Direct and indirect effects of competition on privates incentives to R&D and licensing

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Intro

Overview of results

This article builds on the results of existing literature on technology licensing and analyses how competition in the market for the final good affects the outside innovator's licensing and investment strategies. More in details, this article answers this major research question:

What are the direct and indirect effects of downstream competition in altering the size and the impact of an innovation produced by the upstream innovator?

Overview of the results

This paper shows that competition in the product market exerts a *feedback* effect on innovation **regardless of the licensing scheme adopted by the upstream innovator**.

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Overview of the results

This paper shows that competition in the product market exerts a *feedback* effect on innovation **regardless of the licensing scheme adopted by the upstream innovator**.

- As competition triggers the Arrowian replacement effect, it generally increases the incentives for a firm to adopt an innovation (direct effect), *ceteris paribus*.
- In turn, a sufficiently large innovation may provide the licensees with a robust strategic advantage that forces non-adopters out of business. Ultimately, this raises the licensee's willingness to pay to survive in the market (the indirect effect).

Literature Review

1. **Licensing contracts**
   - (Auction $>$) Upfront fee $>$ Royalties (Katz and Shapiro [1985], **Kamien and Tauman [1986, 2002]**)
   - Royalties $\geq$ Upfront fee (**Sen [2007], Sen and Tauman [2018]**)
   - Two-part tariff (Erutku and Richelle [2007])
   - Partial Adoption (Kamien et al. [1992], **Lapan and Moschini [2000]**)
2. **Competition and innovation**
   - Competition affects the type of innovation (Vives [2008], Beneito et al. [2015])
   - Non-monotonic relation between innovation and competition (Aghion et al. [2015], Delbono and Lambertini [2020])
   - Upstream innovation depends on product market competition (**Marshall and Parra [2019]**)
3. **Industry shake-outs & welfare**
   - Market exit of non licensees (Lahiri and Ono [1988])

Model

Model set up

- Two segments of an industry: upstream (monopolist patentee/innovator) and downstream (n-oligopoly).
- Homogeneous product with linear demand $P(Q) = a - b\,Q$, with $Q = \sum_{i=1}^{n} q_i$
- Downstream firms compete in quantities (Cournot): the intensity of competition is given by n

Two technologies available:

1. patented technology (royalty rate r or upfront fee F) – strategy A
2. old/standard technology (freely available) – strategy B

$$C_i(q_i, \cdot) = \begin{cases} (c - x + r)q_i + F(x) & \text{if} \quad i \in A \\ c\, q_i & \text{if} \quad i \in B \end{cases}$$

- with $F = 0$ if $r > 0$ and viceversa (no two-part tariff)
- c is the marginal cost of production with B
- x is the cost reducing effect/the size of innovation
- tie-breaking rule: A is preferred to B if it comes at no extra costs

To develop a technology of size (quality) x, the upstream innovator invests $I(x) = \gamma\, x^2$

γ is a cost associated to innovation. It can be interpreted as the inverse of the innovator's efficiency $(1/\gamma)$

The revenues from licensing depend on the contract chosen and the number of licensees m.

$$\pi_u = \begin{cases} \sum_{i=1}^{m} q_i\, r - \gamma\, x^2 & \textit{if royalties} \\ \\ m\, F(x) - \gamma\, x^2 & \textit{if upfront fee} \end{cases}$$

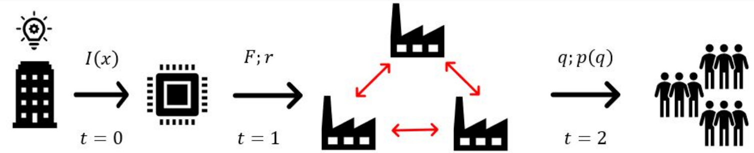
Definition

Sen [2007]. For $k \geq 1$, a cost-reducing innovation is k-drastic if k is the minimum number such that if k firms have the innovation, all other firms drop out of the market, and a k-firm natural oligopoly is created.

Timing of the game

- $t = 0$ the upstream innovator chooses which contract to enforce (r or F) and invests $I(x) = \gamma\, x^2$
- $t = 1$ the innovator decides the number of licensing contracts $m \leq n$ to sell and the price of the license.
- $t = 2$ given the contract type, the price of license and m, downstream firms compete in quantities

Game is solved by backward induction



Royalties

Non-drastic innovations: Adoption decision

Consider the ith firm's choice of technology:

$$C_i(q, x, r) = \begin{cases} (c - (n - i + 1)(x - r))q_i & \text{if } i \in A \\ (c + (i - 1)(x - r))q_i & \text{if } i \in B \end{cases} \tag{1}$$

The innovator's maximisation problem is given by:

$$\max_r \pi_u = \sum_{i=1}^{m} q_i(r, x)\, r - \gamma\, x^2$$

$$r \leq x \qquad \text{P.C.}$$

The participation constraint is binding:

$$r = x \Rightarrow C(q) = c\, q_i$$

Remark 1. *Assume the innovation is non-drastic.* If the licensing contract is a per-unit price, then all firms adopt the superior technology and pay the royalty $r = x$ to the innovator. [Kamien and Tauman, 2002]

Non-drastic innovations: Investment decision

In equilibrium, the innovator choose:

$$x^+ = \frac{n(a-c)}{2\,\gamma(n+1)}$$

It is easy to observe that x^+ depends positively on the intensity of competition n:

$$\frac{\partial x^+}{\partial n} = \frac{a-c}{2\gamma(n+1)^2} > 0$$

Remark 2. As competition increases the innovator's revenues from licensing via royalties, it also increases the incentives to invest and the size of innovation in equilibrium.

K-drastic innovations: Adoption decision

Assume now that the innovator lowers the royalty rate from $r = x$ to $r = \beta x$, with $\beta \in (0, 1)$. Following the definition stated above and using eq. 1, an innovation is k-drastic if it satisfies:

$$x \geq \frac{(a - c)}{m(1 - \beta)} \quad \text{with} \quad m \in [k, n - 1] \qquad \text{C.1}$$

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The innovator's choice is the number of licensees to sell. Depending on the desired number of adopters m, she earns:

$$R_u^{Dr}(m, x, \beta) = \begin{cases} \frac{m\,\beta\,x\,(a-c+x(1-\beta))}{m+1} & \text{if} \quad m \in [k, n-1] \\ \frac{n\,x\,(a-c)}{n+1} \equiv R_u^r & \text{if} \quad m = n \end{cases}$$

K-drastic innovations: Investment decision

A quick comparison of the payoff of the innovator yields to the following condition:

$$R_u^{Dr}|_{m<n} \geq R_u^{Dr}|_{m=n} \quad \text{if} \quad x \geq \frac{(a-c)((m+1)n - \beta m(n+1))}{(1-\beta)\beta m(n+1)} \quad \text{C.2}$$

It is possible to see that, whenever the innovator sets $\beta \in [\beta^*, 1)$, where $\beta^* = \frac{n}{n+1}$, C.2 is subsumed by C.1.

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From C.1, the number of licensees in equilibrium:

$$\frac{\partial \pi_u^{Dr}(x, \beta, \gamma)}{\partial, x} = 0 \Rightarrow x^{Dr}(\beta, \gamma) = \frac{(a-c)\beta}{2\gamma}; \quad m^{Dr}(\beta, \gamma) = \frac{2\gamma}{\beta(1-\beta)}$$

With $\gamma \leq \gamma^{Dr} \equiv \frac{\beta(1-\beta)(n-1)}{2}$ to ensure conditions C.1 is satisfied. As before, C.2 holds when $\beta \in [\beta^*, 1)$.

Results royalties (1)

Proposition (1)

Assume the licensing scheme is a per-unit linear price, and that $\gamma \leq \gamma^{Dr}$*. Then the innovator is willing to license the new technology to a restricted number of firms* $m^{Dr} < n$ *for a discounted royalty-rate* $r^{Dr} = \beta x^{Dr}$*, with* $\beta \in [\beta^{*}, 1)$*. The rationing of licenses is socially efficient.*

Proposition (2)

Competition does not influence ***directly*** *the size of a k-drastic innovation under a royalty-based licensing scheme. However, as* $\frac{\partial \gamma^{Dr}}{\partial n} > 0$ *and* $\lim_{n \to \infty} \beta^{*} = 1$*, it* ***indirectly*** *increases the incentives of an innovator to develop a k-drastic innovation.*

Results royalties (2)

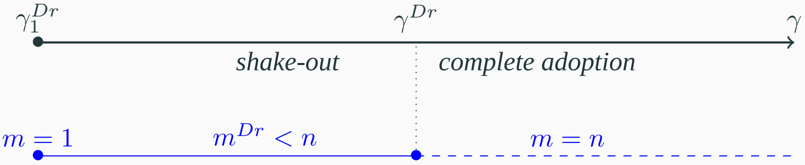


Figure 1: The effects of innovation on market structure, depending on the efficiency of the innovator γ. Notice that $\gamma_1^{Dr} = \frac{\beta(1-\beta)}{2}$ is the threshold below which $m^{Dr} = 1$.

Licensing Fees

General conditions

Let $\pi_A(x,m)$ and $\pi_B(x,m)$ be the profits of the adopting and non-adopting firms, respectively, given the size of innovation x and the number of adopters m.

The maximum fixed fee (T.I.O.L.I. offer) that the m adopting firms are willing to pay is:

$$F \leq \pi_d^A(x,m) - \pi_d^B(x,m-1) \qquad \text{C.3}$$

which is the participation constraint of the innovator's participation problem.

Non-drastic innovations (1)

Using C.3 it is easy to derive the price of the licensing

$$F = \frac{nx(2(a-c) + x(n-2m+2))}{(n+1)^2}$$

from which:

$$x^F = \begin{cases} \frac{2n(n+2)(a-c)}{8\gamma(n+1)^2 - n(n+2)^2} & \text{if} \quad \gamma < \gamma^F \\ \frac{n^2(a-c)}{\gamma(n+1)^2 + (n-2)n^2} & \text{otherwise.} \end{cases}$$

$$m^F = \min\{\bar{m}(n), n\} \quad \text{with} \quad \bar{m}(n) = \frac{2\gamma(n+1)^2}{n(n+2)}$$

Notice that $\bar{m}(n) < n$ if $\gamma < \gamma^F \equiv \frac{n^2(n+2)}{2(n+1)^2}$.

Non-drastic innovations (2)

Proposition (3)

Let the innovator choose a fixed fee licensing regime to license a non-drastic innovation. Then, competition (directly) influences the licensing outcome in two main ways. First, increasing the competitive pressure (given the adoption rate m^F*) magnifies the strategic advantage of adopters and, consequently, their willingness to pay for the innovation, with a positive effect on the equilibrium size* x^F*. Second, as competition lowers the profit margins of the downstream firms, it also hampers the surplus extraction of the innovator. Thus, in order to shield her revenues, the innovator reduces the number of contracts to be licensed in equilibrium (*$\bar{m}_n' < 0$*)*

$$\frac{\partial x^F}{\partial n} \begin{cases} > 0 & \textit{if} \quad \gamma \geq \frac{n^3}{2n+2} \\ < 0 & \textit{if} \quad \frac{n^3}{2n+2} > \gamma \geq \gamma^F \\ > 0 & \textit{if} \quad \gamma^F > \gamma \end{cases}$$

K-drastic innovations (1) - exit of non-adopters

Using C.3 it is easy to derive the price of the licensing

$$F^{DF} = \frac{\left((a-c)(m+n+2) + x\left(-m^2+n+2\right)\right)\left((a-c)(n-m) + x\left(m^2+n\right)\right)}{(m+1)^2(n+1)^2}$$

from which:

$$x^{DF} = \begin{cases} \frac{n(n+2)(a-c)}{2\gamma(n+1)^2} & \text{if} \quad \gamma_1^{DF} < \gamma < \gamma^{DF} \\ \frac{a-c}{4\gamma-1} & \text{if} \quad \gamma \leq \gamma_1^{DF} \end{cases}$$

$$m^{DF} = \max\{1, \bar{m}(n)\} \quad \text{with} \quad \bar{m}(n) = \frac{2\gamma(n+1)^2}{n(n+2)}$$

where $\gamma^{DF} = \frac{n(n+2)^2}{4(n+1)^2}$ and $\gamma_1^{DF} = \frac{n(n+2)}{2(n+1)^2}$ are the thresholds that sorts non-drastic from k-drastic innovations, and k-drastic from 1-drastic innovations, respectively.

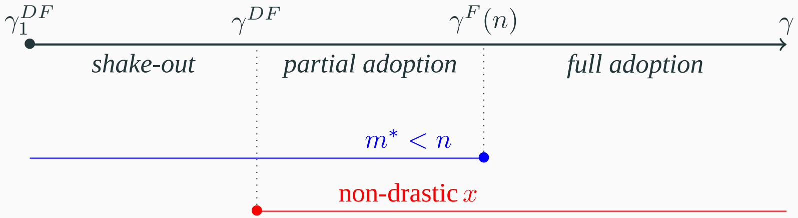
K-drastic innovations (2)

Proposition (4)

Let the innovator choose a fixed fee licensing regime to license a k-drastic innovation. Then, competition influences the size of innovation (directly) by altering the exposure of the market to k-drastic innovations - i.e., by increasing the fragility of the market. In fact, the more intense the competition, the higher the willingness to pay to be among the restricted number of adopters. In turns, this means the innovator would invest more and that the resulting innovation would exert an even larger strategic disadvantage to non-adopters, lowering the required number of contracts necessary for the innovation to have drastic effects on the market ($\bar{m}_n' < 0$*). However, if the innovation is 1-drastic, competition ceases to have any effect on the incentives to invest in innovation:*

$$\frac{\partial x^{DF}}{\partial n} \begin{cases} > 0 & \textit{if} \quad \gamma^{DF} \geq \gamma > \gamma_1^{DF} \\ = 0 & \textit{if} \quad \gamma_1^{DF} \geq \gamma \end{cases}$$

Important thresholds



Important thresholds (2)

Proposition (5)

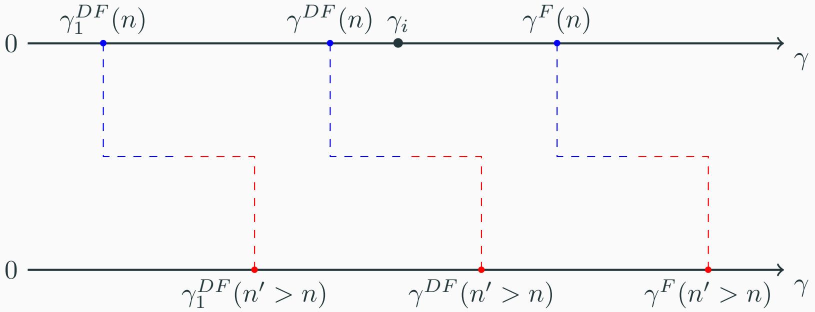
For a given market size n, there is complete adoption of the innovation if the cost of investing is sufficiently high ($\gamma \geq \gamma^F$). Conversely, there is partial adoption ($\gamma < \gamma^F$). Furthermore, when the cost of investing is sufficiently small ($\gamma < \gamma^{DF}$), partial adoption implies an industry shake-out. In this case, only the licensees stay active in the market.

Corollary

Consider a downstream market of size n, and an innovator that faces a cost of investing in innovation $\gamma \in [\gamma_1^{DF}, \gamma^{DF}]$. The introduction of an innovation licensed via upfront fees results in an inefficient allocation of production in the market. If this is the case, the $n - m^* > 1$ firms that do not adopt the new technology can produce positive quantities of the final good with less efficient technology.

Effects of competition on the market structure (1)

All the thresholds γ_1^{DF}, γ^{DF}, and γ_F are positive functions of n.



Effects of competition on the market structure (2)

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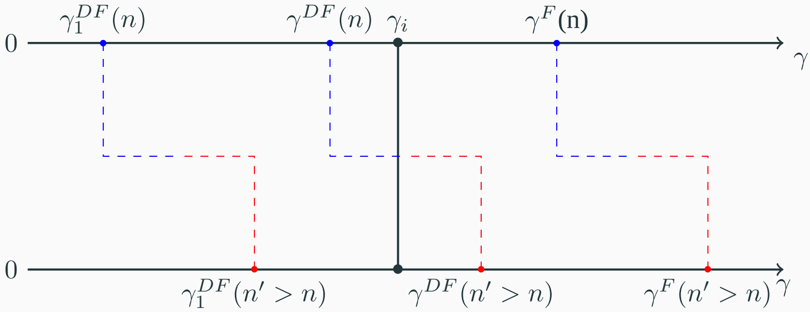
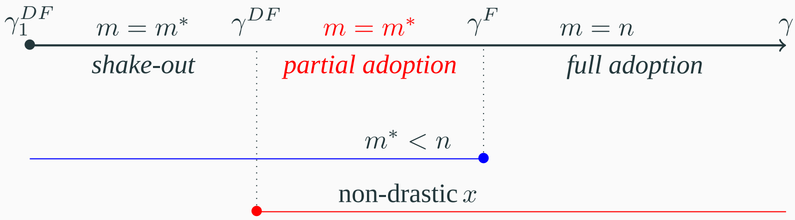


The same innovation may have drastic effects in more competitive markets

Proposition 6. *Under a fixed fee licensing scheme, competition has both a* ***direct*** *and an* ***indirect*** *effect on the incentives to invest in innovation. The* ***direct*** *effect is as described in propositions 3 and 4. Instead, the* ***indirect*** *effect is identified by the sensitivity of the market to drastic effects of the innovation. In particular, as* $\frac{\partial \gamma^{DF}}{\partial n} > 0$ *and* $\frac{\partial \gamma_1^{DF}}{\partial n} > 0$*, the incentives of an innovator to develop a k-drastic innovation increases.*

A bit of Welfare

Welfare - obsolete technology shut down



When $\gamma \in (\gamma^{DF}, \gamma^F)$, we have that $m = m^* < n$ and $n - m^* > 0$ - i.e., both adopters and non adopters produce in the market

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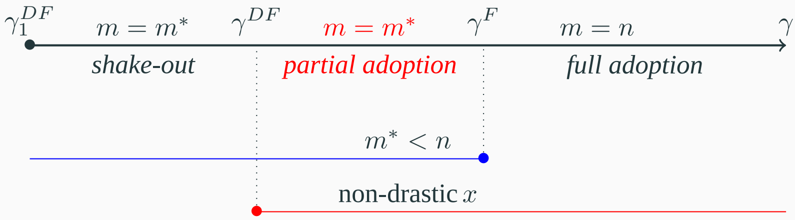

When $\gamma \in (\gamma^{DF}, \gamma^F)$, we have that $m = m^* < n$ and $n - m^* > 0$ - i.e., both adopters and non adopters produce in the market

Remark. *In a vertical market where an innovator supplies a superior production technology, a switch-off of the old technology is never welfare improving. The benefits from efficient reallocation of the production output do not exceed a more concentrated market's diseconomies.*

Conclusions

Conclusions (1)

This article analyses and decomposes the effects of competition on innovation into two main channels:

- **a direct effect that alters the level of investment in innovation in equilibrium**,
- **an indirect effect that affects the sensitivity of the market to large innovations.**

Industry shake-outs are more likely and more intense in markets where competition is quite intense, and only either very efficient innovators or very large innovation can alter the structure of an already concentrated market.

Conclusions (2)

Depending on the cost of innovation, licensing may result in

- full adoption of the innovation, both under per-unit linear price and fixed fee;
- partial adoption with heterogeneous technological endowment, for intermediate innovations under fixed fee;
- the partial adoption with industry shake-out, both under per-unit linear price and fixed fee.

Rationing of licenses is possible also under linear per-unit price in a single-input production function model (Lapan and Moschini (2000) for multi-input production functions models).

Thank you for your attention!

Luca Sandrini