The Optimum Life of a Patent: Reply

By William D. Nordhaus*

In his geometric discussion of the economics of patents F. M. Scherer has clarified many of the results and pointed to some problems. His discussion is confined to the "pure" theory. I wish in this reply to point out some problems with the pure theory and suggest that the implications are rather different from those drawn in Scherer's article.

I. The "Pure" Theory of Patents

The pure case of invention, royalty, and patenting in my work and in Scherer's exposition is based on the following assumptions:

1. The supply of inventors (or inventing firms) is perfectly inelastic. Inventors choose the level of inputs to maximize discounted profits.
2. Inventions are "small" (or "run-of-the-mill") process inventions.
3. There is no uncertainty, and the social rate of discount is equal to the private discount rate.
4. Patents confer complete protection over the invention.
5. There is no technological change, cost reduction, or competitive patenting.
6. The product and factor markets are competitive.

Under these assumptions it can be shown that the optimal life of a patent (T) is given by the solution to the following pair of equations:[1]

$$\phi = \frac{1 + \eta B}{1 + \eta B(1 + k)} \tag{1}$$

$$B'(R)\phi = rs \tag{2}$$

where

η = price elasticity of demand
R = level of inventive inputs
$B = B(R)$ = percentage cost reduction of new process
r = private and social discount rate
s = price of R
$\phi = 1 - \exp(-r\mathrm{T})$
T = optimal life of patent
$k = -B''(R)B(R)/2\,[B'(R)]^2$

Using the best estimates I could obtain for the parameters, I reached the following conclusions:

First, once a life of six or ten years has been reached, the level of welfare generated by the patent system is very insensitive to the life of the patent.[2]

Second, for small inventions, with percentage cost reduction less than 5 percent, the monopoly losses associated with the patent system are small (less than one-fifth of the gains from invention).[3]

Third, there does not seem to be a strong case for major changes in the life of patents. The only suggestion is that for relatively easy inventions, the life may be too long.[4]

II. Imperfections in the Market for Information

In my view, the results of Section I are highly suspect unless it can be shown that assumptions 1 to 6 above are either realistic or unimportant simplifications.[5] We now turn to a discussion of these assumptions.

1. The problem of the supply of invention has been raised by Scherer. He has pointed out—quite correctly—that the pure case assumes that profits are positive at the optimal life, which may not be the case. If

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Some, but not all, of the comments made by F. M. Scherer on an earlier draft were heeded. Remaining problems are the author's responsibility.

[1] See Nordhaus (1969), equations 5.4 and 5.13.

[2] See Nordhaus (1969), Tables 5.2 and 5.3.

[3] See Nordhaus (1969), Table 5.4.

[4] See Nordhaus (1969), Table 5.1.

[5] Some of these problems are discussed in Nordhaus (1969) and (1967).

profits are negative, it is natural to assume the inventor will leave the field.

In fact, the analysis of this possibility is straightforward. We can go through the same analysis for the "total" (or Scherer's "Lebensraum") effect as well as the marginal. For this we replace (2) with the profits constraint:

$$V = B(R)\phi - rsR \geqq 0 \tag{3}$$

where V is discounted profits. We thus use the "marginal" (or Scherer's stimulus) solution, (1) and (2), if the solution gives $V \geqq 0$. If the "stimulus" solution gives negative profits, we use the Lebensraum solution:

$$\frac{RB'(R)}{B(R)} \geqq 1 \tag{4}$$

The condition is that the optimum comes when the elasticity of B (the "Invention Possibility Function") with respect to R is greater than unity. This is the positive profit condition. Equation (4) is easily seen to be the implied optimum in Scherer's Figure 4(c) and can be shown rigorously.

The empirical question raised by Scherer is whether using the stimulus solution is likely to give a seriously biased estimate of optimal life. He implies that the rectangular or stair-step *IPF* is more realistic than the smooth substitution case, and we should thus focus on the Lebensraum solution. I have always assumed that diminishing returns hit the inventor with less vengeance than the stair-step case, but, to my knowledge, there is no firm evidence on the degree of curvature of the *IPF*.

2. The pure case refers only to small process inventions. For "drastic" inventions and process inventions,[6] the inventor can recover a smaller fraction of the gains from invention since the royalty is less than the cost reduction. Given other parameters, then, the optimal life is longer for drastic and product inventions.

3. The model outlined above assumes that the inventor's discount rate is equal to the social discount rate. It is more plausible to assume that inventors are risk averse and require a risk premium on invention. Let r^* be the required rate of return on invention and r the social discount rate (where $r^*/r > 1$). It can them be shown that the equations above are replaced by

$$\phi = \frac{1 + \eta B}{r/r^* + \eta B(1 + k)} \tag{5}$$

$$B'(R)\phi = rs\left(\frac{r^*}{r}\right) \tag{6}$$

It is easily verified that as r^*/r rises (that is as the risk discount rises) the optimal life rises while the equilibrium level of invention may go up or down.

4. We have so far assumed that a patent confers complete protection and gives a complete reward to the inventor. A casual glance at the history of technology suggests that many inventions lead to significant further invention which is generally unprotected by the original patent. In the United States, laws of nature are, by statute, excluded from patent coverage. In these examples, the private reward to invention is diminished by the "narrow" coverage of U.S. patent laws.

An important question for patent policy, therefore, is the extent of "breadth" of coverage of patent laws. Let us denote the breadth parameter, θ. If the invention lowers cost from c_0 to c_1, we assume that after the invention the proportion $1-\theta$ spills out as freely available technology, giving the competitive cost (that is, the cost of the competitive, freely available process, c^* as $c^* = c_1 + \theta(c_0 - c_1)$. If there is zero breadth (as in laws of nature), then $\theta = 0$ and $c^* = c_1$, while for complete protection $\theta = 1$ and $c^* = c_0$. Working through our system we find that the optimal life and breadth are given by

$$\theta\phi = \frac{\eta B + 1}{\eta B(1 + k) + 1} \tag{7}$$

$$\theta\phi B'(R) = sr \tag{8}$$

[6] Drastic inventions are those for which $B\eta > 1$, where η is the point elasticity of demand at the original price. Process inventions are those for which there was no output before the invention.

We thus find that life and breadth go hand in hand. The solution to the system is exactly the same for the composite parameter $\theta\phi$ as it was for the life parameter ϕ when breadth was complete. Thus if breadth is reduced (because giving complete protection is undesirable or impractical) the optimal life must increase to compensate.

5. We have assumed that patenting takes place in a stationary economy, with no general cost reduction or competition from other new inventions. A more realistic assumption would be that the competitive costs decline continuously over the life of the patent. In this case it is clear that the optimal life of the patent is less than the economic life; this allows the government to recoup some of the deadweight loss in the last years of the economic life of the invention. Aside from this point the effect of a progressive economy on patent policy is not clear.

6. The final and perhaps most important problem is the introduction of imperfect competition in the product market. We assume firms try to maximize profits.

In the case of a natural or regulated monopoly—with no threat to entry—patents and the length of patent life are irrelevant. The inventing firm can capture the entire proceeds whether or not a patent has been conferred.

In the more pervasive case of a few large firms and significant barriers to new entry, there is no obvious way of solving the general problem. We can simplify the analysis by assuming that firms do not license inventions to their competitors.[7] In this situation the economic effect of invention will depend on the price response. The inventing firm can keep prices unchanged (as would happen in the run-of-the-mill inventions analyzed above). The social losses and benefits are then exactly those which occur if we treat the firm as an industry. The optimal life is exactly the same as given above. The function of the patent grant is simply to protect the firm against imitation.

A more likely case is that the firm will lower its price by a fraction of the cost saving in order to increase its market share. Whether it succeeds in increasing its share or not, there will be a gain to the economy during the life of the patent over and above the private gain of the firm. If the firm succeeds in increasing its market share, the resulting output will be produced at lower cost, increasing the average efficiency in the industry. On the other hand, if the competing firms respond to the inventing firm by lowering price, this will squeeze some deadweight monopoly loss out of the system and increase efficiency. In either case, some of the rewards will be passed on to consumers immediately. As in the case of product or drastic inventions, this implies optimal life should be slightly higher for these inventions (other parameters unchanged).[8]

It is puzzling that these conclusions contradict the wisdom of most students of both invention and industrial organization. The reason is probably that many inventions which are patented are so trivial as to be worthy of no patent protection at all. But this is an objection to patent protection for trivial patents, not an argument for less protection for oligopolistic industries.

III. Conclusions

The theory outlined above is oversimplified but suggestive. Taking account of all the problems, the following conclusions seem to be justified.

First, a fixed patent life is not optimal in theory, although it may be unavoidable in practice. If we are to err on one side, the analysis suggests too long a patent life is better than too short a patent life. For run-of-the-mill inventions, the losses from monopoly are small compared to the gains from invention. The best way to prevent abuse is

[7] There is some fragmentary evidence that licensing of inventions is an unimportant source of revenue from inventions. See Nordhaus (1969), p. 40, fn. 19.

[8] We have assumed that no competitive, or imitative invention occurs. If it does (say because the legal "breadth" of a patent is narrow), then we can apply the conclusions in point 3 above.

to ensure that trivial inventions do not receive patents.

Second, the complications arising from risk, drastic inventions, imperfect product markets, and "inventing around" patents generally point to a longer rather than shorter patent life.

Third, the argument for compulsory licensing without government subsidy is inconsistent with the model of invention used here. Since licensing is feasible in the absence of compulsory licensing, it cannot (in this model) increase the profits from invention and must therefore lower the level of invention. This will be desirable if and only if the optimal life is less than the actual life (and conversely).

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