output).
- Elimination before firms reach the product market may be hard to detect.
- We aim at investigating the welfare consequences of acquisition decisions firms make before they reach the product market in a model with an imperfect patent office.

Acquisitions and Innovation

- We consider a model of innovation where product market success depends on the quality of the ideas that the firms work on.
- Often, quality is private information, and often both the owner of the idea and its rivals learn about the quality of the idea over time.
- During the innovation process, patents may act as a source of information on the quality of the idea.
- The amount of information transmitted depends on the patent office's precision.
- We parameterize the accuracy of the patent office and investigate its impact on the acquisition decisions of firms.

This paper

- Within acquisitions, we assume idea selection.
- Pay attention to PTO's role in determining the firms' acquisition and idea selection decisions.

- Find: Impact of PTO precision depends on heterogeneity of ideas.
- High share of good projects or if good and bad projects are very similar: precision $\uparrow$, buyouts $\uparrow$;
- Low share of good projects and if good and bad projects are very different: precision $\uparrow$, buyouts $\uparrow$ if precise or $\downarrow$ if imprecise.

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Model

- Two competing firms, $i = 1, 2$, in two-step innovation process.
- Firms use early stage innovation (idea) to find a late-stage innovation that can be commercialized.
- Firms have completed early stage innovation with one of two possible outcomes:
  - Either have a patentable or a non-patentable early stage idea.
  - Assume exogenous probability the idea a firm found is patentable is $\lambda \in (0, 1)$.

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Model

- Assume: Patentable early stage ideas correspond to larger inventive step and, hence, give an advantage in finding the late stage innovation.
- Their early stage ideas determines a firm's type $\theta_i \in \{g, b\}$.
- Firms succeed with late stage innovation with probability p_{θ_i}, where $0 < p_b < p_g < 1$.
- Late stage innovation implies costs of I.

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Model

- Expected profit of firm i if both firms invest (gross of investment I) is

$$\Pi^D(\theta_i, \theta_{-i}) = p_{\theta_i} p_{\theta_{-i}} \pi^D + p_{\theta_i}(1 - p_{\theta_{-i}})\pi^M,$$

  where π^M and π^D are monopoly and duopoly product market profits.
- Expected profit of firm i if the other firm does not invest (gross of investment I) is

$$\Pi^M(\theta_i) = p_{\theta_i} \pi^M.$$

Assumption

1. $I < \Pi^M(b) < \Pi^M(g)$.
2. $\Pi^D(b, g) < \Pi^D(b, b) < I < \Pi^D(g, g) < \Pi^D(g, b)$.

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Complete Information Benchmark

Competition

In the symmetric Nash equilibrium with full information,

1. for (g, g), both firms invest;
2. for (g, b) and (b, g) the good firm invests and the bad does not;
3. for (b, b), firms randomize over investment with probability $\sigma = \frac{\Pi^M(b)-I}{\Pi^M(b)-\Pi^D(b,b)}$.

Complete Information Benchmark

Acquisition Decisions

With full information,

1. for (g, g), one firm acquires the other for $I > 2\Pi^D(g, g) - \Pi^M(g)$, and both firms invest non-cooperatively otherwise;
2. for (g, b) and (b, g), the good firm invests alone, while the bad firm terminates;
3. for (b, b) one firm acquires the other.

- With full information, the private acquisition incentives are higher than the social acquisition incentives.

Incomplete Information

- Assume $I > 2\Pi^D(g, g) - \Pi^M(g)$, i.e., two good firms would prefer a buyout with complete information.
- Firms privately know the type of their early stage idea.

Incomplete Information

- Firms (can) apply for patents to PTO; but PTO makes mistakes.
  - Type I error (false negatives): Applications for patentable innovations are rejected. Probability $a_I \in [0, 1]$.
  - Type II error (false positives): Applications for non-patentable innovations are accepted. Probability $a_{II} \in [0, 1]$.
  - Assumption on errors: $a_I \leq 1 - a_{II}$.
- PTO decision transmits information.

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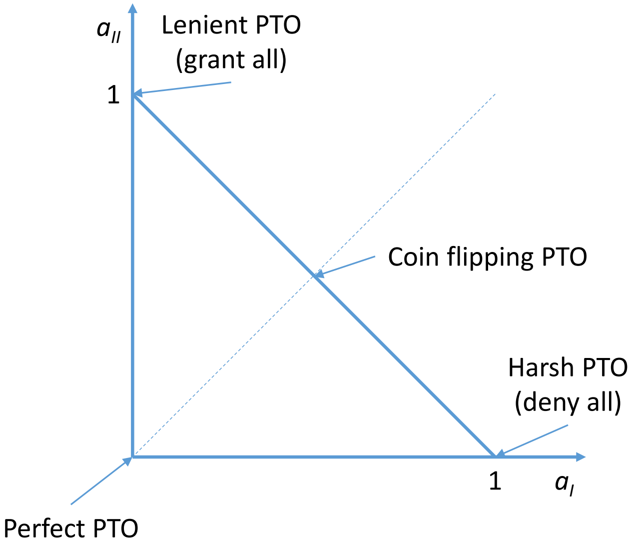

a_I: false negatives; a_{II}: false positives.

Incomplete Information

- Denote the patenting decision for firm i with $\xi_i \in \{P, N\}$.
- Then the posterior probability a firm with patenting decision ξ_i is of type g is given by $\widetilde{\lambda}(\xi_i)$:

$$\widetilde{\lambda}(P) = \frac{\lambda(1-a_I)}{\lambda(1-a_I)+(1-\lambda)a_{II}}$$

$$\widetilde{\lambda}(N) = \frac{\lambda a_I}{\lambda a_I+(1-\lambda)(1-a_{II})}.$$

Incomplete Information

- For an acquisition, firms report their project's type and, based on these reports, determine idea selection and their shares in the joint firm.
- If firms report (g, b),
  - they select the g firm's idea; and
  - assign a share ψ in the joint firm's profit to the inactive partner and a share $1 - \psi$ to the active partner.
- If firms report (g, g) or (b, b),
  - they flip a coin to select an idea; and
  - share the joint firm's profit equally.
- If not incentive compatible and individually rational, firms compete.

Incomplete Information

Competition with asymmetric information

With asymmetric information, if there is no buyout,

1. firms of type g invest with probability 1; and
2. firms of type b invest as follows:
   1. for (P, P), if $I < \underline{I} := \widetilde{\lambda}(P)\Pi^D(b, g) + (1 - \widetilde{\lambda}(P))\Pi^M(b)$, they invest with probability $\sigma_P := \frac{\widetilde{\lambda}(P)\Pi^D(b,g)+(1-\widetilde{\lambda}(P))\Pi^M(b)-I}{(1-\widetilde{\lambda}(P))(\Pi^M(b)-\Pi^D(b,b))}$ and they do not invest otherwise.
   2. for (N, N), if $I < \overline{I} := \widetilde{\lambda}(N)\Pi^D(b, g) + (1 - \widetilde{\lambda}(N))\Pi^M(b)$, they invest with probability $\sigma_N := \frac{\widetilde{\lambda}(N)\Pi^D(b,g)+(1-\widetilde{\lambda}(N))\Pi^M(b)-I}{(1-\widetilde{\lambda}(N))(\Pi^M(b)-\Pi^D(b,b))}$ and they do not invest otherwise.
   3. for (P, N), if $I < \underline{I}$, there exists (i) an equilibrium in mixed strategies in which bad N firms invest with σ_N and bad P firms invest with σ_P; (ii) an equilibrium in which bad P firms enter with probability 1 and bad N firms do not enter and (iii) an equilibrium in which bad N firms enter with probability 1 and bad P firms do not enter. If $\underline{I} \leq I < \overline{I}$, bad N firms do not invest and bad P firms invest with probability 1. If $\overline{I} \leq I$, no bad firm invests.

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Incomplete Information

Bad firm's incentive compatibility constraint

- The bad firm's incentive compatibility constraint is

$$\tilde{\lambda}(\xi_{-i})\psi\left(\Pi^M(g) - I\right) + (1 - \tilde{\lambda}(\xi_{-i}))\frac{1}{2}\left(\Pi^M(b) - I\right)$$
$$\geq \tilde{\lambda}(\xi_{-i})\frac{1}{2}\left(\frac{\Pi^M(g) + \Pi^M(b)}{2} - I\right) + (1 - \tilde{\lambda}(\xi_{-i}))(1 - \psi)\left(\Pi^M(b) - I\right).$$

defining a *lower bound* for the share to the inactive partner:

$$\psi \geq \frac{1}{2} - \frac{\tilde{\lambda}(\xi_{-i})}{4}\frac{\Pi^M(g) - \Pi^M(b)}{\tilde{\lambda}(\xi_{-i})\Pi^M(g) + (1 - \tilde{\lambda}(\xi_{-i}))\Pi^M(b) - I}.$$

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Incomplete Information

Bad firm's individual rationality constraint

- For $(P,P),(N,P),(N,N)$ and for (P,N) as long as $I \notin [\underline{I},\overline{I}[$,

$$\tilde{\lambda}(\xi_{-i})\psi\left(\Pi^M(g)-I\right)+(1-\tilde{\lambda}(\xi_{-i}))\frac{1}{2}\left(\Pi^M(b)-I\right)\geq 0.$$

- For (P,N) as long as $I \in [\underline{I},\overline{I}[$, a bad firm with a patent enters and receives a positive profit in competition, resulting in this IR constraint

$$\tilde{\lambda}(N)\psi\left(\Pi^M(g)-I\right)+(1-\tilde{\lambda}(N))\frac{1}{2}\left(\Pi^M(b)-I\right) \geq \tilde{\lambda}(N)\Pi_i^D(b,g)+(1-\tilde{\lambda}(N))\Pi^M(b)-I,$$

and a(nother) *lower bound* for the share to the inactive partner:

$$\psi \geq \frac{\Pi_i^D(b,g)-I}{\Pi^M(g)-I}+\frac{1-\tilde{\lambda}(N)}{2\tilde{\lambda}(N)}\frac{\Pi^M(b)-I}{\Pi^M(g)-I}.$$

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Incomplete Information

Good firm's incentive compatibility constraint

- A good firm's incentive compatibility constraint,

$$\tilde{\lambda}(\xi_{-i})\frac{1}{2}(\Pi^M(g) - I) + (1 - \tilde{\lambda}(\xi_{-i}))(1 - \psi)(\Pi^M(g) - I)$$
$$\geq \tilde{\lambda}(\xi_{-i})\psi(\Pi^M(g) - I) + (1 - \tilde{\lambda}(\xi_{-i}))\frac{1}{2}\left(\frac{\Pi^M(g) + \Pi^M(b)}{2} - I\right).$$

quite intuitively, never binds.

Incomplete Information

Good firm's individual rationality constraint

- If a bad competitor enters with probability σ, the good firm's individual rationality constraint is

$$\tilde{\lambda}(\xi_{-i})\frac{1}{2}(\Pi^M(g) - I) + (1 - \tilde{\lambda}(\xi_{-i}))(1 - \psi)(\Pi^M(g) - I)$$
$$\geq \tilde{\lambda}(\xi_{-i})\Pi_i^D(g, g) + (1 - \tilde{\lambda}(\xi_{-i}))\left((1 - \sigma)\Pi^M(g) + \sigma\Pi_i^D(g, b)\right) - I,$$

giving three possible *upper bound*s for the share to the inactive partner,

$$\psi \leq \frac{\tilde{\lambda}(\xi_{-i})}{1 - \tilde{\lambda}(\xi_{-i})}\left[\frac{1}{2} - \frac{\Pi_i^D(g, g) - I}{\Pi^M(g) - I}\right] + \sigma\frac{\Pi^M(g) - \Pi_i^D(g, b)}{\Pi^M(g) - I},$$

where $\sigma \in \{\sigma_{\xi_{-i}}, 0, 1\}$ depending on the investment choice of a bad rival in competition.

Incomplete Information

- In most cases, we only need to look at IC_b and IR_g.

Uninformative (or absent) PTO

Entry in competition

Without a PTO, if firms compete,

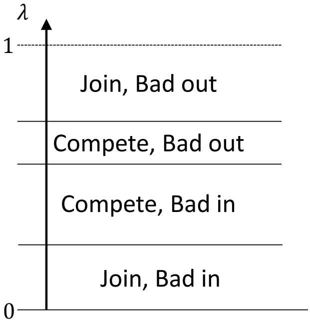
1. a firm of type g always enters; and
2. a firm of type b enters with probability

$$\sigma = \begin{cases} \frac{\lambda \Pi^D(b,g) + (1-\lambda)\Pi^M(b) - I}{(1-\lambda)[\Pi^M(b) - \Pi^D(b,b)]} & \text{if } \lambda \Pi^D(b,g) + (1-\lambda)\Pi^M(b) - I > 0, \\ 0 & \text{otherwise.} \end{cases}$$

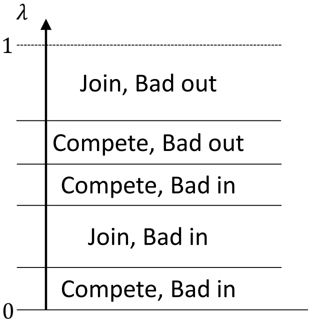
Uninformative (or absent) PTO

Decision to join

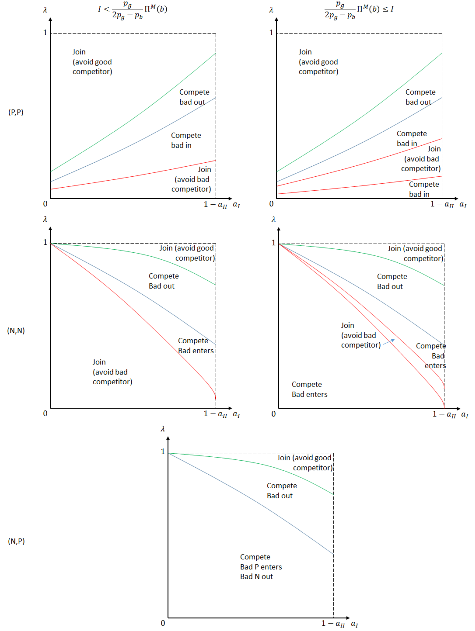
$I < \frac{p_g}{2p_g - p_b}\Pi^M(b)$
g and b are similar



$\frac{p_g}{2p_g - p_b}\Pi^M(b) \leq I$
g and b are different

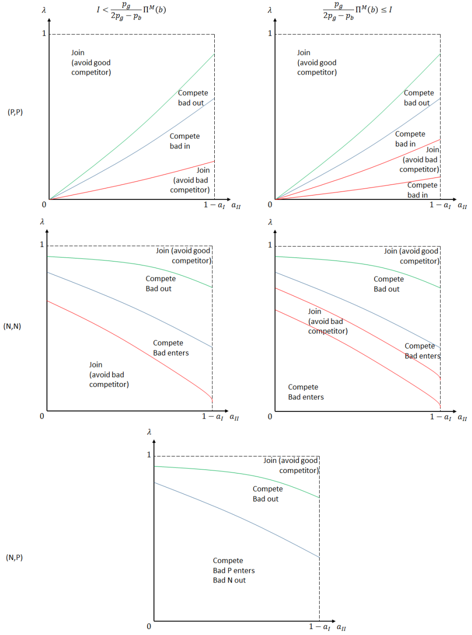


PTO – False Negatives



- Left: g & b similar
- Right: g & b different

PTO – False Positives



- Left: g & b similar
- Right: g & b different

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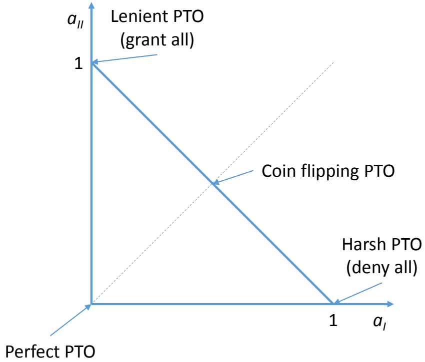
Incomplete Information

The role of PTO precision

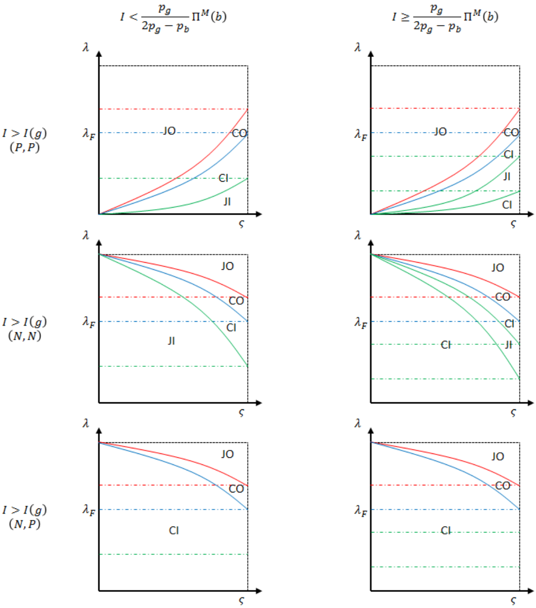
- For high λ, most likely (P, P). More precise PTO leads to more acquisitions.
- For low λ, most likely (N, N). More precise PTO may prevent or induce acquisitions depending on the size of the error and the similarity of good and bad projects.

Alternative formulation

- Policy implications?
- Let the model of the PTO be characterized by ζ (funding) and κ (leniency).
  - $\kappa = a_{II}/a_I$.
  - $\zeta = \sqrt{a_I^2 + a_{II}^2}$.



PTO's funding



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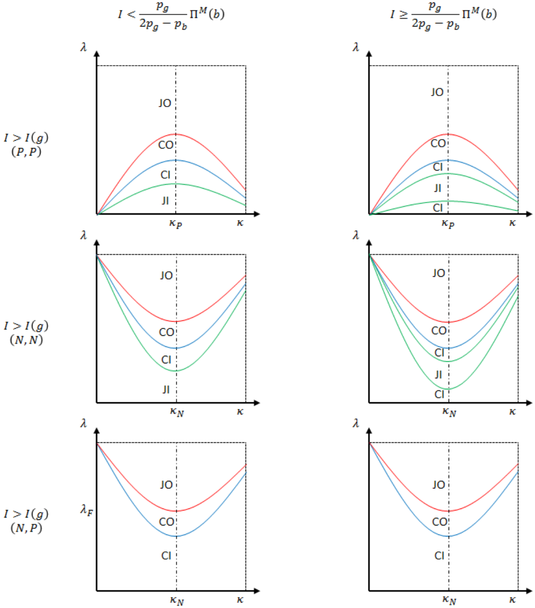
PTO's leniency



We find

- Impact of PTO precision depends on heterogeneity of ideas.
- High share of good projects or if good and bad projects are very similar: precision $\uparrow$, buyouts $\uparrow$;
- Low share of good projects and if good and bad projects are very different: precision $\uparrow$, buyouts $\uparrow$ if precise or $\downarrow$ if imprecise.