Free Licensing in a Differentiated Duopoly

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Introduction, Motivation and Problem

- Technology licensing is a common phenomenon in industries. Technology transfer reduces the licensee's cost of production or improves the quality of the product.
- If the transferor is a non-producing firm, or does not compete in the transferee's market, transfer is always feasible to the extent that it enhances the transferee's profit. Transferor designs a contract to extract maximum possible surplus.
- If the licensor and the licensee compete in the same market place, technology licensing reduces the operational profit of the licensor. But technology licensing may occur if the licensee can fully compensate the loss (by means of fee and/or royalty).
- There is a vast literature discussing the optimal licensing contracts. [Explain the factors]
- There is also a literature that shows that sometimes technology licensing results in an upward shift of the market demand. This further counters the negative effect of technology transfer on the transferor's profit. [e.g., **Shepard** (RJE, 1987), **Stamatopoulos** (CRET 2006), **Stamatopoulos and Tauman** (Math. Soc. Sc., 2008)]

Introduction, Motivation and Problem (Contd.)

Our question is: Can free licensing be profitable?

- The question is not without any context. For instance, the music industry often benefits by allowing free downloading to music consumers. This is indeed the case when consumers' taste heterogeneity and product diversity are sufficiently large [**Peitz and Waelbroeck** (IJIO 2006)].
- Free licensing of innovations in the computer software industry is also common.
- We raise the issue without questioning whether free licensing is optimal. There can be situations when royalty licensing is not possible (weak patent protection) and fee licensing is not profitable. For example, in a Cournot duopoly fee licensing is not profitable unless the unit cost reduction under superiot technology is large enough and/or goods are less substitutes. [e.g., **Marjit** (Eco. Lett. 1990), **Wang** (Eco. Lett. 1998; J. Eco. Bus. 2002)].

Introduction, Motivation and Problem (Contd.)

<u>What we shall do in the paper</u>

- We construct a differentiated duopoly model with quantity competition Initially, one firm holds a superior production technology which, if transferred, will save resources of the transferee, and hence reduce the unit cost of production.
- Further, it is optimal for the licensee to buy (common) inputs from the licensor.
- By sharing its production knowledge the licensor creates competition from the licensee, but the former's loss of profit due to competition may be outweighed by the revenue it earns from the sale of inputs to the competitor; hence free licensing of a superior technology may be mutually beneficial.

Introduction, Motivation and Problem (Contd.)

Existing literature on free licensing

- It focuses mostly on network externalities and the shift of market demand for the product.
- **Conner** (Mgmt. Sc. 1995) analyzes the benefits of market expansion from licensing and derives conditions for which it is profitable for an incumbent to license its technology for free to an entrant who competes in the incumbent's market. The paper suggests that innovator's best strategy may be to encourage clones of its products when a network externality is present.
- **Boivin and Langinier** (Eco. Bull. 2005) assume, the structure of the market influences the market demand. In particular, consumers' willingness to pay for a product is larger when it is duopoly than when it is monopoly. Hence licensing results in an upward shift of the market demand function.
- Free revealing knowledge of the newly innovated products also studied in **von Hippel and von Krogh** (R&D Mgmt. 2006).
- In contrary, no network externality, nor market demand-shift effect in our paper. Moreover, pre-licensing situation is a duopoly.

Introduction, Motivation and Problem (Contd.)

Results of the paper

- Under unconstrained input pricing, free licensing always profitable.
- Under constrained input pricing free licensing of technology profitable under some conditions.
- **First**, free licensing never profitable if products are homogeneous.
- **Second**, when products are less than perfect substitutes, free licensing of technology can be profitable only if the innovation is small and the licensor sells inputs at a sufficiently high price.
- **Third**, if the input production cost increases or the degree of product substitution rises, free licensing is more difficult to occur.
- **Fourth**, an increase in market size reduces the possibility of free licensing.
- Finally, we derive an implication of free licensing in the context of the pollution problem in the production process. In particular, we have shown that the level of pollution will be lowered under specific conditions.

Introduction, Motivation and Problem (Contd.)

Papers discussing licensing in a differentiated good model:

- To mention a few: **Wang and Yang** (Aus. Eco. Papers 1999), **Mukherjee and Balasubramanian** (Res. in Eco. 2001), **Wang** (J. Eco. Bus. 2002), and **Bagchi and Mukherjee** (IREF 2014).
- Our paper differs from those in various respects. [**Explain**]

Some works may be implicated

- **Mukherjee** (Eco. Lett. 2019) and **Mukherjee, Broll and Mukherjee** (J. of Eco. 2009)) although do not discuss free licensing question but can be implicated.
- The literature of **cross-licensing of innovations**, with firms having complementary inputs, may have also implications to free licensing.

Structure of the Model

- Differentiated duopoly with quantity competition
- Market demand : $P_i = a - q_i - bq_j, \quad i \neq j; i, j = 1,2; \; a > 0 \; ; b \in (0, 1).$
- Production technology: Input requirements per unit of output
- Asymmetric technology : Firm 1 possesses superior technology (due to prior innovation)
- Both the products require one common input, and no other inputs are required

- Firm 2's technology: One unit input to produce one unit final good; input production at a cost r per unit; $0 < r < a$.
- Firm 1's technology: m units input for one unit product, $0 < m < 1$; input production at a cost, c, per unit; $0 < c < r$.
- Hence the initial restrictions on the parameters :

(A1) $a > r > c > 0$, $0 < b < 1$ and $0 < m < 1$

Structure of the Model (Contd.)

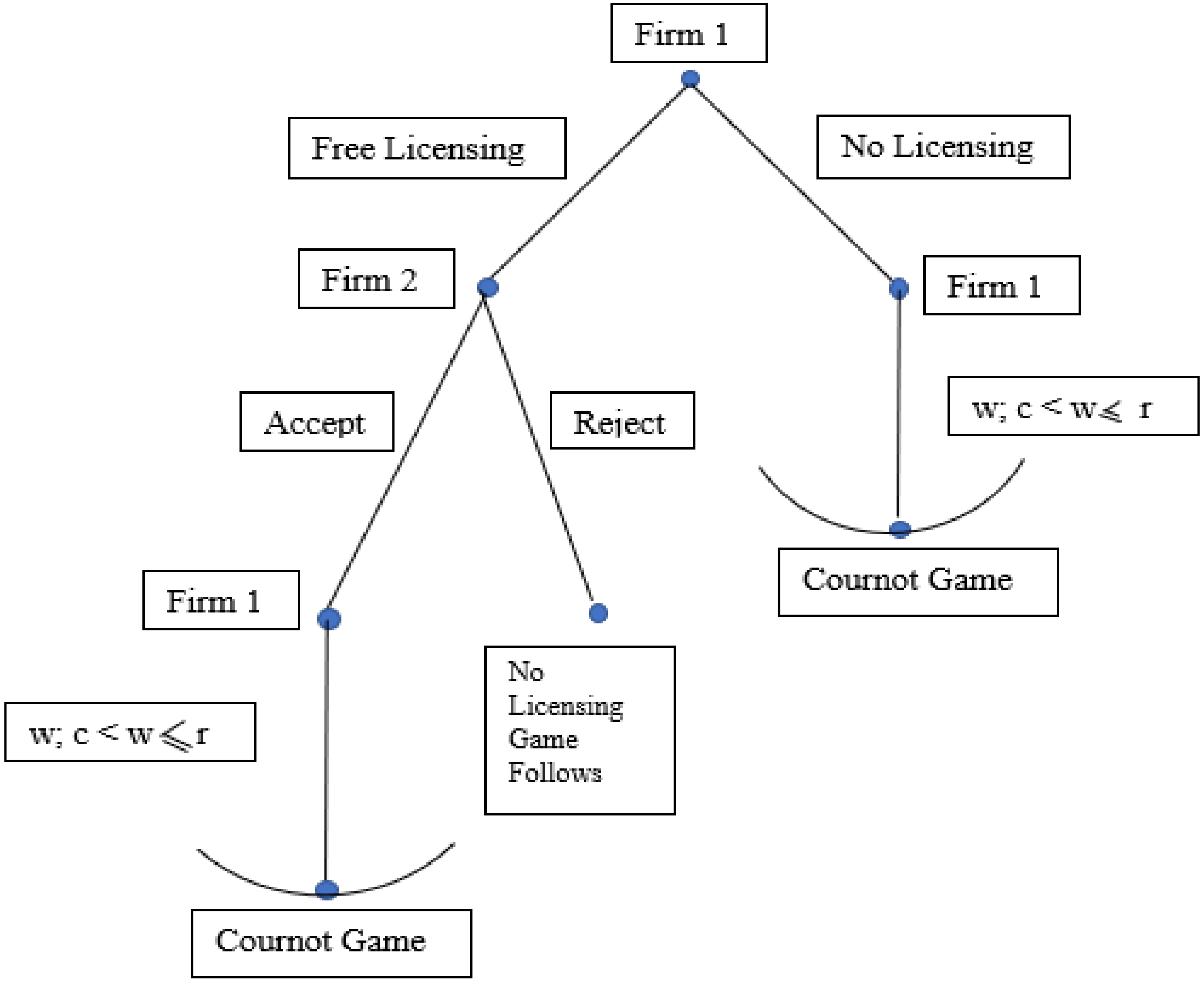
- Given the cost advantage in input production, firm 1 sells inputs to firm 2 at price w, $c < w \leq r$.
- Suppose the unconstrained input price is $\bar{w}$. If $\bar{w} \geq r$, the optimal input price will be $w = r$. This is the case of constrained input pricing.
- If $\bar{w} < r$, firm 1 will charge the unconstrained optimal input price $w = \bar{w}$.

- Assume firm 1's production technology transferable. So firm 1 will decide whether to license its superior production technology to firm 2 for free.

Unit production costs of final goods:

- No licensing: firm 1's - mc; and firm 2's – w
- (Free) licensing: firm 1's - mc; and firm 2's – mw

Game Tree:


Firm 1
Free Licensing
No Licensing
Firm 2
Firm 1
Accept
Reject
w; c < w⩽ r
Cournot Game
Firm 1
No Licensing Game Follows
w; c < w⩽r
Cournot Game

Structure of the Model (Contd.)

- Suppose $\overline{w_n}$ and $\overline{w_f}$ are the unconstrained input prices under no licensing and free licensing, respectively.
- Unconstrained input pricing will occur if $r > \max\{\overline{w_n}, \overline{w_f}\}$
- Constrained input pricing ill occur if $r \leq \min\{\overline{w_n}, \overline{w_f}\}$.
- [A third case is also possible when r belongs to their interval.]

Unconstrained input pricing i.e. $r > \max\{\overline{w_n}, \overline{w_f}\}$

- Derived the optimal input prices under no licensing and licensing. Then $\overline{w_f} > \overline{w_n}$; this means, the licensor can charge a higher input price to extract more surplus due to transferred technology.
- Under this case , r has no role to play.

Proposition 1: *Under unconstrained input pricing, free licensing is always profitable.*

Constrained Input Pricing i.e., $r \leq min\{\overline{w_n}, \overline{w_f}\}$

- **Here both under no-licensing and licensing, the optimal input price is r.**

<u>No licensing equilibrium</u>

- Unit costs of firm 1 and firm 2 are respectively mc and r.
- The profit functions are:,

$$\Pi_1 = [(a - mc) - q_1 - bq_2]q_1 + (r - c)q_2$$

$$\Pi_2 = [(a - r) - q_2 - bq_1]q_2$$

The profit maximizing quantities are: q_{1n} and q_{2n}

Assumption of initial duopoly means $q_{2n} > 0$, i.e.,

$$\text{(A2)} \qquad r < \frac{(2-b)a + bmc}{2} \equiv \bar{r}(m).$$

Equilibrium no-licensing payoffs of the firms are

$$\Pi_{1n} = q_{1n}^2 + (r - c)q_{2n} \qquad \text{and} \qquad \Pi_{2n} = q_{2n}^2$$

Constrained Input Pricing i.e., $r \leq min\{\overline{w_n}, \overline{w_f}\}$(Contd.)

Free Licensing equilibrium

- Unit costs of firm 1 and 2 are respectively mc and mr.
- The profit expressions are:

$$\Pi_1 = [(a - mc) - q_1 - bq_2]q_1 + (r - c)mq_2$$

$$\Pi_2 = [(a - mr) - q_2 - bq_1]q_2$$

- Equilibrium quantities are: q_{1f} and q_{2f}, and payoffs are:

$$\Pi_{1f} = q_{1f}^2 + m(r - c)q_{2f} \quad \text{and} \quad \Pi_{2f} = q_{2f}^2$$

- Comparing : $q_{1f} < q_{1n}$, $q_{2f} > q_{2n}$ and $\Pi_{2f} > \Pi_{2n}$
- But $\Pi_{1f} \gtrless \Pi_{1n}$, because firm 1's operational profit falls certainly, i.e., $q_{1f}^2 < q_{1n}^2$, but its volume of input sale is ambiguous i.e., $mq_{2f} \gtrless q_{2n}$.
- Even when input sale goes up, increased revenue from input sale may not be large enough to overcompensate the loss of operational profit.

Constrained Input Pricing i.e., $r \leq min\{\overline{w_n}, \overline{w_f}\}$ (Contd.)

Conditions for Free Licensing

- Given (A1) and (A2), free licensing will occur if and only if

$$(\Pi_{1f} - \Pi_{1n}) > 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

- We focus on the role of two parameters, m and r . Also study the effect of a change of a, b or c on m and r.

Proposition 2: *Free licensing is never profitable if the products are perfect substitute to each other (i.e., $b = 1$).*

- **Intuition**: If the products are homogeneous, the fierce competition will reduce firm 1's operational profit substantially, making the overall profit to fall.

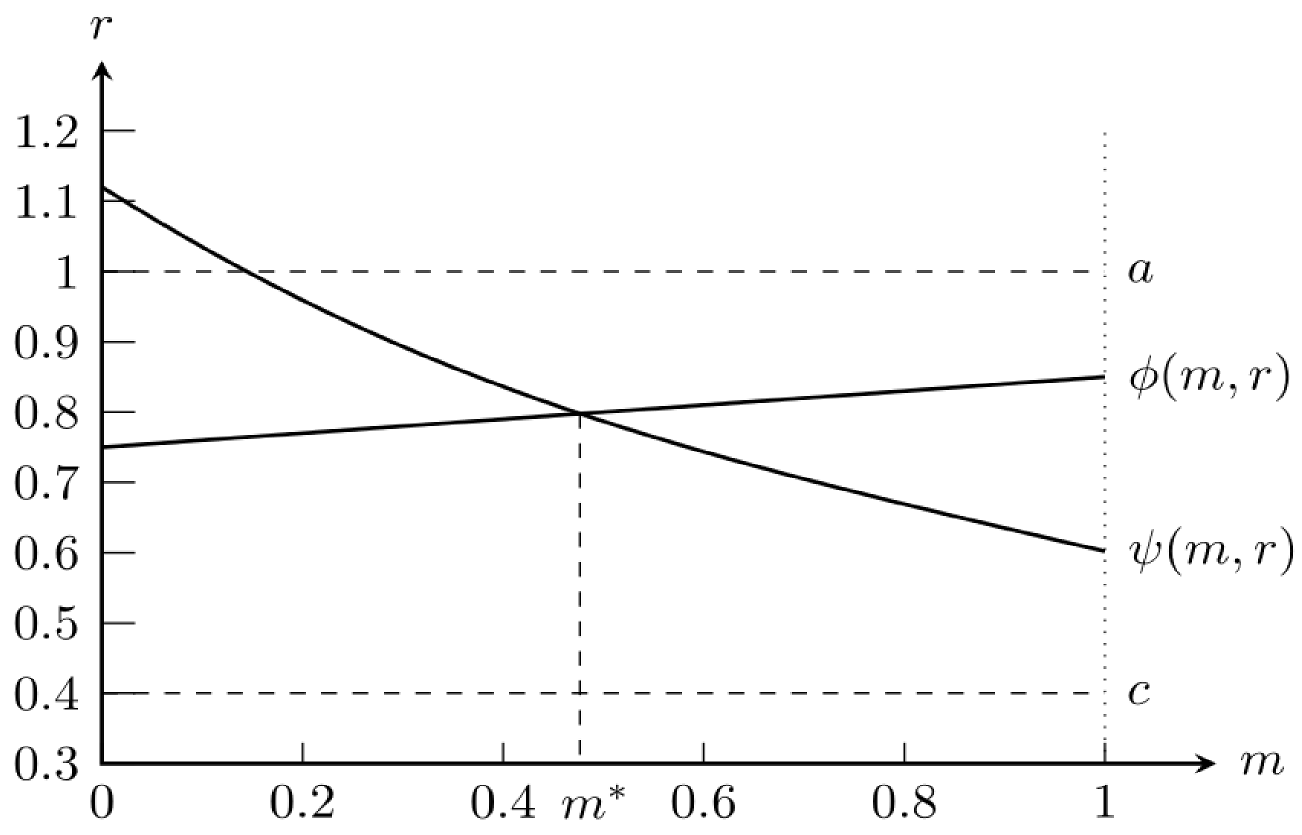
Proposition 3: *If the products are independent (i.e., $b = 0$), free licensing is profitable if and only if $a < r(1 + m)$.*

- **Intuition:** Since products are independent, so there is no competition in the product market, hence firm 1's output and operational profit will remain unchanged. But total input sale to firm 2 may or may not go up. If technology is very superior (that is, m is small enough), effectively input sale to firm 2 will fall, hence revenue from input sale will also fall.

Constrained Input Pricing i.e., $r \leq min\{\overline{w_n}, \overline{w_f}\}$(Contd.)

Conditions for free licensing in general

- Given (A1), we need to satisfy (A2) and (1) simultaneously.
- The locus $\phi(m,r) \equiv (\bar{r}(m) - r) = 0$ is upward sloping. Given any m, therefore for any $r < \bar{r}(m)$, (A2) is satisfied.
- The locus $\psi(m,r) \equiv (\Pi_{1f} - \Pi_{1n}) = 0$ is downward sloping and it intersects the first locus at $m = m^*$. Further, for $r > \underline{r}(m)$, profitability condition (1) is satisfied.



Constrained Input Pricing i.e., $r \leq min\{\overline{w_n}, \overline{w_f}\}$(Contd.)

Main result of the paper:

Proposition 4: *Given assumption (A1) and (A2), for all $m \in (m^*, 1)$, there exist $\underline{r}(m) \in (c, \overline{r}(m))$ such that for all $r \in (\underline{r}(m), \overline{r}(m))$, we must have $\Pi_{1f} - \Pi_{1n} > 0$. Further, $\frac{\partial(\overline{r}-\underline{r})}{\partial m} > 0$ for all $m \in (m^*, 1)$.*

Intuition: Under licensing, firm 1's operational profit always falls. Now, if m is very small (that is, technology is much superior), then under licensing loss of firm 1's operational profit will be to the extent that it cannot be outweighed by the gain from input sale, if any. On the other hand, if r is not sufficiently high, increase in revenue from input sale will not be large enough. And as technological superiority falls, the gap between $\underline{r}$ and $\overline{r}$ increases; this means, the possibility of free licensing also increases.

Constrained Input Pricing i.e., $r \leq min\{\overline{w_n}, \overline{w_f}\}$*(Contd.)*

Illustration: Let $a = 1$, $b = 0.5$ and $c = 0.4$. Then $m^* \approx 0.4745$. Hence, we have the following results given in the following table

m	$\underline{r}$	$\overline{r}$
0.5	0.7858	0.80
0.6	0.7438	0.81
0.7	0.7066	0.82
0.8	0.6733	0.83
0.9	0.6435	0.84

Constrained Input Pricing i.e., $r \leq min\{\overline{w_n}, \overline{w_f}\}$(Contd.)

Comparative Static Analysis

- We have the following result:

$$\frac{\partial m^*}{\partial a} < 0, \quad \frac{\partial m^*}{\partial b} > 0 \ \text{ and } \ \frac{\partial m^*}{\partial c} > 0$$

- Suppose, given the parameter vector (a, b, c, m, r), initially free licensing is profitable, that is, m and r are belong to the relevant interval.

- Now, as a goes up, both the locus shift up, i.e., for every m, both $\bar{r}$ and $\underline{r}$ will be higher.

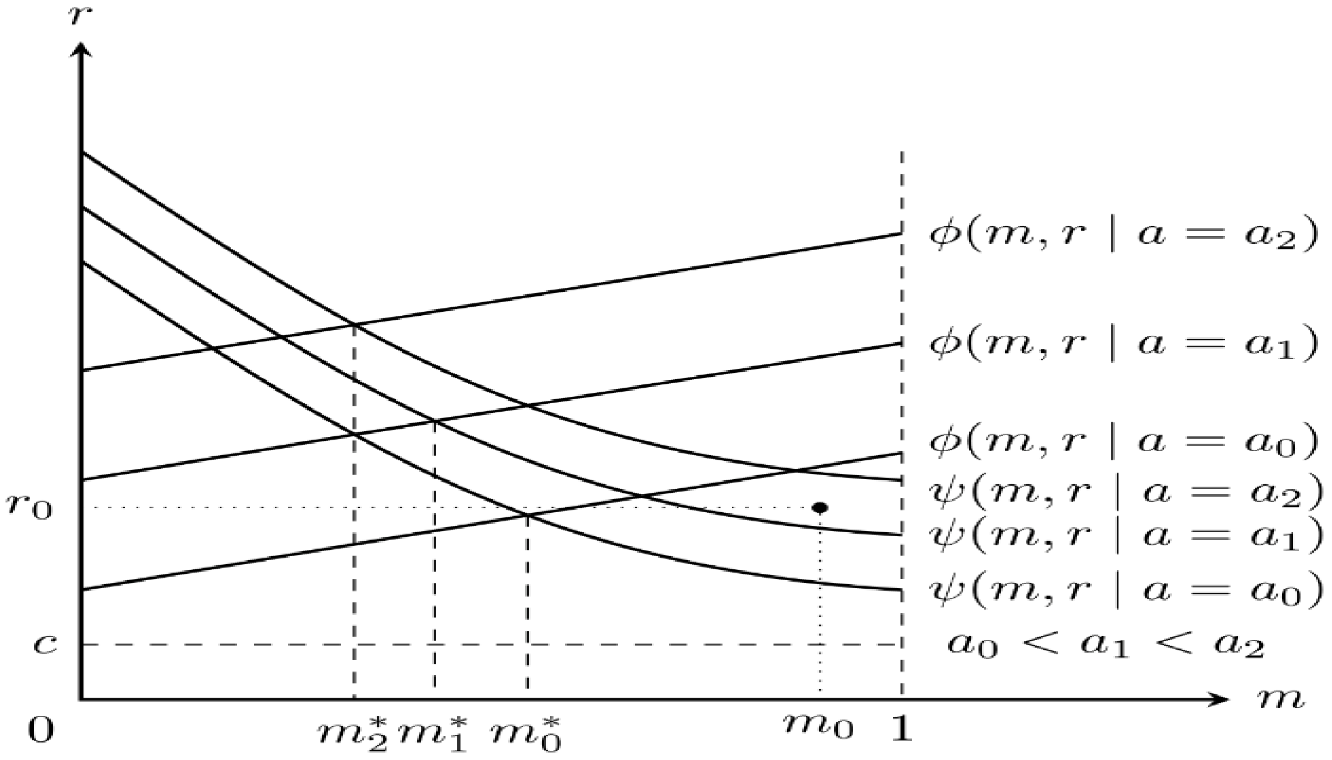
- Then, as $\frac{\partial m^*}{\partial a} < 0$, the cut-off m^* falls, hence the interval of m for feasible free licensing goes up.

- But since $\underline{r}$ goes up as a consequence of an increase in a, the initial (m, r) may or may not be within the new feasible free licensing zone.

Constrained Input Pricing i.e., $r \leq min\{\overline{w_n}, \overline{w_f}\}$ (Contd.)

Comparative Static Analysis(Contd.)

- *If increase in a is small, free licensing will continue to be profitable, but if it is large, in the new parametric situation, free licensing may not be profitable.*



Constrained Input Pricing i.e., $r \leq min\{\overline{w_n}, \overline{w_f}\}$(Contd.)

Comparative Static Analysis (Contd.)

Example: Initial parameter vector $(a, b, c, m, r) = (1.0, 0.5, 0.4, 0.8, 0.75)$. If a goes up to 1.1, free licensing continues to be profitable, but for $a = 1.25$, free licensing conditions fail to be satisfied.

- Finally, since $\frac{\partial m^*}{\partial b} > 0$ and $\frac{\partial m^*}{\partial c} > 0$, therefore when either b or c alone increases, m^*goes up. This means, the possibility of free licensing goes down when either the degree of product differentiation falls or the cost of firm 1's (input) production increases.

Proposition 5: *The possibility of free licensing goes down when either the degree of product differentiation falls or the input cost of firm 1 increases. On the other hand, an increase in market size may reduce the possibility of free licensing.*

Implication of Free Licensing in the Context of Pollution Problem

- We derive the implication in a heuristic manner.
- Let s_0 and s_1 be the pollution per unit of output generated for using backward and superior technologies, respectively; hence $s_0 > s_1 > 0$. After all, production by backward technologies damage the atmosphere, air space and waterbody by means of emitting carbon, gaseous pollutants and other obnoxious chemicals and particles.
- Then pollution generated from production in the no-licensing and post- free licensing situations:

$$L_n = s_1 q_{1n} + s_0 q_{2n}$$

$$L_f = s_1 q_{1f} + s_1 q_{2f}$$

- Then free licensing will reduce overall (global) pollution level if and only if $L_f < L_n$.
- Given $q_{2f} > q_{2n}$, $q_{1f} < q_{1n}$ and $s_1 < s_0$, the sufficient condition for reducing pollution is::

$$\frac{s_0}{s_1} > \frac{q_{2f}}{q_{2n}} \qquad \text{.........................(2)}$$

- It requires that s_1 will be sufficiently smaller than s_0.

Welfare Implications

- Under free licensing each firm's profit goes up, so industry profit increases.
- Industry output also increases, because $q_{1f} + q_{2f} > q_{1n} + q_{2n}$. This means consumers' surplus also increases unambiguously.
- When (2) holds, overall environment becomes less polluted. This further increases welfare. Hence under this situation, the overall welfare under free licensing must increase unambiguously.

Summary

- Studied the possibility of free licensing, with no network externalities, nor demand shift effect.
- Constructed a stylistic differentiated duopoly model with quantity competition. The superior technology reduces the input requirements, and the efficient firm produces inputs at a lower cost, hence the inefficient firm buys inputs from the efficient firm.
- Then the possibility of free licensing arises because under licensing the licensor's loss of profit due to competition can be outweighed under some conditions by the revenue it earns from the sale of inputs to the competitor.
- Under unconstrained input pricing, free licensing is always profitable.

Summary(Contd.)

- Under the assumption of constrained input pricing, free licensing can occur only under some conditions – innovation must not be too small and input price has to be sufficiently large.
- Further, as technological superiority falls, the possibility of free licensing increases.
- If the input production cost or the degree of product substitution goes up, the possibility of free licensing decreases.
- More importantly, an increase in market size also reduces the possibility of free licensing.
- If products are homogenous, free licensing will never be profitable.
- Cost asymmetry prevails even in the post-licensing situation, and if free licensing occurs, both consumers and producers gain, hence total surplus goes up unambiguously.
- Finally, if the superior technology generates relatively less pollution per unit of output, free licensing is likely to reduce overall pollution. In this case overall welfare must goes up.

THANK YOU