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R & D COMPETITION AND OPTIMAL PATENT DESIGN

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Previous studies on optimal patent design calls for different patent breadth-length combinations. This is because their models are based on different nature of competition in the patented product market. This paper explores other key determinants of optimal patent design. This paper shows that optimal patent design depends not only on the nature of competition in the patented product market but also on the nature of R&D technology and the degree of R & D competition.

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I. INTRODUCTION

The purpose of the patent is to facilitate the appropriation of social surplus resulting from an innovation by its innovator and thus to provide legal incentives for R&D. The longer the patent duration or the broader the scope of patent protection, the greater the private values of innovations. However, the stronger the patent protection in time and space, the more the diffusion of new technology is restricted. Thus, to avoid excessive monopoly power, governments fix a finite patent duration. Government also put some limitation on monopoly power over new technology by allowing non-innovators to invent around the patent. By narrowing patent breadth, governments want more competition in the patented product market. This lowers the profits earned by the patent and may increase the expected profits of non-innovators, thus reducing the incentive for R&D.

Therefore, there is a trade-off between the dissemination of new innovations

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and transferring surplus from users to innovators for the incentives for R&D. Due to this trade-off, in designing and tuning the patent system, it is very important to strike the balance between incentives for R&D and the diffusion of new innovations.[1)]

Recently, Gilbert and Shapiro(1990) and Klemperer(1990) have studied on the problem of optimal patent breadth-duration mix. Gilbert and Shapiro(1990) calls for infinite patent length, with patent breadth adjusted to provide specified reward to the patentee.[2)] However, Klemperer(1990) has studied optimal patent design in the market of product differentiation and price competition where either infinite or finite patent duration may be optimal. In a different context, Gallini(1992) studies the case where new technology could be imitated with a cost and the cost depends on the breadth of patent. She shows that a finite patent duration is optimal.

It is likely that their studies have ended up with establishing that optimal patent design differs under different assumptions about the nature of competition in the patented product market. It may be likely that "almost anything could happen". In Klemperer's example, social welfare is increasing in the breadth of patent protection. In Gallini's model social welfare function is convex in patentee's profit. In contrast, Gilbert and Shapiro's optimal policy mix requires that social welfare function be increasing and concave in patent breadth. Since there is no general relationship between social welfare and the patentee's profits, and the breadth of the patent, it is not surprising to see that different models and examples yield contradictory results. The generalization of their results may be, loosely speaking, that the less efficient competition in the patented product market, the more restrictive (wide patent breadth and short patent duration) patent system is socially optimal.

In this paper, we further explore other key factors affecting optimal patent policy than the nature of competition in the patented product market. We focus on the fact that Gilbert and Shapiro(1992) and Klemperer(1992) do not analyze the choice of R&D investment that a patent system generates. They just take the socially desirable amount of R&D as given, and study how the patent system induces firms to invest that specified amount of R&D investment.

However, what incentivates firms to do R&D is the expected profits that could be earned if a firm wins a patent race. The patent design determines innovator's expected profits by governing the degree of competition between innovators and non-innovators in the post-innovation phase. However, before the patent is awarded, firms are also concerned about how difficult the new technology is and how many firms are engaged in R&D, thus what is the winning probability that he or she could win. Thus, the expected profits are controlled by the nature of

[1] See Nordhaus(1969) and Scherer(1972) for a classical analysis of optimal patent duration

[2] The sufficient condition for infinite patent duration to be optimal is social welfare function is decreasing and concave in the innovator's profits as a measure of patent breadth.

R&D sector as well as by the patent design. Hence, firms' choice of R&D investment is determined by the nature of R&D technology and the degree of R&D competition as well as by the patent design.

To analyze the relationship between patent system and the nature of R&D sector, this paper explicitly models R&D races. And we consider two extreme patent systems. The one is a restrictive patent system. The other is a permissive one. As a permissive patent system, this paper introduces a system of multiple patents (MP) in contrast with a restrictive single patent (SP) system in a timeless model. Under SP system, only one firm obtains the patent. However, under MP system, if more than one firm make innovation, patents will be given to all those innovating firms. Thus multiple patentees could operate in the product market. In reality, since the duration of patent is fixed, the degree of competition in a patented market is determined by the scope of patent protection. Then, MP and SP regime are analogous to wide and narrow breadth of patent protection, respectively.

We can show that R&D investment does depend not only on the patent design but also on the nature of R&D competition. Thus, in designing and tuning the patent system, we should consider the nature of R&D technology and the degree of R&D competition. First of all, it is easy to show that firms do invest more in SP regime than MP regime. We also can show that if new technology is relatively difficult to innovate, then firms invest less than socially optimal. The patent system should give more incentive for R&D in this case. Thus, SP regime is better than MP regime in this case. However, if new technology is relatively easy to innovate, then the private incentive to innovate could be excessive. Thus, a permissive patent system is better than a restrictive one in this case. However, this model also suggests that if new technology is "very difficult" to innovate, MP regime may be better than SP regime. Furthermore, under some restrictive assumptions, we could show that MP regime is superior to SP regime when the number of firms in R&D sector is "very large".

In the next section, we introduce SP and MP system in a timeless model and derive firm's optimal choice of R&D efforts under both regimes. In section III, we set up the social welfare functions and study the relationship between a patent system and the nature of R&D sector. The conclusion of this paper follows in section IV.

II. THE MODEL

Consider n firms engaging in R&D for a new technology (or product). Consider also two different patent regimes, single patent system and multiple patent system. Under SP system, only one firm obtains the patent. Since there is no concept of 'being ahead or behind' in R&D competition phase in this timeless example, if more than one firm make innovation under SP system, a single patentee is randomly selected among multiple innovators. However, under MP system, if more than one firm make innovation, patents will be given to all those innovating firms. If more than one firm make innovation and market the new product, it is assumed that they do Cournot competition. Thus each firm earns symmetric profit π_k where π_k is the individual firm's profit when k number of patentees do Cournot competition in the product market for $k=1,\dots,n$. Without loss of generality, it is assumed that $k\pi_k<(k-1)\pi_{k-1}$ for $k\geq 2$, i. e. industry profit decreases as the number of firms (patentees) increases in the product market.

Following Lee and Wilde (1980), let $C(p_i)$ denote the R&D cost of firm i which yields the success probability p_i, $p_i\in[0,1]$ for $i=1,\dots,n$. We assume that (i) $C'(p)>0$, (ii) $C''(p)>0$ (iii) $C(0)=0$ and (iv) $C(1)>\pi_1$. Assumptions (i) and (ii) imply that the cost function is strictly increasing and strictly convex. Assumption (i) leads us to interpret that the greater R&D investment implies the higher p. Thus we can interpret p as "R&D intensity" or "R&D efforts." Assumption (iv) implies that it is not optimal to spend R&D resources to innovate with certainty.

Single patent regime: Suppose that each firm competes in R&D under a system of single patent. Firm 1 will choose p_1 to maximize its expected profit denoted by V_1^s.

$$V_1^s=p_1\{f_0\pi_1+f_1(\pi_1/2)+\dots\dots+f_{n-1}(\pi_1/n)\}-C(p_1) \tag{1}$$

where $f_k=f_k(p_2,p_3,\dots,p_n)$ is the probability density that k number of firms make innovation among other $(n-1)$ firms. Suppose that the other $(n-1)$ firms choose p. Then $f_k(p)=\binom{n-1}{k-1}p^{k-1}q^{n-k}$ where $q=1-p$. Let denote that $\varphi^s(p)=\sum_{k=1}^{n}\binom{n-1}{k-1}p^{k-1}q^{n-k}(1.k)$. Thus (1) can be written as[3)]

$$V_1^s=p_1\pi_1\varphi^s(p)-C(p_1) \tag{1'}$$

Clearly, $\varphi^s(p)$ does not depend on firm 1's choice p_1. Thus it is easy to derive the following first order condition of (1).

[3] Using the fact that $\binom{n}{k}=(n/k)\binom{n-1}{k-1}$ and that $\binom{n}{k}p^kq^{n-k}$ is a binomial probability distribution with k hits, we can write $\varphi^s(p)=(1/np)(1-\binom{n}{0}p^0q^n)=(1/np)(1-q^n)$ under symmetry condition. Therefore, (1) can be also written as $V_1^s=p_1\pi_1\varphi^s(p)-C(p_1)=(p_1/p)(\pi_1/n)(1-q^n)-C(p_1)$.

$$\pi_1 \varphi^s(p) = C'(P_1) \tag{2}$$

Multiple patent regime: Under a system of multiple patents, firm 1 would choose p_1 to maximize the following expected profit denoted by V_1^m.

$$V_1^m = p_1 \{f_0 \pi_1 + f_1 \pi_2 + \ldots\ldots + f_{n-1}\pi_n\} - C(p_1).$$

The sequence of $\pi_1, \pi_2, \ldots\ldots, \pi_n$ depends on market demand structure. Suppose that π_k can be written as a proportion of π_1. Let $\pi_k = \eta_k \pi_1$. Then η_k is an individual firm's share of π_1 when k number of patentees compete in the product market for $k \geq 1$. Note that $\eta_k = 1$ and $\eta_k < (1/k)$ for $k = 2, \ldots, n$ since $k\pi_k < (k-1)\pi_{k-1}$ for $k \geq 2$. Suppose that the other $(n-1)$ firms choose p. Then $\sum_{k=1}^{n} f_{k-1}\pi_k = \pi_1 \sum_{k=1}^{n} \binom{n-1}{k-1} p^{k-1} q^{n-k} \eta_k$. Let denote $\varphi^m(p) = \sum_{k=1}^{n} \binom{k-1}{n-1} p^{\varepsilon-1} q^{n-k} n_k$. Then (3) can be written as

$$V_1^m = p_1 \pi_1 \varphi^m(p) - C(p_1) \tag{3'}$$

Similarly, $\varphi^m(p)$ does not depend on firm 1's choice p_1. Thus the first order condition of (3′) is given by

$$\pi_1 \varphi^m(p) = C'(p_1) \tag{4}$$

Optimal R&D Choice: To derive a closed-form solutions for equation (2) and (4), we assume $C(p) = Ap^2/2$ where $A = \beta\pi_1$ and $B \geq 2$ for $n \geq 2$. Using this simple explicit functional form, we can easily solve firm 1's best response function under SP regime denoted by $p_1 = B^s(p)$ from (2).

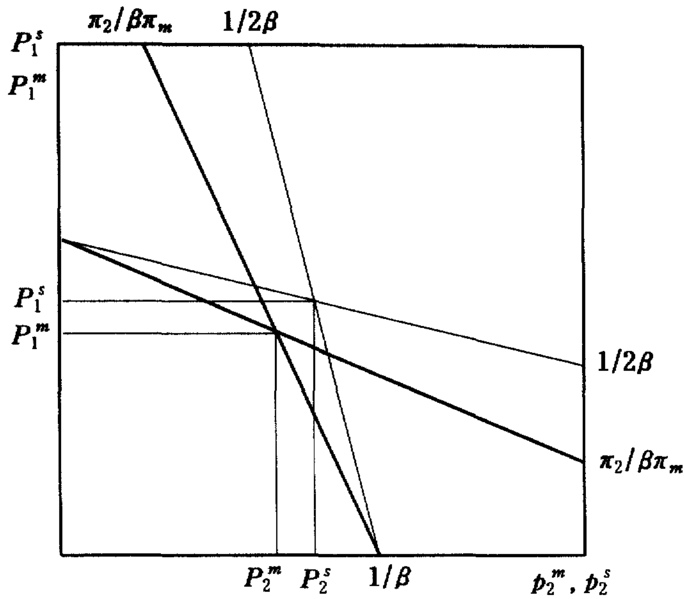
$$p_1 = B^s(p) = \frac{\varphi^s(p)}{\beta} \tag{5}$$

Thus, the symmetric equilibrium denoted by p^s is given by

$$p^s = \frac{\varphi^s(p^s)}{\beta} \tag{6}$$

For example, when $n = 2$, the best response function of firm 1 to firm 2's choice of p_2 is $p_1 = B^s(p_2) = \frac{1-(p_2/2)}{\beta}$. It is depicted by the dotted line in [Figure 1]. The Nash equilibrium of the game is given by the intersection of the two best response functions. When $n = 2$, the symmetric equilibrium R&D

[Figure 1] Optimal R&D efforts under single and multiple patent regime



intensity is $p^s = \frac{2}{2\beta+1}$. Note that p^s does not depend on the market demand conditions(i.e. η_k) but only on the efficiency of R&D technology(β).

Under MP regime, with the simple quadratic R&D cost function, it is easy to derive the best response function denoted by $p_1 = B^m(p)$. From equation (4), we have

$$p_1 = B^m(p) = \frac{\varphi^m(p)}{\beta} \tag{7}$$

Thus, the symmetric equilibrium denoted by p^m is given by

$$p^m = \frac{\varphi^m(p^m)}{\beta} \tag{8}$$

For example, when $n=2$, the best response function of firm 1 to firm 2's choice of p_2 is $p_1 = B^m(p_2) = \frac{\pi_1 - p_2(\pi_1 - \pi_2)}{\beta\pi_1} = \frac{1-p_2(1-\eta_2)}{\beta}$. The solid line in [Figure 1] depicts it. The Nash equilibrium is given by the intersection of the two best response functions. When $n=2$, the symmetric equilibrium R&D efforts are $p^m = \frac{(\beta-1)\pi_1^2 + \pi_1\pi_2}{\beta^2\pi_1^2 - (\pi_1-\pi_2)^2} = \frac{1}{\beta+1-\eta_2}$. It is easy to see that $p^s > p^m$ if $\eta_2 < 1/2$. Note that if $\eta_2 = 1/2$, then $p^s = p^m$.

Proposition 1: If $\pi_1 > k\pi_k (i.e. \eta_k < 1/k)$ for $k = 2, \ldots, n$, then $p^s > p^m$.

Proof: Using the definition of η_k, $\varphi^s(p)$ and $\varphi^m(p)$ and comparing (6) and (8), it is easy to establish that $p^s > p^m$ if $\pi_1 > k\pi_k$ for $k = 2, \ldots, n$. *Q.E.D.*

Note that $\pi_1 > k \cdot \pi_k (i.e.\ \eta_k < 1/k)$ for $k = 2, \ldots, n$. holds for all general demand structures. Proposition 1 holds because SP regime gives more incentive for R&D than MP does. This is simply because, when more than one firm make innovation, each firm earns collusive profits under SP regime but it earns Cournot competitive profits under MP regime.

Ⅲ. WELFARE COMPARISON

Social planner's problem: The social planner chooses optimal R&D efforts of each R&D firm denoted by p^*, given n, to maximize the social welfare denoted by $W(p)$. Let S be the maximum attainable social surplus from new innovation. Then the social planner's problem can be written by

$$Max\ W(p) = \{1 - (1 - p)^n\}S - nC(p) \tag{9}$$

The first order condition can be given by the following.

$$S(1 - p^*)^{(n-1)} = C'(p^*) \tag{10}$$

Under the simple quadratic R&D cost function, the first order condition becomes $S(1 - p^*)^{(n-1)} = \beta\pi_1 p^*$. Suppose that the monopoly profit is given by $\pi_1 = \alpha S$ where $\alpha < 1$. Thus α is the maximum share of appropriable private value to the total social value of new innovation.[4)]

After normalizing S to one, we have

$$\frac{(1 - p^*)^{n-1}}{p^*} = \beta\alpha. \tag{11}$$

Suppose that $n = 2$. Then $p^* = 1/(1 + \beta\alpha)$. Thus, by comparing (6), (8), and (11), we could state:

Proposition 2: In the case of $n = 2$, with the quadratic cost function defined above, $p^s > p^* > p^m$ if $\beta(1 - \alpha) > 1/2$. On the other hand, $p^s > p^* > p^m$ if $\eta_2 < \beta(1 - \alpha) < 1/2$. Finally, $p^s > p^m > p^*$ if $\beta(1 - \alpha) < \eta_2$.

[4] Note that α has been the main concern in the line of studies on optimal patent policy: how to design patent system and control α in order to award π_1. In this model, α is the inherent private incentive for R&D relative to social value of an innovation.

Proposition 2 implies that R&D investment does depend on the nature of R&D technology as well as on the patent system. If new technology is relatively difficult to innovate(β is high) (or if the maximum attainable share of private value to total social benefit from new innovation is relatively small, i.e. is small), then $p^* > p^s > p^m$. The patent system should give more incentive for R&D in this case. Thus, SP regime is better than MP. On the other hand, suppose that new technology is easy to innovate. For example, let $\beta \rightarrow 2$. Then if $\alpha > 3/4$, we could have $p^s > p^m > p^*$. Thus, if the technology is relatively easy to innovate (or if the private share of the social surplus of new innovation is high, i.e. α is high), then the private incentive to innovate could be excessive. The patent system should give less incentive for R&D. Thus a permissive patent system is better than a restrictive one in this case.

Welfare comparison between MP and SP regime: The patent regime switch affects social benefit through the change in the incentives for R&D, market efficiency and total R&D cost. To compare the social benefit between both patent regimes, we need to set up a social welfare function. Following our superscripting convention, the social welfare function in each regime can be written by

$$W^s(p^s) = \{1-(1-p^s)^n\}\{S-D_1\} - nC(p^s) \tag{12}$$

$$W^m(p^m) = S\{1-(1-p^m)^n\} - \sum_{k=1}^{n}\binom{n}{k}(p^m)^k(q^m)^{n-k}D_k - nC(p^m) \tag{13}$$

where D_k is the social deadweight loss when k patented firms compete in the new product market for $k=1, \dots, n$.

Note that (12) is the special case of (13) when $k=1$. Suppose that $D_1 = \gamma\pi_1$ for $\gamma > 0$. Suppose also that deadweight loss decreases in the number of patentees at the same rate of individual profit, i.e. $D_k = \eta_k D_1$. Thus $\alpha \cdot r$ is the proportion of deadweight loss to the total social benefit of an innovation under SP regime, which is constant and independent of k. Under MP regime, $D_k = \eta_k \alpha\gamma S$ for $k=1, \dots, n$. Since η_k is decreasing in k, D_k is also decreasing in k.

Using these parameters, the social welfare function in each regime can be written by

$$W^s(p^s) = \{1-(1-p^s)^n\}(1-\alpha\gamma)S - nC(p^s) \tag{12$'$}$$

$$W^m(p^m) = S\{1-(1-p^m)^n\} - \sum_{k=1}^{n}\binom{n}{k}(p^m)^k(q^m)^{n-k}\eta_k\alpha\gamma S - nC(p^m) \tag{13$'$}$$

First of all, consider the case that there are only two R&D firms. Then, it is easy to see that

$$W^s(p^s) = \frac{8\beta - 8\beta\alpha\gamma - 4\alpha\beta}{(2\beta+1)^2} S \tag{14}$$

$$W^m(p^m) = \frac{(2\beta+1-2\eta_2) - (2\beta-\eta_2)\alpha\gamma - \alpha\beta}{(\beta+1-\eta_2)^2} S \tag{15}$$

Note that each term in equation (14) and (15) indicates the expected gross social benefit, the expected deadweight loss and total R&D cost, respectively.

It is easy to see that p^m increases in η_2 for $0 \leq \eta_2 \leq 1/2$. Recall that $p^s = p^m$ if $\eta_2 = 1/2$. Thus, it is easy to see that $W^s(p^s) - W^m(p^m) = -2\alpha\gamma/(2\beta+1)^2 < 0$ from (14) and (15) if $\eta_2 = 1/2$. Note that $D^s = D_1 \alpha\gamma S$ under SP regime. However, it is $D_2 = \eta_2 \alpha\gamma S < D_1$ under MP regime. Note also that $W^m(p^m)$ does not depend on η_2 while $W^m(p^m)$ does. When $\eta_2 \rightarrow 1/2$, the difference between $W^s(p^s)$ and $W^m(p^m)$ comes only from the difference in the deadweight losses when both firms make innovation.

It is also easy to see that $\partial p^s/\partial\beta = -4/(2\beta+1)^2 < 0$ and $\partial p^m/\partial\beta = -1/(\beta+1-\eta_2)^2 < 0$ for $\beta \geq 2$. Since higher β implies higher marginal cost of R&D, firms decreases their R&D investment as increases. Furthermore, it is also easy to see that $\partial(p^s - p^m)/\partial\beta = \dfrac{-(3-2\eta_2)\beta(1-2\eta_2)}{\{(2\beta+1)(1+\beta-\eta_2)\}^2} < 0$ for $\beta \geq 2$. Thus, if new technology becomes very difficult to innovate, the gap between p^s and p^m gets smaller. Therefore, if new technology is "very difficult" to innovate, then the difference between $W^s(p^s)$ and $W^m(p^m)$ results from the difference in market efficiency. Hence, if new technology is "very difficult" to innovate, then MP regime may be better than SP regime.

To compare the social benefits for $n > 2$, we need to know about how market efficiency changes as the number of patentees in the product market increases. For simplicity, suppose a linear demand where the inverse demand function is given by $P_k = a - bQ_k$, where $a > 0$, $b > 0$ and the subscript k represents the number of firms in the product market as before. If each firm has post-innovation constant marginal cost denoted by $c \geq 0$, then it is easy to derive that

$$P_k = (a+ck)/(k+1)b, \quad q_k = (a-c)/(k+1)b, \quad Q_k = kqk = k(a-c)/(k+1)b$$

where q_k and Q_k are output per firm and industry output, respectively. In a perfectly competitive case, we have $P = c$ and $Q^c = (a-c)/b$. Thus, the maximum attainable social benefit is given by

$$S = \int_0^{(a-c)/b} (a - bQ - c)\,dQ = \frac{(a-c)^2}{2b} \tag{16}$$

Therefore, $\alpha = 1/2$. It is easy to establish that

[Table 1] Welfare Comparison Between Single and Multiple Patent Regime: When n Varies[1) 2) 3)]

n	2	3	4	5	10	15	20	30
p^s	0.4000	0.3468	0.3124	0.2855	0.2129	0.1782	0.1553	0.1279
p^m	0.3904	0.3345	0.2970	0.2695	0.1960	0.1574	0.1351	0.1088
B^s	0.6401	0.7213	0.7765	0.8138	0.9087	0.4973	0.9658	0.9835
B^m	0.6284	0.7053	0.7558	0.7920	0.8871	0.9234	0.9451	0.9684
C^s	0.1601	0.1804	0.1952	0.2037	0.2266	0.2380	0.2413	0.2454
C^m	0.1524	0.1678	0.1764	0.1816	0.1921	0.1859	0.1825	0.1774
D^s	0.1600	0.1803	0.1941	0.2034	0.2272	0.2368	0.2415	0.2459
D^m	0.1359	0.1383	0.1415	0.1347	0.1187	0.1060	0.0954	0.0791
W^s	0.3200	0.3606	0.3872	0.4066	0.4549	0.4724	0.4831	0.4922
W^m	0.3400	0.3991	0.4379	0.4757	0.5763	0.6315	0.6673	0.7118

1) when = 2.
2) The monopolist's profit is normalized to one.
3) $W = B - D - C$, where B is gross expected social benefit, D is expected social deadweight loss, and C is total R&D cost.

$$D_k = S/(k+1)^2 \text{ and } \pi_k = 2S/(k+1)^2 = 2D_k \text{ for } k = 1, \ldots, n. \tag{17}$$

Note that $\pi_k = 4\pi_1/(k+1)^2$. Thus $\eta_k = 4/(k+1)^2$ for $k = 1, \ldots, n$ and $\gamma = 1/2$. For $n > 2$, we do some numerical exercise. [Table 1] summarizes the results of numerical analysis when demand is linear where $a = 1$, $b = 1$ and $c = 0$. [Table 1] shows, given β, how the incentives for ***R&D*** and the social benefits change as the number of the firms in R&D sector changes. We are interested in how the associated variables move as n increases given β.

From [Table 1], it is easy to see that, given β, both p^s and p^m decrease in n. This is because the expected payoffs in both regimes decreases in the number of firms engaging in R&D. However, the expected profit in MP regime decreases in n faster than that in SP regime because $\eta_k < 1/k$ for all $k \geq 1$. Note that the expected number of innovators is $E(k) = np(n)$. If we treat n as a continuous value, we have $\partial E(k)/\partial n = p + n(\partial p/\partial n)$ for $\partial^2 p/\partial n^2 > 0$. Suppose that $\partial^2 p/\partial n^2 > 0$ as shown in [Table 1]. Then, for small n, p is relatively sensitive to n and $\partial E(k)/\partial n$ may be negative or positive. For large n, the absolute value of $\partial p/\partial n$ becomes small and $\partial E(k)/\partial n$ may be positive. For a simple linear demand case, we have $\partial E(k)/\partial n > 0$ for $n \geq 2$ shown in [Table 1].

Note that the increase in the expected number of innovators decreases the expected deadweight loss in MP regime. Thus, D^m in [Table 1] is first increasing for small n and then decreasing in n. However, D^s is 25% of gross expected social benefit for all n. Hence, the gap between D^m and D^s widens in n. On the other hand, for large n, since the absolute value of $(\partial p/\partial n)$ is small, $\partial nC(p)/\partial n = C(p) + nC'(p)(\partial p/\partial n) > 0$. Furthermore, as n increases, total R&D cost becomes more important due to the duplication of R&D investment. As long as p^s is greater than p^m, the duplication cost of R&D is greater in SP regime than that in MP regime.

This numerical simulation analysis suggests that higher R&D incentives are not always beneficial to the society. Strong patent protection for enough R&D incentives may require too high R&D cost and too much deadweight loss, especially for large n. More importantly, this numerical analysis infers that, in designing the patent system, we should consider the degree of R&D competition.

The numerical analysis is greatly facilitated by assuming that demand is linear. Of course, the results depend on the specification of market demand. However, what really matters is that there will be some important welfare loss arising from monopoly pricing in a restrictive patent regime. There may be some welfare loss arising from duplication cost. This would be the same case for a variety of demand functions.

Ⅳ. CONCLUSION

This paper tries to show that optimal patent design depends not only on the nature of competition in the patented product but also on the nature of R&D technology and the degree of R&D competition. Thus, in designing and tuning the patent system, we should consider the nature of R&D technology and the degree of R&D competition as well as the nature of competition in the product market. We have shown that if new technology is relatively difficult to innovate, then firms invest less than socially optimal. Thus, a restrictive patent regime is better than a permissive patent regime. However, if new technology is relatively easy to innovate, then the private incentive to innovate could be excessive. Thus, a permissive patent system is better than a restrictive one. We have also shown that if new technology is "very difficult" to innovate, a permissive patent regime may be better than a restrictive one. We have tried to show that the degree of patent protection should be related with the degree of R&D competition. Under some restrictive assumptions, we have shown that MP regime may be superior to SP regime when the number of firms in R&D sector is "very large".

The welfare comparison study in this timeless model infers that the disadvantage of SP regime may lie in the lack of policy variables to balance between the incentives for R&D and the dissemination of the innovation. In a dynamic setup, SP regime has the conventional policy variable, patent duration, which could be used to strike the balance between the incentives for R&D and the diffusion of innovation. However, the patent duration is practically fixed for all industries. Thus, appropriate treatment of the scope of patent protection is important based on the nature of competition in the product market and the nature of R&D sector. This task is about tuning the patent system optimally rather than about designing optimal patent system.

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