To License or Not: The Case of a New Information Technology Product

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Abstract

A firm with a new Information Technology (IT) product may consider licensing it to firms in the same industry or other industries. The impact of the new product on the operating costs of the firms is usually uncertain. The costs may increase or decrease as a result of the new product. Once the new IT product is used for some time, however, firms come to know the actual cost impact. We develop a duopoly two-period model with one firm owning a new IT product. We consider two licensing options: (1) one-time licensing for both periods at the beginning of the first period, (2) period-by-period licensing. With the first option, no licensing occurs for very low and very high expected values of cost reduction; otherwise, licensing may occur. For high expected values of cost reduction, the licensor prefers period-by-period licensing to licensing only once at the beginning of the first period for both periods. For low expected values, the licensor is indifferent between the two options and for very low expected values, the licensor again uses the second option, i.e., it licenses at the beginning of each period.

1. Introduction

The capabilities of new Information Technology (IT) products have been improving continually over the years. The potential of such products to provide a competitive edge is also well understood (e.g., American Airlines’ SABRE, McKesson’s Economost). Many firms have introduced new technology hoping to cut their costs and/or to improve the quality of their end products. Cash, McFarlan, McKinney and Vitale (1988) suggest that firms constantly look for creative ways to use IT products to get a leg up on the competition.

Developers of innovative IT products are not exclusively IT product vendors. Firms that are well cognizant of the needs of their specific industry often develop innovative IT products for their own use. Such firms may keep the innovation proprietary in order to gain a strategic cost or quality advantage. For example, Bankers Trust kept a portion of its foreign exchange trading system (REMOs) proprietary (Hanley, Leonard and Glossman 1991). Firms may also license the new technology to other firms, including their competitors, to generate extra revenues in the form of licensing fees. For example, Bankers Trust licenses most modules of REMOs to other trading houses.

Sometimes firms license their products to competitors because of the threat of imitation. They are concerned that if they do not license some other firm may develop a similar system and license, thereby not only neutralizing their competitive edge but also depriving them of the potential licensing revenues. Clemons (1991) provides an interesting analysis of Merrill Lynch's licensing decision that involved such a concern. However, not all systems can be imitated in the short run. Patents provide a certain degree of protection to the licensor. The difficulty and uncertainty associated with systems development projects for novel IT products may also discourage some potential imitators.

The development of a licensing strategy is further complicated because the business value associated with a new IT product is not usually known a priori. Typically, over a period of time, firms are able to assess the value of the product. Another dilemma facing the innovator is, whether to license a product immediately upon development or to wait for the uncertainty surrounding the value of the product to clear. Because the technology is considered "risky", should the
In this paper, we focus on new IT products that have a potential impact on costs. In the case of licensing immediately after development, we show that when the expected cost reduction is high irrespective of the extent of uncertainty associated with the value of the new product, the innovator is better off keeping the technology proprietary. On the other hand, if the expected cost reduction is low and uncertainty is low, the innovator is better off licensing. We also show that even if the expected cost reduction is negative, the innovator might be better off postponing a licensing decision until a more precise knowledge of the value of the technology is acquired rather than licensing hastily.

In the next section, we discuss the motivation for our model. In section 3, we develop a two-period model. In section 4, we consider the case of the licensor charging a one-time fixed licensing fee for both periods at the beginning of the first period. We analyze the conditions under which licensing may occur. In section 5, we compare period-by-period fixed-fee licensing and one-time fixed-fee licensing. We discuss our results in section 6. We conclude with a discussion of the limitations of the model and directions for future research in section 7.

2. Motivation

New IT products can have an impact on the operating costs of firms. For example, an expert system for dealing with routine tasks (Leonard-Barton and Sviokla 1988) can reduce costs. However, the impact of the new IT products on cost is usually uncertain. Potential adopters of IT face substantial uncertainty regarding the actual benefits of IT products. Occasionally, this uncertainty remains even after an organization has deployed the technology (Bakos and Kemerer 1992). For example, it is often difficult for an organization to establish in advance what a software product will do in its operating context and what the associated implications will be (Rosenthal and Salzman 1990). The costs may increase or decrease as a result of the new product. Research on the business value of IT does not unequivocally point to a positive impact of IT (Loveman 1988, Brynjolfsson 1991). Once the new IT product is used for some time, however, firms come to know the actual cost impact.

A firm with a new IT product may consider licensing to firms in the same industry and other industries. Information systems organizations are becoming increasingly open to trading their systems and technology with other organizations - even competitors (Moad and Williams 1988). Aware of the business value that can be extracted by marketing new IT products, developers are flooding the Patent and Trademark Office with applications (Russe 1991). In many cases the new systems may not be patentable and hence would face the threat of imitation by the competition. However, developing a complex system similar to a competitor's is not always an easy task. For example, the development of a comprehensive expert system may take a considerable amount of effort (Meyer and Curley 1991). The development of a large scale system requires a team of people with the right mix of talent and can be a lengthy proposition. Of course, this long incubation period can constitute a competitive advantage to the original developer (Leonard-Barton and Sviokla 1988).

Consider the case of Lincoln National Life Management Company. It formed Lincoln National Risk Management, Inc. to pioneer an underwriting expert system effort. The cost-reduction due to the system was expected to add approximately 10 percent to pretax profits. Lincoln National Risk Management conducts underwriting R&D and actively markets its patented Expert System to the insurance industry (Meyer and Curley 1991). By licensing the Expert System, Lincoln National gives its competitors an opportunity to cut their costs, thereby intensifying the competition. However, it receives additional revenue in the form of licensing fees.

Consider another example. A team of General Electric (GE) engineers implemented a software system called Engineous that emulates a design engineer's use of a computational simulation and optimization models to explore a problem's design space, which can be very large for complex systems. Although Engineous had been a proprietary product, internal to the company, GE officials have considered commercializing it by licensing the technology to large users (Ashley 1992).

Given the potential of IT to generate innovative products, we address the following research questions:

- Under what conditions is it optimal for a firm with a new cost-reducing IT product to license it?

- Should the licensor issue a perpetual license with a one-time charge, or offered on a term-by-term basis (Martin and McClure 1983),

- Should the licensor issue a perpetual license with a one-time charge or make licensing decisions on a period-by-period basis?

In order to investigate these research questions, we develop a game-theoretic model. Our work follows a stream of research employing the theory of industrial
organization to study the timing and dissemination of IT innovations (see, for example, Barua, Kriebel and Mukhopadhyay (1991), Davamanirajan, Kriebel and Mukhopadhyay (1991)). We build on the model formulated by Katz and Shapiro (1985). They consider an innovation by a firm in a two-firm industry (duopoly) that reduces the constant marginal cost. The firms compete with quantity as their choice variable (Cournot Competition). They conclude that major innovations will not be licensed and minor innovations will be licensed. However, in their model, the game is played only once (static), the products are homogeneous, there is no uncertainty, and all relevant information is common knowledge to all the players. Since the cost impact of new IT products is usually uncertain, we model a situation in which the cost impact is initially uncertain (costs could decrease or increase) and the actual cost impact becomes known after a period when the product is used by a firm. We also allow for heterogeneous products and consider price as the choice variable for the competing firms (Bertrand competition).

3. Model

We consider an industry with two firms \( i \) and \( j \) (duopoly) that sell differentiated products. The firms strategically position themselves in the market place by choosing the prices of their products appropriately. They are risk neutral and hence maximize the expected values of their profits. We anticipate that the results obtained from this duopoly analysis can provide insights for other kinds of markets (e.g., oligopoly) as well. A duopoly situation can also be used to model a scenario with a dominant firm and the rest of the industry.

The demand function for firm \( i \) is given by,

\[
q_i = a - bp_i + dp_j
\]

\( b > d > 0 \). \( a, b, \) and \( d \) are the demand function parameters. \( p_i \) is the price charged by firm \( i \). A firm can gain market share by cutting its price. This simple linear demand function allows for differentiated products. The price elasticity of demand of firm \( i \)’s product is \(-b\). The cross price elasticity of demand is \(d\). Hence, the values of \( d \) between \( 0 \) and \( b \) reflect varying degrees of substitutability with the level of substitutability increasing with \( d \).

The cost function of firm \( i \) is,

\[
f(q_i) = cq_i
\]

\( c > 0 \) is the constant marginal cost. The profit of firm \( i \) is, \( \pi_i = p_iq_i - cq_i \). Firm \( i \) owns a new IT product capable of changing the marginal cost from \( c \) to \( c - \epsilon \) and is considering licensing the product.

Our model is developed as a game with two periods. This dynamic game scenario enables us to model the initial uncertainty in the value of technology and the realization of the actual value at a later point in time. In the first period, the firms do not know the exact value of cost impact (\( \epsilon \)), but they know that it is distributed uniformly between \( x \) and \( y \) where \( x < 0 \) and \( y > 0 \). That is, costs could increase or decrease as a result of the new technology. At the end of the first period, the firms learn the actual value of cost improvement if at least the innovating firm had used the technology in the first period.

Given a period, the payoffs of the firms depend on a set of decisions that they take during the period. These decisions are sequentially dependent. For example, firm \( j \)’s acquisition decision is contingent on firm \( i \)’s licensing decision. A series of stages within a period are used to model these interdependent decisions.

One-time Licensing

Figure 1 illustrates the stages in each period.

In this scenario, the innovating firm seeks to license the technology for both periods, at the beginning of the first period.

First Period: The amount that firm \( j \) is willing to pay for the license depends on the incremental profit it expects to realize by the use of the new technology. In the first stage, firm \( i \) picks a fixed fee \( (F) \) for licensing the new product for two periods. Knowing this fee, in the second stage, firm \( j \) decides whether to acquire the technology. In the third stage, the firms simultaneously and independently choose their first-period prices.

Second Period: In the first stage, depending upon the actual cost reduction, the firms that used the new product in the first period decide whether they should continue using it. They would continue using it if the actual value of cost reduction is greater than zero. In the second stage, the firms independently and simultaneously choose their second-period prices.

Period-by-Period Licensing

Figure 2 illustrates the stages in each period.

In this case, the innovating firm \( i \) makes the licensing decision for each period at the beginning of that period. Let \( F_p \) be the fixed fee charged for licensing in period \( p \).

First Period: In the first stage, firm \( i \) picks a fixed fee for licensing the new product for a period. Knowing this fee, in the second stage, firm \( j \) decides whether to acquire the technology. In the third stage, the firms simultaneously and independently choose their first-period prices.
Second Period. If at least one firm had used the technology in the first period, the firms learn the actual value of cost reduction at the beginning of the second period. In the first stage, firm i picks a fixed fee (which may be different from the fee in the previous period) for licensing the new product for a period. Knowing the fee, in the second stage, firm j decides whether to acquire the technology. In the third stage, the firms simultaneously and independently choose their second-period prices.

4. One-Time Licensing

The subgame perfect equilibrium solution concept is used to obtain the equilibrium values. We go backwards and first solve for the second period and the price competition stage of the first period. Next, we solve for the acquisition decision of firm j. Finally, we consider the licensing decision of firm i in the first period.

Corresponding to the second period and the price competition stage in the first period, there are three cases to be analyzed:
(i) No firm uses the new IT product
(ii) Firm i uses the product and licensing does not occur.
(iii) Licensing occurs and both firms use the product.

The resultant mathematical expressions are provided in the Appendix.

Case I: No firm uses the new product
When none of the two firms uses the new IT product, their cost structures are identical in both periods. Hence, their profits are equal. The degree of substitutability between the products is a major determinant of the profits.

Case II: The innovating firm i uses the product and licensing does not occur

Second Period
At the beginning of the second period, the firms know the exact cost impact of the new IT product. If there had been a cost reduction, firm i will continue to use the technology in the second period. Its lower marginal cost gives it a competitive advantage. It reaps the benefits in the form of profits that increase with the degree of cost reduction. On the other hand, firm j's profit decreases with the degree of firm i's cost reduction.

However, if the new product has not had a favorable impact on its cost structure, firm i will revert back to its old technology. Now none of the firms will have a cost advantage and the profits of the firms will be equal in the second period.

First Period
The firms have different cost structures. The cost structure of firm i is dependent on the new technology. The profit of firm i increases with the expected cost reduction and the profit of firm j decreases with the expected cost reduction.

The expected profit of firm i in the second period is higher than its expected profit in the first period. This is because, the exact cost impact of the new technology will be known at the beginning of the second
Firm $i$ will continue using the new product only if it results in a cost reduction.

**Case III:** Licensing occurs and both firms use the product

**Second Period**

The two firms have identical cost structures. If the firms realize a cost reduction, they will continue to use the new technology in the second period. If the cost impact is not favorable, the firms will revert back to their old technologies.

**First Period**

The marginal cost of both firms is dependent upon the cost impact of the new product. For both the firms, the second period expected profits are higher than the first-period expected profits. This is because, the exact value of the cost reduction is known at the beginning of the second period. The firms will continue using the technology only if it results in cost reduction.

**Firm $j$’s Acquisition Decision**

Firm $j$ acquires the IT product if the licensing fee is less than its total incremental profit as the result of licensing, where the total incremental profit is the excess profit firm $j$ obtains by using the technology in both periods over the case when it does not use the technology in either period. Assume that firm $i$ is able to set the maximum possible price. Then, the fixed fee is equal to the total incremental profit acquired by firm $j$ by adopting the new technology in the first period.

**Firm $i$’s Licensing Decision**

The decision criterion for the innovating firm is similar. It issues a license if its profits are higher as a result of licensing. Thus its total payoff from licensing includes its total profits over the two periods when both competitors use the technology in each period, plus the fixed licensing fee. This payoff must exceed its total profit over the two periods when it has the exclusive right to the technology. Therefore, firm $i$ issues the license if industry profits are higher in the presence of licensing than in the absence of licensing.

If the level of differentiation between the firms’ products is very high, the pricing decisions of one firm have a relatively small effect on the demand and the profit of the other firm. Hence, it is always profitable for firm $i$ to license to firm $j$. From now on, we assume that the level of substitutability between the products is high and study the conditions under which licensing may occur.

The following propositions analyze the conditions under which licensing or no licensing occurs. The popular press gives examples of licensing of innovative IT products to competitors. While we know that, in general, a license may be perpetual with a one-time charge or offered on a term-by-term basis (Martin and McClure 1989), popular press does not report the licensing details. Thus it is difficult for us to interpret our results in the light of the examples found in the popular press. So while discussing our results we will use numerical examples to illustrate our analysis. The cross price elasticity of demand ($d$) is chosen to be 0.9 (high substitutability). The price elasticity of demand ($-b$) is $-1$. The other demand function parameter $a$ is equal to 1. The initial marginal cost of the firms ($c$) is 5. Thus, the data corresponding to the examples are: $a = 1, b = 1, d = 0.9, c = 5$. Note that the numerical examples are used only to illustrate the results derived and that the results are not specific to the numerical examples.

**Proposition 1** If the expected cost reduction is very high, irrespective of the degree of the uncertainty associated with the technology, licensing does not occur.

In figure 3, we provide an illustrative comparison of the licensing and no-licensing scenarios. The difference in the industry profits under the two conditions is shown. The positive portion of the graph indicates the conditions under which licensing occurs. The negative portion corresponds to the condition under which licensing does not occur. As shown, licensing does not occur when the expected value of cost reduction exceeds a certain threshold value.

If the expected cost reduction is very high, the technology leads to a very significant cost reduction. If firm $i$ does not license, the intensity of competition is dampened. Hence its profit increases significantly. In this case, the significant expected cost reduction provides a "strategic" advantage for firm $i$. The firm would lose this advantage by licensing and the licensing fee does not compensate for the loss. For example, an insurance company with an innovative underwriting system may not want to license its system to its competitors immediately because the high cost reduction can provide a strategic advantage for the company.

**Proposition 2** If the expected cost reduction is positive and low and the uncertainty associated with the technology is low, licensing occurs.

As shown in figure 3, when the expected cost reduction is low and positive, licensing occurs.

This scenario corresponds to the case where the cost reduction is not significant. Not licensing does not help firm $i$ much because even in the absence of licensing, the intensity of competition remains high. Thus firm $i$ is better off licensing and making higher
Figure 3
X AXIS: UPPER LIMIT OF THE DISTRIBUTION
OF COST IMPACT (y)
Y AXIS: DIFFERENCE BETWEEN INDUSTRY
PROFITS IN THE CASE OF LICENSING AND NO-
LICENSE SCENARIOS
The lower limit of the distribution of cost impact is fixed at -0.5.

Figure 4
X AXIS: UPPER LIMIT OF THE DISTRIBUTION
OF COST IMPACT (y)
Y AXIS: FIXED FEE THAT FIRM i IS WILLING
TO PAY TO ACQUIRE THE LICENSE
The lower limit of the distribution of cost impact is fixed at -0.5.

Figure 5
X AXIS: UPPER LIMIT OF THE DISTRIBUTION
OF COST IMPACT (y)
Y AXIS: DIFFERENCE BETWEEN FIRM i'S
PROFITS WHEN IT USES THE NEW PRODUCT
AND WHEN IT DOES NOT
The lower limit of the distribution of cost impact is fixed at -0.5.
profits through licensing fees. For example, a bank developing a credit card processing system may not expect the system to provide it a distinct advantage over its competitors if the relative cost reduction is not very high. In that case it will license its product and use the licensing revenues to enhance profitability.

An increase in the variance in technology increases the expected cost reduction in the second period. So an increase in variance has the same impact as an increase in expected cost reduction. Therefore, as variance increases, the tendency not to license increases.

**Proposition 3** If the expected value of the technology is negative and very low, no licensing occurs, but the innovating firm might still use the new product.

As shown in figure 4, when the expected cost reduction is negative, beyond a certain point, firm j is not willing to purchase the license. However as shown in figure 5, using the new IT product may have a positive impact on firm i's expected profits.

If the expected benefit from the new IT product is negative and very low, firm j is not willing to purchase the license. For example, sometimes firms own new products for which the potential benefits might appear to be very low. In such circumstances, the firms will have a tough time finding potential licensees. But it might be still profitable for firm i to try the new product. This is because if the actual cost reduction turns out to be positive, its profits will increase.

5. Period-by-Period Licensing

In the case of period-by-period licensing, the innovating firm makes the licensing decision for a period at the beginning of that period. For a given period, licensing occurs when the expected cost reduction is positive and exceeds a threshold value (see Appendix). Firm i has the flexibility to make a licensing decision at the beginning of second period after the uncertainty surrounding the value of the technology clears. Likewise, if firm i decides to license, firm j has the option to make an acquisition decision after the exact cost reduction is known.

Now, let us compare one-time and period-by-period licensing from the point of view of the innovating firm i.

**One-Time vs. Period-by-Period Licensing**

**Proposition 4** For high expected values of cost reduction, the innovating firm prefers period-by-period licensing to one-time licensing.

The profit of firm i is higher under period-by-period licensing. Therefore it is optimal for firm i to license at the beginning of each period. If the expected cost reduction is greater than a threshold value, firm i does not license at the beginning of the first period under both the licensing options considered. But in the case of period-by-period licensing, it has the flexibility which can potentially improve the profitability if the technology fails to meet the high expectations in the first period.

**Proposition 5** For low, positive expected cost reduction with a low uncertainty associated with the value of the technology, the innovating firm is indifferent between one-time and period-by-period licensing.

In this case, the cost reduction does not exceed the threshold value. Both in the case of one-time licensing and period-by-period licensing firm i will license the new product at the beginning of the first period. In the period-by-period licensing option, the firm expects to license the product in the second period also if it actually leads to cost reduction. So firm i is indifferent between the two licensing options.

**Proposition 6** If the expected cost reduction is negative and low and licensing occurs in the case of one-time licensing, period-by-period licensing is better for the innovating firm than one-time licensing.

When the expected cost reduction is less than zero, as we have seen earlier, in the case of one-time licensing, there are situations in which firm j is willing to purchase the license. But, firm j will not purchase the license in the case of period-by-period licensing since the cost is expected to increase. Still, firm i is better off waiting for a period to understand the cost impact clearly before considering licensing. It is not an optimal strategy to get firm j into purchasing a two-period license in the presence of uncertainty of this nature. This proposition concludes that just because expected cost reduction is negative it may not be optimal for firm i to hastily adopt a one-time licensing strategy. The one-time fixed fee that firm j is willing to pay will have the expected negative impact in the first period factored in.

6. Discussion

More and more firms are developing innovative IT applications and are exploring licensing opportunities. We have used a game-theoretic framework to study the licensing phenomenon. This framework is suitable for the study of strategic IT products in general. We have constructed a rigorous theory-based model of reality and proceeded in a logical manner to derive our results. We have been able to consider the
important elements of a real world licensing problem and analyze their impact on the licensing decision. On the other hand, this approach requires analytical tractability and this imposes constraints on the construction of the resultant model, thus limiting the richness of analysis a case study may offer.

Based on our analysis, we show that the licensing decision for new IT products that impact costs, is dependent upon the expected cost reduction and the size of the variance of the cost impact. These two factors determine whether cost reduction becomes a strategic issue. We also show how the two different modes of licensing, one-time licensing and period-by-period licensing might be appropriate under different circumstances.

We discuss the application of our model using two examples below, based on reports available in the popular press. The purpose of these examples is to provide an appreciation of our analysis. However, due to the limited disclosure of data in the popular press, our interpretation sometimes considers multiple possibilities about certain aspects of the two examples.

**Example 1: Weyerhauser Company**
Management at Weyerhauser Co.’s pulp and paper mill has been using an internally developed tool to lower costs (Inglesby 1987). The mill host computer system called Prosmart gathers operating and financial data and delivers it in graphic form to key employees. Introduced in July 1985, Prosmart has produced annual savings of more than $1 million. Weyerhauser Information Systems introduced a commercial version of Prosmart as a general plant or mill-host package for continuous and batch processing operations in diverse industries. Weyerhauser started licensing Prosmart a couple of years after they introduced the system. One possible reason for this action is that the expected cost reduction was so high that they did not want to license initially (Proposition 1). Even if the expected cost reduction is high, eventually it may be worth licensing, if the system is relevant to a variety of firms. Weyerhauser made the decision to generalize the applicability of their package before licensing so that they do not license Prosmart just to their direct competitors. Another possible reason could be that Weyerhauser wanted to clear the uncertainty surrounding the benefits of the system before developing generalized packages (Proposition 6). One more possibility is that Prosmart might have generated a strategic advantage in the short run. After a while, anticipating development of similar systems, Weyerhauser might have decided to market its system. We note that our model did not consider the anticipation of the immediate imitation of the novel IT product.

**Example 2: Citibank**
Citibank licenses its Comprehensive Banking System (CBS) to other banks. It claims that CBS can reduce their data processing costs by as much as 20%. One reason for Citibank’s decision to license the software could be that the expected cost reduction for Citibank was not significantly high (Proposition 2). The driving force behind the decision could also be the threat of imitation. It is also possible that because of barriers against interstate banking (until a few years ago), most of the licensees might not have been Citibank’s direct competitors.

7. Conclusion

With more and more companies considering the possibilities of licensing their systems, licensing novel IT products has become an important issue today. In this paper, we have analyzed some of the factors influencing the licensing decisions of new IT products that impact costs. We have taken into consideration the fact that the cost impact is usually uncertain and often known after a period of use. We have also examined two modes of licensing, period-by-period licensing and one-time licensing. We expect our analysis to be of significance to firms in making their licensing and acquisition decisions.

There are certain limitations to our model. Our future research is geared towards overcoming these limitations. For example, we have assumed that both firms know the exact cost impact if at least one firm uses the new technology in the first period. At present, we are extending the model to incorporate asymmetric information - a firm that does not use the new product in the first period does not know the exact cost reduction at the beginning of the second period. We plan to examine firm-specific cost reduction where the cost reduction for one firm is independent of the cost reduction achieved by the other firm. We are also considering a more general pricing policy for the license with both fixed fee and royalty.

We have assumed that one of the firms owns a novel IT product to start with. An interesting extension will be to incorporate the development stage in the model. Another research question involves the case where the potential licensor is an independent researcher that is not one of the firms in the industry (Kamien and Tauman 1984, 1986). Although it is often difficult to imitate competitors’ systems in the short run, an analysis of the impact of the threat of imitation on licensing will be useful. Clemons (1991) discusses Merrill Lynch’s decision to allow Bloomberg to sell its pre-
nier analytics package to their largest competitors. The threat of imitation was one of the major factors influencing Merrill Lynch's decision.

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9. References

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10. Appendix

Notation

Superscript $i$ indicates second-period values
Superscript $s$ is used when only one firm uses the technology
Superscript $t$ indicates the case when both firms use the technology
Superscript $n$ is used when no firm uses the technology
Subscript $u$ is used when the technology is cost-reducing

One-time Licensing

Case I: No firm uses the new product

The profit of each firm is given by $K(A^2 + A(Bz_1 + B^2z_2))$ where $K = \frac{(2a + a - c)(2b - d)}{(4b^2 - 4b)}$ and $A = (2ab + ad - c(2b^2 - d^2 - bd))^2$.

Case II: Licensing does not occur

Second Period

The expected value of firm i’s profit is, $K(A^2 + 2ABz_1 + B^2z_2)$. The expected value of firm j’s profit is, $K(A^2 - ADz_1 + D^2z_2)$ where, $B = (2b^2 - d)$. $D = bd$, $z_1 = \frac{A^2}{2}$, $z_2 = \frac{b^2}{3(9-7)}$.

First Period

The expected value of firm i’s profit is, $K(A^2 + 2AB\hat{e} + B^2\hat{e}^2)$. The expected value of firm j’s profit is, $K(A^2 - 2AD\hat{e} + D^2\hat{e}^2)$

Case III: Licensing occurs

Second Period

The expected profit of each firm is, $K(A^2 + AGz_1 + G^2z_2)$, where $G = (2b^2 - d^2 - bd)$.

First Period

The value of the expected profit of each firm is,
Proof of proposition 1
If \( \epsilon > \frac{\sqrt{2} \bar{z}}{z_1} \), then \( \frac{(\bar{z} J + I)}{z_1} < 0 \). This violates the condition for firm \( i \) licensing to firm \( j \).
Therefore, if \( \epsilon > \frac{\sqrt{2} \bar{z}}{z_1} \), firm \( i \) will not license the new IT product.

Proof of proposition 2
Consider the case \( \frac{(\bar{z} J + I)}{z_1} > 0 \). Then, \( \frac{(\bar{z} J + I)}{z_1} > 0 \).
Now the condition for licensing to firm \( j \) is satisfied.
Therefore, if \( \epsilon < \frac{\sqrt{2} \bar{z}}{z_1} \) and \( \frac{(\bar{z} J + I)}{z_1} > 0 \), firm \( i \) would license to firm \( j \). If \( \epsilon < \frac{\sqrt{2} \bar{z}}{z_1} \) and \( \frac{(\bar{z} J + I)}{z_1} < 0 \), firm \( i \) may or may not license to firm \( j \). As the variance increases keeping \( \bar{z} \) constant, \( \frac{\surd \bar{z}}{z_1} \) increases and the tendency of firm \( i \) to not license increases.

Proof of proposition 3
If \( z_1 + 2\bar{z} < 0, F < 0 \). Therefore, firm \( j \) is not willing to purchase the license when \( z_1 + 2\bar{z} < 0 \), for \( \pi_i^t + \pi_i^{tu} + F > \pi_j^t + \pi_j^{tu} \).
So for firm \( i \) to use its new technology, this condition has to be satisfied. If \( \epsilon < 0 \) and \( z_1 + 2\bar{z} > 0 \), firm \( i \) may or may not license its technology.

Proof of proposition 4
With one-time licensing, firm \( i \)'s expected profit is,

\[
\pi_i^t + \int_0^t \pi_i^{tu} f(t)\,dt + \int_0^y \pi_i^{uu} f(t)\,dt
\]

With period-by-period licensing its expected profit is,

\[
\pi_i^t + \int_0^t \pi_i^{tu} f(t)\,dt + \int_0^y (\pi_i^{tu} + F_2) f(t)\,dt + \int_{\epsilon_a}^y \pi_i^{uu} f(t)\,dt
\]

The profit of firm \( i \) is higher under period-by-period licensing.

Proof of proposition 5
If firm \( i \) licenses only once, its profits are given by,

\[
F + \pi_i^t + \int_0^t \pi_i^{tu} f(t)\,dt + \int_0^y \pi_i^{uu} f(t)\,dt
\]

If it licenses at the beginning of each period, its profits are given by,

\[
F + \pi_i^t + \int_0^t \pi_i^{tu} f(t)\,dt + \int_0^y (\pi_i^{tu} + F_2) f(t)\,dt
\]

The profit of firm \( i \) is the same whether it licenses once or at the beginning of each period since \( F = F_1 + \int_0^y F_2 f(t)\,dt \).
Therefore, firm \( i \) is indifferent between the two options.

Proof of proposition 6
In the case of one-time licensing, firm \( i \)'s profit is given by,

\[
F + \pi_i^t + \int_0^t \pi_i^{tu} f(t)\,dt + \int_0^y \pi_i^{uu} f(t)\,dt
\]

In the case of period-by-period licensing its expected profit is,

\[
\pi_i^t + \int_0^t \pi_i^{tu} f(t)\,dt + \int_0^y (\pi_i^{tu} + F_2) f(t)\,dt
\]

The profit of firm \( i \) is higher under period-by-period licensing if \( \pi_i^t > \pi_j^t - \pi_j^t + \pi_j^t \), which is true. So it is optimal for firm \( i \) to license at the beginning of each period.