

When is a commitment to licensing rivals credible?

Mihkel Tombak¹

May, 2008

ABSTRACT

When lobbying for the adoption of a technology standard, patent holders often make a commitment to license a technology on fair, reasonable and non-discriminatory terms ("FRAND"). A theoretical model is developed to examine when such commitments to rival firms are credible. We examine the licensing of a modest cost reducing technological innovation to rivals with differing costs in Cournot markets. Licensing would be widespread with royalties rates which are discriminatory. It is found that when one royalty rate is posted then more efficient, large, rivals would find such rates prohibitive. The robustness of the results to asymmetric differentiated Bertrand product markets and implications for the Qualcomm case and policy are discussed. It is found that commitments to FRAND are not credible and firms should seek to set royalties before agreeing to a technology standard.

Keywords: Licensing, technological innovation, size distribution of firms

JEL: D45, O32, L11

¹ Rotman School of Management, and University of Toronto at Mississauga, 3359 Mississauga Rd. North, Mississauga, Ontario, CANADA L5L 1C6. e-mail:mihkel.tombak@rotman.utoronto.ca. The author would like to acknowledge the comments of Vincenzo Denicolo, Thomas Gehrig, Joseph Harrington and Piero Tedeschi, and the seminar participants at CIRANO, EARIE, Workshop in IO in Helsinki, Workshop on Licensing in Milano, Queens University, and the WZB on an earlier version of the paper. Also appreciated is the financial support of NSERC, and University of Toronto.

Introduction

In January, 1998 the European Telecommunications decided to choose the W-CDMA technology to be the multiple access techniques for the third-generation mobile telephone system. Also, the International Telecommunications Union (ITU) has accepted W-CDMA as part of the IMT-2000 family of 3G standards. Since then many of the communications companies and many major suppliers of mobile telephony technology have adopted WCDMA 3G for their third generation technology. Part of that technology standard contained technology which has been patented by Qualcomm Inc., of San Diego, CA. In order that the standard be adopted, Qualcomm committed to the international standard setting bodies that it would license its technology on fair, reasonable, and non-discriminatory terms ("FRAND"). In July of 2005, Broadcom announced that it will commence litigation against Qualcomm and filed a complaint in the U.S. district court of New Jersey. In October of 2005 Broadcom, Ericsson, NEC, Nokia, Panasonic, and Texas Instruments each filed complaints against Qualcomm with the European Commission. These companies allege that Qualcomm has violated its commitments to FRAND among other things by charging discriminatory royalties and other exclusionary practises.

This study examines whether such FRAND commitments to the licensing of technology to rivals are credible. Credible commitments are ones in which the owner of the technology has a private incentive to license its technology in the absence of any contractual obligation. When licensing to rivals, the seller of the technology must take into consideration not only the licensing revenues from a particular buyer but also the effect of the license on its own product market profits and on the profits to other potential buyers of the technology. Through pricing the seller can affect which and how many firms would be sold licenses as well as the profitability of licensing. While we do not test for "fair" pricing, we are able to test for an incentive to broadly license as opposed to discrimination. Tests for discrimination, however, would necessarily involve the analysis of a model where the firms were asymmetric.

As technology standards are set by product market rivals, we explore the incentives to license a cost reducing technology when the innovator is also active in the product market and its rivals (and potential licensees) differ in marginal costs. Different marginal costs can also be construed

as a cost of "getting around" the patent. Product market competition is modelled as asymmetric Cournot. With asymmetric firms, an innovation is then potentially "drastic" to some rivals and "modest" to others. Here we focus on innovations that are modest for all rivals so that licensing is not crucial for those firms to remain in the market.

We also examine how the firm size distribution in the industry affects the diffusion of new technologies and the rewards for innovation. The innovator by choosing the price, which firms to license and how many licenses to sell can have an essential impact on firm-size distribution. We model the market for the innovation as one where the innovator announces a posted price for the license to all its competitors, who then choose to accept or reject the offer. In effect, under the posted price (making a take-it-or-leave-it offer) the licensor uses maximum bargaining power but loses the ability to discriminate between potential licensees and on price. Here we study how the royalty rate chosen by the innovator affects *who* obtains a license and the diffusion of the innovation. We then discuss how those results may change if the product market competition were differentiated Bertrand with asymmetric marginal costs.

Arrow (1962) spurred considerable debate in industrial economics circles by showing that an owner of a unique cost reducing innovation would obtain more revenue by licensing for a certain royalty fee to all firms in a perfectly competitive market. This appeared to refute the Schumpeterian claim that that some monopoly power increases the incentives for innovating. As Kamien and Schwartz (1982, Chapter 2) point out, however, Arrow's analysis concerned a given market structure of the industry purchasing the innovation and not of the structure of the innovation producing industry. These industries could be one and the same as indicated in the following statement

"Sometimes the highest profits are obtained by the owner of the rights to an invention if it simultaneously uses the invention as an input in its own production *and* rents its use to others."

Baumol (2002, pg. 12)

Our analysis examines imperfectly competitive markets in which the industry producing and utilizing the innovation are one and the same and where the firm-size distribution could change with licensing. In this context, we find that the diffusion of licenses can be restricted depending

on the pricing and the price-setting mechanism used. For an excellent survey of the literature in licensing see Kamien (1992).

Gallini (1984), Gallini and Winter (1985) and Katz and Shapiro (1985) have examined the incentives of one producer to license its process technology innovation to another producer under duopolistic market structures. The incentive in Gallini (1984) was to deter the rival from investing in R&D and possibly produce an even better process technology. Gallini and Winter (1985) extended the innovation game of Reinganum (1983) to examine how licensing would affect incentives of duopolists to engage in R&D and how it would subsequently impact on industry costs and market structure. They found that licensing stimulates R&D when industry variation in costs is low and when industry concentration is low. In their model, the innovator always has an incentive to license. We also examine the issues of industry costs and structure, albeit in an asymmetric oligopolistic industry, and we focus on how the innovator markets his R&D result.

Gallini and Wright (1990) examine the problem of information asymmetry in licensing technology, as the licensor may have more information about the quality of the innovation than does the licensee. They show how the form of payment to the inventor (fixed fee versus an output based royalty) can be used to overcome, to some degree, the market failure that may result from such information asymmetries. This is particularly a problem when the inventor is independent of the industry purchasing the technology. As we focus on how the innovator markets his invention, our analysis is one with complete information. Our firm asymmetries are simply of the form of marginal cost differences *ex ante* the innovation and licensing. Moreover the inventor is also a participant in the final output market. In this context there is an additional argument for the use of royalties instead of fixed fees – the innovator can keep its product market rival's marginal costs higher and mitigate business "stealing".

Kamien and Tauman (1986) analyze the decision of an owner of an invention to use fixed fees versus royalties in licensing to a symmetric oligopolistic industry which competes in a Cournot fashion. They compute the number of licenses sold and find that licensing via a fixed fee is superior for both inventor and consumers and that a "drastic" innovation is licensed to a single

producer. In our model with asymmetric producers the innovation is "modest". Furthermore, as the innovator in our model is also a producer our analysis has certain strategic product market considerations which are absent in Kamien and Tauman's model, weighing in favor of royalties in our setting. Royalties were shown to be superior to upfront fees in the duopoly model analyzed by Wang (1998) and, simultaneously and independently of this analysis, for the symmetric Cournot oligopoly by Kamien and Tauman (2001). Here we investigate what would be the optimal royalty rates in an asymmetric Cournot oligopoly setting.

Few studies have examined, as we do, the issue of *who* is licensed (an irrelevant issue when it is assumed that the firms are symmetric). This is, of course, essential when examining the issue of discrimination. Exceptions are Rockett (1990) and Spiegel (2003). Rockett argues that innovators may be selective about whom they license, and analyzes the effect of post-patent competition on the choice of to whom a drastic innovation license would be sold. She analyzes a model of a three firm industry where one firm is the innovator and the two remaining firms are differentiated in terms of their competitive strength. She finds that a patentholder would license the weak competitor in order to retain a dominant position once the patent expires with a view to deter a stronger rival from entering. Spiegel (2005) in his examination of a winner-take-all patent race between three firms finds that *ex ante* the innovation, licenses of interim knowledge may take place to the stronger rival. Our analysis examines an n-firm oligopoly, focusing on the patent period or time period during which the technology is confidential. The technological innovation examined here is of the nondrastic type so that issues about exit and entry are not addressed. We also find that that the licensed rivals would be the weaker ones but in addition we find that the diffusion of licenses depends on the size distribution of firms and on the pricing of the license. Furthermore, we find that the extent of diffusion of licensing will be affected by how the license is priced and the degree of asymmetry - a more symmetric market and price discrimination between licensees can lead to greater diffusion.

This study is organized as follows. We develop and analyze the basic asymmetric Cournot model of product market competition and the surpluses and costs attributable to a license for a cost reducing innovation. We then examine how that surplus may be divided between innovator and licensee through pricing and establish who the innovator would license under the different

regimes. We consider whether and how our results would change under the product market regime of differentiated Bertrand with asymmetric marginal costs. In the final section we summarize and discuss the conclusions.

2. The Surplus from Licensing

In this section we develop the basic model of the product market competition and from that derive the surpluses from licensing a cost reducing innovation. These surpluses will then be used in the subsequent derivation of optimal patterns of licensing and in the calculation of the returns to innovation.

We begin with the computation of product market equilibrium profits given the marginal costs of the firms.

2.1 Product Market Competition between Asymmetric Firms

We assume that there are n firms producing a homogeneous good where the firms can be rank ordered according to their marginal costs with firm 1 having the lowest marginal cost. Let c_i represent the marginal cost of firm i where $c_1 < c_2 < c_3 < \dots < c_n$. These marginal costs can then be represented by differences from that of the most efficient firm, i.e., $c_j = c_1 + \varepsilon_j'$ where ε_j' is the difference in marginal costs between firm j and firm 1. We also assume a linear inverse demand function $P = \alpha - \beta Q$ where Q is the industry output and P is the price. Under perfect information the Cournot equilibrium outputs, price and profits are given by:

$$q_i^* = \frac{\left(\alpha - c_1 - n\varepsilon_i' + \sum_{j \neq i}^n \varepsilon_j' \right)}{\beta(n+1)}, \quad P^* = \frac{\left(\alpha + nc_1 + \sum_{j=2}^n \varepsilon_j' \right)}{n+1}, \quad \text{and} \quad \pi_i = \beta(q_i^*)^2. \quad (1)$$

The derivation of the above expressions is given in Tombak, 2002, Appendix A. The distribution of the marginal cost differences ε_j' then determine the size distribution of firms in the industry. For example, larger differences in the ε_j' would result in a distribution with a larger variance, and clustering of ε_j' s among small values or large values would result in skewed size-distributions.

A cost reducing innovation would increase consumers' surplus. As we can see from the above equation, equilibrium prices depend on the average of the marginal costs. A cost reducing innovation would reduce the marginal costs of a firm and thereby reduce the equilibrium price. From the above we can see that firms' equilibrium profits decrease as a firm's rivals become more efficient. A cost reducing innovation by a rival will then decrease equilibrium quantities and profits. As the equilibrium price decreases the industry output must have increased. As the innovator profits increase and it is relatively more efficient it obtains a disproportionately greater share of that industry output. The rivals, being relatively less efficient, would then yield some of their share of the market to the innovator. Hence for those firms that do not enjoy the cost reduction, the innovation would have a negative effect on their equilibrium profits.

An innovation by some firm i , by luck or by design reducing c_i to $c < c_i$, changes the marginal cost differences $c_j = c + \varepsilon_j$ where ε_j is the difference in marginal costs between the j th firm and the innovating firm i (i.e., $\varepsilon_j = c_i - c + \varepsilon_j'$). With the new distribution of marginal costs all the noninnovating firms become smaller with correspondingly lower equilibrium profits while the innovator becomes larger with larger profits. Without loss of generality and to focus on the effect of firm asymmetries we will henceforth assume that $\alpha - c = 1$ and that $\beta = 1$. Our assumption that the innovation is "modest" implies that no firm is driven to exit from the market

as a result of the innovation, i.e., $c_n < \frac{\left(1 + \sum_{j=1}^{n-1} \varepsilon_j\right)}{(n+1)}$. That is, if all the noninnovating firms other

than the n^{th} firm license the technology and reduce their marginal costs then the n^{th} firm would still not drop out of the market.

2.2 The Revenues and Costs of Licensing

We now compute the net surplus available to the innovator from licensing. All those who license the innovation enjoy a marginal cost reduction to c . The surplus to a licensee would then be the equilibrium profits it would obtain with this new low marginal cost (π_j^l , where the superscript denotes licensing) less its equilibrium profits without the license (π_j). This increased surplus can arise from increased profit margins and increased output which results in increased industry output as well as business “stealing” from the rivals of the licensee. This licensee j is one of the existing rivals of the licensor. Both of these payoffs would change with the granting of m licenses. The licensor, however, could experience a cost of licensing if he loses some profits in the product market by making a rival more efficient ($\pi_i - \pi_i^l$, the result of business being “stolen” by the licensee) and reduces the product market equilibrium price. The net surplus that might be captured by licensing is then the difference between the surplus to the licensee(s) and the cost to the licensor.

Given the product market equilibrium profits the demand curve for licenses is determined by:

$$\pi_j^l - \pi_j = (q_j^l - q_j)(q_j^l + q_j) = \frac{n\varepsilon_j}{(n+1)^2} \cdot \left[2 \left(1 + \sum_{\substack{k \in M \\ k \neq j}}^n \varepsilon_k \right) - n\varepsilon_j \right] \quad (2)$$

where M is the set of licensed firms the summation in the above expression is then the sum of the ε 's of all firms not in the set M and not that of firm j . The benefit of the license to the licensee is seen in incremental product market profits when there is a set M of other firms with the license.

Since the derivative of (2) with respect to ε_j is $2(n/(n+1)) q_j$ the above value of a license increases in ε . Thus smaller firms value the license more. With licensing of firm j the quantity for any other firm given in (1) will go down by the ε_j term. In the computation of q_j the j^{th} firm takes into consideration that the innovator may license to other firms. Thus, as more licenses are granted to its rivals the $\Sigma\varepsilon$ term would decrease and the price each licensee would be willing to pay would decrease correspondingly.

We will examine the use of royalties by which this surplus might accrue to the out-licensor. Royalties, as a per unit fee or a percentage of sales fee for the use of the technology, play a role in the majority of licenses (see Caves, Crookwell, and Killing, 1983). When the innovator is also a participant in the product market royalties have an advantage in that this mode of pricing keeps the marginal costs of the licensees above c . If the innovator sets a royalty fee of r per unit of output sold, the marginal costs of all licensees are then $c + r$ and their outputs defined in (1) would be adjusted accordingly. The revenues to the licensor would then be rq_j^l where q_j^l is the Cournot quantity of the licensee after licensing the technology.

The cost of licensing is the lost product market profit of the licensor due to licensing, and this cost will depend on which and how many firms are licensed. Granting a license makes the rival more efficient and will reduce the asymmetry in the product market. The cost to the licensor of providing the m^{th} license with a fixed fee to firm j given product market profits in (1) is:

$$COST_i = \pi_i - \pi_i^l = (q_i - q_i^l)(q_i + q_i^l) = \frac{1}{(n+1)^2} \cdot \varepsilon_j \left[2 \left(1 + \sum_{\substack{k \in M \\ k \neq j}}^n \varepsilon_k \right) + \varepsilon_j \right] \quad (3)$$

This cost to the innovating firm i of licensing to firm j is increasing in ε_j , hence decreasing with the size of the rival. This occurs as the license makes a rival more efficient, and the greater ε_j , the

greater this efficiency effect. Also, licensing decreases asymmetry in the industry.² The above cost of licensing, however, can be mitigated to some degree by charging per unit royalties. If the innovator can perfectly price discriminate and charge a royalty rate to licensee j of $r_j = \varepsilon_j$ then the price in the product market (P^*) remains constant, the distribution of outputs remain the same, the licensing revenues are $\varepsilon_j q_j$, and $COST_i = 0$. This leads to the following result:

Proposition 1: The innovator has an incentive to license at least one rival.

Proof:

At $r_j = \varepsilon_j$ there is no change in the product market profits and the innovator obtains royalties of $\varepsilon_j q_j$. Q.E.D.

The out-licensor, however, may find it optimal to charge royalty rates different from ε_j in which case there will be some business "stealing" effect which is computed below. Some of that business "stealing" is from the innovator which is computed in $COST$, but some of the business "stealing" is from non-licensing rivals from which the out-licensor acruces some benefit through the royalty. If the optimal royalty for a given licensee were to deviate from (be less than) the efficiency differential then the net surplus from such a royalty based license would be

$$NS_j^r = r_j q_j^l - \pi_i + \pi_i^l = \frac{r_j}{(n+1)} \left(1 - nr_j + \sum_{\substack{k \in M \\ k \neq j}}^n \varepsilon_k + \sum_{\substack{k \in M \\ k \neq j}}^n r_k \right) - \frac{(r_j - \varepsilon_j)}{(n+1)^2} \cdot \left[2 \left(1 + \sum_{\substack{k \in M \\ k \neq j}}^n \varepsilon_k + \sum_{\substack{k \in M \\ k \neq j}}^n r_k \right) + \varepsilon_j + r_j \right] \quad (4)$$

As shown above, the net surplus from any one license under royalty pricing depends on the royalty rate charged to the other licensees. We now consider the question of to which rival firm the innovator prefers to grant an exclusive license under the different pricing schemes.

² For a further discussion of the effect of reducing the variance in marginal costs in a Cournot setting (albeit while

Proposition 2. When exclusively licensing the licensor would prefer to grant the license to rival j for which $\varepsilon_j > r_j^$ and ε_j closest to*

$$r_j^* = \frac{n+3}{2(n^2+n-1)} \left(1 + \sum_{k \neq j}^n \varepsilon_k \right). \quad (C1).$$

Proof:

Taking the derivative of NS_j^r with respect to r_j we find the optimal royalty rate (r_j^*) and that the licensor would prefer to grant an exclusive license .

Q.E.D.

Proposition 2 shows that the rival to which the innovator would prefer to license is determined by the market structure, and by the firm-size distribution. In other words, the above Proposition shows that the innovator would want to discriminate between in-licensors. For example, if the innovator faced only two rivals, firms j and k ($\varepsilon_j > \varepsilon_k$, $n=3$) then firm j would be the preferred licensee when $\varepsilon_j < \frac{1}{5}(1+\varepsilon_k)$. As both the revenues (2) and the costs (3) to the innovator of lost product market profits are greater when licensing inefficient rivals, the Proposition implies that the revenue effects dominate the cost effects for those firms for which $\varepsilon_j > r_j^*$ as defined by (C1) and the cost effects dominate the revenue effects when $\varepsilon_j < r_j^*$.

The Proposition states that the optimal licensee could be one with intermediate levels of efficiency. An innovator who charges royalty fees would maximize the licensing revenues defined by $r_j q_j$ less any costs of business stealing resulting from a royalty rate which deviates from ε_j .³ The optimal revenue stream is achieved by licensing a rival j which satisfies (C1). The innovator must balance the increased royalty rate he could charge with the output over which

keeping the average marginal cost constant) see Salant and Shaffer (1999).

³ Comparing r^* in the Proof of Proposition 1 to that ε_j which yields zero Cournot quantities for firm j indicates that at $n=2$ r^* is constrained to be equal to ε_j .

that royalty rate would be applied. Smaller (less efficient) firms which would be willing to pay a larger royalty rate for the cost reducing technology, however they would also have the lowest output over which that rate would be applied. Larger (more efficient) rivals would not be willing to pay such a high rate but that rate would be applied over a larger output. More inefficient rivals would be interested in licensing on the same terms as the optimal licensee and would deliver the same licensing revenue stream but, under those terms, they would become more efficient and engage in more business stealing from the licensor. As the royalty rate is close to ε_j for the optimal licensee, the licensor is less concerned with any loss in product market profits that would result from the licensing of a less efficient firm. This result contrasts with that of Rockett (1990) as her analysis included the effects of licensing on the post-patent period when entry may occur and licensing revenues would not be taken into consideration.

The innovator is also faced with the strategic question of whether to grant an exclusive license or to broadly diffuse its technology. The maximum **total** net surplus may be obtained from the granting of several licenses. The total net surplus would then be the sum of the net surpluses for each of the m licenses calculated above taking into consideration that each of those net surpluses vary with m and with the pricing of the license, i.e., the total net surplus is $TNS = \sum_m (\pi_i^l(m) - \pi_i(m-1)) - \pi_i(m=0) + \pi_i^l(m)$. This payoff obtained with fixed fees is compared to the royalties from licensing the same set of licensees in the following proposition.

The profit for a price discriminating, royalty charging out-licensor is,

$$\sum_{j \in M} \varepsilon_j q_j = \frac{1}{(n+1)} \sum_{j \in M} \varepsilon_j \left(1 + \sum_{k \notin M} \varepsilon_k + \sum_{k \in M} r_k - n \varepsilon_j \right).$$

The condition in the proposition shows that if the number of nonlicensees were small ($\sum_{k \notin M} \varepsilon_k$ small), the rival firms were relatively efficient (ε_j small) and small in number (low n) then royalties may be preferred. If the out-licensor were perfectly price discriminating and charged royalties then the technology would be diffused to all rivals, i.e., $m=n-1$. In this case, $\sum_{k \in M} \varepsilon_k$

would be zero and the above condition would be reduced to $-4 + (n-1) \sum_{j \in M} \varepsilon_j^2 > 0$. The use of royalties keeps rivals' costs high and will not reduce the willingness of other licensees to pay. This would lead to a greater proliferation of licenses. In what follows we focus on which firms would be in the set of licensees.

Perfect price discrimination may draw the wrath of antitrust authorities due to dissimilar treatment of what may appear to be similar transactions, so we now turn to the examination of alternative pricing mechanisms. How much surplus the innovator will accrue depends on how the innovation is marketed. In the analysis of Arrow (1962) all the surplus was extracted as all the licensees were symmetric and price discrimination was a moot issue. As we shall see, under the following different pricing settings, less than all the surplus is captured by the innovator and market asymmetries and the price set will have an effect on the diffusion of the innovation.

3. Licensing under one posted price

In this section we analyze the offering licenses to all licensees at a certain royalty rate. We restrict our analysis to prices in the form of royalty rates as this form is the most popular⁴, it was the form of price chosen by Qualcomm, and (as shown in Tombak, 2006) it led to greater diffusion. In the first case, the innovator chooses a royalty rate and potential licensees accept or reject the offer. The posted price acts as a commitment device enabling the licensor to gain bargaining power. Proposition 1 indicates that there is a value in being able to discriminate between licensees. But an examination of the values licensees place on the license (2) suggests that those rivals most interested in the license may not be those firms the innovator would want to license (by Proposition 1).

⁴ Rostoker (1984) found that royalties alone were used in 39% of the licenses he studied.

We examine the effects of the innovator selling via the announcement of one price for the license.⁵ We will examine the case where that price is in the form of a per-unit fee, or royalty. The licensing agreement could (but need not) stipulate the number of licenses to be granted. Potential licensees can then accept or reject the offer. This mechanism is similar to the “chutzpah” mechanism described and found to be optimal for licensing symmetric firms in Kamien (1992). Under this market mechanism the innovator utilizes the maximum bargaining power at his disposal but loses the ability to discriminate between buyers. McAfee (1999) examines auctions of capacity and his model shares a feature with ours – the identity of the winner of the auction matters to the losers and smaller firms would be willing to pay more for the capacity. Our analysis examines sales with an additional feature – the identity of the winner(s) matter to the seller as well.

All those who accept the offer for a license enjoy a marginal cost reduction to c . The maximum price a licensee would be willing to pay would then be the equilibrium profits it would obtain with this new low marginal cost (π_j^1) less its equilibrium profits without the license (π_j). This difference in the equilibrium profits with and without a license determines the demand curve for licenses. Those firms with a value greater than the stated fee would accept the offer. The number of licenses sold, and the specific buyers of the technology, would then be determined by the intersection of the fee with the demand curve. This presents a potential problem to the licensor as he has limited control over who would accept and thereby obtain his technology. The licensor experiences a cost of licensing in that he loses some profits in the product market by making a rival more efficient ($\pi_i - \pi_i^1$). These costs would be different for different licensees while the revenue would be the same (q_r).

Given a royalty rate r an existing rival j would purchase a license if $c_j > c + r$ or if $\varepsilon_j > r$. We then have a precise ordering of the licensees willing to pay the royalty. In this case, the

⁵ A Vickery auction where the innovator announces the number of licenses to be auctioned would result in a similar allocation of licenses but the innovator would obtain somewhat less licensing revenue. In the auction of m licenses with complete information the m licensees would simply bid slightly more than the value to the $m+1^{\text{th}}$ potential licensee. With the price setting mechanism the licensor sets the price to slightly less than the value to the m^{th} potential licensee.

innovator simultaneously sets the royalty rate and number of licenses granted in order to maximize licensing revenues less the costs defined in (3), i.e.,

$$\begin{aligned} \text{MAX}_{m,r} \quad TNS_r &= m \cdot r \cdot q_r - (\pi(m=0) - \pi_i^l(m)) = \\ &= \frac{m \cdot r}{(n+1)} \cdot \left(1 + \sum_{k=2}^{n-m-1} \varepsilon_k - (n-m+1)r \right) - \frac{1}{(n+1)^2} \left(\sum_{l=n-m-1}^n \varepsilon_l - mr \right) \left[2 \left(1 + \sum_{k=2}^{n-m-1} \varepsilon_k \right) + \left(\sum_{l=n-m-1}^n \varepsilon_l + mr \right) \right] \end{aligned}$$

where, q_r is the equilibrium quantity produced under license by a firm, and m is the number of licenses granted. Clearly, the maximum royalty rate which would yield the sale of m licenses would be where $r = \varepsilon_{n-m}$ and the royalty rate for selling $m+1$ licenses would then be ε_{n-m-1} . As shown in Proposition 1, in this situation the innovator would always sell at least one license as the first license would not involve any lost product market profits. However, as more licenses are sold then the royalty rate must decrease, the lost product market profits COST to the innovator increases. Royalty revenues may increase or decrease depending on the incremental royalty revenue of the added in-licensee and the extent of business stealing the set of licensees obtain from the set of non-licensees.

Lemma 1: Under posted pricing of licenses the diffusion of licenses will be greater if the rivals consist of a cluster of inefficient firms where the efficiency differential between rival licensees $\varepsilon_{n-m-1} - \varepsilon_{n-m}$ is small.

Proof:

The total net surplus maximizing licensing royalty is determined by the point where the difference function $TNS(r=\varepsilon_{n-m-1}) - TNS(r=\varepsilon_{n-m}) \leq 0$. Given the sequence of licensees (from smallest to largest) the TNS maximizing number of licensees is given by m that satisfies,

$$\begin{aligned}
& (\varepsilon_{n-m-1} - \varepsilon_{n-m})m \left[\left(1 + \frac{2}{n+1}\right) \left(1 + \sum_{k=2}^{n-m-1} \varepsilon_k\right) - (n-m+1)(\varepsilon_{n-m-1} - \varepsilon_{n-m}) \right] \\
& + \varepsilon_{n-m-1} \left(1 + \sum_{k=2}^{n-m-1} \varepsilon_k - (n-m+1)\varepsilon_{n-m-1}\right) \leq 0. \quad (C2)
\end{aligned}$$

By the condition for positive Cournot quantities and by the ranking of the ε 's, the first term above is always negative while the second term is positive. Inefficient rivals ensures that ε_{n-m-1} and the positive portion of (C2) is large while the clustering of rival firms with similar marginal costs ensures that the negative portion of (C2) is small. Consequently, the condition to stop licensing is then not met.

Q.E.D.

The first term in (C2) represents the licensing revenues lost from the nonmarginal licensees from decreasing the posted price. The second term in (C2) is the licensing revenues gained from the additional licensee. As the above condition is governed by the ε 's and n , the royalty rate and the diffusion of licenses depends on the size-distribution of rival firms. In the extreme case of symmetric rivals then $\varepsilon_{n-m-1} - \varepsilon_{n-m} = 0$ and all rivals would be licensed with the posted price equal to the ε 's.

For an example where posted pricing leads to limited diffusion, say there were 4 firms with $\varepsilon_2 = 0.1$, $\varepsilon_3 = 0.2$, and $\varepsilon_4 = 0.3$. The condition to stop licensing (C2) becomes negative as m goes from 1 to 2 and $TNS(m=1) = 0.06$ while $TNS(m=2) = 0.02$. In this example only one license would be sold at a rate of $r = 0.3$. In this example the licensor's prelicensing profits are 0.1024 so one license increases the innovator's profits by almost 60%! If the efficiency of the second largest rival were $\varepsilon_3 = 0.28$, then 2 licenses would be sold at a royalty rate of 0.28, illustrating a greater diffusion of the innovation under posted prices when rivals are less differentiated. Comparing these two numerical examples illustrates how the size distribution of firms interacts with the royalty rate and that exercising price discrimination can facilitate the diffusion of a technology.

4. Differentiated Bertrand Product Markets

In this section we discuss to what extent our results are robust to the particular form of product market competition. Clearly, firms could not exist with asymmetric marginal costs in homogeneous Bertrand product markets so we examine markets of differentiated products. In the case where the location of firms is fixed, the incentives to proliferate licenses increase but the preferred licensees may change. This is due to the costs in lost product market profits to the innovator would depend on the location of the licensee. Firms farther away from the innovator would have less of an impact on the product market profits of the innovator. Again, firms with higher marginal costs would be willing to pay more as their surplus from decreasing their marginal costs would be greater. Consequently, the preferred licensees would be those with higher marginal costs and located furthest from the innovator. But as only firms adjacent to the innovator have direct effects on the product market profits of the innovator the costs of licensing would be diminished compared to that of the previous analysis. Thus, the incentives to proliferate the license would be greater with differentiated Bertrand and fixed locations.

If locations were variable then we must first address the issue of where firms locate when there are asymmetric marginal costs. Does a firm locate closer to, or farther from a more efficient rival? To answer this question, consider the simple case of the Hotelling model where consumers are uniformly distributed on a unit line and have quadratic transportation cost. As shown in Meza and Tombak (2006), the more efficient firm has an incentive to move closer to its less efficient rival, while the less efficient firm wants to maximally differentiate itself from more efficient firms to avoid price competition.

The effect of a proliferation of licenses of the innovation using one royalty rate will be that some rival firms will become more efficient and they could move towards the out-licensor. In this case, there will be a cost of licensing to the innovator in terms of a smaller market area. However, this will again be primarily when licensing of adjacent rivals, the costs of licenses to rivals located farther from the innovator will be by and large second order effects. Furthermore, licensing to a small set of licensees far away from the licensor can allow the licensor to capture some of the business “stealing” effects from nonlicensing rivals. Thus the basic feature, that

both the seller and the other buyers are concerned with the identity of the buyer(s), is revealed in this analysis as well. Therefore, our result on a diffusion of licenses is robust to the type of product market competition.

5. Conclusions and Discussion

The selling of a good or service where the identity of the buyer(s) is of interest to both the seller and the other buyer(s) is studied. We have developed and analyzed a model of marketing a license of a cost reducing technology to rival firms where those firms are asymmetric in marginal costs. We examine *which* firms are sold licenses under different pricing regimes – price discrimination and one posted price. We find that the innovator has an incentive to license to rivals but if not allowed to price discriminate would set a royalty rate which is prohibitive to large rivals.

We also discuss how robust the results are to an alternative product market competition mode – that of asymmetric differentiated Bertrand. This alternative mode of competition retains the feature that both the seller and the buyers regard the identity of the buyer(s) as important. There is still an aversion to making rivals more efficient. In this case, however, more efficient rivals would be licensed if they are located far from the innovator. The result of the proliferation of licenses still holds. Royalties would keep rivals at a distance. As differentiated Bertrand adds a new dimension along which firms can be distinguished, the ability of the licensor to discriminate between licensees becomes all the more important.

These results have implications for antitrust and technology policy. For example, courts in some antitrust cases and the legislatures of certain countries have mandated licensing at a certain royalty rate. In effect, they have required that the technology be marketed under the posted price regime. This study suggests there are circumstances (firm-size distributions) where such mandates would lead to unsatisfactory results and that allowing the innovator to price discriminate while requiring the nonexclusive licensing can yield superior outcomes for technology diffusion and for consumers.

In terms of the Qualcomm case, the results suggest that Qualcomm would indeed have an incentive to price discriminate. Also, the analysis suggests that if Qualcomm were to set one royalty rate it would do so at such a rate which large firms (the more efficient firms) would find prohibitive. Note that those firms filing complaints with the EU are very large firms (Nokia, Ericsson, NEC, Broadcom, etc.). Under either pricing regime, Qualcomm cares about who licenses its technology and its tendency will be to discriminate. It is found that commitments to FRAND are not credible and firms should seek to set royalties before agreeing to a technology standard.

References

Arrow, K., 1962, "Economic Welfare and the Allocation of Resources for Invention", in *The Rate and Direction of Inventive Activity: Economic and Social Factors*, Conference No. 13, Universities- National Bureau of Economic Research, Princeton University Press, Princeton, NJ.

Baumol, W., 2002, *The Free-Market Innovation Machine – Analyzing the growth miracle of capitalism*, Princeton University Press, Princeton, NJ, U.S.A.

Caves, R., H. Crookwell, and J. Killing, 1983, "The Imperfect Market for Licensing" *Oxford Bulletin of Economics and Statistics*, Vol. 45, August, pp. 249-267.

D'Aspremont, C., J.J. Gabsewicz, and J.-F. Thisse, 1979, "On Hotelling's 'Stability in Competition' ", *Econometrica*, Vol. 47, No. 5, pp. 1145-1150.

Gallini, N., 1984, "Deterrence by Market Sharing: A Strategic Incentive for Licensing", *American Economic Review*, Vol. 74, December, pp. 931-941.

Gallini, N., and R. Winter, 1985, "Licensing in the theory of innovation", *RAND Journal of Economics*, Vol. 16, No. 2, Summer, pp. 237-252.

Gallini, N., and B. Wright, 1990, "Technology transfer under asymmetric information", *RAND Journal of Economics*, Vol. 21, No. 1, Spring, pp. 147-160.

Kamien, M., 1992, "Patent Licensing", Chapter 11, *Handbook of Game Theory with Economic Applications*, (R. Aumann and S. Hart, eds.), Elsevier Science Publishers, Amsterdam, NL.

Kamien, M., and N. Schwartz, 1982, *Market Structure and Innovation*, Cambridge University Press, Cambridge, England.

- Kamien, M., and Y. Tauman, 1986, "Fees versus Royalties and the Private Value of a Patent", *The Quarterly Journal of Economics*, **CI**, No. 406, (August), pp. 471-491.
- Kamien, M., and Y. Tauman, 2001, "Patent Licensing: The Inside Story", MEDS Working Paper, Kellogg Graduate School of Management, Northwestern University.
- Katz, M. and C. Shapiro, 1985, "On the Licensing of Innovations", *RAND Journal of Economics*, Vol. 16, pp. 504-520.
- Katz, M. and C. Shapiro, 1986, "How to License Intangible Property", *The Quarterly Journal of Economics*, **CI**, No. 406, (August), pp. 567-589.
- Meza, S., and M. Tombak, 2006, "Location and price competition with cost asymmetries", University of Toronto working paper.
- Reinganum, J., 1983, "Technology Adoption under Imperfect Information" *Bell Journal of Economics and Management Science*, Vol. 14, No. 1, Spring, pp. 57-69.
- Rivette, K, and D. Klein, 2000, "Discovering New Value in Intellectual Property", *Harvard Business Review*, January-February, pp. 2-12.
- Rockett, K., 1990, "Choosing the competition and patent licensing", *RAND Journal of Economics*, Vol. 21, No.1, Spring, pp. 161- 171.
- Rostoker, M., 1984, "A survey of corporate licensing", *IDEA*, **24**, pp. 59-92.
- Salant, S., and G. Shaffer, 1999, "Unequal Treatment of Identical Agents in Cournot Equilibrium", *American Economic Review*, **89**, pp. 585-604.
- Spiegel, Y., 2005, "Licensing interim R&D knowledge", working paper, Department of Economics, Tel Aviv University.
- Takalo, T., and K. Kultti, 2000, "Incomplete Contracting in a Research Joint Venture: The Micronas Case", *Research Policy*, Vol. 30, No. 1, pp.67-77.
- Thurow, L, 1997, "Needed: A New System of Intellectual Property Rights", *Harvard Business Review*, September-October, pp. 95-103.
- Tombak, M., 2002, "Mergers to Monopoly", *Journal of Economics and Management Strategy*, Vol. 11, No. 3, pp. 513-546.
- United States Department of Commerce, *Survey of Current Business*, Government Printing Office, Washington, D.C., October, 1998.
- Wang, X.H.,1998, "Fees versus royalty licensing in a Cournot duopoly", *Economics Letters*, **60**, pp. 55-62.