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Optimal Patent Length and Breadth
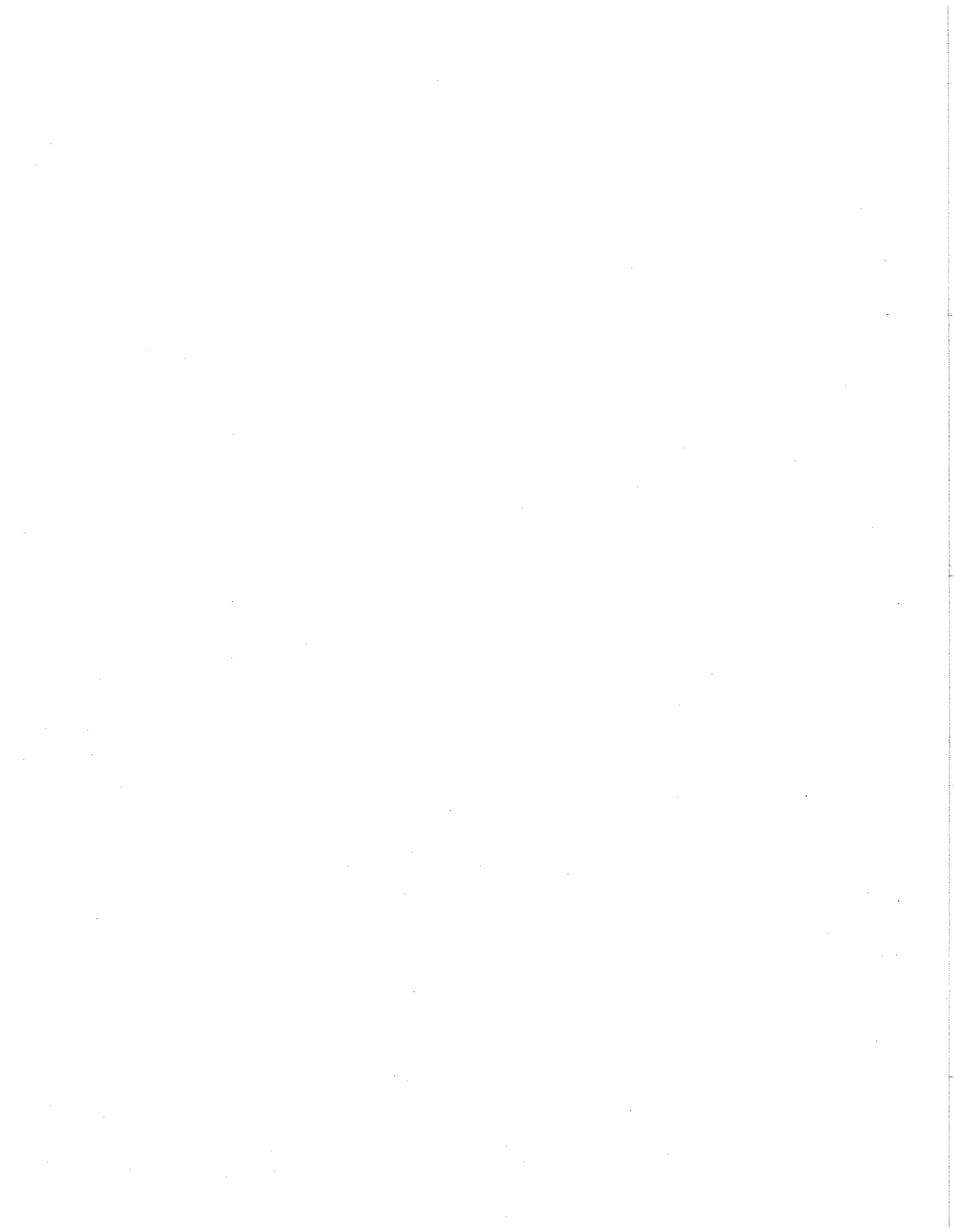
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Abstract

In providing rewards to innovators, there is a tradeoff between patent length and breadth. This paper provides quite general conditions under which the optimal patent policy involves infinitely-lived patents, with patent breadth adjusting to provide the required reward for innovation.

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Optimal Patent Length and Breadth

Richard Gilbert and Carl Shapiro

1. Introduction

The primary purpose of the patent system is to reward innovators. Unfortunately, because these rewards are based on the creation of market power, they necessitate some welfare loss. Much of the debate about patent policy had focused on this tradeoff between the dynamic benefits associated with innovation and the static costs of patent monopoly power. This debate has been cast in terms of the optimal lifetime for patents.[1]

Patent policy can be decomposed into two parts: first, a choice of how *much* to reward each patent, and second, how to *structure* each given reward. While the question of how much to reward patentees necessarily requires some estimate of the elasticity of supply of inventions, the efficient way in which to structure a reward of given size does not. It is this latter question that we address here. In particular, we examine the socially optimal mix between patent *length* and patent *breadth*, for a given size of the patentee's prize.

Our work suggests that the conventional analysis of optimal patent length, based on the tradeoff between the incentives for innovation and the extent of static monopoly deadweight loss, has been misplaced, or at least takes too limited a view of the instruments that make up "patent policy." When patent policy is viewed to be a choice of both patent breadth and patent length, we find that the optimal length is typically infinite. The appropriate margin on which patent policy should operate is not patent length, but rather patent breadth or scope.

By the "breadth" of a patent we mean the degree of protection afforded to the patentee during the lifetime of the grant. Any aspect of patent or antitrust law that assigns stronger property rights to the patent holder, thus permitting him to earn a higher flow of profits

[1] See, for example, Nordhaus (1969) and (1972) and Scherer (1972).

during the lifetime of the patent, we shall describe as *broader* patent protection. We shall discuss different examples of patent breadth below.

Recognizing that patent policy consists of determining patent breadth as well as length, we are led to the following policy question: What is the optimal mix between patent length and breadth as instruments to reward innovation? We show here that under rather general conditions the socially optimal way to reward patentees is to provide patents of infinite length. A special case of our general findings appears in Tandon (1982). He shows in an example using linear demand and constant marginal costs that optimal patent lifetimes are infinite when patent policy consists of a patent lifetime and a royalty rate for compulsory licensing.

Why are infinitely-lived patents optimal? Increasing the breadth of the patent typically is increasingly costly, in terms of deadweight loss, as the patentee's market power grows. When increasing the length of the patent, by contrast, there is a constant tradeoff between the additional reward to the patentee and the increment to deadweight loss, at least if the underlying environment is stationary. So, the socially cost-effective way to achieve a given reward to innovators is to have infinitely-lived patents with enough breadth to attain the required reward level.

2. The General Result

We study the socially cost-effective way in which to achieve any given reward, V, for an innovation. This cost-effectiveness problem is a necessary piece of optimal patent policy.

There are two instruments available to achieve the desired reward: the length of the patent and its breadth. The length is simply the lifetime of the patent grant, which we denote by T. Patent breadth is less straightforward, since "breadth" can mean many different things. We discuss different interpretations of patent breadth below. But any definition of breadth involves the idea that a broader patent allows the innovator to earn a higher flow rate of profits during the lifetime of the patent. So we begin with a reduced-form specification in which we simply identify breadth with the flow rate of profits, π, available to the patentee while the patent is in force.

Optimal patent policy consists of choosing T and π to maximize social welfare, W, which equals the sum of consumer surplus and profits, subject to achieving the given

reward V for the patentee. The key tradeoff is that between social welfare and profits, $W(\pi)$ on a flow basis. The assumption that $W'(\pi) < 0$ reflects the idea that broader patents confer greater market power and associated deadweight loss. Once the patent has expired, flow profits decline to $\bar{\pi}$ and flow social welfare rises to $\bar{W}$.

Assuming a stationary environment, discounted social welfare is given by

$$\Omega(T,\pi) = \int_0^T W(\pi)e^{-rt}dt + \int_T^\infty \bar{W}e^{-rt}dt,$$

and the present value of the patentee's profits are

$$V(T,\pi) = \int_0^T \pi e^{-rt}dt + \int_T^\infty \bar{\pi}e^{-rt}dt.$$

The optimal mix between length and breadth involves maximizing $\Omega(T,\pi)$ subject to $V(T,\pi) \geq V$. Our main result is

Proposition 1. *Suppose that $W''(\pi) < 0$, i.e., patent breadth is increasingly costly in terms of deadweight loss. Then optimal patent policy calls for infinitely-lived patents.*

Proof. Define $\phi(T)$ as the flow of profits required in order to achieve a total reward to the patentee of V if the lifetime of the patent is T. By definition,

$$V \equiv \int_0^T \phi(T)e^{-rt}dt + \int_T^\infty \bar{\pi}e^{-rt}dt = \phi(T)\frac{1-e^{-rT}}{r} + \bar{\pi}\frac{e^{-rT}}{r}. \tag{1}$$

Differentiating (1) with respect to T gives

$$0 = (\phi(T) - \bar{\pi})e^{-rT} + \phi'(T)\frac{1-e^{-rT}}{r}. \tag{2}$$

Now consider the total welfare that is achieved if the patent lifetime is set at T and the breadth of the patent at $\phi(T)$. Total welfare is $\Omega(T,\phi(T))$. Differentiating with respect to T we have

$$\frac{d\Omega}{dT} = \frac{\partial \Omega}{\partial T} + \frac{\partial \Omega}{\partial \pi}\phi'(T).$$

Since $\partial\Omega/\partial T = (W(\pi) - \bar{W})e^{-rT}$ and $\partial\Omega/\partial\pi = W'(\pi)(1-e^{-rT})/r$, we have

$$\frac{d\Omega}{dT} = (W(\phi(T)) - \bar{W})e^{-rT} + W'(\phi(T))\frac{1-e^{-rT}}{r}\phi'(T).$$

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Substituting from (2) for $\phi'(T)$ gives

$$\frac{d\Omega}{dT} = (W(\phi(T)) - \bar{W})e^{-rT} - (\phi(T) - \bar{\pi})W'(\phi(T))e^{-rT}.$$

If $W'' < 0$, then

$$-W'(\phi(T)) > \frac{\bar{W} - W(\phi(T))}{\phi(T) - \bar{\pi}}.$$

Hence $\dfrac{d\Omega}{dT} > 0$ as required. Increasing T always raises welfare, so an infinitely-lived patent is optimal. ∎

The key condition for Proposition 1 is that increasing the patentee's rewards on a flow basis is increasingly costly in terms of social welfare, *i.e.*, $W''(\pi) < 0$. We next explore conditions under which this condition is met, looking more closely at the meaning of the patent breadth variable.

3. Optimal Patent and Antitrust Policy

We analyze here optimal patent policy for a particular interpretation of patent breadth: when patent breadth corresponds to the ability of the patentee to raise the price for the single product that embodies its innovation. Another important aspect of patent breadth is the size of the region in product space that is protected from infringement. This type of breadth has been analyzed in independent work by Klemperer (1988) who emphasizes substitution between the patentee's products and similar, unpatented products. He too finds that there typically is no interior optimal to the optimal patent "shape" problem.

Both patent and antitrust policies can constrain the patentee to set a price that is less than the monopoly price. First, imitation of the innovation may permit rivals to produce competing products, in which case these rivals' cost of production serves as an upper bound for the price the patentee can set and earn sales. Greater protection from infringement — greater patent breadth — therefore makes a higher price feasible. Second, attempts by the patentee to set price above some level may require practices (such as price-restricted licenses) that will call forth antitrust suits, either from private parties or from the government. Finally, the patentee may be subject to compulsory licensing at "reasonable fees" which again imposes a price ceiling. In all of these cases, patent breadth

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translates into a maximum price the patentee can charge, or, equivalently, a minimum quantity he must sell.

Consider a process or product innovation for which the (inverse) demand is given by $p(x)$. Welfare is $w(x) = B(x) - C(x)$, where $B(x) \equiv \int_0^x p(z)dz$ is the total benefit function and $C(x)$ is the patentee's cost function. Profits are $\varphi(x) = xp(x) - C(x)$. Call x_m the monopoly output and x^* the welfare-maximizing output. In the relevant range, $x_m < x < x^*$, $\varphi'(x) < 0$ and $w'(x) > 0$. Define $g(\pi)$ as the inverse function of $\varphi(x)$, i.e., $\varphi(g(\pi)) \equiv \pi$. Then $W(\pi) = w(g(\pi))$.

Proposition 2. *If profits and welfare are both concave in output, then welfare is concave in the patentee's profits, so the optimal patent lifetime is infinite.*

Proof. Taking derivatives of $W'(\pi)$ twice, we have

$$W''(\pi) = w'g'' + w''(g')^2. \tag{3}$$

Since $w' > 0$ and $w'' < 0$, $W''(\pi) < 0$ if $g'' < 0$. But $g'(\pi) = 1/\varphi'(g(\pi))$, so

$$g''(\pi) = -\frac{\varphi''(g(\pi))g'(\pi)}{\varphi'(g(\pi))^2}.$$

With $\varphi'' < 0$, and since $g' < 0$ in the relevant range, we indeed have $g'' < 0$. ∎

Remark. *The conditions of Proposition 2 are met if the demand and marginal revenue curves slope down and the marginal cost curve slopes up. But even weaker conditions will suffice to establish the concavity of welfare in the patentee's profits. Suppose that marginal costs do not decrease with output, $c'' \geq 0$. Define $\epsilon \equiv -p(x)/xp'(x)$ as the elasticity of demand and let θ be the elasticity of ϵ with respect to price. Then direct calculations demonstrate that $W''(\pi) < 0$ if $\theta > -(1-m)/m$ where $m \equiv (p - c')/p$ is the markup. If the elasticity of demand is constant or increasing in price, this condition is surely met.*

Even if the weak conditions of Proposition 2 or the preceding remark are not met, we still know that infinite lifetimes are optimal for "small" patents:

Proposition 3. *For prices sufficiently close to marginal cost, welfare is concave in the patentee's profits. Therefore, for small values of the patentee's reward, V, the optimal policy involves an infinitely-lived patent.*

Proof. Since welfare is maximized when price equals marginal cost, *i.e.*, when $x = x^*$, we know that $w'(x^*) = 0$ and $w''(x^*) < 0$. For prices close to marginal cost, w' is close to zero and w'' is still negative. Therefore, from equation (3), $W'' < 0$ at such prices.

Consider any candidate optimum policy with a finite lifetime, $(\hat{\pi}, \hat{T})$. If $W''(\hat{\pi}) < 0$ then we know from the proof of Proposition 1 that a slight decrease in π, with the necessary increase in T to leave V unchanged, will increase welfare. If $(\hat{\pi}, \hat{T})$ is to be an optimum, we must therefore have $W''(\hat{\pi}) > 0$, in which case a marginal increase in T would in fact lower welfare.

For small values of V, however, we can always find a *non-marginal* change that raises welfare. Refer to Figure 1. From the properties we have established for the $W(\pi)$ function, we know there must exist a $\tilde{\pi} < \hat{\pi}$ with the following two properties: (a) the ratio of flow deadweight loss to flow profits is the same at $\tilde{\pi}$ as at $\hat{\pi}$, and (b) $W(\pi)$ is concave on the interval $(\tilde{\pi}, \hat{\pi})$. Now consider the alternative policy of allowing a flow of profits $\tilde{\pi}$ over a long enough time period to give a total reward of V. For V small enough, this is always possible, since the flow rate of profits need only be rV. Since this new policy has the same ratio of deadweight loss to "excess profits" $(\pi - \tilde{\pi})$ as does the candidate optimum, and the total excess profits are the same, the total deadweight loss must also be equal. In other words, the new policy is just as good as the candidate optimum. But the new policy can be improved upon with a marginal change to reduce flow profits and increase patent length, since $W''(\tilde{\pi}) < 0$. We can conclude that the original candidate optimum was not in fact optimal. ∎

The optimal policy for small values of V calls for $T = \infty$ and $\pi = rV$. With price close to marginal cost, the deadweight loss is proportional to $(p - c')^2$, so the ratio of deadweight loss to patentee profits approaches zero as V does so. This is a local version of our general theme, that the social costs of patent prizes are minimized by keeping prices as close as possible to marginal cost, *i.e.*, with narrow but lengthy patents.

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Propositions 2 and 3 suggest to us that when we consider several instruments of optimal patent policy, *e.g.*, the scope of protection from imitation as well as the length of the patent grant, then quite generally optimal policy calls for infinitely lived patents. In this sense, previous emphasis on the optimal length of patents seems misplaced. If one takes a broader view of patent policy, either to include protection from imitation or to include antitrust treatment of intellectual property, the policy margin of patent length is not a useful one on which to operate.

The optimality of infinitely-lived patents carries over to a patentee offering a range of products relying on the same patent. In this case the optimal policy involves infinitely-lived patents along with Ramsey pricing, since Ramsey pricing is the (static) solution to the problem of achieving a given profit level at least social cost. In the case of products with independent demands, the constant of proportionality between the markup of the each good and its elasticity of demand is an increasing function of the overall required profit level, V.

4. Conclusions

This short paper reports a simple but general result in the design of optimal patent policy. If one interprets patent policy broadly enough to include at least one policy instrument that affects the flow of profits from the sale of the patented product, then optimal policy quite generally calls for infinitely-lived patents.

Given the overall level of rewards to innovators, our analysis suggests that appropriate treatment of intellectual property calls for longer patent lives combined with narrower protection from patent infringement or more careful antitrust treatment of patent practices such as the provisions of licensing contracts. Of course, if the current level of rewards to innovators are viewed to be inadequate, then it may be appropriate to give stronger protection from infringement even as patent lifetimes are extended. Our point is that longer patent lifetimes are optimal, whatever one believes about the overall level of rewards to innovators.

On the other hand, we must express a warning about the policy-relevance of our finding here. The most important limitation in our analysis is its focus on a single innovation.

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In practice, inventions build on each other, and a long patent grant may have deleterious effects on the incentives of other firms to engage in related research, for fear that they will always be at the mercy of the original patentee. What would have happened in telecommunications, for example, if the telephone were still patented?[2]

In particular, there appears to be a danger that an overly-long patent would retard subsequent innovation by establishing monopoly rights to an entire line of research. If this is the case, the tradeoff between deadweight loss and profits at the margin would no longer be constant as the patent lifetime increases. Rather, there might be increasing social costs in comparison to patentee profits as the patent grant is extended in time. Further modeling of markets with a sequence of related innovations will be required to characterize optimal patent policy in such settings.

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[2] It would appear that the efficacy of licensing arrangements will be important in evaluating long-lived patents in the context of ongoing technological progress. Note also that defining infringement and enforcing the patent may become more costly over time. This too would be a force favoring finite patent lifetimes.

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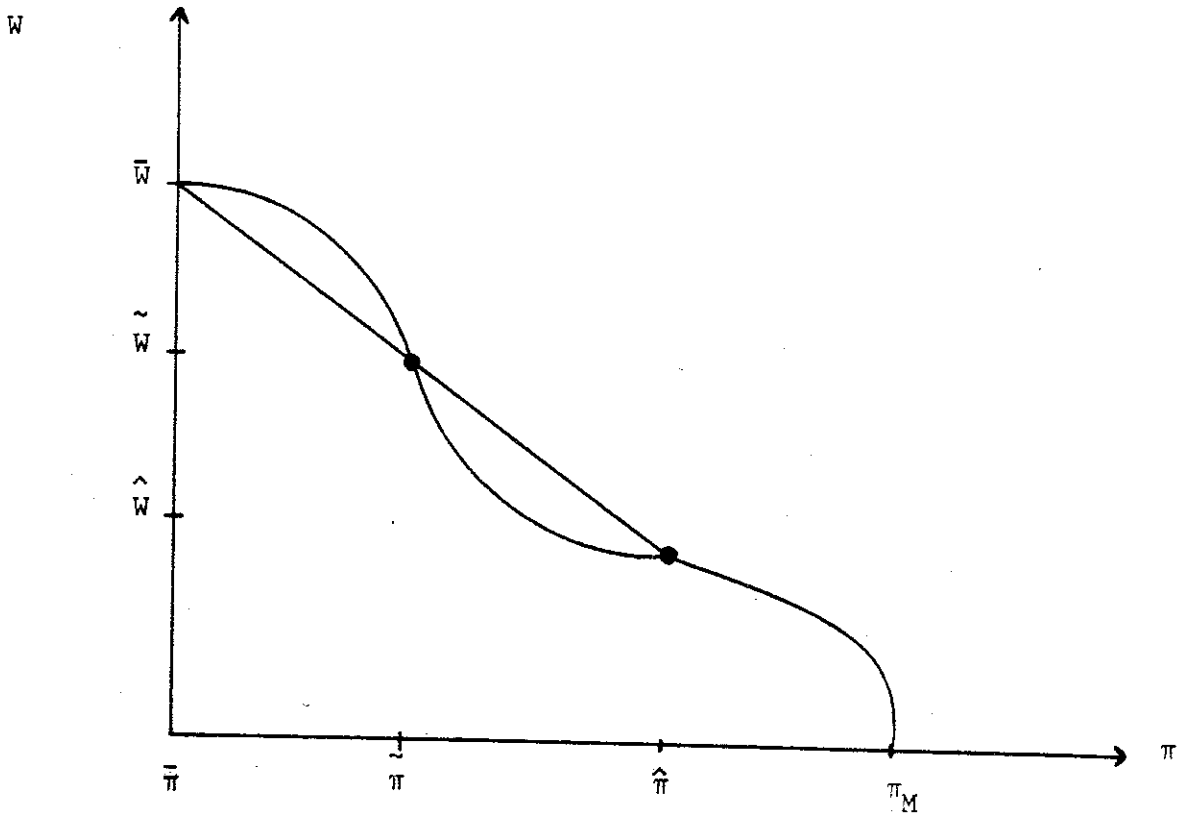Tandon, Pankaj (1982) "Optimal Patents with Compulsory Licensing," *Journal of Political Economy*, **90**, 470–486.

Figure 1

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