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Abstract: An important discussion in recent years is the introduction of product patents and the abolition of process patents. In a model with endogenous number of innovating firms, we show that whether product patent increases R&D is ambiguous, and depends on the type of market demand and the cost of R&D. If the market size increases with number of firms, product patent reduces R&D investment if the cost of R&D is sufficiently large, and higher product differentiation increases the possibility of lower R&D under product patent. If the market size does not increase with number of firms, product patent always increases R&D investment. Though, in general, product patent may increase welfare if it reduces R&D investment, we show that, in case of linear demand, welfare is always lower under product patent than process patent.

Key Words: Entry; Process patent; Product patent; R&D

JEL Classifications: O31; O34; O38; L11; L13; D43

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Does product patent reduce R&D?

1. Introduction

An important discussion in recent years is the introduction of product patents and the abolition of process patents. Under the current WTO (World Trade Organization) regime, one of the most debated issues is the use of product patent across the world and the debate gathered momentum due to the Dunkel proposal in connection with Trade Related Intellectual Property Rights (TRIPS). The basic argument goes as follows. If there is process patent, it allows more firms than only the original innovator to produce similar products with non-fringing different processes. Hence, the original innovator does not able to get the full return from its R&D, which, in turn, may reduce the incentive for original innovation. In contrary, product patent allows only the original innovator to produce this particular product, thus increases the incentive for R&D by providing monopoly benefit to the original innovator.

Though the above argument is certainly appealing, it is important to see how product patent affects the incentive for R&D in presence of many potential innovators. In a simple model with free entry, we show that product patent may reduce R&D if the cost of R&D is sufficiently large and the market size increases with number of firms. Further, higher product differentiation, which may occur due to the reasons different from product characteristics such as different brand names, different after sales service, etc., increases the possibility of lower R&D under product patent. But, if the market size does not increase with number of firms, product patent always increases R&D. So, whether product patent increases R&D depends on the type of industry, which may differ according to the cost of R&D and the number of R&D capable firms.

On one hand, product patent increases profit of the patent holder by eliminating competition in the product market. But, on the other hand, when there are many active innovators, product patent reduces each innovator's probability of getting the patent, thus reducing the expected return from R&D. We show that the latter effect dominates the former if there are few active innovating firms. Though it seems paradoxical, this is quite intuitive. When there are few active firms in the market, profit of an innovator in the product market is very much similar under product and process patents. However, since the product patent allows only the patent holder to produce the product, it reduces an innovator's expected profit by making the R&D competition into a tournament. So, if the cost of R&D is sufficiently large, which, in equilibrium, ensures fewer active firms, R&D may be lower under product patent compared to process patent.

Though product patent increases market concentration, which creates negative impact on social welfare, it may also tend to increase welfare by reducing R&D investment when the market size depends on number of firms. Hence, in general, the effect of product patent on welfare is ambiguous if the market size depends on number of firms. However, in case of linear demand function, we show that product patent reduces welfare. But, if the market size is independent of the number of firms, product patent always reduces welfare.

There is already a vast literature showing the effect of patent protection on R&D and welfare. However, rather than addressing the question of product versus process patent, the previous literature mainly consider how strengthening the patent protection affects an economy. As a representative sample, one may look at Chin and Grossman (1990), Segerstrom et al. (1990), Diwan and Rodrik (1991), Grossman and Helpman (1991), Romer (1991), Deardorff (1992), Helpman (1993), Lai (1998) and Glass and Saggi (2002).

However, after the Dunkel proposal in connection with TRIPS, the world economic scenario is changing, and it may be more relevant to see the effect of product patent vis-àvis process patent on R&D and welfare. For example, India, so far issuing process patents under its ‘Patent Act 1970’, had to amend its patent law in 2005 to allow product patent in order to comply with TRIPs. In a recent paper, Marjit and Beladi (1998) show that the imposition of product patent in the developing countries may reduce welfare of these countries by discouraging the innovators from the developed countries to sell their products in the developing countries with small markets. However, unlike the present paper, they did not consider the effect of different patent systems on R&D.

The remainder of the paper is organized as follows. Section 2 describes the model and shows the results. Section 3 discusses two extensions of our model. Section 4 concludes.

2. The model and the results

Consider an economy with large number of firms. Each firm is able to invent a new product by investing an amount K^2 in R&D. The marginal cost of production for this product is constant, and is assumed to be zero, for simplicity.

We consider two types of patent systems in the following analysis, viz., product patent and process patent. If there is product patent, after the R&D stage, one of the innovating firm gets patent to produce the product. Hence, if n firms do R&D, each firm’s probability of getting the patent is $\frac{1}{n}$. In contrast, if there is process patent, all innovating firms can produce the products by using a slightly different process for the product. However, we assume that the products of these firms may be imperfect substitutes, which may be due to the reasons different from product characteristics such as different brand names, different after sales service, etc.

We consider the following game. At stage 1, the firms decide whether to invest in R&D or not. To avoid the coordination problem in R&D, which does not add anything to the main purpose of this paper, we consider that the firms decide sequentially whether to do R&D or not. A firm decides to invest in R&D until its net profit from R&D is negative. So, the zero profit condition determines the equilibrium number of firms. At stage 2, the firms take their production decision. If there is product patent, only the patent holder produces at stage 2. But, under process patent, all the innovating firms produce like Cournot oligopolists. We solve the game through backward induction. Further, for analytical convenience, we consider number of firms as a continuous variable.

Let us assume that the inverse market demand function for the i th firm is

$$P = a - q_i - \gamma \sum_{i \neq j} q_j \,, \tag{1}$$

where $\gamma \in [0,1]$ denotes the degree of product differentiation.[1] The products are isolated for $\gamma = 0$, and they are perfect substitutes for $\gamma = 1$.

2.1 Product patent

If there is product patent and n firms do R&D at stage 1, the expected gross profit of the i th innovating firm is $\frac{\pi^m}{n}$, where $\pi^m = \frac{a^2}{4}$. Hence, at stage 1, a firm decides to do R&D until

$$\frac{a^2}{4n} = K^2 . \tag{2}$$

Therefore, the equilibrium number of innovating firms under product patent is

[1] This demand function is due to Bowley (1924) and is generated from the utility function $U(q,I) = \sum_{i=1}^{n} aq_i - \frac{1}{2}\left(\sum_{i=1}^{n} q_i^{\,2} + 2\gamma \sum_{i \neq j} q_i q_j \right) + I$, where I is the numeraire good.

$$n^{pd} = \frac{a^2}{4K^2}. \quad (3)$$

2.2 Process patent

If there is process patent and n firms do R&D at stage 1, the gross profit of the ith innovating firm is π^c, where $\pi^c = \frac{a^2}{(2+(n-1)\gamma)^2}$. So, at stage 1, a firm decides to do R&D until

$$\frac{a^2}{(2+(n-1)\gamma)^2} = K^2. \quad (4)$$

Hence, the equilibrium number of innovating firms under process patent is

$$n^{pr} = \frac{(a-2K+K\gamma)}{K\gamma}. \quad (5)$$

2.3 Comparing R&D under product and process patents

Let us now compare R&D investments under product and process patents.

Proposition 1: *Consider the number of firms as a continuous variable.*

(i) Product patent reduces R&D if $\gamma < 1$ and the cost of R&D is sufficiently large, i.e., $K > \frac{a\gamma}{2(2-\gamma)}$.

(ii) As the products are becoming more differentiated (i.e., γ decreases), the possibility of higher R&D under process patent increases.

Proof: (i) A firm's gross profit under product patent (i.e., left hand side (LHS) of (2)) is greater than that of under process patent (i.e., LHS of (4)) if and only if

$$\gamma \begin{matrix} \geq \\ < \end{matrix} \frac{2}{(\sqrt{n}+1)}. \tag{6}$$

The right hand side (RHS) of (6) is 1 for $n=1$, whereas it tends to 0 as $n \to \infty$. This implies that for $\gamma < 1$, there exists $n^*(\gamma) = \frac{(2-\gamma)^2}{\gamma^2}$ such that LHS of (2) is equal to LHS of (4).

Now, define $K^*(\gamma)$ as the cost of R&D such that, given the degree of product differentiation, the equilibrium number of firms is $n^*(\gamma) = \frac{(2-\gamma)^2}{\gamma^2}$. Hence, we have $\frac{a^2}{4n^*} = \frac{a^2}{(2+(n^*-1)\gamma)^2} = K^{*2}$, which gives $K^* = \frac{a\gamma}{2(2-\gamma)}$. Therefore, if $K > (<) K^*(\gamma)$, the equilibrium number of firms doing R&D is lower (higher) under product patent compared to process patent.

(ii) Since LHS of (6) decreases with γ, it proves the result. Q.E.D.

Whether the incentive for R&D will be higher under product patent or process patent depends on the trade-off between higher competition under process patent and the lower chance of getting patent under product patent. If the product market is very concentrated, competition under process patent does not reduce each firm's profit significantly. Further, product differentiation helps to reduce competition between the firms. So, if the market is very concentrated, the loss of profit due to the lower chance of getting patent under product patent dominates the loss of profit under process patent due to product market competition. But, if the product market is not very concentrated, the loss of profit under process patent due to competition effect becomes significant and dominates the loss under product patent due to lower chance of getting patent, thus creates higher incentive for R&D under product patent. Since, in equilibrium, fewer (more) firms enter the market when the cost of R&D is very large (small), R&D reduces (increases) with product patent for very large (small) cost of R&D.

It should be noted that if the products are perfect substitutes, i.e., $\gamma = 1$, the profit loss under process patent due to higher competition is always higher than the profit loss under product patent due to lower chance of getting patent. Unlike product differentiation, if the products are perfect substitutes, more firms do not increase the total size of the market and thus, do not provide the benefit of higher market size under process patent. Our result shows that the benefit of product differentiation is crucial for lower R&D under product patent.

It may be worth mentioning that the main message of Proposition 1 remains even if we consider the firms as integers. However, under the integer constraint, product patent may not reduce R&D for any $\gamma < 1$, and we need to modify Proposition 1(i) slightly. For example, if there are two firms doing R&D, gross profit of each firm under process patent is $\frac{a^2}{(2+\gamma)^2}$, which is lower than each firm's expected gross profit under product patent, i.e., $\frac{a^2}{8}$, provided γ is sufficiently lower than 1. Hence, with integer constraint, product patent can reduce R&D for relatively large R&D costs provided the products are not very close substitutes, i.e., γ is not very high.

Though the gross industry profit plus consumer surplus is always higher under process patent, product patent may reduce the number of R&D firms and save R&D costs if the products are differentiated. Hence, in general, the effect of product patent on welfare, which is the summation of net industry profit and consumer surplus, is ambiguous if the products are imperfect substitutes.[2] However, in case of demand function (1), the following analysis shows that welfare is always higher under process patent.

Using (3), we find that welfare under product patent is

$$W^{pd} = \frac{a^2}{8}, \tag{7}$$

whereas using (5) and realizing that the net profits of the firms under process patent are zero welfare under process patent is

$$W^{pr} = \frac{(a-K)(a-2K+K\gamma)}{2\gamma}. \tag{8}$$

The comparison of (7) and (8) shows that $W^{pd} \overset{\geq}{\underset{<}{}} W^{pr}$ provided

$$a^2\gamma \overset{\geq}{\underset{<}{}} 4a^2 - 12aK + 4aK\gamma + 8K^2 - 4K^2\gamma. \tag{9}$$

RHS of (9) increases with γ, and it is greater than the LHS of (9) at $\gamma = 0$.

Hence:

Proposition 2: *Given the demand function (1), welfare is higher under process patent.*

Marjit and Beladi (1998) shows that product patents in developing countries may reduce their welfare by preventing the innovators from the developed countries to sell their products in the developing countries. Though the above result is in line with the welfare implications of Marjit and Beladi (1998), we show that product patent may reduce welfare even if the market is served under both product patent and process patent.

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[2] If the products are perfect substitutes, it is clear that product patent reduces welfare since it increases both

3. Discussion

3.1 Possibility of imitation

Section 2 has assumed away the possibility of imitation under process patent. In other words, we implicitly assume that knowledge about the technologies can be acquired only through R&D, which may be due to the existence of tacit knowledge. However, the common criticism against process patent is the possibility of imitation by the competitors that reduces profit of the initial innovator. Now, we examine how the analysis of the previous section is affected by the possibility of imitation under process patent.

Let us assume that each firm has the capability of imitating the technology of the competitor at a cost $I^2 < K^2$. However, it should be clear that imitation is feasible only under process patent.

Since the cost of imitation is lower than the cost of innovation, if a firm innovates the technology under process patent, it is optimal for the remaining firms to imitate this technology rather than inventing this product through own R&D. However, imitation will occur until the net profit of each imitator is 0. Hence, it is trivial that if all the imitators get zero net profit, the net profit of the initial innovator will be negative, which means that there will be no innovation under process patent. However, innovation will occur under product patent until the net expected profit of each firm is zero. Therefore, in this situation, product patent always increase R&D, and this is the standard argument for product patent.

However, if there are multiple innovators, process patent can increase R&D even in the presence of imitation if the net profit of each imitator is not equal to 0, which is possible if we consider the firms as integers rather than a continuous variable. This is shown in Figure 1.

Figure 1

R&D investment and market concentration.

The curves PD and PR show the expected gross profit of a firm under product patent and process patent respectively. The lines K^2 and I^2 show the costs of R&D and imitation. We show a situation where $\pi_i^{pd}(n) > K^2 > I^2 > \pi_i^{pd}(n+1)$ and $\frac{\pi_i^{pr}(n-1)}{(n-1)} > K^2 > \frac{\pi_i^{pr}(n)}{n}$, which implies that there will be n firms under process patent but $(n-1)$ firms under product patent. This is in contrast to the standard argument for product patent, and confirms our result of the previous section. However, it must be noted that while $(n-1)$ firms do original innovation under product patent, only one firm does original innovation and other $(n-1)$ firms do imitative innovation under process patent.[3]

3.2 A different demand formulation

The analysis of section 2 has considered a demand function that is mostly used in the literature and is due to Bowley (1924). An important feature of this demand function is to consider that the market size increases with number of firms. Our discussion on perfect substitutes after Proposition 1 suggests that one would expect that R&D would be higher under product patent when the number of firms does not affect total market size. The purpose of this subsection is to see whether this is indeed the case even if we introduce imperfect substitutes. For this matter we analysis the effects of different patent systems on R&D by using the demand function due to Shubik and Levitan (1980) that eliminates the

[3] Since the net profit of each imitator is greater than the net profit of the innovator under process patent, it may create the free-rider problem, and may not encourage a firm to do the original innovation. This problem can be resolved with mixed strategies of the firms between R&D and imitation or with different time preferences of the firms. However, since this complication will not add to the main purpose of this paper, we assume away the free-rider problem by considering a pre-assigned sequence of R&D decision of the firms.

effect of number of firms on the market size.[4] Like section 2, we assume away imitation in this subsection.

Let us consider the following inverse demand function for the i th firm

$$p_i = a - \frac{(n+\gamma)}{(1+\gamma)}\left(\frac{\gamma}{n+\gamma}q_1 + \frac{\gamma}{n+\gamma}q_2 + \ldots + q_i + \ldots + \frac{\gamma}{n+\gamma}q_n\right), \tag{10}$$

where γ shows the degree of product differentiation. If $\gamma = 0$, (10) becomes $p_i = a - nq_i$ and implies that the products are isolated. But, the products are perfect substitutes when $\gamma \to \infty$ and the inverse demand function (10) becomes $p_i = a - (q_1 + q_2 + \ldots + q_i + \ldots + q_n)$.

If there is product patent, only one firm will produce in the market even if there are n firms doing R&D at stage 1. Hence, the expected gross profit of the i th innovating firm is $\frac{\pi^m}{n}$, where $\pi^m = \frac{a^2}{4}$. Therefore, the number of firms under product patent will be determined by the condition similar to equation (2), and it will be

$$\frac{a^2}{4n} = K^2. \tag{11}$$

However, the analysis will be affected by this new demand formulation when there is process patent. If n firms do R&D under process patent, the gross profit of the i th innovating firm is $\pi^c = \frac{a^2(1+\gamma)(n+\gamma)}{(2n+\gamma n+\gamma)^2}$. Therefore, the equilibrium number of firms doing R&D under process patent is determined by

$$\frac{a^2(1+\gamma)(n+\gamma)}{(2n+\gamma n+\gamma)^2} = K^2. \tag{12}$$

The comparison of LHS of (11) and LHS of (12) shows that the former is always greater than the latter. Therefore, for a given number of firms doing R&D, the incentive for R&D

[4] Though the demand functions due to Bowley (1924) and Shubik and Levitan (1980) behave similarly for a given number of firms, they perform differently as number of firms change. One may refer to Martin (2002)

is always higher under product patent than process patent. Hence, the following result is immediate.

Proposition 3: *If the market size does not increase with more firms, R&D investment is always higher under product patent than process patent.*

Since, here product patent always increases R&D investment and also increases market concentration compared to process patent, it is trivial that welfare reduces with product patent for the demand function (10).

4. Conclusion

An important discussion in recent years is the abolition of process patent system and the introduction of the product patent system. The main argument for this advice considers that product patent prevents competition in the product market and allows the patent holder monopoly power in the market, thus increasing its profit and the incentive for R&D.

However, if there are many potential innovators, the type of patent protection affects the equilibrium number of firms and therefore, affects R&D investment. We show that whether product patent increases R&D investment is ambiguous. Product patent may reduce R&D investment if the cost of R&D is very large. So, whether product patent increases R&D investment may depend on the type of industry that may differ according to the cost of R&D and the number of R&D capable firms.

Though product patent increases market concentration, it may increase welfare by reducing R&D investment. Hence, in general, the welfare effect of product patent is

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for a discussion on this issue.

ambiguous when the market size changes with number of firms. However, we show that, in case of linear demand, welfare reduces with product patent. If the market size is independent of number of firms, product patent always reduces welfare

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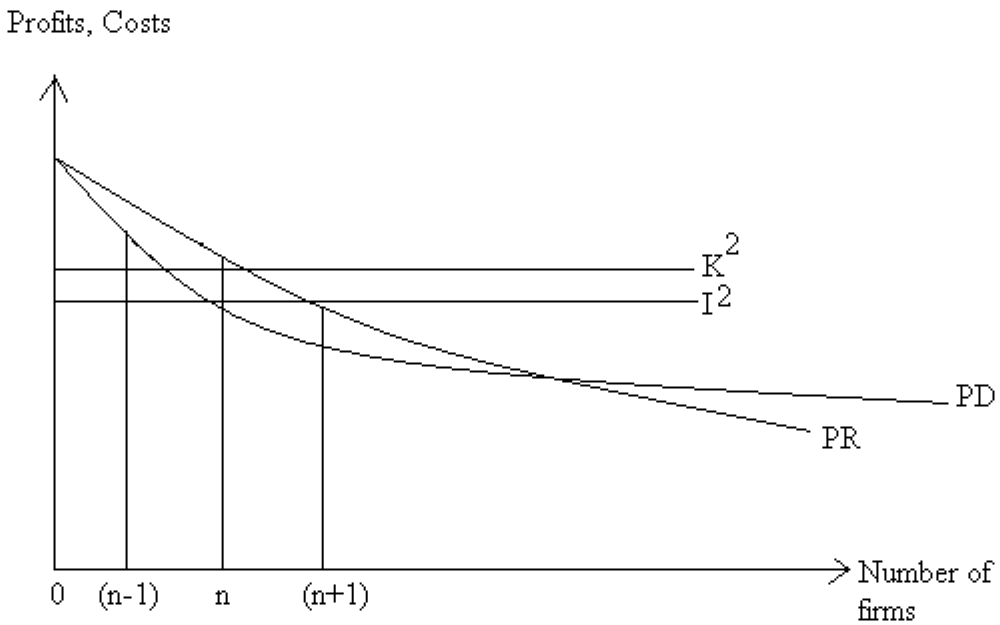

Figure 1: Higher R&D under process patent than product patent in presence of imitation