UNIVERSITÉ DE MONTRÉAL

THE EX POST PROFITABILITY OF LICENSING TECHNOLOGY

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Introduction

Our modern understanding of inventive activity may be traced back to Sir Francis Bacon (1561-1620). His extensive writings on such matters as the inductive method of reasoning, frameworks for science and the advancement of learning, encouraged Renaissance societies to alter their natural environments. He proposed that man study rather than worship nature in order to overcome its hardships. This represented a complete break from the medieval revealatory school of thought which sanctioned societies to suffer under the limitations of the natural environment and God.

Apart from the basic elements provided by nature, all goods available to society are the result of inventive activity. In a dynamic society, product innovations either fulfil new needs as they are created, or act as substitutes for existing goods. While noting that the variety of products stem from creative invention, we must not overlook the innovative methods by which their fabrication is permitted. This contribution of innovation to the fabrication process is one of the most important dimensions of industry performance to date. We therefore define inventive activity to encompass both product innovation and process innovation.

This paper examines a type of relationship, namely licensing, which permits agents to exchange technological information regarding their innovative activities. This review of the literature was intended to familiarise the author with the various licensing strategies available to the inventor, and identify the various constraints confronting the inventor when licensing. To realise this, we have attempted to demonstrate how, and to what extent, these constraints affect the actions of both parties to the licensing contract. We also consider third party effects by examining the implications of licensing on the social welfare.

We begin our enquiry by chronologically reviewing the literature dealing with product and process innovations. We demonstrate how the field of economics has contributed to our present understanding of the profitability of licensing innovation to the inventor, to society, and to the industry concerned. Finally, we examine the consequences of licensing on the structure of industry by deriving relationships between the number of firms constituting the industry and the different licensing strategies available to the inventor.

The current literature on technology licensing is divided into two broad groups: ex ante incentives to develop technology and license and ex post licensing which determines the value of a patent. The ex ante incentives to license include the strategic element of sharing information to dissuade competitors from imitating or developing similar innovations through R&D activities. For example, a licensee shall have less of an incentive to invest in R&D and invent around the patent once its marginal costs are reduced through the purchase of the cost-reducing technology.

The ex post incentives to license deal mainly with choosing the most profitable industry structure once the technology has been developed. This static analysis assumes that no similar innovations occur prior, during, or after licensing has taken place.

When comparing ex ante and ex post effects of licensing on efforts to develop superior technologies, we observe that the ex ante incentives to license tend to discourage technological development, whereas the ex post incentives encourage technology development. In the case of the ex post incentives, licensing yields rents to the inventor from the replacement of relatively inefficient methods of production. The opportunity to obtain these rents, through licensing, acts as an additional stimulus to develop further cost-reducing innovations, beyond the existing benefit of obtaining the lowest cost position in the

market. This ex post incentive to license is stronger when the costs of production of existing technology are relatively close.

When the cost of production are far apart the incentive to license is relatively non existent, since the firm with the superior technology is capable of effectively extracting the rents of his superior technology through his own production. Under this scenario, the desire to license comes from the ex ante or a strategic incentive to license. As mentioned, the firm with the superior technology may license his technology to dissuade lower technology firms from developing their respective innovations. Licensing therefore serves the strategic purpose of preventing the potential erosion of his low cost market position by his rivals' discovery of superior technologies. Furthermore, the ex ante incentive to licenses permits the high cost firms to realise rents through the elimination of privately wasteful research expenditures. These two ex ante effects therefore tend to discourage the development of additional technologies.

In summary, we conclude that on the one hand the ex post incentive to license encourages the development of superior technologies of production whereas, on the other hand, the ex ante incentive to license discourages the development of superior technologies of production.

Our study is concerned with the ex post strategies to license technology.

1. Technology, Information and the Patent System

The activities of technological research and invention may be viewed, in the economic sense, as the production of information. Given the intangible nature of information, the efficiency of this market is constrained by two factors: incomplete appropriability on the supply side, and indivisibility in its use on the demand side.

In the absence of legal protection, a market for new technologies will not exist because once communicated by its discoverer, the information may be reproduced and disseminated by others at little or no additional cost. Since the owner is not able to extract the total value of his information, he will not sell it to others in a market. The only effective means for the inventor to appropriate the maximum value of his technology is when proprietary rights over information are provided through patent protection, or for the monopoly owner to internalize its value within the firm.

With sufficient legal protection, information becomes an appropriable commodity. These proprietary policies provide the original owner with a monopoly power over its dissemination and efficient use allowing him to extract its maximum value.

At the same time, these intellectual property rights may lead to resource misallocation. For example, the inventor may not share his technology with many firms when society as a whole would benefit from a larger dissemination.

For reasons of analytical simplicity, we assume that the value of information is completely appropriable by its owner - that is, the proprietary system enforced through legal means provides pure patent protection. Imitation through disclosure and reverse engineering simply does not exist. We should note, however, that no amount of legal protection can make such an intangible good as information completely appropriable.

Information, by definition is also indivisible in its use. This indivisible nature creates, in the neoclassical sense, an allocational problem because the use of information cannot be adjusted to reflect the rate of production. Information shall therefore be purchased and adopted in its entirety, according to the extent that it increases the efficiency of the existing method of production, or creates new opportunities for rent-seeking activity. These

pecuniary considerations shall be the focus of our inquiry on the licensing of cost-reducing and product innovations.

2. Licensing to a Monopolised and Competitive Industry

In a pioneering piece on the rewards to inventive activity, Kenneth Arrow[1] developed a method to gauge the financial incentives resulting from the adoption of a cost-reducing process innovation by different industry structures. Although his analysis is limited to analysing the financial reward of both an inventor which licenses his technology to a competitive industry, and a monopolised industry which develops the innovation himself, his methodology provides a technique for comparing the profitability of different industry structures adopting cost-reducing innovations.

Arrow compares the case of licensing a cost-reducing innovation to a competitive industry using a unit royalty **r** or to a monopolised one using a lump-sum payment. Within his framework, **D** is the demand for the product and **Rm** the marginal revenue curve. c and c' respectively represent the cost of production before and after adoption of the new technology. For analytical simplicity, he assumes these costs are constant for all levels of production.

The study also distinguishes between two types of innovation: drastic and non-drastic. When the monopoly price of a product after adoption of the innovation p_m' is greater than the preinvention cost of production c, the process innovation is qualified as non-drastic. Drastic innovations occur when the post-adoption monopoly price of the products is less than the original preinvention cost of production p_m' < c.

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1.   Arrow, Kenneth, <u>Economic Welfare and the Allocation of Resources for Invention</u>, *The Rate and Direction of Inventive Activity*, R.R. Nelson, Princeton, New Jersey, Princeton University Press, 1962.

2.1 Non-drastic Cost-reducing Innovations

Figure 1 compares the increased profitability for a monopolised and competitive industry which adopts a non-drastic cost-reducing innovation. These profit increments also represent the maximum amount the licensor may demand for his new technology.

Prior to adoption, the monopoly sells quantities x_m at price p_m. Profits for the monopolist are represented by the area $p_m abc = P$. After adopting the innovation, the monopolist shall equate his marginal revenue Rm to his new unit costs c' and expand his output to x_m'. The new monopoly price is p_m' and profits are $p_m'dec' = P'$. The difference between these two levels of profitability $P'-P$, represents the maximum amount the monopolist is willing to pay to acquire the new technology.

Figure 1
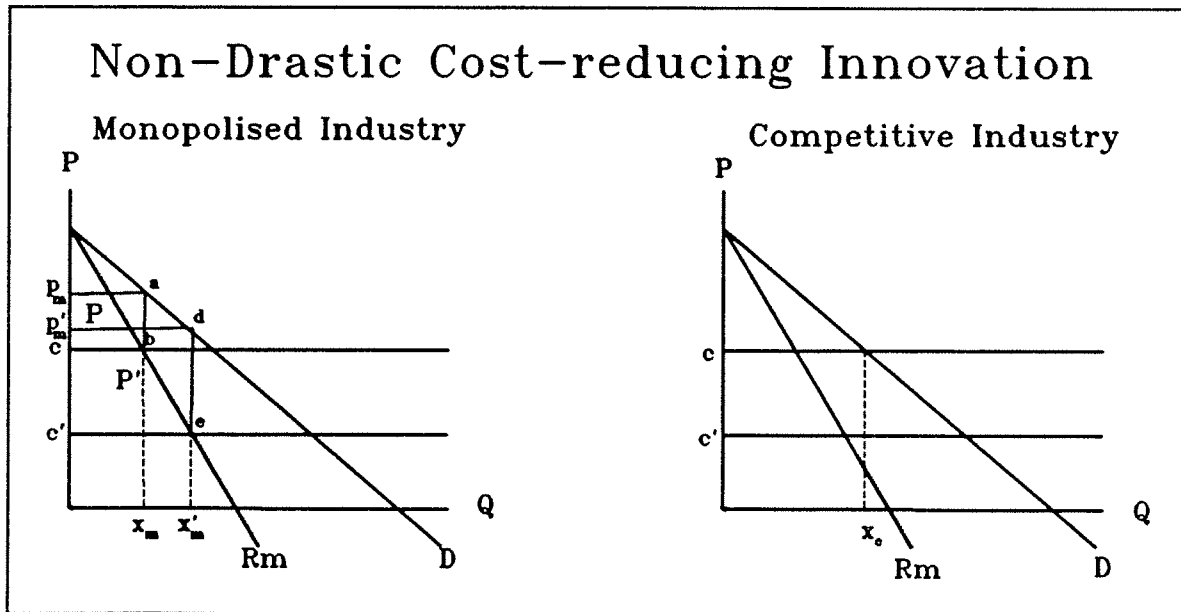
Similarly, the competitive environment initially sells at unit cost c a quantity x_c. Within this competitive industry the post-adoption price cannot exceed the original price c, otherwise firms will continue producing with the existing technology. The inventor shall therefore set his royalty at $r = c-c'$, and reap an amount $x_c(c-c')$ for his efforts.

By comparing the monopolist's incentive to adopt the cost-reducing innovation $P'-P$ with the amount $x_c(c-c')$ which the inventor acquires from the competitive industry, we conclude that the incentive is greater for the monopolised industry since $P'-P < x_c(c-c')$. The inventor shall therefore license his innovation to the competitive industry.

In the case of the monopolised industry, we see that the consumer's welfare, in terms of consumer surplus, is increased once the monopolist adopts the cost-reducing innovation. In the competitive industry, the inventor extracts all benefits for himself, yielding no additional gains for the consumer. The absolute amount of consumer surplus after adoption of the non-drastic innovation is less in the monopolised industry than the competitive industry due to the lower price offered by the latter. Under these circumstances, licensing to the competitive industry offers greater benefits to the consumer.

2.2   Drastic Cost-reducing Innovations

Figure 2 illustrates the case when the inventor has developed a drastic cost-reducing innovation. When licensing to the competitive industry, the inventor shall maximize his profit by calculating the monopoly price p_m' and setting the unit royalty at $r = p_m'-c'$, thus extracting the amount $P' = x_m'(p_m'-c')$.

The monopolist's incentive to adopt the new technology is again $P'-P$, the difference between the monopoly profits after adopting the innovation and the original monopoly profits without the innovation. We see that the incentive for the monopolist $P'-P$ is less than the incentive for the competitive industry $P' = x_m'(p_m'-c')$.

For these reasons, Arrow states that "the preinvention monopoly power acts as a

Figure 2

Figure 2. Drastic Cost-reducing Innovation
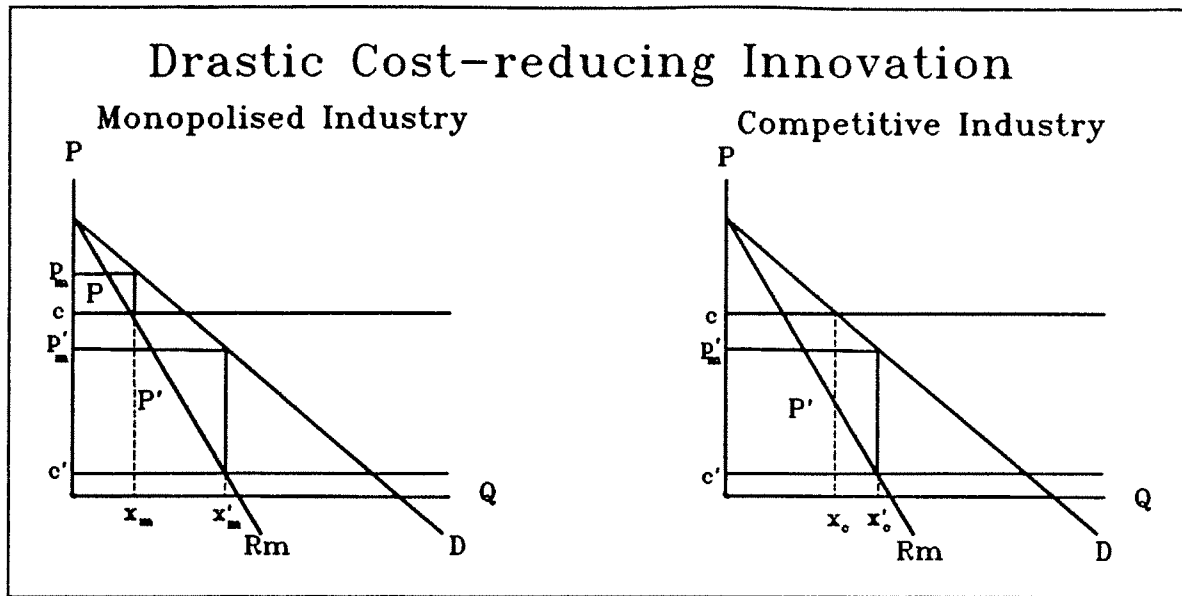
strong disincentive to further innovation"[2]. He further shows that the difference in the two incentive schemes (competition versus monopoly) decreases as c' decreases, which implies that industry structure becomes less relevant for drastic innovations. However the incentive to innovate or the rewards to invention increase as c' decreases.

The post adoption social benefit in terms of consumer surplus are equal for both industry structures, since the royalty is established to extract monopoly rents at price p_m'.

The results of Arrow's analysis indicate that for either a drastic or non-drastic innovation, a competitive industry has a greater incentive than a monopolised one to develop a cost-reducing innovation when the inventor is capable of charging different fee structures.

2.   Ibid., pp. 620.

3. A Re-examination of the Profitability of Licensing

Harold Demsetz[3] challenged Arrow's view that the maximum royalty revenue is greater when licensing a cost-reducing innovation to a competitive industry than a monopolised industry. According to Demsetz, it is incorrect to argue that a perfectly competitive market creates a greater incentive than a monopolistic one, because the competitive output is larger. Demsetz also argues that Arrow's model inherently assumes that the monopolist inventor can charge different royalty rates for the different industry structures, and that the monopoly producer does not exercise his market power when choosing the quantity produced. When corrections are made to compensate for scale economies and discriminating royalties, Arrow's conclusions are either partially or completely reversed: the incentive to innovate for the inventor is at least as great when he licences to the monopoly producer as when he licenses to the competitive industry.

To illustrate these corrections, consider Figure 3 which represents the case of a cost-reducing innovation for a monopolised and competitive industry. We shall consider two variations on Arrow's analysis. The first case examines the royalty revenue, price and quantity produced by both structures of

Figure 3
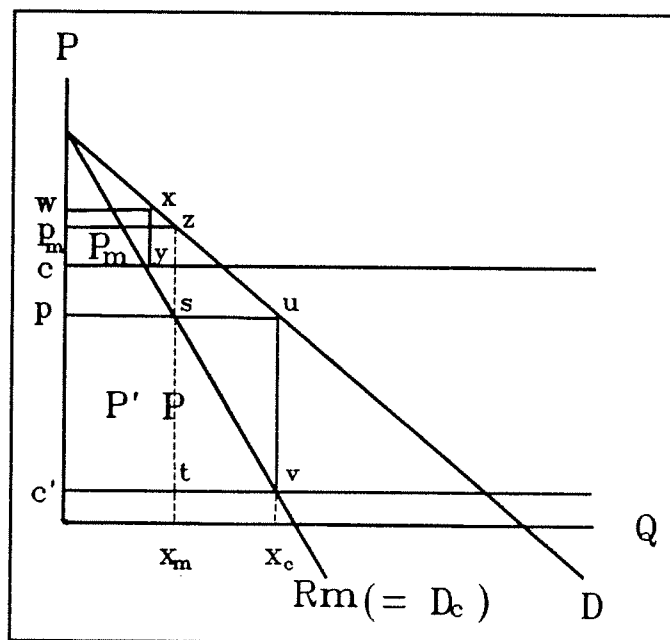
3.   Demsetz, Harold, *Information and Efficiency: Another Viewpoint*, Journal of Law and Economics, Vol. 12, 1969, pp. 1-22.

industry when the inventor charges uniform royalties. Although the results of this first case do not depart from Arrow's analysis, it serves as an introduction of the monopolist's ability to restrict production, and provides the basis for Demsetz' critique of Arrow's analysis. The second case examines the incentive for both industry structures to adopt the innovation when the adverse monopoly effects are removed.

3.1   Unit Royalty Licensing

If we suppose that either regulations or competing inventions prevent the inventor from discriminating between the competitive or monopolised industry, the inventor's profit maximising unit royalty is $r = p-c'$. Both industry structures shall accept p as the unit cost of producing their products. Under this cost structure, the competitive industry shall pay a total royalty of $P = puvc'$ to the inventor, and produce a quantity x_c at price p.

The profit maximising monopolist shall incorporate the unit royalty $p-c'$ into his cost of production and set his level of production at x_m where his marginal revenue equals his unit costs of production p. The total royalty revenue received by the inventor shall be $P' = \frac{1}{2}P = pstc'$, one half the royalty revenue of the competitive industry. The inventor shall therefore license to the competitive industry when the monopoly producer uses his market power to restrict production.

Under competitive production, the consumer surplus shall increase, due to the lowering in purchase price from c to p. The post-adoption benefits to the consumer, shall be at least as large under competitive production as they are under monopoly production. The increase in consumer surplus depends on the degree of cost reduction of the innovation. Under uniform royalties, the inventor shall find it advantageous to license to the competitive industry, thus permitting the maximum benefit to the consumer.

3.2 Removing the Normative Monopoly Effects

In order to remove the normal restrictive effects of a monopoly, suppose the product demand D_c for competitive industry is equal to the marginal revenue curve $\mathbf{Rm}$ of the monopolist (see Figure 3). Prior to adoption, the monopolist receives rents equal to $\mathbf{P_m = wxyc}$. After adoption, the monopoly rent of the innovation is $\mathbf{P' = pstc'}$ since the monopolist restricts production to $\mathbf{x_m}$. The inventor may increase the innovation's rent to $\mathbf{P = puvc'}$ by placing a price ceiling of $\mathbf{p}$ on the product, and extract from the monopolist an amount $\mathbf{P' + p_m zsp - P_m}$ if the monopoly restricts production, or an amount $\mathbf{P - P_m}$ if a ceiling is placed on the sale price by the inventor.

The best the inventor can achieve from the competitive industry is to charge a unit royalty of $\mathbf{p - c'}$, to obtain royalty revenues of $\mathbf{P' = pstc'}$. By comparing the maximum royalty revenue, we arrive at the conclusion that the inventor shall choose to license to the monopolist since $\mathbf{P - P_m > P' + p_m zst - P_m \geq P'}$.

Demsetz therefore concludes that under uniform unit royalties, and when the normative output restricting effects of monopoly production are removed, the incentive to invent is no smaller for the monopolist than the competitive industry. This result could be interpreted as the incentive per unit of production is larger for the monopolist than for the competitive environment.

These results imply a paradox of licensing. On the one hand, the monopolist has a greater incentive to develop and/or adopt a process innovation. On the other hand the licensor will achieve greater royalty revenue from the competitive industry if all firms purchase the process innovation. The royalty revenue derived in the second case will depend on how many competitive firms adopt the innovation. These considerations shall be

examined further when we review licensing and Cournot competition amongst firms.

Y. Ng[4] questions Demsetz's method for excluding the normative monopoly effects:

> It seems to me that Demsetz's method of isolating the restrictive effect of monopoly is questionable. The pre-invention output levels of competition and monopoly are equalized, but the post-invention levels are not; the monopoly output is twice that of the competition output. This causes a bias in favour of the monopoly.[5]

Ng's argument is similar to the views expressed by Demsetz regarding Arrow's policy recommendations. Whereas Demsetz claims that Arrow's analysis favours competition since industry output was initially larger for this industry structure, Ng argues that Demsetz method of equating pre-innovation output favours a monopolised industry since the post-innovation output is larger.

Ng is able to remove these biases by developing a method which equates both the pre- and post-invention quantities for the monopolised and competitive industry. The results of his model support Arrow's views that an inventor will have a greater incentive to sell a drastic cost-reducing innovation from a buying industry which is competitive.

3.3 Bilateral Monopoly Bargaining and Risk

These examinations have supposed that the inventor exercises a certain monopoly power when choosing his royalty revenue. Demsetz's analysis indicates that the monopolist inventor charges a lump-sum payment from the monopolist. Arrow bypassed the inconvenience of a lump-sum payment by assuming that the monopolised industry was also the monopolist inventor. In reality, there is no reason to suppose that the rent from the

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4.   Ng, Y.K., *Competition, Monopoly, and the Incentive to Invent*, Australian Economic Papers, Vol. 10, 1971, pp. 45-49.

5.   Ibid., pp. 47.

invention shall be split in this manner.

Yamey[6] explores the effect of the bilateral monopoly bargaining in the pricing process and the manner in which it affects the degree of risk-bearing confronting the inventor and monopolist. Under a lump-sum payment, the monopolist absorbs any future risk of unforseen demand contractions and future obsolescence of the cost-reducing innovation. This would make the purchase of the innovation riskier than mentioned, and would reduce the amount the monopolist would be willing to pay for it. By the same token, it would reduce the risks confronted by the inventor.

When the inventor has committed resources (in the form of irrecoverable costs) to develop his innovation prior to licensing, he is in danger of being exploited by the monopolist. For example, the monopolist could threaten to refuse purchase of the innovation in order to obtain a discount on the purchase price. The amount of the discount would depend on the credibility of the threat to refuse purchase of the innovation. This exploitation would be tempered by the monopolist's desire to purchase additional innovations in the future from the same or other inventors, or by the inventor licensing to a greater number of firms.

The risk of exploitation by the monopoly-producer could also be eliminated if the inventor obtained a licensing contract based on the amount of cost reduction prior to any financial outlays on his part. This type of agreement would distribute the risk between both parties. The monopolist would accept the demand contraction and future obsolescence of the innovation risks, while the inventor would assume the risks of unsuccessful development or limited degree of cost reduction. This solution, however, may be aggravated if fixed costs

6.   Yamey, B.S., *Monopoly, Competition and the Incentive to Invent: A Comment*, Journal of Law and Economics, Vol. 13, 1970, pp. 253-256.

must be born by the monopolist to adopt the cost-reducing process, and if the innovation

affects the quality of the output. In any event, a conditional payment is not likely to secure

for the inventor the full amount of the lump-sum payments discussed above.

4. Elasticity of Demand Considerations

Up to this point, we have examined which industry structure has the greatest incentive

to purchase either a drastic or non-drastic cost-reducing process innovation using a lump-sum

payment and uniform unit royalties.

Morton Kamien and Nancy Schwartz[7] have extended this type of analysis to examine

how the elasticity of demand affects the incentive to invent for both industry structures.

Their analysis is four-fold. In a first instance, they compare the incentive to innovate for a

monopolist under an elastic and less elastic demand schedule with equal initial levels of

production. In a second instance, they reproduce the same comparison for a competitive

industry. We shall only provide an intuitive description of these two sections. The third

section demonstrates that the incentive to innovate is greater for the monopolised structure

when the elasticity of demand and initial market size for the two industry structures are

equal. The fourth section determines the special elasticity of demand conditions which

permit the incentive to innovate to be larger for the competitive industry than the

monopolised one. These last two results shall not be developed since they do not further our

understanding of the incentive to invent.

For a monopolised structure, the industry facing the more elastic demand curve has a

greater incentive to innovate. This result bears directly from the fact that the more elastic

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7.   Kamien, M.I. & Schwartz, N.L., *Market Structure, Elasticity of Demand, and the Incentive to Invent*, Journal of Law and Economics, Vol. 13, 1970, pp. 241-252.

demand schedule will allow for a greater expansion of production upon adoption of the cost-reducing innovation. In particular, the invention is viewed as an input to the production process and its employment does not diminish its availability for any additional units produced. Consequently, the invention contributes to reducing the cost for a larger number of units in the elastic demand case, allowing more unit profits to be collected. This result holds for both drastic and the non-drastic process innovation in the case of a monopoly but only for a drastic innovation in the competitive industry.

In the case of a competitive industry, the profitability of the non-drastic cost-reducing innovation only depends on the extent of the cost reduction. This result may be explained by noting that in this non-drastic case, the level of production does not change after adoption since the post-adoption price (new process cost plus royalty) cannot surpass the preinvention cost, otherwise it shall not be adopted by the firms. The licensor therefore charges a unit royalty equal to the amount of the cost reduction and receives royalty revenues equal to the initial level of production times the unit royalty. Assuming identical initial levels of production, the incentive to invent will only depend on the degree of cost reduction of the new process innovation.

Certain implication suggest themselves from the analysis of the elasticity of demand on the incentive to innovate. To the extent that we relate more elastic demand curves to the long-run and less elastic curves with the short-run, we may infer that the long run incentive to innovate is greater than the short-run incentive. Kamien and Schwartz's examination suggests:

> From the standpoint of government regulation of industry, our analysis
> suggests that encouragement of new product lines that cause the demand curve
> confronted by a monopolist to become more elastic may be at least as potent a

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method for stimulating invention as the more traditional antitrust policy.[8]

5.   Product Innovations

Although a disproportionately large share of the economic literature on licensing deals with process innovation, more recent studies advance models which analyze licensing strategies for new product innovations. This paper reviews two studies which deal exclusively with product innovations.

John McGee's[9] examination investigates the elements which compel an inventor to license a new product innovation using a unit royalty. Using Marshallian derived demand analysis, McGee determines the demand for the patent of a product innovation. He also studies the optimal strategic choice of industry structure available to the licensor for the new product when different constraints such as diseconomies of scale and licensing and policing costs exist. Although the results of his analysis are somewhat trivial, the methodology he uses to arrive at his results are interesting.

5.1   Licensing with Scale Diseconomies

When there are no scale economies in production and no substitutes for the product innovation, the inventor prefers to license to a sole producer. This enables him to easily extract monopoly profits for his efforts. Constraints of production, such as scale diseconomies may, however, encourage the licensing to many producers.

Figure 4 illustrates McGee's analysis when scale diseconomies exist. The demand for the new product innovation is **D**, and the long run supply curve is the cost of production

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8.   Ibid., pp. 252.

9.   McGee, John S., *Patent Exploitation: Some Economic and Legal Problems*, Journal of Law and Economics, Vol. 9, 1966, pp. 135-162.

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under competitive production.

According to Marshallian derived demand, the demand price (or royalty) for the patent (in product equivalents) is the difference between the demand price for the product **D** and the unit production cost **c**. This derived demand for the patent is represented in Figure 4 as **dd**, and its corresponding marginal revenue is **rm**.

Figure 4
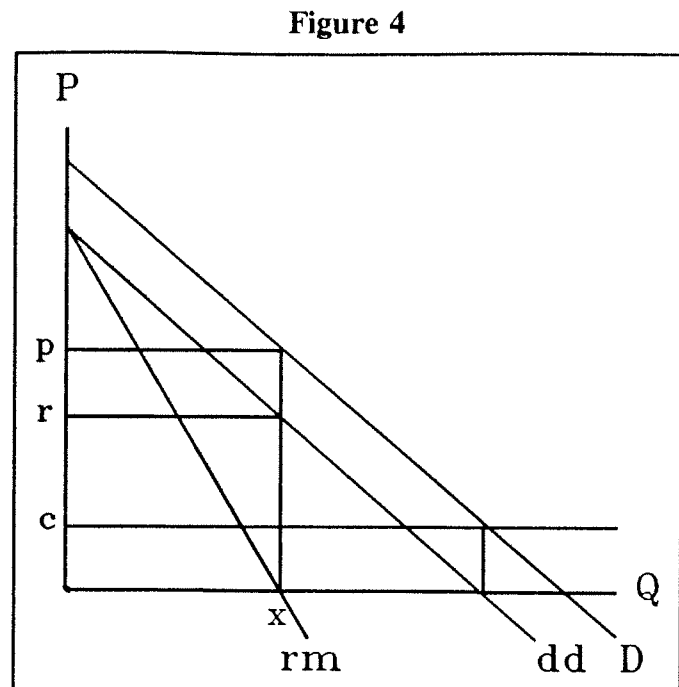
Assuming there exist no licensing or policing costs, the patentee can determine the size x and price **p** of the whole producing industry by choosing the appropriate unit royalty r=p-c which maximises his royalty revenues (**rm**=0). Under these conditions, the industry is effectively monopolized by the patentee even though the firms are producing the product under competitive conditions.

McGee argues that there is nothing inherently "evil" or "anti-economic" to charging monopoly rents for the innovation since the patentee has provided some new consumer satisfaction with a new product. The patentee has simply not created the maximum amount of consumer satisfaction through his choice of the non-zero royalty.

5.1.1 Elements Affecting the Choice of Industry Structure

The author also examines other elements, such as policing costs, rising long run supply curves and spatially separate markets, which may compel the licensor towards sole production even when scale diseconomies exist.

If the cost of policing multiple licenses is greater than the diseconomies of large scale production, the licensor will have an incentive to license to a single manufacturer. Under these conditions, the removal of the inefficiency of policing licenses through large scale production, would both reduce the competitiveness criteria of the new industry while increasing the benefits to the consumer and licensor due to higher output and lower prices.

Secondly, the author assumed a constant long run supply function for the producing industry. Suppose the long run supply curve was upward sloping, reflecting different cost structures amongst the firms. The most efficient licensees would earn rents under uniform licenses. A portion of these rents could be acquired by the licensor through production, if his costs were identical (or even slightly higher) to many, but not all of the licensees. This result would increase the profits to the licensor, and lower the price to the consumer.

Licensing across markets with different demand price elasticities for the product is somewhat problematic for the licensor. To maximise royalty revenue, the licensor should charge higher unit royalty for low-elasticity markets, and lower royalties within the high-elasticity market. This discriminatory strategy is optimal for the licensor if the markets are spatially separate. Otherwise, customers will shift from high-royalty licensees to low-royalty licensees, reducing the licensor's royalty revenue.

5.2   Licensing with Scale Economies

In the case that no diseconomies in scale production exist, the licensor prefers, but does not necessarily licence to a single manufacturer. This results from each party's desire to maximise profits according to differing demand considerations.

Figure 5 illustrates the paradox clearly. The demand for the new product is **D**, with its corresponding marginal revenue **Rm**. With unit cost of production c, and allowing for

competition in production, the derived Marshallian demand for the patent is **dd** and its corresponding marginal revenue is **rm**. To simplify the analysis, policing and monitoring costs of licenses are zero.

Figure 5

The licensor would sensibly choose a unit royalty **r**, which would yield a price p_1, and a quantity x_1. The paradox comes about if the licensor sell his patent to a single manufacturer. Under sole production, the monopolist would restrict production to x_2 at price p_2, thus reducing the licensor's royalty revenue.
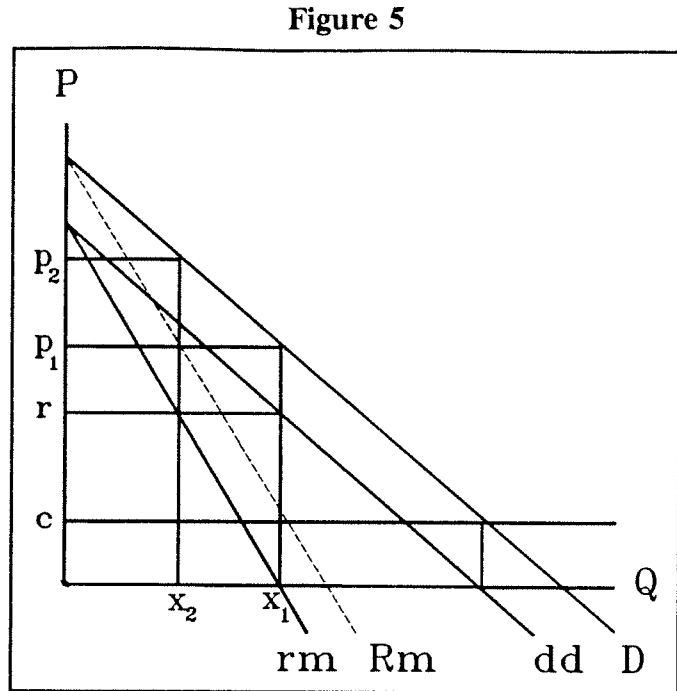
There exists many ways to remedy this situation. First, the licensor may himself become the manufacturing monopolist, thereby maintaining production at x_1. Secondly, the licensor may stipulate in the licensing contract that a maximum price p_1 be charged (or similarly a quantity x_1 be sold). This second method presupposes that the licensor has access to pertinent information regarding the monopolist manufacturer's costs and level of production. A third method would be to auction the license to the highest bidder. This last scheme will be studied further when we consider auctions for licenses.

6. Cournot Competition and the Incentive to Innovate

The preceding inquiries compared the incentive to invent of two polarised market structures: pure competition and pure monopoly. We have seen that the licensor may extract the maximum profit using unit royalty payments in the case of a competitive industry and a

lump-sum payment in the case of a monopolised industry. These models did not require the simultaneous use of a fixed fee and unit royalty to extract all private benefits of the cost-reducing innovation.

We now extend our review of this subject to an intermediate market structure determined by Cournot competition. This type of examination allows us to infer the relationship between licensor revenue and the number of firms while introducing the use of a two part licensing contract (fixed fee and unit royalty).

Morton Kamien and Nancy Schwartz[10] have provided a detailed analysis of this relationship using a Cournot oligopoly model. Although their analysis was intended to explain how the market structure and the type of innovation alters the profit-seeking motive of technological development (ex ante demand-pull), their analysis does shed light on the ex post profitability of licensing technology for various classifications of innovations. Given the fact that many of the subsequent works in this area are based on similar models, we shall expose their work in great detail.

Their examination assumes **n** identical firms facing a linear inverse demand function: $P(Q) = a\text{-}bq$, where **a** and **b** are positive constants. The innovation reduces the unit cost of production from **c** to **c'** (see Figure 6).

Under Cournot competition, total industry output is initially:

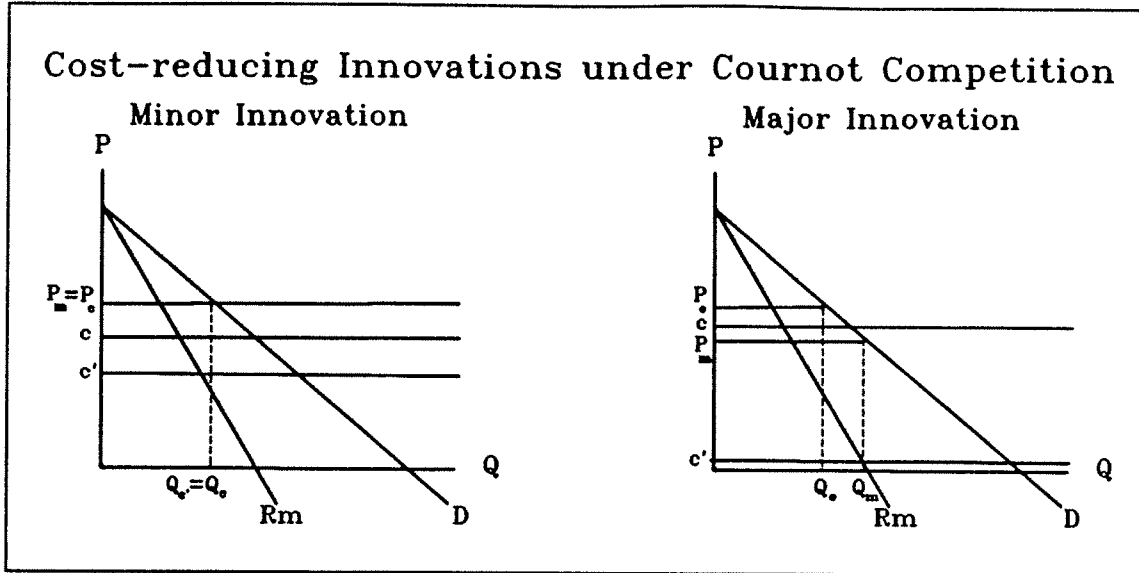$$Q_c = n(a\text{-}c)/(n+1)b$$

and price is:

$$P(Q_c) = (nc+a)/(n+1)$$

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10.   Kamien, M.I., & Schwartz, N.L., Demand-pull and Market Structure, *Market Structure and Innovation*, Cambridge University Press, Cambridge, 1982, pp. 36-48.

Figure 6

Cost—reducing Innovations under Cournot Competition

Minor Innovation   Major Innovation

From these results we can determine the post-adoption monopoly price $P(Q_m)$ and

quantity Q_m and profits π_m produced by setting $n=1$, at unit cost c':

$$P(Q_m) = (c'+a)/2$$

$$Q_m = (a-c')/2b$$

$$\pi_m = (P(Q_m)-c')Q_m = (a-c')^2/4b$$

Kamien and Schwartz distinguish two types of cost-reducing innovations: major and

minor as opposed to drastic and non-drastic in Arrow's analysis. In Arrow's model, a

drastic innovation occurs when a monopoly's post-adoption price of the good produced is less

than the pre-adoption cost of producing the good. For a major innovation, the benchmark

for comparison is the pre-adoption Cournot equilibrium price rather than the price that would

prevail under perfect competition. Therefore, a major innovation is defined by a post-

innovation monopoly price $P(Q_m)$ which is less than the initial Cournot price $P(Q_c)$. Under

these circumstances, the post-adoption monopoly output Q_m is greater than the initial Cournot

quantity Q_c.

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6. Cournot Competition and the Incentive to Innovate

For a non-drastic innovation, Arrow permitted the post-adoption monopoly price to exceed the pre-adoption cost (competitive pre-adoption price). In the case of a minor innovation, the post-adoption Cournot price shall not exceed the pre-adoption Cournot price, otherwise firms will continue producing with the existing technology. For these reasons the post-adoption industry output $Q_{c'}$ and price $P(Q_{c'})$ shall equal the preinvention Cournot quantity Q_c and price $P(Q_c)$. This result is similar to the competitive industry's pre- and post-adoption price and quantity which remained the same for Arrow's non-drastic innovation. We see that under this new classification, major innovations are sold to a relatively monopolised industry and minor innovations to a more competitive industry.

Prior to adoption, the Cournot firms are realising an industry profit of:

$\pi_c = (P(Q_c)-c)Q_c = n(a-c)^2/b(n+1)^2$ which is equally divided among the n firms. To simplify the analysis, it is assumed that the licensor of the cost-reducing process allows the firms to maintain this level of industry profits π_c after adoption of the innovation. This assumption partially rules out the possibility that the firms will develop their own competing innovations. We also assume that the licensor is not a manufacturer in this industry.

The inventor claims for his efforts the difference between the post-invention monopolist profit π_m and the pre-invention Cournot industry profit π_c. This is achieved, in the minor innovation case, by charging a unit royalty $r=c-c'$. This shall reward the inventor with the amount $rQ_c = (c-c')n(a-c)/(n+1)b$.

6.1 Unit Royalty and Fixed Fee Licensing

In the case of a major innovation, the determination of the reward is not so immediate. As mentioned above, a major innovation is characterised by a lower post-innovation price and larger post-innovation level of production. The licensor must structure

the licensing contract such that it preserves the original industry profits π_c, while inciting the Cournot firms to expand production from Q_c to Q_m (it is assumed that the structure of the industry does not change). This result may be achieved if the licensor charges a unit royalty of $r = (n-1)(a-c')/2n$ and a fixed licensing fee of $F = (a-c')^2/4bn^2 - (a-c)^2/b(n+1)^2$. Using this licensing contract, the licensor shall receive for his efforts the following total rewards:

$\pi_m - \pi_c = (a-c')^2/4b - n(a-c)^2/b(n+1)^2$ (a summary of these results may be found in Table 1).

Table 1:   Summary of Unit Royalty, Fixed Fees and Total Rewards to Inventor for a Minor and Major Cost-reducing Innovation

Innovation Type	Unit Royalty	Fixed Fee	Rewards to Inventive Activity
Minor	c-c'		$(c-c')Q_c =$ $(c-c')n(a-c)/(n+1)b$
Major	$(n-1)(a-c')/2n$	$(a-c')^2/4bn^2 - (a-c)^2/b(n+1)^2$	$\pi_m - \pi_c =$ $(a-c')^2/4b - n(a-c)^2/b(n+1)^2$

If the preinvention industry structure is a monopoly $n=1$, the licensor may extract this total amount via the fixed fee only. On the other hand, when the preinvention industry structure is competitive, the licensor can extract the whole amount using only a unit royalty.

Kamien and Schwartz' analysis gives rise to several observations which shall be repeated here. First, the inventor's total reward for either a major or minor innovation increases with the amount of competition n he is licensing it to. From this result, we can infer that market power attenuates the incentive to invent. This is consistent with Arrow's and Jackson's[11] examination of market structure and the incentive to innovate.

Differentiating the inventor's rewards with respect to a (which would constitute a parallel shift of the demand curve) indicates that the reward also increases with market size.

11.   Jackson, R., *Market Structure and the Rewards for Patented Inventions*, Antitrust Bulletin, Vol. 16, 1972, pp. 911-926.

This supports Schmookler's[12] propositions that market size and firm growth act as stimulants to innovation.

The total additional benefit to society, in terms of the consumer surplus for the major innovation is $Q_c(P_c-P_m)+(Q_m-Q_c)(P_c-P_m)=(P_c-P_m)(Q_c-Q_m)/2$, which is positive. For the minor innovation, price and quantity are maintained, thereby yielding no additional consumer surplus.

Kamien and Schwartz advance additional notions which must be considered when judging the profitability of licensing a cost-reducing innovation. Their first contention is that this type of examination is a partial equilibrium analysis. A general equilibrium framework would take into account the cost changes in all industries when calculating the net benefit to society. For example, the reduction in cost in one industry would increase demand for the product and for some of its inputs. This could have the effect of raising the price of these inputs and lowering the cost-savings of the innovation. The social benefit should therefore be calculated in net rather than gross terms to truly gauge the benefits to society, the inventor and the industry.

7. Firm Profits and the Private Value of a Patent

The preceding analysis was limited by the assumption that firms can preserve their pre-invention profits after adoption of an innovation. This constraint does not allow for the possibility that some firms, as a result of competition to use the patent, will purchase the innovation even though it results in lower profits. Making concessions for this possibility requires the comparison between profits without adoption of the innovation and profits with

12.   Schmookler, J., *Invention and Economic Growth*, Harvard University Press, Cambridge, Massachusetts, 1961.

the use of the innovation.

Morton Kamien and Yair Tauman's[13] study of licensing contracts allows for competition in use of the process innovation. Their examination permits us to calculate the number of firms which actually adopt the innovation and the total profit obtained by the licensor. In addition, this study compares the profitability of licensing using only a fixed fee, only a royalty, contracting costs, and a profit sharing arrangement between inventor and licensees. This examination also permits the study of the social welfare implications of each licensing or profit sharing strategy enumerated above.

The assumptions of this model are that n firms compete in the Cournot fashion, produce homogenous products and have identical horizontal marginal cost functions initially. The aggregate demand for the good is given by $p=a-Q$, where $a>c$ and Q denotes the industry's total level of production. The invention of the patent holder shall reduce the marginal cost of production (from c to $c-\epsilon$).

To compare the profitability of licensing to the inventor, we must examine whether the firms purchase or not the innovation given the

Game Tree 1
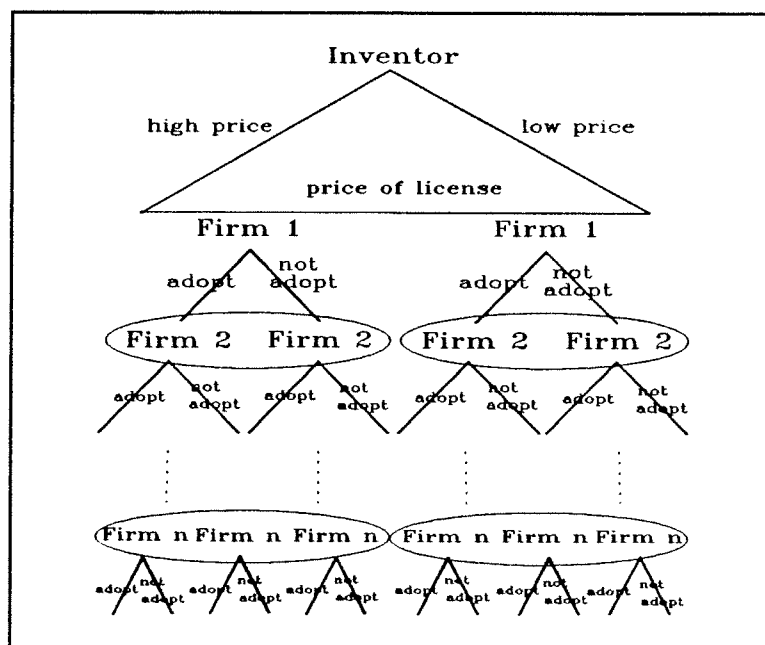
13.   Kamien, M.I., & Tauman, Y., *Fees Versus Royalties and the Private Value of a Patent*, Discussion Paper, Northwestern University, Evanston, Illinois, September 1984.

7. Firm Profits and the Private Value of a Patent   25

amount charged for the license (i.e. the fixed fee α or royalty β). This is realised through the analysis of a non-cooperative game where the inventor announces his price (fee or royalty) for the technology to each firm in the first stage and firms determine their strategies to purchase or not in the second stage (see Game Tree 1). The firms decision to adopt the innovation will rest on the incremental profits the innovation will generate given the number of licenses sold and the payment charged for the license.

7.1 Fixed Fee Licensing

Using a fixed fee licensing contract, firms adopting the new technology will produce with the following cost function:

$$F_i(q_i) = \alpha + (c-\epsilon)q_i$$

Firms not adopting the innovation will use the old technology:

$$F_i(q_i) = cq_i$$

Assuming that total industry output is a Cournot equilibrium, the production level of each firm may be uniquely determined for each fee level α of the inventor, and adoption strategy of the n firms $(\tau_1, \tau_2, ..., \tau_n)$. The profit of each firm is therefore:

$$\pi_i = q_i(p-c+\epsilon)-\alpha \quad \text{for firms adopting the innovation, and}$$

$$\pi_j = q_j(p-c) \quad \text{for firms not adopting the innovation.}$$

The profit of the inventor (patent holder) is:

$$\pi_{PH} = \Sigma_i \alpha$$

Kamien and Tauman determine the number of licenses k, the profit of the inventor π_{PH}, and the profit of each firm i: π_i, which characterise the subgame perfect equilibrium in pure strategies for non-drastic and drastic innovations. To ensure that a given set of strategies form a subgame perfect equilibrium in pure strategies, (1) the inventor's

equilibrium strategy α^* (price of license) must be a best reply strategy to the equilibrium strategies $(\tau^*_1, \tau^*_2, ...,\tau^*_n)$ (adopt innovation or not) of the n firms, and (2) each firm's equilibrium strategy τ^*_i must be a best reply choice to each other firm's equilibrium strategy and all the strategies of the inventor α. The results of these equilibrium strategies are summarized in Table 2. We see that the number of licenses sold, and profits to the inventor and to the firms depend on the existing industry structure, the costs of production and the degree of the cost reduction.

Table 2: Summary of the Equilibrium Number of Licenses Sold, Inventor's Profits and Firm Profits for Non-drastic and Drastic Cost-reducing Innovations

	Non-drastic Innovation		Drastic Innovation
		Boundaries of Equilibria	
k	n	$n \le (2/3)\{(a-c)/\epsilon+1\}$	1
	$(a-c)/2\epsilon+(n+2)/4$	$(2/3)\{(a-c)/\epsilon+1\} \le n \le 2\{(a-c)/\epsilon-1\}$	
	$(a-c)/\epsilon$	$2(a-c)/\epsilon \le n$	
π_{PH}	$\{2n^2/(n+1)^2\}\epsilon^2\{(a-c)/\epsilon+1-n/2\}$	$n \le (2/3)\{(a-c)/\epsilon+1\}$	$\{(a-c+\epsilon)/2\}^2-\{(a-c)/(n+1)\}^2$
	$\{2n/(n+1)^2\}\epsilon^2\{(a-c)/2\epsilon+(n+2)/4\}^2$	$(2/3)\{(a-c)/\epsilon+1\} \le n \le 2\{(a-c)/\epsilon-1\}$	
	$\{n(n+2)/(n+1)^2\}\epsilon(a-c)$	$2(a-c)/\epsilon \le n$	
π_i	$\{(a-c)^2-\epsilon(k-1)(2(a-c)-\epsilon(k-1))\}/(n+1)^2$	Firms adopting innovation	$\{(a-c)/(n+1)\}^2$
	$\{(a-c-k\epsilon)/(n+1)\}^2$	Firms not adopting innovation	

7.1.1 Non-drastic Innovations

Several conclusions may be drawn from these results. We consider first the case of a non-drastic innovation. Using a fixed fee α only, the number of licenses k is a non-increasing function of the degree of cost reduction ϵ, and k does not exceed $(a-c)/\epsilon$ for any number of firms - that is the number of licenses decreases when the degree of the cost reduction increases.

A second result which may be drawn is although the profit of each firm decreases

with the degree of cost reduction ϵ, the inventor's profit increases with ϵ. When the industry is purely competitive (i.e. $n \rightarrow \infty$), the inventor's profit is equal to $\pi_{PH} = \epsilon(a-c)$. The intuition for these results follow directly. For a small innovation (ϵ small), the inventor can only charge a minimal fee since the existing technology competes with the innovation. It is the notion of competing technology which permits the firms to appropriate the largest share of the rents accruing from the innovation. If the innovation reduces the cost of production further, the existing technology becomes less attractive to the firm. This permits the inventor to increase the license fee demanded and increase his share of the rents from the innovation. The inventor's ability to raise the license fee is limited by the fact that a fixed fee licensing contract is not an efficient instrument to extract the rent of the innovation when few firms actually purchase the license.

The most profitable number of firms **n** in the industry for the inventor when he licenses his technology depends on the degree of the cost reduction ϵ. For small ϵ the number of firms in the industry is proportional to $(1/\sqrt{\epsilon})$ - that is the number of firms should decrease with any increase in the cost reduction.

This last result gives the impression that the most profitable strategy for the patent holder is to license to one firm. This does not occur since sole production will raise the price above c and the other firms will enter the industry. This, in turn, will lower the monopolist's market share which shall reduce the fee the firms are willing to pay for the license.

7.1.2 Drastic Innovations

When the cost-reducing innovation is drastic, sole production is the only subgame perfect equilibrium. The patent holder's profit again increases with the degree of the cost

reduction ϵ, while the profit of the sole producer does not depend on ϵ. Although the equilibrium specifies sole production, this is not the most profitable strategy for the patent holder. This results from the fact that a fixed fee contract does not efficiently extract all the rents of the innovation because it does not vary with the level of production. With many firms, the inventor is able to establish a relationship between the fee level and the aggregate level of production (represented by the number of firms). Competition thus permits the fixed fee to better reflect the level of production. On the other hand, the incremental Cournot profit outcome for the firms do not cover the fixed fee required by the licensor, so no additional firms will purchase the license.

A final conclusion of the fixed fee license is that for any $\epsilon > 0$, each firm's profit decreases as a result of the cost-reducing innovation unless the innovation is drastic and the resulting monopoly breaks even. Whether the innovation is drastic or not, total production increases, and consumer's are better off due to the lower market price.

7.2 Unit Royalty Licensing

We now examine the case when licensing is performed using only a unit royalty β. This model is similar to the preceding fee only model. The industry is divided into firms which adopt the licenses, and $n-k$ firms which do not.

The royalty revenue is given by: $\pi_{PH} = \Sigma_i^k \beta q_i$, the profits of the firms adopting the innovation is: $\pi_i = (p-c+\epsilon-\beta)q_i$ and those not adopting the innovation, $\pi_j = (p-c)q_j$.

There exists a unique subgame perfect equilibrium solution for this game which is independent of the level of the cost reduction ϵ. At equilibrium, all n firms purchase the innovation when a unit royalty is used since this licensing contract does not reduce firms' profits. For a non-drastic innovation, the profit maximising royalty is ϵ, and $(a-c+\epsilon)/2$ for a

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drastic one.

When comparing the benefits of a unit royalty with a fixed fee, we conclude that the patent holder receives a lower profit using a royalty, except in the particular case of pure competition where the profits of the two methods coincide. The inventor's lower profit is because a unit royalty licensing contract maintains the level of industry production at the pre-adoption level, whereas the fixed fee licensing contract permits industry output to be expanded. As expected, the licensor still receives greater profits from the drastic innovation than the non-drastic one.

With regard to the firms, the use of a royalty is more advantageous to them, because their profits are not lowered when adopting the innovation as was the case of a fixed fee licensing contract. In the case of a non-drastic innovation, the firms profits do not change after adoption, and for a drastic innovation their profits increase.

Consumers are worse off when the licensor uses only a unit royalty. This is because the unit royalty maintains the price level. When the innovation is non-drastic, the Cournot level of production and market price do not depart from their pre-innovation levels. For a drastic innovation, the firm's Cournot level of profits and output increase after adoption, yielding incremental benefits to consumers.

In summary we conclude that both society and the inventor find it more advantageous to use a fixed fee rather than a royalty. Only the firms prefer the use of a unit royalty.

7.3   Fixed Fee and Unit Royalty Licensing

Kamien and Tauman also examine the case when a licensor uses both a fixed fee α and unit royalty β to extract the innovation's rent from the n Cournot firms. Their model is similar to the two preceding, where the inventor offers a list of potential licensing contracts

in the first stage, and firms adopt or reject the contract in the second stage. This game also has a unique subgame perfect equilibrium in pure strategies.

This analysis indicates that using a two part licensing contract is a superior strategy for the inventor than either one part contracts since the inventor is capable of both efficiently extracting the amount of the cost reduction while expanding production. The inventor however, is least able to increase his profits when the industry is characterised as perfectly competitive (n→∞). Under these circumstances, the patent holder realises the same profit as he would using either the fixed fee or unit royalty licensing contracts.

A second interesting result emanating from this analysis, is that for a large number of firms n, the fixed fee contract yields a larger consumer surplus than the equilibrium levels of a unit royalty and two part licensing contract. This occurs because under a fixed fee license, the level of production increases while the Cournot equilibrium price decreases.

7.4 Contracting Costs and Profit Sharing

Kamien and Tauman also study the effect of an additional cost, namely contracting costs, which are incurred by the patent holder. Examples of this type of cost could include training or technical assistance to use the patent. To reflect this, the cost function is assumed to be increasing with the number of licenses sold.

When this type of additional cost is added to their analysis, we observe that if the number of firms n is sufficiently large, each licensee shall be charged only a fee and not a royalty. The licensor shall also only issue a total number of licenses $k = (a-c)/\epsilon$, which is identical to the result obtained under a fixed fee licensing scheme.

The authors also study the impact of a profit sharing agreement between licensor and firms. This arrangement permits the licensor to receive a share of the firm's profits rather

than using a linear royalty or fixed amount. They conclude that this profit sharing method is equivalent to the use of a fee for the inventor.

8.   Fixed Fees when the Inventor is also a Producer

Kamien and Schwartz's analysis of the profitability of licensing technology assumed that the industry structure (i.e. the number of firms) did not change after adoption of the cost-reducing innovation. In reality, licensing does cause structural changes in the industry since industry output is often expanded. Kamien and Tauman extended this model to allow for a reduction in industry profits. A second constraint of all the previous studies was that the inventor was not permitted to participate in production. We shall see that when all these assumptions are relaxed, licensing to a rival firm may, or may not be less profitable than being the sole producer employing the new technology.

To examine this, Michael Katz and Carl Shapiro[14] develop a three stage, asymmetric duopoly licensing game of R&D rivalry. Their analysis focuses on three questions. What are the demand and cost considerations which incite a patent holder to share its innovation to it's rival duopolist via a fixed fee patent license? How are the incentives to innovate affected by the possibility of patent licensing? Thirdly, are private intentions to share innovations socially optimal?

The three stages of this game are: the development stage, the licensing stage and the output stage (see Game Tree 2). The game is solved backwards employing the concept of a perfect Nash equilibrium. In the development stage, both firms compete to develop the innovation and acquire the rights to the cost-reducing innovation. This competition to

14.   Katz, M.L., & Shapiro, C., *On the Licensing of Innovations*, Woodrow Wilson Discussion Paper #84, Princeton University, Princeton, New Jersey, October, 1984.

develop the technology is modeled as a bidding game to acquire an innovation. For example, each of the two firms submit a bid to acquire a cost-reducing innovation, subject to the seller's reservation bid. When at least one of the bids exceed the minimum bid, the highest offer obtains the rights to
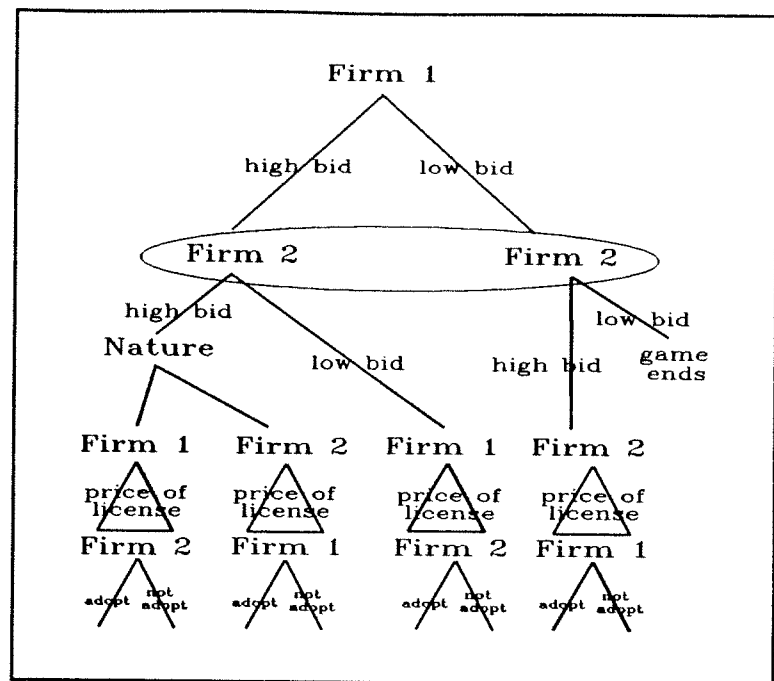
the technology (successfully develops the technology) at the price bid. The other firm does not obtain the technology and makes no payment. If the offers are equal, and exceed the minimum bid, the technology is randomly distributed (by nature) to one of the two firms. When neither firms' offer is greater or equal to the seller's reservation bid, the technology is not transferred (neither firm succeeds in developing the innovation).

Once the development stage is completed (ie. one of the two firms has developed the technology) the game proceeds to the licensing stage, where the decision to license is determined. In this stage, the two firms bargain over the cost of the license. The authors make the strong assumption that the bargaining game between the firms will result in a Pareto efficient outcome - that is licensing will occur if and only if it raises the firms' joint profits.

In the output stage, firms compete in the product market through either price or quantity competition. This stage is a standard duopoly pricing or output game.

8.1 Fixed Fee and Unit Royalty Licensing

Once a manufacturer has developed a cost-reducing innovation, it will always be profitable to license it to rivals if there are no restrictions on the type of licensing contract. Using the unit royalty, the inventor-manufacturer is able to sustain his rival's price and output, thus preserving the industry price, output and profits. The fixed fee allows the inventor-manufacturer to share the cost savings of the innovation permitting a Pareto improvement for both firms. For these reasons, there always exists a licensing agreement which Pareto dominates not licensing.

In practice, however, licensing is not as common as this analysis would propose. This may result from the inventor-monopolist's inability to monitor his rival's level of production which allows the licensor to avoid the per unit charges. To account for these difficulties, the remainder of this chapter will deal with fixed fee licenses only.

8.2 Fixed Fee Licensing

As mentioned above, the inventor-manufacturer will license a technology to its rival using a fixed fee, if the resultant industry profitability is increased. We therefore examine the impact of licensing on joint profits.

Suppose firm 1, of initial cost c_1, has developed a cost-reducing innovation which he may license to firm 2, of initial cost c_2. The joint profit for the duopolies is: $\pi = P(Q)Q - c_1 q_1 - c_2 q_2$. To determine the effect of this license on industry profits we differentiate this profit function with respect to c_2:

$$d\pi/dc_2 = (P + Q(dP/dQ) - c_1)(dQ/dc_2) + (c_1 - c_2)(dq_2/dc_2) - q_2$$

Katz and Shapiro distinguish three effects of lowering firm 2's cost (i.e. licensing).

1- an aggregate output effect
2- an output mix effect
3- a direct cost effect

The aggregate output effect will tend to lower industry profits if $dQ/dc_2 < 0$, since firms produce too much from a private point of view and $(P+Q(dP/dQ)-c_1) < 0$. The output mix effect $(c_1-c_2)(dq_2/dc_2)$ will also lower industry profits because $c_1 < c_2$: firm 1 must be at least as efficient as firm 2, otherwise the effect is absent $c_1 = c_2$. The direct cost effect $(-q_2)$, on the other hand will increase industry profits because any increase in the level of firm 2's production will be at a lower cost as the firm's unit costs fall.

Fixed fee licensing shall occur if, industry profits increase, and they can be divided between both duopolists. This occurs when the direct cost affect is larger than the combined effect of aggregate output and output mix. This is achieved when the cost reduction of the innovation is small (i.e. $c_1 = c_2$ prior to adoption) and if and only if the conjectural variation parameter $(\tau = dq_j/dq_i$: $\tau = 0$ for Cournot and $\tau = -1$ for marginal cost pricing) and the elasticity of the inverse demand curve $(\epsilon = Q(d^2P/dQ^2)/(dP/dQ)$: $\epsilon = 0$ for linear demand curve) obey the following relationship: $(1+\tau)(2+\epsilon) > 0$. This relationship holds when the demand curve is linear. Therefore, it shall always be profitable to license a small innovation if the pre-adoption costs of production are equal $c_1 = c_2$ and the demand curve is linear.

In the case of larger innovations and asymmetries in the efficiency of existing technologies of production, the results are the opposite. In particular:

> If a firm 1 would enjoy an effective monopoly absent licensing, and if firm 1 is at least as efficient as firm 2 with the innovation, then firm 1 will not license to firm 2.

and

If firm 1 is close to having an effective monopoly by exclusion, then exclusion is optimal.[15]

The intuition is as follows: firm 1 is able to appropriate the rents of the innovation through sole production - that is he obtains an effective monopoly through exclusion. Industry joint profits in this case include the effective monopoly profits plus his rival duopolist's profit. If licensing occurs, joint profits will fall below joint profits with exclusion since competition in the output stage will result in lower prices. Viewed in this sense, the additional rents accruing to firm 1 through licensing minus his loss of industry profits due to competition is less than his effective monopoly profits with exclusion.

8.2.1 Comparison of Private and Social Benefits

Katz and Shapiro also examine whether the private benefits of licensing using a fixed fee payment correspond to the social welfare benefits. Their findings indicate that so long as industry's output is increased as a result of a single firm's cost reduction, any fixed fee license which is privately profitable is also socially welfare enhancing. This is because when output is expanded, the price falls, yielding an incremental consumer surplus. Furthermore, since industry profits are a component of total surplus (by definition), any increase to joint profits also increases total surplus.

Having defined that when licensing is privately profitable, it is also welfare enhancing, one may ask if licensing arrangements are always socially attractive. The answer to this question is surprisingly no. To illustrate this point, consider the case of a licensee with high initial costs (compared to the monopolist) and small output. Because the licensee's production costs are greater than the monopoly price, exclusion would force this marginal

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15. Ibid, pp. 13-16.

producer to withdraw from the market. Licensing to him will have a negligible effect on output and maintain the pre-innovation industry price. This contributes no additional social welfare benefit. On the other hand, the output of the licensor will decrease with licensing, since the industry price is maintained above the monopoly price with exclusion. This causes a first-order welfare loss to society. Exclusion is therefore socially welfare enhancing since the high-cost producer will no longer maintain industry price above the monopoly price.

9. Optimal License Fees for a New Product

Except for John McGee's cursory examination of product innovations presented earlier, all of our inquiries into licensing dealt with contracts for cost-reducing process innovations. Process innovation are easier to model since they may be specified by the cost considerations of firms in a particular industry.

Morton Kamien, Yair Tauman, and Israel Zang[16] develop a model which examines the profitability of product innovations. To realize this, they define a new product in terms of it's cost of production - that is, the cost of producing the new product was initially too high to make its production profitable. They suppose that as a result of technological improvements, the production of the new good becomes potentially profitable. This new product is termed "superior", and the existing substitute is the "inferior" product throughout this review.

This approach permits us to study how the introduction of a new product affects the market structure for both the new and existing product, the prices of both products and the profits of the inventor and the firms. Assumptions of the model state that firms not

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16.   Kamien, M.I., & Tauman, Y., & Zang, I., *Optimal License Fees for a New Product*, Discussion Paper No. 665, Centre for Mathematical Studies in Economics and Management Science, Northwestern University, Evanston, Illinois, 1985.

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purchasing the license for the superior product will continue production of the inferior product. Also, it does not allow any firm to produce both goods simultaneously. Finally, licenses are restricted to fixed fees only.

In this analysis, the demand curves for the superior product (identified by **j**) and inferior product (identified by **i**) are the following:

$$X_i = \begin{matrix} P_j\text{-}P_i & \quad P_j \geq P_i \\ 0 & \quad P_j \leq P_i \end{matrix}$$

$$X_j = \begin{matrix} b\text{-}P_j\text{+}\epsilon P_i & \quad P_j \geq P_i \\ b\text{-}(1\text{-}\epsilon)P_j & \quad P_j \leq P_i \end{matrix}$$

From these demand functions we may derive the following inverse demand functions:

$$P_i = \text{Max}\{(b\text{-}X_i\text{-}X_j)/(1\text{-}\epsilon),0\} \qquad X_i > 0$$

$$P_j = \text{Max}\{(b\text{-}\epsilon X_i\text{-}X_j)/(1\text{-}\epsilon),0\}$$

The firm's profit levels for each type of product is:

$$\pi_i = x_i(P_i\text{-}c_i)$$

$$\pi_j = x_j(P_j\text{-}c_j)\text{-}\alpha$$

where α is the price of the fixed fee license. If **k** represents the number of licenses sold, the inventor's profit is:

$$\pi_{PH} = k\alpha$$

The analysis is a three stage non-cooperative game involving the licensing of the superior product to firms producing the existing inferior product (see Game Tree 3). It is assumed that all participants in the game have full and complete information. The game is solved recursively using the subgame perfect Nash equilibrium.

In the first stage the inventor announces the price of a license to produce the superior product. He sets his fixed fee such that it maximises his profit subject to the number of firms

purchasing the license in stage two of the game. The licensor acts as a Stackelberg leader since he determines his optimal license fee by foreseeing the number of licenses sold in the second stage of the game. The relationship between the price of a license and the number purchased allows the inventor to establish a
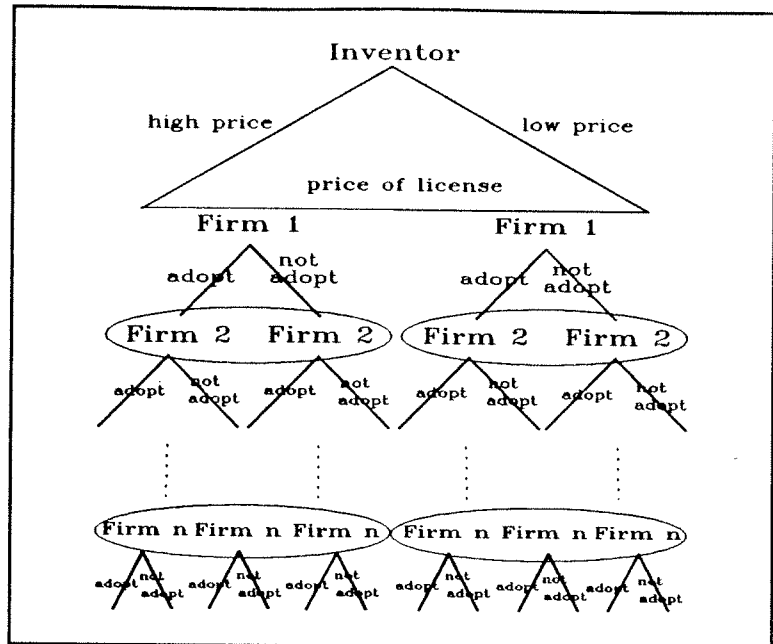
demand function for his license. In the second stage the inferior product manufacturers decide independently and simultaneously whether they will purchase the license. The firms will purchase the license if the profit realised as a producer of the superior good minus the license fee is at least as large as would be the profit producing the inferior good. In the third stage, the producers in each product industry determine independently and simultaneously the quantities that each shall produce. This establishes the Cournot equilibrium quantities produced, prices and profits for both the inferior and superior product and for every combination of the number of licenses sold.

The derived profit functions which the firms use to determine their strategies are:

$$\pi_i(n,k) = x_i^2/(1-\epsilon)$$

$$\pi_j(n,k) = x_j^2/(1-\epsilon)-\alpha$$

In the second stage, the number of licenses sold k is an equilibrium if no firm has any incentive to deviate from their choice to purchase or not the license. The firms purchasing

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9. Optimal License Fees for a New Product

the innovation will not deviate if their incremental profits upon adoption of the license is greater than the license fee:

$$\alpha \leq \pi_j(n,k)\text{-}\pi_i(n,k\text{-}1) \quad 1 \leq k \leq n$$

Similarly, firms not purchasing the innovation will not deviate if the license fee is greater than the incremental profit gained by purchasing the license:

$$\alpha \geq \pi_j(n,k+1)\text{-}\pi_i(n,k) \qquad 0 \leq k \leq n\text{-}1$$

From these two equilibrium conditions, we are able to derive the following upper and lower bounds for the license price:

$$\alpha(n,k) \geq \alpha(n,k+1)$$

The inventor chooses the number of licenses issued, by maximising his profit function $k\alpha$ subject to this license price constraint.

There exists three unique subgame perfect equilibria in pure strategies for this game.

9.1 Drastically Superior Product Innovations

The first equilibrium occurs when the superior product is drastically superior to the inferior product. A product is defined as drastically superior when its monopoly price is below the marginal cost of producing the inferior product. In this equilibrium, the inventor licenses his drastically superior product to only one firm and the producers of inferior products drop out of the market since their costs are above the monopoly price of the superior product.

The inventor is not able to extract the maximum monopoly profit of his innovation because the ensuing monopoly price would permit the production of the inferior product by the n-1 firm oligopoly. This competition of the n-1 firms would have the effect of reducing the size of the superior product market, thus rendering sole production unprofitable.

However, if the inferior product was produced under perfectly competitive circumstances, the inventor would be able to extract the total monopoly profit since the sole producer's opportunity cost is zero.

9.2   Perfect Competition in the Inferior Product Industry

The second unique solution arises when the superior product is not drastically superior and the inferior good is produced in a perfectly competitive industry. Under this scenario, the inventor licenses to only a small number of firms and production of the inferior good does not cease. Since the number of firms producing the inferior good is great, the inventor is able to extract the entire profit from the superior good industry.

The inventor shall not increase the number of licenses for the superior product because competition in the superior good market would lower the profits he is extracting from them. On the other hand increasing the number of licenses removes producers from the inferior market and drives up the price. This increases the demand for his substitute superior product and the profit he is extracting from this industry. The inventor must strike a balance between these two opposing forces when choosing the number of licenses sold.

9.3   Cross-price Elasticity of Demand

The last unique equilibrium occurs when the price of the superior good affects the demand for the inferior good, but the price of the inferior good has a negligible effect on the demand for the superior good. This may occur when the inferior product is produced in a perfectly competitive industry. There does exist an intermediate case which supports this equilibrium when the number of firms in the inferior product industry is small.

This unique equilibrium has the following effects on profits, price and quantities. If the producers of the inferior product do produce positive quantities, the Cournot price of the

inferior product declines after introduction of the superior good. Secondly, the profit of the licensee remains the same as it was prior to adoption, however, the profit of the non-licensees decreases. Finally the sum of the profits of the inventor, and the producers of both goods will increase after introduction of the new product.

10. Threatening Contracts and Auctions for Licenses

The preceding game-theoretic studies have examined licensing contracts based on either a fixed fee, a unit royalty, or both. Kamien and Tauman's analysis indicated that a fixed fee contract was more profitable to the inventor than royalty contracts. This arises because the fixed fee contract exploits the demand interdependancies between firms. Firms which did not purchase the fixed fee contract found themselves worse off than prior to the introduction of the innovation. It is this threat of loosing profits which incites firms to accept higher fees for a given technology.

Another method of obtaining this type of threatening contract is through the creation of an auction for licenses which restricts the number of licenses issued. By not limiting the number of licenses issued, the auction allows the number of licenses supplied to equal the number of licenses demanded, which is equivalent to a pure fixed fee pricing mechanism. This method does not exploit the demand interdependancies of the existing producers. By restricting the number of licenses which shall be granted, the inventor is able to increase the profitability of his invention.

> Essentially, the innovator appropriates some of the oligopolists' initial property rights to their oligopoly profits, by threatening them with the lower profit level that they would earn if some of their rivals obtained licenses and they did not.[17]

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17. Shapiro, C., *Patent Licensing and R&D Rivalry*, American Economic Review, Vol. 25, May 1985, pp. 25-30.

Katz and Shapiro[18] study the consequences of this type of threatening contract through their development of an auction model for licenses. Their model was mainly intended to determine the effect of research joint ventures on the development and adoption of innovations. For our purpose, we shall only review the chapters which deal with auctions for licenses because it adds yet another licensing strategy to our review.

Their model is specified solely by the number of licenses available k^a, the minimum bid $\underline{b}$ required by the inventor, the quantity of licenses demanded k^b and the equilibrium number of licenses traded k^e. For our analysis, it is useful to imagine a sales strategy $(k^a, \underline{b}) = (k^e, 0)$ as a quantity sales strategy and $(k^a, \underline{b}) = (n, \underline{b})$ as a price strategy (ie. fixed fee licensing).

In this examination, all or part of the licenses are sold in the following manner: the highest bid firm pays the amount bid (if greater than the set minimum). The second highest bid obtains the license for the second highest amount bid (if greater than the set minimum). This continues until all the licenses have been sold or the remaining bids are below the minimum bid set by the inventor. Since all firms know the bids of the other firms, in any bidding equilibrium, all firms who actually purchase the license pay the same price b^e.

Under this stratified bidding scheme, each firm is willing to bid the difference between his profits if he obtains the patent and his profits if he is unsuccessful at the auction. Firms are therefore concerned with the total number of firms desiring to purchase the license k^b when selecting their bids.

The inventor's strategy is to limit the number of licenses issued k^a. Limiting the

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18.   Katz, M., & Shapiro, C., *How to License a Patent*, Woodrow Wilson Discussion Paper #82, Princeton University, 1984.

number of licenses issued increases the threat of lower profits to the unsuccessful firms. For these reasons the equilibrium number of licenses sold will be equal to the minimum of either the number issued k^a or the number desired k^b: $k^c = Min\{k^a, k^b\}$.

By determining the different equilibria which may occur for any number of licenses sold and various minimum bidding prices, Katz and Shapiro are able to determine the optimal auction strategies for the inventor. Their first result is that the profit-maximising inventor need not impose a strictly positive minimum bid when he restricts the number of licenses issued $(k^a < n, 0)$. This minimum bid requirement is redundant unless the inventor wishes to sell the license to all firms in the industry $k^a = n$. This first result may be understood by realising that at equilibrium, only a discrete number of firms desire purchasing the license. Imposing a minimum bid will not encourage additional firms to purchase the license, but rather, it shall reduce the number bought since less firms shall find it profitable to purchase it at equilibrium. Therefore, neither the inventor or the firms gain through the imposition of a minimum bid. This result may be stated as follows:

$$\pi_{PH}(k^a < n, 0) \geq \pi_{PH}(k^a < n, \underline{b} > 0)$$

The second result of their analysis is that the quantity sales strategy $\pi_{PH}(k^a < n, 0)$ is more profitable for the inventor than a simple fixed fee price strategy $\pi_{PH}(n, \underline{b} > 0)$. To demonstrate this, we use the previous identity and compare $\pi_{PH}(k^a < n, \underline{b} > 0)$ to a simple price strategy $\pi_{PH}(n, \underline{b} > 0)$. Proving that $\pi_{PH}(k^a < n, \underline{b} > 0)$ is greater than $\pi_{PH}(n, \underline{b} > 0)$ is trivial, since, as mentioned, imposing a quantity restriction exploits the demand interdependancies to purchase the license, between the firms. Restricting the number of licenses to less than the number of firms in the industry encourages the firms to bid more than the reservation bid, particularly when they are faced with reduced profits if they are

unsuccessful to secure the license. Licensing to less firms is always more profitable for the inventor, paribus ceteris. We therefore have that:

$$\pi_{PH}(k^* < n, 0) \geq \pi_{PH}(k^* < n, \underline{b} > 0) > \pi_{PH}(n, \underline{b} > 0)$$

a quantity sales strategy is always superior to a simple price strategy.

Other optimal strategies may be determined by specifying the profit functions of the firms which purchase the license. When the firm's profit function increases with the number of licenses sold (this could be possible if the innovation will become an industry standard) and the profit to the inventor increase with the number sold, the optimal sales strategy for the firm is to sell licenses to all **n** firms in the industry or to only **n-1** firms. If only the inventor's profits increase with the number of licenses issues, selling **n-1** licenses dominates selling less licenses. Intuitively the inventor trades off increased profits from selling more licenses against a less effective threat he imposes on firms by allowing more licenses.

In summary we have examined that a pure pricing strategy such as a fixed fee license is not the optimal sales strategy for the inventor. The inventor can do better if he restricts the number of licenses issued. This will threaten the firms to bid larger amounts for the license thereby increasing the inventor's profits. We have also seen that if the inventor does not intend to sell licenses to all firms in the industry, he does not have to set a minimum bid in the stratified auction. Furthermore, we determined how specific conditions on the firms' and inventor's profits may encourage the inventor to license to all firms in the industry.

Conclusion

In this paper, we have reviewed many factors which may be incorporated into the study of the profitability of licensing technology. The exogenous elements to be considered by the inventor when licensing include: pre- and post-invention costs of production, pre-

invention industry structure, pre-invention market size, and the elasticity of demand.

We have also reviewed the actions which may be used by the inventor to maximise his profits, given the exogenous elements mentioned above. These include: the particular terms of the licensing agreement (fixed fee only, royalties only, a combination of fixed fees and royalties, and profit sharing arrangements) and the strategies which threaten firms profitability (fixed fees and auctions with restrictions on licenses).

With respect to production costs, drastic (and major) innovations tend to be more profitable to the inventor than non-drastic (and minor) innovations. A cost-reducing innovation in an industry which has a more elastic demand curve will also offer greater reward to the inventor than one which is less elastic.

Ultimately, the benefits of all innovations are distributed between the inventor, the firms in the market and consumers (and in a general equilibrium framework, the firms in other industries). Since the patent system bestows a monopoly power upon the inventor, he is able to choose the terms of the contract (when no competing licenses exist) which will extract monopoly rents for his innovation. This possibility of profit maximising behaviour, on the part of the inventor, can involve structural changes in the industry. We have seen that these changes will at least preserve the consumer surplus. Concessions may be made to the terms of the contract which increase the benefits to the consumer while preserving the monopoly rents to the inventor.

We have also seen that the a licensing contract which threatens the profits of producers is superior to any type of linear pricing contract (i.e. royalty, fixed fee, profit sharing or some combination thereof).

In conclusion we would like to recommend additional areas of study with respect to

licensing contracts for innovation. As mentioned in this paper, there exists a scarcity of studies dealing with product innovation and licenses. This is somewhat disconcerting, given the fact that a disproportionately large share of product innovation are developed by individual inventors and small firms. Usually, these small players do not have the resources nor the capabilities to produce and market their innovations, and would therefore license more often to other firms.

Other areas of research could be the study of additional methods of exchanging information. Perhaps furthering the analysis of the different types of auctions would provide welfare enhancing mechanisms for licensing technology. Incomplete information models are also of interest, since, as discussed, various risks are associated with the exchange of technical information.

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