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Incentives for Product and Process Innovations: A Case for the Drug Industry

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Abstract

We consider an interaction of competing firms in an integrated world market and study their R&D incentives under each of product patent and process patent regimes. We follow a framework generally observed in the drug industry. We show that product patent regime leads to a larger R&D investment. Consumers may also benefit from product patenting. However, if the number of goods is large enough, the choice of patent regime loses significance with respect to R&D incentives.

Key words: Innovation; process patenting; product patenting; drug industry.
JEL Classifications: F23; L13; O34

1. Introduction

The R&D literature discusses various issues like: incentives for R&D investment; R&D incentives and market structure; R&D investment and the size of the firms; incentives for cooperative and non-cooperative R&D; imitation, patent protection and R&D; etc. Broadly speaking, there are two types of innovations, product innovations and process innovations. A product is anything that has the capability to satisfy some specific need or want. So a product may be defined in terms of its ability to generate utility. Hence two products are different in the sense that these satisfy two different utility or needs. Then product innovation means either introducing altogether a new product or service, or substantially improving the quality of an existing product. And given a product in the above sense, a process innovation means innovating a new method of producing the product. It may mean producing exactly the same product by a superior method so that the marginal cost of production gets reduced if production takes place through this new process. The other interpretation should be innovations of the similar products, with different input mix, which satisfy almost the same need.

The second interpretation is more closely applicable to the innovations in the pharmaceutical industry. To understand this, one can think of innovations of drugs to cure some disease. Any drug that targets a specific disease must have some basic components (B). So all drugs that fall in this drug group have B as common, but they differ in respect of the other components (A). Therefore all drugs $\{X_i\}$ fall in the product group X, where $X_i = X(B_X, A_i)$, that is, the i-th variety of X uses the basic component B_X, common to all drugs in this group, plus varying components A_i; $i = 1,2,3,...m$ (say). Thus X_i and X_j are two varieties of the same drug (group X), which differ in respect of using different input mix.

There are in fact innumerable examples. Consider one group of antitussive drugs (cough suppressants) each of which contains Codeine as one important component. This group includes drugs like CODOKUFF, APIDIN, BRONOLAX, CODERAN, CONDOMOLINDON, etc. These drugs however differ in respect of other compounds. CODOKUFF contains Chlorpheniramine maleate, APIDIN contains Aspirin and Caffeine, BRONOLAX contains Ephedrine and Diphenhydramine, CODERAN contains Diclofenac, and CONDOMOLINDON contains Paracetamol. Another group of antitussive drugs like COFORM, COFSYRYL and COREX-DX each contains Dextromethorphan as one common substance. In addition, COFORM contains Pseudoephedrine (decongestant) and Chlorpheniramine (antiallergic), COFSYRYL contains Pseudoephedrine and Cetirizine (antiallergic), and COREX-DX contains Chlorpheniramine maleate and Menthol (decongestant). Antidiarrhoeal drugs like ALDIAMYCIN, ALFUMET and DEEMET have common composition of Furazolidone (antibacterial) and Metronidazole (antiamoebic). Then ALDIAMYCIN contains, in addition, Belladona tincture (analgesic and antispasmodic), and DEEMET contains Dioxanide furoate. For treatment of migraine pain drugs like ERGOPHEN and MIGRIL are prescribed. These drugs have one common compound Ergotamine tartrate. In addition, ERGOPHEN contains Belladonna dry extract and Phenobarbitone, whereas MIGRIL contains Cyclizine hydrochloride and Caffeine. Antipyretic, antiallergic drugs like ACTICOLD and ALGI TAB contain Paracetamol and Chlorpheniramine maleate in common, but ACTICOLD has an additional composition Pseudoephedrine and ALGI TAB has Caffeine.

Thus examples can be multiplied, but the basic point is that there are groups of drugs such that each group (X) contains some common components (B_X), but within the group the drugs differ in respect of other components (A_i). Then protecting innovation B_X is equivalent to protecting the whole group of products $\{X_i\}$. Call such protection as protection by product patent. On the other hand, protection of each X_i separately means basically protecting (B_X, A_i) as a whole where (B_X, A_i) and (B_X, A_j) generate two close drugs with the similar/same therapeutic value. This is called process patenting. X_i basically denotes product X produced by using the i-th process. Under process patenting we assume that each X_i (and so A_i) is distinctly different to get patent under process patenting. It is in this backdrop that we examine the incentive of a firm for product innovations and process innovations.

1.1 Motivation and Objective of the Paper

Recently, countries have signed the TRIPs (trade-related intellectual property rights) agreement[1] and are thus under obligations to amend their legislations in compatibility with the provision of TRIPs. The WTO has been set up for policing and enforcing the agreement. One debatable aspect of this agreement has been the replacement of process patents by product patents.[2] While most of the north countries followed product patenting even in the pre-TRIPs era, the southern countries (e.g., India) mostly practiced process patenting in their domestic countries. This was particularly the case in pharmaceutical industries (see India's Patent Act 1970). The southern firms would imitate the northern innovations by means of inventing around almost at a negligible cost. Hence, given the fact that most of the products are innovated in the north, the northern firms had the strict disadvantage to compete with the southern firms in the rest of the world outside the northern market. Then, introducing product patents in the south will obviously prevent the southern imitators from competing with the northern firms in the same market during the patent period. It is argued that product patenting by the south will provide additional R&D incentives to the innovators, thereby all countries will gain ultimately.

1.2 Literature Survey

[1] For conceptual aspects of the international patent protection, see Maskus (1990), Subramanian (1991), Kabiraj (1994), and Greenaway and Sapir (1992).

[2] Product patenting implies protection of new active compound or the good itself irrespective of the method by which it has been produced, whereas process patenting protects the method of production. Therefore, patenting products will block the development of the products by another process.

While there is a big literature that discusses the incentives of the south to extend the northern patent protection[3], there are only a few papers in the theoretical literature that talk about the R&D incentives of the innovators under two types of patent regimes, viz., product patenting and process patenting. So our concern in this paper is to examine which patent regime provides a larger incentive for conducting R&D.[4] The argument that is provided in favor of product patenting in the north-south structure appears to be misplaced, if not erroneous. The north-south models generally assume that products are innovated in the north, and then the southern imitators are responsible for innovating different processes of production for the same product.[5] In that sense product innovations and process innovations seem to follow a sequence, as if they belong to two different classes, and then the northern innovators are assumed to have incentives for product patenting and the southern innovators have incentives for process patenting. But if we like to study logically the R&D incentives of firms under different patent regimes, we must look at the problem from the viewpoint of all innovators taken together.

Furthermore, the existing literature seems to look at product- and process innovations as two distinctly different activities. But, in fact, a product innovation should be associated with at least one process innovation at the same time, otherwise the existence of the product cannot be justified (Kraft, 1990). Then it is logically possible that different firms simultaneously come up with the same product but with different processes of production. Since international patent rules are applicable to all firms equally, it is also reasonable to assume that the successful innovators will operate in an integrated world market. The north-south models divert attention to other issues rather than the incentives of the firms under two patent regimes. To focus specifically on the patent regimes and the corresponding R&D incentives of firms, we therefore assume away the issues of imitation, free-riding and spillovers. We show that product patenting

[3] See, for instance, Chin and Grossman (1991), Deardorff (1990, 1991), Diwan and Rodrik (1991), Yang (1998), Kabiraj (2000), Kabiraj and Banerjee (2002), and Banerjee and Kabiraj (2011). Sakakibara and Branstetter (2001) provide an empirical study on the effect of patent protection on R&D innovation.

[4] There is empirical literature that studies the relation between firm size and R&D expenditures on product- and process innovations. Generally the proportion of R&D expenditure on process innovation is larger for the large size of the firms. See, for instance, Fritsch and Meschede (2001) and Cohen and Klepper (1996).

[5] The north-south set up presumes that the firms in the north and in the south have different types of R&D (say, creation versus imitation). But there are evidences to prove that southern firms have the ability to take up creative innovations. See Mathew and Mukherjee (2014), for instance.

will lead to a larger R&D investment. Under product patent regime, all successful firms will get patents if they have different products. But under process patenting regime, all firms, successfully inventing the same product, may get patents if they have different processes of production. Product patent is preferred because it lessens competition in the product market.

Although there are a large number of papers prepared in the context of new international patent rules, only a few of them provide some theoretical analysis on product vs. process patenting. First, consider the works by Marjit and Beladi (1998) and Vishwasrao (1999). Both these papers have the north-south framework, but neither of these papers discusses the comparative R&D incentives under the two patenting regimes. In Marjit and Beladi, given the significant dispersion of income distribution across countries, under product patenting the northern firms may not cover all the southern markets. Process patenting, on the other hand, would lead to a lower price. Thus product patenting may result in a significant loss in terms of consumers' surplus. On the other hand, Vishwasrao derives welfare implications of both product and process patenting in the context of technology transfer. The paper also provides a comparative discussion of these two regimes. Recently, Mukherjee and Sinha (2013) have provided a theoretical model showing the conflicting interests of the northern and the southern governments and also the northern and the southern firms about the choice of patent regime. There are situations when the northern firms prefer process patent regime in the south. In another paper Mukherjee and Ray (2007) have studied the effect of product and process patents on firm profits and welfare. It is shown that, for small cost of imitation, each firm's profit under process innovation falls but overall welfare is higher. However, in an infinitely repeated game framework, product patenting yields a larger welfare.

In the present paper we discuss the incentive of a firm to invest in R&D under each of product patent and process patent regime. We consider a finite-good framework. Our framework seems to be apt for the drug industry where each such product is produced using many processes. As a result we observe many close drugs to exist for the same disease with possibly little variation in therapeutic values. We have already illustrated this aspect. We show that under product patent regime the firms have larger incentives to invest in R&D. This is what is desired to be achieved under new international patent rules by switching from process to product patenting. Our paper also mitigates the apprehension that consumers will always be worse off. Not only will many new products be innovated under product patent regime, it may benefit the consumers as well.

The layout of the paper is the following. In the second section we provide the model and results of the paper. Consumers' welfare from patent protection is discussed in the third section. Finally, the fourth section is a conclusion.

2. Model

Consider the following scenario. There are two firms interacting in R&D for product/process innovations. By product innovation we mean inventing a product along with a method of production. Consider that there are 'n' ($n \geq 2$) conceivable non-infringing products, $X_1, X_2, \ldots, X_n$, which have the potential of getting innovated. To simplify the analysis, we assume that $X_1, X_2, \ldots, X_n$ are independent. We further assume that the market demands for these products are the same and identical.

Assume that there are m alternative methods of producing each of these goods; $m \geq 2$. Therefore, the problem of each firm is to decide which product to invent and which process of production to select. The unit cost of producing each product corresponding to any process is assumed to be the same and constant.[6] Thus, their selection of products may be matching (i.e., choosing the same product) or mismatching (i.e. choosing different products), and even if they select the same product, they may differ in respect of their choices of production processes.

[6] By this assumption we rule out the selection of a product on consideration of cost of production.

Now, given the outcomes of their R&D decisions, which innovations will be protected by patents depend on the existing patent rules. We consider two alternative patent regimes, viz., product patenting and process patenting. Under product patent regime, only one firm can get a patent for a product irrespective of its process of production. Thus, if both firms select two different products (this occurs with probability $((n-1)/n)$, any firm who comes up with the innovation will get the patent for its product. When both choose the same product (this occurs with probability $1/n$) and only one firm succeeds, the successful firm gets the patent; but if both are successful, we assume that each firm gets the patent with probability one-half (1/2). On the other hand, under process patent regime, even if both firms choose the same product but two different processes of production, any successful firm can get the patent for its innovation. However, if they have the same process of production at the same time, then only one firm can get the patent and each firm gets the patent with probability one-half (1/2). Of course, when they choose different products, under either regime each product will get protection.

We assume that the R&D outcomes are probabilistic. The R&D technology for each product (associated with one method of production) is given by $\mathcal{R}(p, \alpha)$, where $\mathcal{R}$ is the resource cost of innovation associated with the success probability p, $0 < p < 1$ and $\alpha > 0$ is a shift parameter. Let us assume $\mathcal{R} = \alpha R(p)$ and make the following assumption about the $R(.)$ function.

Assumption: *The function is twice continuously differentiable with the properties:* $R'(.) \geq 0$, $R''(.) > 0$, $R'(0) = 0$ *and* $R'(1) = \propto$.

The above assumptions are fairly innocuous. The positive second derivative captures diminishing returns in R&D activity, while the familiar Inada-type end point conditions are imposed to ensure interior solutions. We further assume that each firm is risk-neutral.

We have the following game structure. In the first stage, each firm decides which product to produce, and given their choice of product, they also decide the process of production. In the second stage, the firms decide their R&D investment that determines the probability of success. Then at the end of this stage, given the outcomes of R&D, which firm or firms will be covered under patent protection is determined based on the prevailing patent rules. Finally, in the third stage, the firms compete in the product market as quantity setter. Given the assumptions about the market demand and cost of producing goods, we denote the monopoly payoff by M and duopoly payoff of a firm by D (when both firms compete with the same product); therefore, $M > 2D$.

Finally, we assume that product choice by a firm is a random draw and independent. Given that there are 'n' products, therefore each firm chooses a product with probability $1/n$. Similarly, given the choice of a product, the choice of a process by the firm is again a random draw. Thus each process of production is chosen with probability,

$1/m$.

2.1 Product Patent Regime

Let us first consider the product patent regime.[7] Denoting by p_i the probability that the i-th firm will come up with a success in R&D, the expected net payoff of firm i from its R&D decision will be given by,

$$\widehat{\Pi}_i(p_i, p_j) = \frac{1}{n}\left[\frac{p_i p_j}{2}M + p_i(1-p_j)M\right] + \frac{n-1}{n}p_i M - \alpha R(p_i), \quad i,j = 1,2;\; i \neq j \qquad (1)$$

The first term of the expression on the right hand side denotes the expected net revenue when both firms have chosen the same product, and the middle term is the

[7] For algebraic convenience we assume that the length of patent (either product or process) protection (T) is 1. Obviously, there will be no qualitative change in the results of our analysis if $T > 1$ and finite (given any discounting rate).

expected profit when they choose two different products. The first order conditions satisfying the optimal R&D investment are

$$\frac{1}{n}\left[\frac{p_j}{2}M + \left(1-p_j\right)M\right] + \frac{n-1}{n}M = \alpha R'(p_i), \quad i,j = 1,2;\;\; i \neq j \tag{2}$$

We assume symmetric equilibrium, $p_i = p_j = p$. Therefore, the optimal p will be solved from the following condition,

$$\phi(p) \equiv M - \frac{M}{2n}p = \alpha R'(p) \tag{3}$$

Note that the second order condition is necessarily satisfied. Further, $\phi(p)$ is linear and downward sloping, with $\phi(0) = M$ and $\phi(1) \equiv \frac{2n-1}{2n}M$. Therefore Eqn. (2) gives a unique solution of $p = \hat{p}$.

2.2Process Patent Regime

Now suppose that only process patenting is available. Then the expected net payoff of a firm under process patenting is,

$$\begin{aligned}\widetilde{\Pi}_i\left(p_i,p_j\right) = \frac{1}{n}\left[\frac{1}{m}\left\{\frac{p_i p_j}{2}M + p_i\left(1-p_j\right)M\right\} + \frac{m-1}{m}\left\{p_i p_j D + p_i\left(1-p_j\right)M\right\}\right] \\ + \frac{n-1}{n}p_i M - \alpha R(p_i), \quad i,j = 1,2;\;\; i \neq j\end{aligned} \tag{4}$$

Note that in this case when both the firms choose the same product but different processes and when both are successful, both the firms get patent, and so the market is duopoly. The first order conditions for solving optimal success probability are,

$$\begin{aligned}\frac{1}{n}\left[\frac{1}{m}\left\{\frac{p_j}{2}M + \left(1-p_j\right)M\right\} + \frac{m-1}{m}\left\{p_j D + \left(1-p_j\right)M\right\}\right] + \frac{n-1}{n}M \\ = \alpha R'(p_i), \quad i,j = 1,2;\;\; i \neq j\end{aligned} \tag{5}$$

Again, assuming symmetric equilibrium, $p_i = p_j = p$, the optimal p is solved from the following condition,

$$\varphi(p) \equiv M - \left(\frac{M-D}{n} - \frac{M-2D}{2mn}\right)p = \alpha R^{'}(p) \tag{6}$$

Again, $\varphi(p)$ is linear and downward sloping, with

$$\varphi(0) = M \quad \text{and} \quad \varphi(1) \equiv \frac{2m(n-1)+1}{2mn}M + \frac{(m-1)}{mn}D.$$

Moreover, the second order condition is satisfied. Hence we shall get from Eqn. (6) the unique solution of $p = \tilde{p}$.

2.3 Product vs. Process Patenting and R&D Incentives

Given (3) and (6), we are now in a position to state the main result of the paper.

Proposition 1: *Product patenting provides a larger R&D incentive to the innovators than process patenting*.

Proof: Consider Eqns. (3) and (6). We have $R'(p)$ rising and each of $\phi(p)$ and $\varphi(p)$ falling. Moreover, $\phi(0) = \varphi(0)$ and $\phi(p) > \varphi(p)\ \forall p > 0$. Therefore, we must have $\hat{p} > \tilde{p}$. This proves the proposition. QED

[FIGURE 1 HERE]

The above result is demonstrated in *Figure 1*. The intuition is the following. When the firms choose different products, it does not matter whether it is a product patent regime or a process patent regime. But when they come up with the same product innovation, under product patenting only one firm is granted the patent for the product and so it emerges as monopoly, but under process patenting both the firms can get the patent for the product if they have different processes of production. Thus process patenting leads to more competition whereas product patenting lessens product market competition.

2.4 Some Observations

We can make the following observations. *First*, the result underlying Proposition 1 does not depend on m, except that we need $m \geq 2$. Note that only $\tilde{p}$ depends on m, but $\hat{p}$ is independent of m. Now, as m increases, $\varphi(p)$ shifts down for any given $p > 0$, hence $\tilde{p}$ falls. The reason is that as m increases, chances of emerging as monopoly decreases, therefore incentives for innovation under process patenting fall.

Second, suppose n goes up, i.e., the number of conceivable products increases. From Eqn. (3) and (6) one can easily derive that $\frac{d\hat{p}}{dn} > 0$ and $\frac{d\tilde{p}}{dn} > 0$ i.e., R&D incentives under both product and process patenting go up. Geometrically, as n increases, both $\phi(p)$ and $\varphi(p)$ shift up resulting in an increase of both $\hat{p}$ and $\tilde{p}$. The intuition is simple. As n goes up, probability of choosing the same product by both the firms falls, hence there is less chance of infringing on the other's innovation. So each investor will be willing to spend a larger amount on innovation. Now given that both $\hat{p}$ and $\tilde{p}$ are increasing in n and that each of $\hat{p}$ and $\tilde{p}$ has an upper bound, hence as n becomes very large, distinction between product patenting and process patenting becomes blurred. This means, we have $\underset{n \to \propto}{Lt} (\hat{p} - \tilde{p}) = 0$. Geometrically, both the function $\phi(p)$ and $\varphi(p)$ tend to be horizontal and coincide.

Third, if all conceivable products are assumed to be substitutes, our result will remain unchanged. When the choices of products are different, there is as such no difference between product patent and process patent in our case. The reason is that if we assume these goods to be substitute to each other, the middle terms of the right hand side of Eqn. (1) and (4) will undergo a change, but in either case the middle terms will have the same expression.

Fourth, if α is lower, i.e., if R&D becomes easy, $\alpha R'(p)$ function in Figure 1 shifts down. Since both $\phi(p)$ and $\varphi(p)$ are downward sloping and $\alpha R'(p)$ is rising function, hence both $\tilde{p}$ and $\hat{p}$ will increase.

Fifth, in the model we have assumed quantity competition in the product market. Suppose that the firms compete in prices. One can then easily see that our results will go through. Under price competition with homogeneous goods we must have $D = 0$, and then again $\phi(p) > \varphi(p)\ \forall p > 0$.

Finally, in our structure, the firms have a lot to gain if the firms under consideration could cooperate and coordinate their product choices. Consider that each firm chooses a distinct product, say firm 1 chooses X and firm 2 chooses Y. Then each firm chooses p to maximize $pM - \alpha R(p)$. By choosing different products, each firm can generate monopoly profit with probability 1 (subject to successful innovation). Clearly, no firm has any incentive to mimic the other firm's choice. If it would do so, it would mean that there would be positive probability to compete, which would only reduce the payoff from M to D. In this equilibrium there is no difference between the two regimes of patent protection.

3. Consumers' Welfare

In this section we shall discuss the implication of product patenting vis-à-vis process patenting for the consumers. Those who favor process patenting often argue that product patenting will hurt the consumers by creating monopoly in different markets. This argument may however be contested because product patenting leads to higher investment in R&D. In our context we compare consumers' surplus under these two patent regimes.

Let s^m and s^d denote consumers' surplus in a market under monopoly and duopoly, respectively; therefore, $s^d > s^m$ due to existence of the usual deadweight loss. If p be the probability of success in equilibrium, then the expected consumers' surplus under product patenting is:

$$\hat{S} = \frac{1}{n}[1-(1-p)^2]s^m + \frac{n-1}{n}[2p^2 + 2p(1-p)]s^m = \frac{1}{n}p(2n-p)s^m \qquad (7)$$

Similarly, the expected consumers' surplus under process patenting is given by

$$\begin{aligned}\tilde{S} &= \frac{1}{n}\left[\frac{1}{m}\{1-(1-p)^2\}s^m + \frac{m-1}{m}\left\{p^2 s^d + 2p(1-p)s^m\right\}\right] \\ &\quad + \frac{n-1}{n}[2p^2 + 2p(1-p)]s^m \\ &= \frac{1}{n}p\left[\left\{\frac{2-p}{m} + 2\frac{m-1}{m}(1-p) + 2(n-1)\right\}s^m + \frac{m-1}{m}ps^d\right] \qquad (8)\end{aligned}$$

Now compare (7) and (8) for the same values of p. Since $s^d > s^m$, we must have $\tilde{S}(p) > \hat{S}(p)$, that is, for the same probability of success, process patenting generates larger consumers' surplus. In equilibrium we have already shown in Proposition 1 that $\hat{p} > \tilde{p}$. Moreover, from (7), $\frac{d\hat{S}}{dp} = 2\frac{s^m}{n}(n-p) > 0$; therefore $\hat{S}(\hat{p}) > \hat{S}(p)$ for $\hat{p} > p$. Hence, depending on the R&D function and other values we have the possibility that $\hat{S}(\hat{p}) > \tilde{S}(\tilde{p})$. To summarize, we can write the following proposition.

Proposition 2: *While product patenting always benefits the producers, consumers may also be benefited.*

Since product patenting provides a larger incentive for R&D, the firms will invest more in R&D under product patent than under process patent. This has a beneficial effect upon the consumers.

4. Conclusion

The new international patent rules have called for enforcing product patent across all countries. This has created a commotion among the developing countries which so far allowed only process patenting. Ultimately, the countries have signed the TRIPs agreement. It is argued that product patenting will encourage R&D, and therefore, all countries will benefit. This paper provides a framework to examine whether product patenting will generate a larger incentive to the innovators for doing R&D compared to process patenting. Since under process patenting all firms producing the same product, but with different processes, can get patent protection, process patenting will lead to more competition in the product market. Hence R&D investment will be less under process patenting. On the other hand, larger R&D investment enables larger or more innovations, hence consumers may gain in spite of having monopoly distortion in different markets due to product patenting. Finally, our paper has utilized the framework akin to drug industry; hence our results have implication for R&D issues in drug industry.

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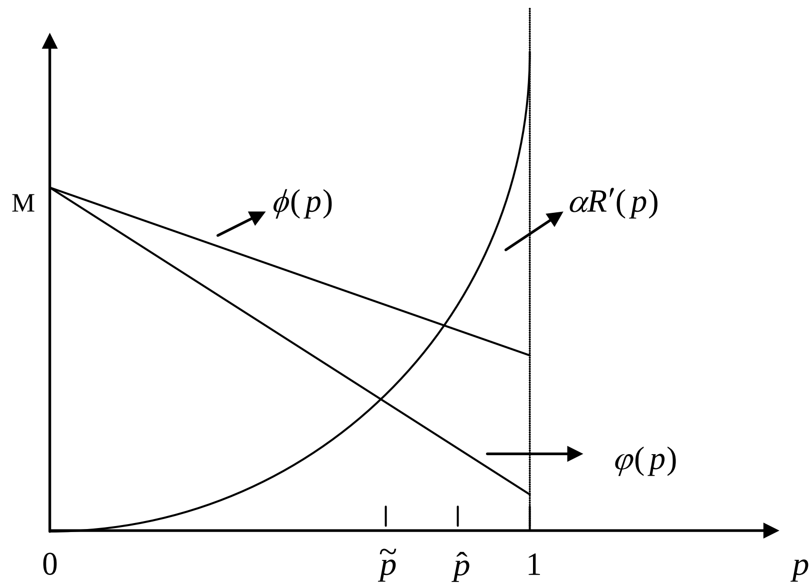

Figure 1: R&D incentives under two patent regimes