Financially Constrained Innovation, Patent Protection and Industry Dynamics

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Introduction

- The recent growth wave has been characterized by growth in highly innovative industries and in entrepreneurship (especially in the US and in connection to IT).
- These processes have been parallel to an explosion in patenting and VC financing.
- The link between IPRs strenghtening and patenting activity is clear, but some scholars doubt of the overall positive effect on innovation or, at least, point out the posible non-monotonicity of the relationship between IPRs protection and innovation.

- Too much or too little protection?
  - Too little protection
    - More protection would induce more innovation (Denicolò (2007)).
  - Too much protection
    - Perception that patent protection might be reducing innovation. Heller and Eisenberg(1998) denotes this effect "the tragedy of the anti-commons".
    - Litigation has become an important indirect cost of innovation.
    - Proposals to reduce patent protection or to eliminate it completely (Boldrin and Levine (2007)).

- The literature on cumulative innovation (e.g. O'Donoghue et al (1998)) argues for
  - Full protection against imitation,
  - Some protection against future innovation.

... but this is done in the context of a quality ladder, where things like the "tragedy of the anti-commons" cannot occur.

This Paper

- Goal:
  To revisit the discussion on the net advantages of IPRs protection in the context of an industry-dynamics model.

- In order to do that we
  1. present a model of industry dynamics with endogenous innovation, and
  2. a quality ladder model of (linear) growth.

- Our main findings are that
  1. protection against innovative entry is detrimental to welfare.
  2. protection against imitation involves a nontrivial trade-off (imitation reduces the hurdle to innovative entry).

- We also study the effects of financial constraints. In order to do that we
  1. present a theory of (partial) licensing based on financial constraints, and
  2. embed this model in the industry setup.
- We show that if FCs get relaxed, IPRs protection should diminish.

The Industry

- An infinite-horizon industry with discount β.
- A measure-one continuum of independent business niches.
- At t a measure x_t of niches is occupied by active patent holders that obtain a profit flow $a > 0$.
- The remaining $1 - x_t$ niches are occupied by Bertrand competitors that make 0 profits.
- Each period monopoly might be lost through:

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  2. **Innovation:**
     - After imitation, innovation occurs with *endogenous* probability q_t.
     - A patent grants the incumbent a probability λ_2 of winning the legal dispute against the innovator.

From Invention to Successful Entry

- There is an infinite stock of identical risk-neutral potential entrepreneurs.
- Entrants at $t-1$ must pay
  - the cost of innovation, normalized to 1, and
  - a cost of entry Φ.
- Innovation occurs at t.
- Denote as
  - p_t the probability that an innovator is successful,
  - v_t the present value of profits from incumbency.
- There will be entry as long as

$$\beta p_t v_t \geq 1 + \Phi.$$

- Successful development faces two hurdles:
  1. Innovation race, modeled as congestion in entry:

e_t	$\Rightarrow$	$\dfrac{1}{1+e_t}$	$\Rightarrow$	$q_t = \dfrac{e_t}{1+e_t}$
(developing inventions)		(prob. of generating a challenger product)		(challenged niches)

  2. The incumbent's opposition occurs via an IPRs dispute.

$$\rightarrow p_t \equiv \{1-\lambda_2[1-(1-\lambda_1)\delta]x_{t-1}\}\frac{1}{1+e_t}.$$

Remark: Competitive incumbents do not to dispute entry

- Simple way of capturing their lower resistance.
- Justified by:
  1. Competition among incumbents might imply a lower price for a license to the entrant.
  2. Prior successful imitation may identify old patent was invalid.
  3. Damages in case of litigation (or the possible settlement outcome) can be expected to be lower, since they are related to forgone profits.

Equilibrium

- The **present value of profits** from monopoly incumbency, v_t, can be recursively written as

$$v_t = a + \beta \left[1 - (1-\lambda_1)\delta\right] \left[1 - (1-\lambda_2) q_{t+1}\right] v_{t+1}.$$

- The **law of motion** for the stock of active patents is

$$x_t = [1 - (1-\lambda_1)\delta]x_{t-1} + \{1 - [1 - (1-\lambda_1)\delta]x_{t-1}\}q_t.$$

- The **free entry** condition can be written as

$$V_t = \beta p_t v_t - (1+\Phi) \leq 0,$$

with $q_t V_t = 0$ and where the probability that a developer becomes a monopolist is

$$p_t = \{1 - \lambda_2[1 - (1-\lambda_1)\delta]x_{t-1}\}(1 - q_t).$$

Analysis of Equilibrium

Definition

Given an initial condition x_0, an equilibrium is a sequence of non-negative triples (q_t, x_t, v_t), for $t = 1, ...\infty$, that satisfy the three conditions:

- Present value equation for v_t,
- Law of motion of x_t, and
- Free entry condition for innovators.

- In an equilibrium with positive entry, the previous conditions can be summarized into two, which depend on (v_t, x_t), as

$$\beta[1-(1-\lambda_1)\delta]\frac{1-(1-\lambda_2)x_t-\lambda_2[1-(1-\lambda_1)\delta]x_{t-1}}{1-[1-(1-\lambda_1)\delta]x_{t-1}}v_t - v_{t-1} + a = 0,$$

$$\beta(1-x_t)\frac{1-\lambda_2[1-(1-\lambda_1)\delta]x_{t-1}}{1-[1-(1-\lambda_1)\delta]x_{t-1}}v_t - (1+\Phi) = 0.$$

Steady State

- The Steady-State can be written as

$$\left[1-\beta[1-(1-\lambda_1)\delta]\frac{1-[1-\lambda_2(1-\lambda_1)\delta]x_{ss}}{1-[1-(1-\lambda_1)\delta]x_{ss}}\right]v_{ss}-a=0, \quad (1)$$

$$\beta(1-x_{ss})\frac{1-\lambda_2[1-(1-\lambda_1)\delta]x_{ss}}{1-[1-(1-\lambda_1)\delta]x_{ss}}v_{ss}-(1+\Phi)=0, \quad (2)$$

with

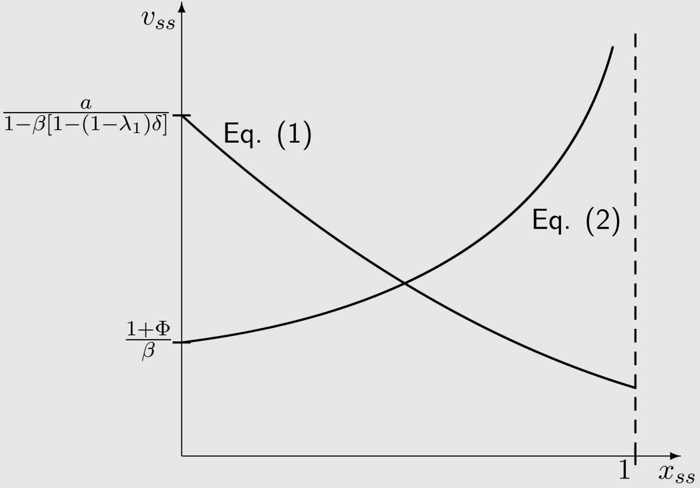
$$q_{ss}=\frac{(1-\lambda_1)\delta x_{ss}}{1-[1-(1-\lambda_1)\delta]x_{ss}}.$$

Lemma

There exists a unique steady-state equilibrium. This equilibrium has $x_{ss} > 0$ if and only if

$$\beta \frac{a}{1 - \beta[1 - (1 - \lambda_1)\delta]} > 1 + \Phi. \tag{3}$$

This equilibrium is locally stable and exhibits monotonic convergence in the state variable x_t and saddle-path convergence in the jump variable v_t.


v_{ss}
$\frac{a}{1-\beta[1-(1-\lambda_1)\delta]}$
Eq. (1)
Eq. (2)
$\frac{1+\Phi}{\beta}$
1
x_{ss}

Comparative Statics

	IP Protection a/ Imitation λ_1	IP Protection a/ Innovation λ_2
Entry, q_{ss}	?	$-$
Active patents, x_{ss}	$+$	$-$
Value of patents, v_{ss}	$+$	$+$

- Comments:
  - Ambiguous effect of net imitation risk on innovation (incumbency-rents vs. entry-hurdle). ▸ Figure
  - Unambiguous effects of $\lambda_2 \Rightarrow$ bad for innovation. ▸ Intuition

Welfare Implications

- Let us interpret innovation as in a standard quality ladder model with limit pricing.
- Welfare = Net utility of a unit mass of consumers

  (Entrepreneurs and incumbents make 0 profits).

  - Additive preferences; discount factor β.
  - Unit demand of good jt gives $U_{jt} = A_{jt} - P_{jt}$.
- Innovative entry in niche j increases A_j by a:
  - Monopolized niches: $\Delta U_j = \Delta A_j = a$ *immediately*.
  - Competitive niches: $\Delta P_j = a$ ($\Rightarrow \Delta U_j{=}a$ after *next* entry)
- Imitation increases welfare by a only in previously monopolized niches.

- In the steady state, consumer net utility grows *linearly* over time.
- The natural welfare measure is the NPV of consumers' utility gains in steady state:

$$W_{ss} = \underbrace{x_{ss}}_{\text{active patents}} \{ \underbrace{(1-\lambda_1)\delta}_{\text{imitation rate}} + \underbrace{[1-(1-\lambda_1)\delta](1-\lambda_2)q_{ss}}_{\text{innovation rate}} \} \underbrace{\left[\frac{a}{1-\beta}\right]}_{\text{NPV of } \Delta U}$$

- The effect of changes in any parameter can be decomposed as

$$\frac{dW_{ss}}{d\theta} = \frac{\partial W_{ss}}{\partial \theta} + \frac{\partial W_{ss}}{\partial q_{ss}}\frac{dq_{ss}}{d\theta} + \frac{\partial W_{ss}}{\partial x_{ss}}\frac{dx_{ss}}{d\theta},$$

where $\partial W_{ss}/\partial q_{ss} > 0$ and $\partial W_{ss}/\partial x_{ss} = W_{ss}/x_{ss} > 0$.

Innovation and Welfare (effect of λ_2)

Protection of incumbents *against innovation*...

- *Reduces* turnover ($\{\cdot\}$) for given q_{ss} and x_{ss}.
- *Reduces* innovation (q_{ss}).
- *Reduces* the proportion of monopolized niches (x_{ss}).
  $\Rightarrow$ Unambiguously detrimental to welfare.

- This result is opposite to what it is obtained in the literature. Typically *forward breadth* tries to balance incentives for current and future innovators.
- Here we show that the pressure of competitive entry provides enough incentives.

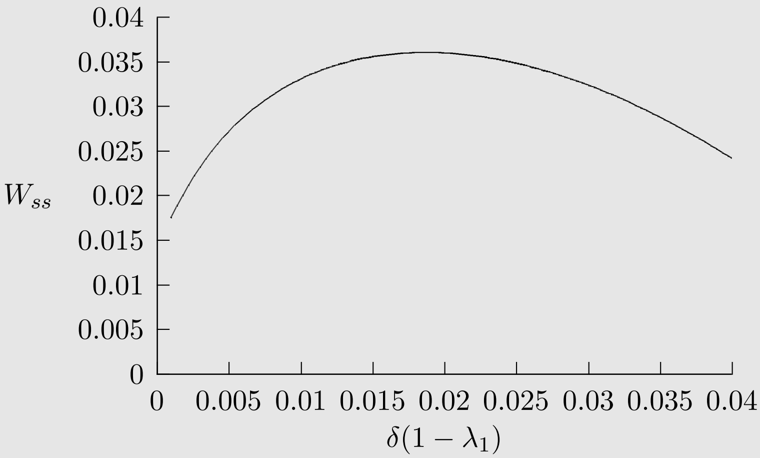
Imitation and Welfare (effect of λ_1)

Protection of incumbents *against imitation*...

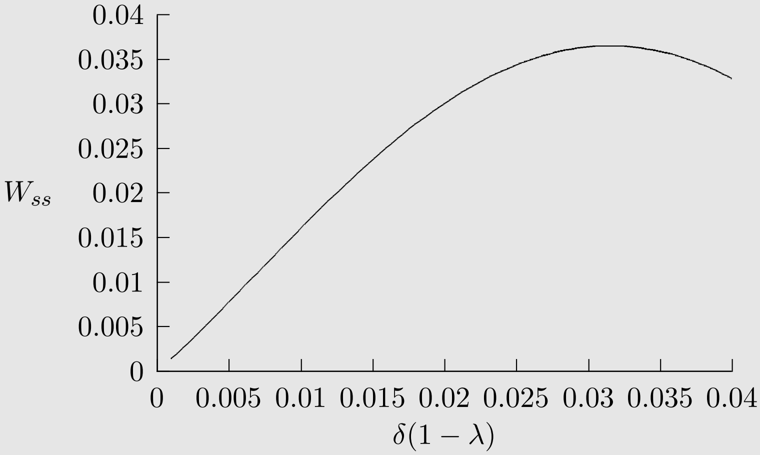
- *Reduces* turnover ($\{\cdot\}$) for given q_{ss} and x_{ss}.
- Has *ambiguous* effects on innovation (q_{ss}).
- *Increases* the proportion of monopolized niches (x_{ss}).
  $\Rightarrow$ Overall effect is ambiguous.

- As opposed to the literature, full protection against imitation (*backward breadth*) might not be optimal. Imitation facilitates future entry.

- Optimal imitation risk may be interior.



- In practice, an independent choice of λ_1 and λ_2 may not be feasible.



Financing the Development

- Suppose now that the entrepreneur does not have any funds at $t-1$ to pay 1 necessary for development (assume Φ is non-pecuniary).
- Development takes the form of
  - Measure-one continuum of development paths.
  - At most one path can lead to a new product in t.
- Developing a path also requires proper management

Management	Prob. of Success	Private benefits
Diligent	p_t	0
Negligent	0	b

- The innovator can
  - borrow funds to develop a proportion $1-\alpha_t$ of paths, and
  - license the remaining α_t to another firm.

- The development cost paid by a third party increases in c (non-transferable know-how or utility gain from entrepreneurial effort).
- We focus on the *interesting* case:

Assumptions

1. $\beta p_t v_t > 1 + c,$
2. $\beta p_t v_t > b > c.$

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Assumptions

1. $\beta p_t v_t > 1 + c$,
2. $\beta p_t v_t > b > c$.

- The investment has NPV>0 even if undertaken by a licensee.
- Diligent management is efficient.
- Financial constraints shape the solution to the development problem:
  - E would prefer to develop her invention fully in-house, however,
  - Internal development is not incentive compatible if a large part of v_t must go to the financier.

- The competitive deep-pocketed licensees pay *in total*

$$T = \alpha_t \left[\beta p_t v_t - (1+c)\right].$$

- Financing is possible if
  1. Competitive financiers participate,

$$(1-\alpha_t)\beta p_t R_t \geq (1-\alpha_t) - T.$$

  2. E engages in diligent management (IC),

$$(1-\alpha_t)\beta p_t (v_t - R_t) \geq (1-\alpha_t) b.$$

Results

- E optimally licenses the smallest proportion of paths that satisfies IC:

$$\beta p_t v_t - 1 = \alpha_t^* c + (1 - \alpha_t^*) b$$

Proposition

If $b < \beta p_t v_t - (1 + c)$, the entrepreneur can develop her innovation fully in-house, obtaining a net payoff $\beta p_t v_t - (1 + c)$. Otherwise, she out-licenses a fraction

$$\alpha_t^* = 1 - \frac{\beta p_t v_t - 1}{b - c} \quad (4)$$

of the development paths and keeps the remaining fraction in-house, obtaining a a net payoff $V^* = (1 - \alpha_t^*) b$.

The Free-Entry Condition

- The previous free-entry condition now reads

$$V_t = \beta p_t v_t - (1 + \alpha_t^* c) \leq \Phi_0$$

with $q_t(V_t - \Phi_0) = 0$.

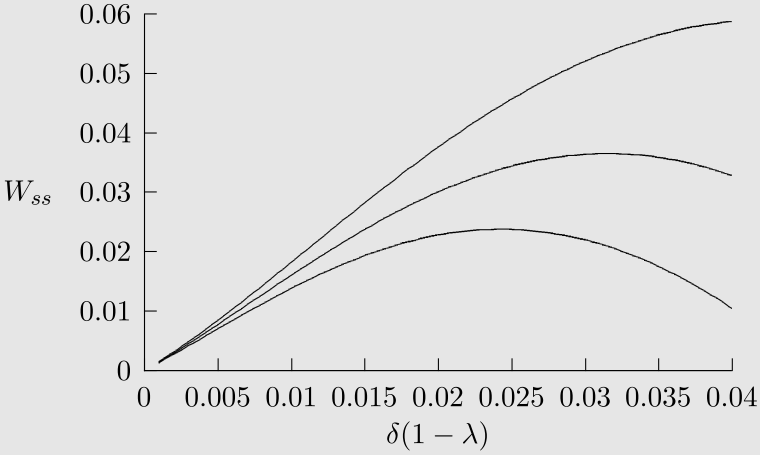
- We can pin down α_t as

$$V_t = (1 - \alpha_t^*)b = \Phi_0 \longrightarrow \alpha_t^* = \alpha^* = 1 - \frac{\Phi_0}{b}.$$

- The previous results can be reproduced by rewriting

$$\Phi_1(b) \equiv \Phi_0 + \left(1 - \frac{\Phi_0}{b}\right) c.$$

Financial Constraints and Optimal IPRs Protection



- Hence, weaker FCs should be associated with weaker IPRs.
- Why?
  - Weaker FCs allow a firm to internally develop more of the innovation.
  - As a result, the cost of licensing decreases, making innovation more socially valuable.
    That is, if we exclude the costs from congestion, the social cost of an innovation can be loosely interpreted as

$$1 + \Phi_1(b)$$

    increasing in b.
- Alternatively, we can interpret this result as saying that if innovators are more likely to come by we need to protect them less against imitation.

Concluding Remarks

- IPRs protection has opposite effects for the dynamics of innovative industries:

  Protecting the rents of incumbent innovators may discourage the entry of new firms.
- We have developed a model that allows us to analyze these trade-offs and how they get qualified in the presence of financial constraints.
- The distinction between imitation and innovation yields novel insights as for how the former interacts with the latter:
  1. Minimal protection against innovation is *always* optimal.
  2. But optimal protection against imitation may be interior (some imitation is dynamically beneficial to innovation)

- Financial constraints
  1. Provide a rationale for partial licensing.
  2. Dampen innovation and welfare.
  3. Alter some of the trade-offs for IP protection:
     - With tighter financial constraints, entrepreneurs out-license a larger fraction of their innovations.
     - Turnover among IPR holders is a less powerful source of incentives to innovate.
     - Protection against imitation becomes relatively more important (and the incumbency-rent effect gains importance relative to entry-hurdle effect)

Supporting Material

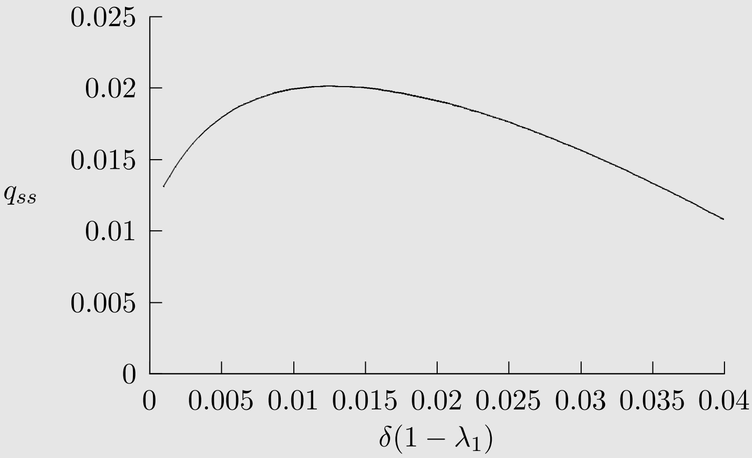


Figure: Steady-state entry and imitation risk. Parameters: $a = 0.1$, $\beta = 0.96, \lambda_2 = 0.5$, $b = C = 0.3$, and $\Phi = 0.15$.

Return

Why is x_{ss} decreasing in λ_2?

- Protecting innovators against further innovators involves an intertemporal trade-off
- Consider a simpler model w/o congestion, w/ one potential entrant per period & protection λ_2:
  - Value of incumbency

    $v = a + \beta\lambda_2 v \Rightarrow v = \frac{a}{1-\beta\lambda_2} \Rightarrow \frac{dv}{d\lambda_2} > 0$ (incumbency-rents effect)

  - Net gains from entry

    $\pi = (1-\lambda_2)v - \Phi = \frac{(1-\lambda_2)a}{1-\beta\lambda_2} - \Phi \Rightarrow \frac{d\pi}{d\lambda_2} < 0$ (entry-hurdle effect dominates!)

Return