

A note on innovation and patent protection: Intertemporal imitation-risk smoothing

Walter G. Park*

Department of Economics, The American University, 4400 Massachusetts Ave., NW Washington, DC 20016, USA

Received 6 September 1996; accepted 19 November 1996

Abstract

In the presence of imitation risks, a value-maximizing firm intertemporally smooths those risks across current and future new technologies. Thus changes in patent protection levels can affect the timing of innovation by affecting an agent's motive for imitation-risk smoothing.

Keywords: Patents; Innovation; Imitation; Intertemporal choice

JEL classification: O31

1. Introduction

Much has been mentioned about the market power effect of patent protection. Studies on the role of intellectual property rights (IPRs) show the market power effects of patents to limit the benefits of IPRs on trade and growth. Maskus and Penubarti (1995), for example, argue that IPRs have two opposing effects on trade—a *market enhancement effect* and a *market power effect*—and determine which effect dominates empirically. In their study of IPRs and growth, Gould and Gruben (1996, p. 346) argue that 'in highly protected, uncompetitive markets, agents are unlikely to innovate much themselves, perhaps preferring to ... preserve their market share.'¹ Thus, one drawback of strengthening patent protection is that it may prolong the status quo technology.

While these thoughts about the market power effects of IPRs are valid, they do need to be qualified. Whether it is optimal to preserve markets for existing technology depends on whether the agent cannot do better by innovating. In other words, in an intertemporal context, a firm enjoying patent protection weighs the benefits of using its existing (protected) technology versus innovating to bring in a new technology (which may displace the status quo technology). With this in mind, the analysis

*Tel.: +1 202 885 3774; fax: +1 202 885 3790; e-mail: wgp@american.edu

¹See also Magee et al. (1989).

below illustrates another motive² determining the timing of innovations. Here, the firm intertemporally smooths the risk of imitation between current and future technologies by its choice of date of innovation. A change in the strength of patent protection alters the hazard of imitation, and depending on how this affects the market power of current and future technology, innovation can be encouraged or discouraged.

2. Analysis

Consider the following decision-theoretic framework. The representative firm's value is:

$$V = \int_0^T e^{-rt} \{ [1 - F(t)] \pi_M + F(t) \pi_O \} dt + \int_T^\infty e^{-rt} \{ [1 - F(t - T)] \pi'_M + F(t - T) \pi'_O \} dt - R(T) \quad (1)$$

where F is the (cumulative) probability at time zero that some rival(s) will have imitated by time t , and R the research and development cost function. Once imitation has occurred, the firm's instantaneous flow of profits falls from the monopoly amount π_M to the oligopoly amount π_O —hence $[1 - F(t) \pi_M + F(t) \pi_O]$ is the *expected* instantaneous profit flow. π'_M and π'_O are the post-innovation profit flows. F is specialized to be the exponential distribution (i.e. $F(t) = 1 - e^{-ht}$, where $h \geq 0$ is the hazard rate of imitation).

It is assumed that with stronger patent protection, the hazard rate is lower than it would otherwise be, but it need not be zero unless laws are enforced perfectly and no imitator has the ability to circumvent patent restrictions. In addition, several other assumptions are made.

1. Innovation leads to a greater flow of profits: $\pi'_M > \pi_M$ and $\pi'_O > \pi_O$. Thus even if both current and future new technologies are imitated, the firm still has an incentive to innovate in order to capture the higher oligopoly profits.
2. Dates of invention and innovation, T , coincide. There are no 'sleeping patents'.
3. Oligopoly profits π_O (and π'_O) are independent of the hazard rate, h , though more realistically they should depend on h . As h increases, the flow of profits approaches the competitive amount. This, however, is quite an innocuous assumption, and does not affect the main result.
4. $R' < 0$ and $R'' > 0$. These assumptions reflect the 'time-cost' tradeoff associated with research and development projects. There are costs to innovating too soon. Overtime use of resources (which face decreasing returns), parallel projects in order to do more experiments simultaneously (which could otherwise be done sequentially were the targeted date of innovation postponed), and less opportunity for learning, all work to make it more expensive to complete a project earlier. However, there are diminishing returns to waiting too long to innovate. This would occur if the invention's potential faces diminishing returns to further R&D investments. For example, researchers *learn by doing* the project; but further learning over time does not necessarily improve

²In addition, that is, to the time-cost motive studied in the literature. See, for example, Kamien and Schwartz (1982) and Scherer and Ross (1990).

the quality of the invention much more. Another cost to waiting too long, of course, is that the firm forgoes the higher profit flows associated with the innovation.

5. In the above problem, the firm invents only once (innovation is not ongoing).
6. The innovation is assumed to displace the previous or existing technology.
7. The hazard rate of imitation, h , is the same for the innovation as it is for the existing technology.

The last three assumptions are relaxed later. For now, let T^* be the optimal date of innovation. That is $V'(T^*)=0$ and $V''(T^*)<0$. To see how changes in patent protection levels affect T^* , the following examines how changes in the hazard rate affect the first-order condition $V'(T^*)$. Since $\partial V'/\partial h = -V''\partial T/\partial h$, and assuming the second-order condition holds, it is the case that

$$\text{sgn } \partial T/\partial h = \text{sgn } \partial V'/\partial h$$

Now $\partial V'/\partial h \geq 0$ (or <0) according to

$$\frac{r}{(r+h)^2}(\pi'_M - \pi'_O) \cong Te^{-hT}(\pi_M - \pi_O) \quad (2)$$

Underlying the optimal choice of T (the innovation date) are two motives: on the one hand (under $h=0$), there is the conventional time-cost tradeoff for determining T^* . On the other hand, for $h>0$, the innovator desires to *smooth the risk* of imitation intertemporally. Changes in imitation risk affect both the profitability of the existing technology and the profitability of the future new technology. The value-maximizing firm would want to balance the risks intertemporally so as to maximize the (total) earnings stream from both technologies (new and existing).

To understand the ‘intertemporal efficiency’ condition Eq. (2) better, note first that $-(\pi'_M - \pi'_O)$ and $-(\pi_M - \pi_O)$ represent the ‘loss’ in instantaneous profits due to imitation. Once a firm’s technology is imitated, the firm forgoes monopoly earnings. The LHS of Eq. (2) is thus the firm’s *present* discounted value of monopoly gains forgone if the *future* new technology were imitated; the RHS of Eq. (2) is the present discounted value of the monopoly gains forgone if the *current* technology were imitated. As the hazard rate, h , increases permanently, on the one hand the firm gets to enjoy less profit from the current technology and on the other hand it gets to enjoy less profit from the future new technology.

The question is which loss is greater. If the $\text{LHS} > \text{RHS}$, the expected loss to future imitation is greater than the expected loss to current imitation. Hence it is optimal for the firm to postpone the date of innovation. This allows the firm to enjoy the profit stream from the current technology longer and delay the hazard of imitation of the future new technology, for recall that the hazard rate of imitation of the future new technology is $F(t-T)$. Thus, too early a T results in a greater risk of the future new technology’s being imitated during the life of the firm; hence, postponing the date of innovation diminishes the lifetime hazard of imitation of the future innovation. In this way, the firm can maximize the value due to both technologies (current and new). Thus, when the $\text{LHS} > \text{RHS}$, $\partial T/\partial h > 0$. If, on the other hand, the $\text{LHS} < \text{RHS}$, then $\partial T/\partial h < 0$ and a higher hazard rate (i.e. weaker patent protection) causes greater expected losses to the current technology vis-à-vis the new. The firm is induced to switch more quickly to the new technology by innovating sooner. Likewise, if the $\text{LHS} < \text{RHS}$, stronger patent protection causes the optimal T^* to increase, and the firm hangs on to its existing technology longer.

The question thus is whether the LHS or RHS of Eq. (2) is likely to be larger, and under what conditions. Differentiating both sides of Eq. (2) with respect to h , and evaluating it at the point where the LHS=RHS (that is, at the point where $\partial T/\partial h=0$), it is seen that $\partial \text{LHS}/\partial h > \partial \text{RHS}/\partial h$ if $T^* > 2/(r+h)$. In this case, T^* is concave upwards with respect to h . This relationship arises if post-innovation profits are significantly large.³ In this situation, decreasing the hazard rate from some positive rate towards zero (or increasing patent protection) initially stimulates innovation (i.e. encourages firms to switch out of the existing technology to the new) but eventually discourages innovation when h gets very small (or when stronger patent protection significantly raises the market power of the existing technology).

For minor innovations, however, raising the hazard rate away from zero delays innovation since imitation of the future innovation would drastically lower its profitability. But if the hazard rate is already quite high, raising the hazard rate leads to greater expected losses from the imitation of the current technology, and thus encourages innovation to occur sooner.

To summarize, imitation risk, h , affects the timing of innovation, T , given the agent's desire to smooth that risk intertemporally between current and new technologies. The relationship between T and h (for determining whether T rises or falls as h changes) is nonlinear. For large (small) innovations, this relationship is concave upwards (downwards). Before concluding, some simple extensions to the above framework are considered.

2.1. Sequence of innovations

Here, the representative firm optimally chooses dates of innovation $(T_1, T_2, \dots, T_J, \dots)$ to maximize

$$V = \left(\int_0^{T_1} e^{-rt} \pi_1^e dt + \int_{T_1}^{T_2} e^{-rt} \pi_2^e dt + \dots + \int_{T_J}^{\infty} e^{-rt} \pi_J^e dt - R(T_1) \dots - R(T_J) - \dots \right)$$

where $\pi_j^e = [1 - F(t - T_j)]\pi_{jM} + F(t - T_j)\pi_{jO}$, and $j = 1, \dots, J$ technologies. While the analysis gets more complex, essentially the same principle applies. In addition to the time-cost motive for selecting innovation intervals, the firm must also spread the risks of imitation over time across all the technologies (existing and new). To the extent that a future invention is expected to suffer the most losses from imitation, the firm can either delay its introduction or innovate the next generation level sooner.

2.2. Asymmetric hazard rates

Suppose the hazard rate of the future new technology differs from that of the earlier technology. This could be the case if the more sophisticated technology is harder to imitate. In this case, if tighter

³To see this, evaluate V' when $h=0$. The optimal date T^* solves $rT^* = \ln[(\pi_M' - \pi_M)/R']$. Now rT^* would exceed 2 if the gap between post-innovation and pre-innovation profits per R&D cost savings were large enough (as it should be for major and/or high quality inventions). Thus, if $T^* > 2/r$, it is also the case that $T^* > 2/(r+h)$ for $h > 0$. Hence, for significant innovations, T^* is concave upwards in h .

patent protection lowers the hazard rate of the current technology only, the profitability of the current technology is higher. This encourages the firm to postpone innovation in order to enjoy the current technology longer. Hence $\partial T/\partial h < 0$.

2.3. New technology does not displace existing technology

In this case, the choice of timing of innovation, T , involves no tradeoff between the profitability of the current technology and that of the future new technology. There is therefore no need to smooth the imitation risks between them. Hence, a lower hazard rate of imitation here would make the future new technology more profitable, hence innovation would occur sooner. Thus $\partial T/\partial h > 0$.

3. Conclusion

This paper discussed an intertemporal imitation-risk smoothing motive for determining the timing of innovation. These intertemporal considerations indicate that the market power effect of patents applies not just to contemporaneously existing technologies but also to future (potential) technologies. Hence, whether or not agents will want to preserve the market for existing technologies is more complex.

Except in cases where the hazard rates differ between the new and old technologies, or where the new technology does not displace the existing technology, changes in the hazard rate of imitation have ambiguous effects on the timing of innovations. It is likely though, for major innovations, that stronger patent protection spurs innovation when patent regimes are relatively weak, but eventually delays innovation when patent regimes become too strong. In the latter case, firms would prefer to hold on to existing technologies longer.

Acknowledgments

I am grateful to Philip Auerswald for helpful comments and criticisms.

References

- Gould, D.M. and W.C. Gruben, 1996, The role of intellectual property rights in economic growth, *Journal of Development Economics* 48, 323–350.
- Kamien, M. and N. Schwartz, 1982, *Market structure and innovation* (Cambridge University Press, Cambridge, UK).
- Magee, S., W. Brock, and L. Young, 1989, *Black hole tariffs and endogenous policy theory: Political economy in general equilibrium* (Cambridge University Press, Cambridge, UK).
- Maskus, K. and M. Penubarti, 1995, How trade-related are intellectual property rights?, *Journal of International Economics* 39, 227–248.
- Scherer, F.M. and D. Ross, 1990, *Industrial market structure and economic performance* (Houghton Mifflin, Boston, MA).