A study of Equilibrium Licensing Fee in Strategic Bargaining
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1 Introduction

After an innovation has been developed and patented, there are both social and individual incentives for firms to license the existing technology. With licensing agreement, the industry can avoid the ‘wasting’ investment on the technology which is already existing. The incumbent can design and negotiate a contract with a licensing fee covering the loss on profits. On the other hand, entrants can avoid the uncertainty and cost of R&D. Gallini (1984) shows that an incumbent firm may even license its production technology to prevent potential entrants from developing better technology.

Another interesting issue is how the gain from licensing be distributed. Kamien and Taumen (1986) study an incumbent licensing to an oligopolistic industry. They assume the incumbent acts as a Stackelberg leader and they found that with appropriate contract design the incumbent can exploit all the gain from licensing in that circumstance. However, in reality, this scenario seldom happens, the potential entrants or licensees do share part of the gain from licensing. Their model does not consider potential entrants ability in obtaining their own, possibly better, technology. The split of gain from licensing should depend on their bargaining power. In Caves et al. (1983) survey, about 40 percent of the gain from licensing belongs to the licensors.

In this paper, I study the licensing agreement using strategic bargaining model. It is natural to describe licensing using strategic bargaining process. There is a social gain from licensing agreement and both incumbent and potential have some kinds of bargaining power. The incumbent has the existing technology, whereas the potential entrants have a choice to develop their own technology. Under some assumptions, an agreement equilibrium can be achieved. An advantage of this approach is that an analytic equilibrium licensing fee can be obtained. Then a comparative static analysis can be applied on the equilibrium licensing fee.
2 Model setup and Bargaining process

Consider a model with one incumbent and one potential entrant. The bargaining process is depicted in Appendix 1. The incumbent owns technology and earns monopoly profit \( \pi_M \) if the entrant does not enter the market. The entrant has the ability to invest in R&D to develop the identical technology owned by the incumbent. With some probability R&D will be successful, then the entrant will enter the market and each of them earns duopoly profit \( \pi_D \). Before making investment, the entrant has the alternative by paying the incumbent a royalty and use the existing technology. The negotiation of licensing can be described by a bargaining process. In each time period, with length \( \Delta \), the nature chooses either E or I to make an offer \( l \) with equal probability. Then the other firm can either reject or accept the offer. If the offer is accepted, then E will earn \( \pi_D - l \) and I will earn \( \pi_D + l \). If the offer is rejected, then E chooses an investment level \( x \). With probability \( f(x) \), E will succeed in R&D, then E earns \( \pi_D - x \) and I earns \( \pi_D \). With probability \( 1 - f(x) \), E will fail and back to negotiation in the next period and I will earn \( \pi_M \) for one period. The bargaining process will repeat again. Time is valuable, and there is a discount factor \( \delta = e^{-r\Delta} \).

2.1 Assumptions

(A.1) \( \pi_M = \alpha \pi_D \) where \( \alpha > 2 \)

(A.2) \( f(x) \) is twice differentiable, \( f'(x) > 0, f''(x) < 0, \lim_{x \to 0} f'(x) = \infty \), and \( \lim_{x \to \infty} f'(x) = 0 \)

(A.3) \( \exists x \) such that \( f(x)\pi_D - x > 0 \)

(A.1) is a natural assumption for the profit structure in monopoly and duopoly. (A.2) states that as investment level increases the probability of success increases and the increasing rate of probability of success decreases. (A.3) guarantees that investment in R&D is a credible threat to the incumbent. Otherwise, the incumbent would believe that the entrant can never earn positive profit from R&D. In that case, I’s best strategy is never license her technology and earn monopoly profit.

From (A.2) and (A.3), there exists a unique optimal investment level \( \bar{x} \) that maximize E’s outside option \( f(x)\pi_D - x \). Since I am interested in the case where two firms reach agreement, what E can earn when agreement is
reached must not less than what she can earn from her outside option, that is

\[ \pi^D - l \geq f(\bar{x}) \pi^D - \bar{x} \]

\[ \Rightarrow l \leq \pi^D - f(\bar{x}) \pi^D + \bar{x} \]

For I, what she can earn when agreement is reached must not less than what she can earn from not reaching the agreement, so

\[ \pi^D + l \geq f(x) \pi^D + (1 - f(x)) \alpha \pi^D \]

\[ \Rightarrow l \geq (1 - f(x)) (\alpha - 1) \pi^D \]

Together, we have

\[ (1 - f(\bar{x})) (\alpha - 1) \pi^D \leq l \leq \pi^D - f(\bar{x}) \pi^D + \bar{x} \]

\[ \Rightarrow \frac{\bar{x}}{\pi^D} \geq (1 - f(\bar{x})) (\alpha - 2) \]

(A.4) \[ \frac{\bar{x}}{\pi^D} \geq (1 - f(\bar{x})) (\alpha - 2) \]

If \( \alpha \) (i.e. the difference between monopoly and duopoly profits) is too large, then this assumption will be violated. Because \( \pi^M \) is much larger than \( \pi^D \), I will take the opportunity of getting monopoly profit and will not accept any offer by E. This assumption will also be violated if \( f(\bar{x}) \) is too small. In this case, I believes that with high possibility E will fail and I will get monopoly profit, so I will refuse to accept any offer. On the other hand, when \( \bar{x} \) is too small, it is too easy for E to get the technology, so E will invest for the technology directly, then no agreement will be reached.

3 Solution

By stationary property, the solution can be characterized by

\[ \pi^D + l_E = f(x) \Delta \pi^D + (1 - f(x) \Delta) \left\{ (1 - \delta) \pi^M + \delta (\pi^D + \frac{l_E + l_I}{2}) \right\} \]

\[ \pi^D - l_I = f(x) \Delta \pi^D + (1 - f(x) \Delta) \left\{ \delta (\pi^D - \frac{l_E + l_I}{2}) \right\} \]

\[ f'(x) \left[ (1 - \delta) \pi^D + \delta \frac{l_E + l_I}{2} \right] = 1 \]
The first equation gives the condition that the incumbent is indifferent between accepting and rejecting the entrant’s offer $l_E$. If I accept E’s offer, then I will receive duopoly profit plus the royalty. If I rejects the offer, E will make it’s optimal investment to duplicate I’s technology. With probability $f(x)\Delta$, E succeeds and I gets $\pi^D$. While with probability $1 - f(x)\Delta$, E fails and I gets one period monopoly profit $\pi^M$ and $\pi^D$ plus expected royalty after the first period. The second equation gives the equivalent condition when I makes offer. By solving the two equations for $l_E$ and $l_I$ gives and let $\Delta \rightarrow 0$,

$$l_E, l_I \rightarrow l = \frac{r\pi^M + x}{2[r + f(x)]} = \frac{r\alpha\pi^D + x}{2[r + f(x)]}$$

The above equation is incomplete in characterizing the equilibrium licensing fee. The entrant’s outside option need to be included. E should get at lease her outside option $f(x)\pi^D - \bar{x}$. Therefore, the licensing fee is at most $\pi^D$ minus $f(x)\pi^D - \bar{x}$, which is equal to $[1 - f(x)]\pi^D + \bar{x}$. The equilibrium licensing fee $l$ and investment level $x$ is characterized by two equations:

$$l = \min \left\{ \frac{r\alpha \pi^D + x}{2[r + f(x)]}, (1 - f(x))\pi^D + \bar{x} \right\}$$

$$f'(x) \left[ (1 - \delta)\pi^D + \delta l \right] = 1$$

4 Comparative Statics and Analysis

A plain and straightforward comparative static result is that both $l$ and $x$ increase as $\pi^D$ increases. The proof is demonstrated in the appendix. A somewhat more interesting result is the interpretation of the second equation. From the first equation, $l$ is strictly smaller than $\pi^D$. Then the second equation implies that the optimal investment level $x$ is less than $\bar{x}$. $\bar{x}$ is the optimal investment level when licensing is not available. So, for E, the opportunity of accessing to license allow E to rely on self R&D in a smaller extent. Even though the optimal investment level $x$ will never be realized, it implicitly determine the equilibrium licensing fee.

The second equation also implies that $l$ and $x$ move in the same direction. The most interesting comparative static analysis should be on the change in $x$ and $l$ caused by different functions $f$. However, this involve some technical difficulties. Suppose the entrant has two investment projects with different
‘probability functions’ \( f \) and \( g \). Further assume, without licensing opportunity, \( f \) and \( g \) give the same optimal investment level without licensing \( \bar{x} \) and

\begin{enumerate}
\item \( f(\bar{x}) = g(\bar{x}) \)
\item \( f(x) > g(x) \) if \( x < \bar{x} \)
\item \( f(x) < g(x) \) if \( x > \bar{x} \)
\end{enumerate}

Without license opportunity, the two projects give the same investment level and profit. Hence E is indifferent between \( f \) and \( g \). \( g \) involves more uncertainty in a sense that the probability of success increases more rapidly as investment level increases. With the opportunity to get the technology through licensing, the investment level decreases. And it is in the region where \( f(x) > g(x) \). So, E has a higher probability to succeed with project \( f \). Consequently, a higher bargaining power and lower licensing fee. Although E is risk neutral, when the R&D project involves less uncertainty, E will end up paying less licensing fee to the incumbent.

5 Conclusion

Unlike the classical strategic bargaining model of split a dollar, the licensing model studied here has strictly positive impasse point. Therefore, the entrant’s outside option, the function \( f \) determines both the incumbent’s and the entrant’s expected profit for leaving the negotiation. And hence \( f \) determines both parties’ bargaining power in the bargaining process. The simple comparative statics result shows that the licensing fee is increasing with duopoly profit. The duopoly profit simply determines the scale of licensing fee and has nothing to do with their relative bargaining power.

Intuitively, the risk neutral potential entrant only care about the expected profit and can bear the risk. However, with accessing to the opportunity of getting the existing technology through licensing, the entrant’s optimal investment level reduces. And the reduction of investment level leads the entrant to a higher probability of success if the probability function is the one with less uncertainty. Therefore, a less uncertainty R&D project will give the entrant more bargaining power in the licensing process and result in a lower licensing fee.
References


Appendix 2

$l$ and $x$ are nondecreasing in $\pi^D$.

**proof:**

\[
 l = \min \left\{ \frac{r \alpha \pi^D + x}{2[r+f(x)]}, (1 - f(\pi)) \pi^D + \pi \right\}
\]

\[
 f'(x) \left[ (1 - \delta) \pi^D + \delta l \right] = 1
\]

$(1 - f(\pi)) \pi^D + \pi$ is nondecreasing in $\pi^D$. For $l = \frac{r \alpha \pi^D + x}{2[r+f(x)]}$, from the second equation:

\[
 f'(x) = \frac{1}{(1 - \delta) \pi^D + \delta l}
\]

\[
 \Rightarrow f''(x) = -\frac{1}{(1 - \delta) \pi^D + \delta l} \frac{\partial l}{\partial x}
\]

So $\frac{\partial l}{\partial x} > 0$ since $f''(x) < 0$. 

plug $l = \frac{r \alpha \pi^D + x}{2[r+f(x)]}$ into the second equation, and take derivative with respect to $\pi^D$:

\[
 f'(x) \left[ (1 - \delta) + \delta \frac{(r \alpha + \frac{\partial l}{\partial \pi^D}) (r + f(x)) - f'(x) \frac{\partial l}{\partial \pi^D} (r \alpha \pi^D = x)}{2[r+f(x)]^2} \right] + f''(x) \frac{\partial l}{\partial \pi^D} \left[ (1 - \delta) \pi^D + \delta \frac{r \alpha \pi^D + x}{2[r+f(x)]} \right] = 0
\]

\[
 \Rightarrow -f'(x) \frac{\delta r (r+f(x))}{2[r+f(x)]^2} = \frac{\partial x}{\partial \pi^D} \left[ \frac{\delta (r+f(x)) - f'(x) (r \alpha \pi^D + x)}{2[r+f(x)]^2} + f''(x) (1 - \delta) \pi^D + \frac{\delta (r \alpha \pi^D + x) f''(x)}{2[r+f(x)]} \right]
\]

The term inside the bracket is negative and the LHS is also negative. Hence $\frac{\partial x}{\partial \pi^D}$ and $\frac{\partial l}{\partial \pi^D}$ are positive.
Appendix 1  Bargaining Process

\[
(\pi^D + l_i, \pi^D - l_i) \quad \text{Invest} \quad X
\]

\[
(\pi^D + l_E, \pi^D - l_E) \quad \text{Invest} \quad X
\]