Adoption Timing of Technology Innovative Investment Project in Economic Rents Perspective: 
The New-Generation TFT-LCD Panel Makers Cases

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Abstract: A hi-tech firm can capture the economic rents (the above-normal return) if the position with strategic benefit of innovative activities has been implemented under uncertain technology development progress, uncertain market demand, and irreversible cost. An approach to evaluate the technology innovation project with the option pricing technique is proposed in this work, to simulate the uncertainty of the project using the volatility of the project value. We have considered that the expected economic rents induced by innovative technology usually declines over time and postpone for carrying out the innovative technology may erode the value of the project. The appropriate investment timing will make a substantial influence on the competitive advantage induced by innovative technology. The value of the technology innovation project as well as the optimal timing could be derived.

Area/Track: Finance (Other Areas, as “capital budgeting decision analysis”)

Key Words: Technology Innovation, Optimal Timing of Technology Adoption, Economic Rents, the New-Generation TFT-LCD Panel Makers

INTRODUCTION

The hi-tech firms must adopt strategic activities of technology innovation to reach competitive positions nowadays. Apply technology innovation is the main force and a formidable strategy in the hi-tech industry. The innovative activities generally disclose a set of strategic investment opportunities accompanied with uncertain technology developments and market demands. The necessary precursor for hi-tech firm to capture excess profits is to endure the uncertainty risks induced by some technology innovation investment projects.

An effective strategic management for the technology innovation investment projects involves various decisions such as which new technology to be adopted and when to implement the new technology. Problems, such as the intrinsic uncertainty for new technology, the inherent intangible nature of expected benefits, the availability of technical and economic information about the new technology, the need to develop new competencies and skills, the role played by learning process, and the irreversibility of the innovative investment, should all be taken into consideration in the decision making process (Scarso, 1996). Additionally, capital intensive is also commonly inhered in the technology innovation investment project.

In today’s hyper-competitive marketplace, many products like those that memory chips and TFT-LCD TVs are characterized by short life cycles and rapidly-declining sales prices. These imply that the amount of revenue generated may be decreasing because of completing a product as its adoption timing is delayed. In such an environment, there is a decided preference for the maximization of product revenues under the innovative technology adoption timing as an important objective. Strictly speaking, the focus of this work will be the economic rents, i.e., the excess profit over the opportunity cost of capital. Economic rents occur only if comparative competitive advantage exists. Because of the recurrent role played in influencing the strategic alternative for the competing firms, innovative technology is one of the main ways to achieve competitive advantage. A hi-tech firm can capture the economic rents (the above-normal return) if the position with strategic benefit of innovative activities has been implemented. Since the expected economic rents induced by innovative technology declines usually over time, any postpone for carrying out the innovative technology may erode the value of the project. The appropriate investment timing will make a substantial influence on...
the competitive advantage induced by innovative technology; however, the traditional capital budgeting procedures using the discounted cash flow concepts usually ignore the aforementioned problems. The traditional DCF method has serious shortcomings in analyzing projects when information concerning future investment decisions is complicated. It might be worthwhile to have some other techniques to evaluate the projects with the characteristics of high uncertainties and intensive capital requirements. An option approach is proposed to overcome these limitations. The research results of Smit and Ankum (1993) is adopted. The micro-economic tools would be employed to analyze aspects of competition (i.e., the competitive advantage) for the technology innovation investment project. We particularly concern the innovative rents bearing uncertainties for the forecasting of operating cash flows. Innovative rents are interpreted in their Schumpeterian sense as the reward for the first commercialization of an invention (Reenen, 1996). The application of option theory could be employed as an analytical tool to evaluate investment projects.

It has seen a growing application of financial option theory to real-asset investment, giving rise to what has been called the real options literature (Cortazar, et. al., 1998). These studies consider a firm that makes some decision analysis contingent on the particular realization of one or more relevant investment decision issues. Different issues have been studied using real option approach. Examples include the timing of the investment decision (Lee, 1988, McDonald and Siegel, 1986), the investment schedule (Majd and Pindyck, 1987), the corporate investment strategy (Smit and Ankum, 1993), the new technologies/products adoption (Scarso, 1996, & Cortazar, et. al., 1998), and the privatization BOT infrastructure project evaluation (Sheu, et. al., 1999). The real option approach seems to provide a powerful tool for the assessment of technology innovation investment project because it provides ways to account for irreversibility of the capital and uncertainty of the future. It also explicitly recognizes that investment timing, which could be mimicked to the exercise timing of a call option on a dividend-paying stock, affects returns (Scarso, 1996).

This paper is devoted to explore the evaluation of innovative technology as well as the timing to carry out the project. Observing the similar characteristics between the adoption timing of innovative technology and a call option on a dividend-paying stock, we apply the real option pricing technique to evaluate the innovative technology investment projects. Using the proposed procedure, an innovative technology strategy could be formulated accordingly. Using the proposed procedure, a numerical case of the new-generation TFT-LCD panel plant investment project in Taiwan is provided as an example to demonstrate the proposed procedure. There is a new wave of competition lies ahead in the global TFT-LCD panel industry, as all of the top-five players in the arena were ready to jump into construction of the world’s most advanced (eighth-generation, 8G) production lines in order to embrace the lucrative business opportunities generated by the large-screen (46 or 50 inches) LCD TVs. The first 8G production line investment project in Taiwan was announced in the beginning of 2006; however, there is no 8G production line constructed in the end of 2007. One may postulate that if the firm was in a slumped technology/market condition, it may be better to defer the project until the technology/market develops maturely in the future to start the project. The aim of this paper is to propose a procedure using real option approach. The proposed procedure could be applied to price the innovative project and decide the appropriate adoption timing. The strategic planning with the economic rent concepts under competition over time is studied in Section 2; we will adopt the real option approach in this section. Section 3 contains a case about the new-generation TFT-LCD panel plant investment project in Taiwan is provided as a numerical example to demonstrate the proposed procedure. Finally, concluding remarks are drawn in Section 4.

**PROBLEM FORMULATION AND PROPOSED PROCEDURE**

Smit and Ankum’s work (1993) is adopted to derive an investment timing decision procedure. Using the economic rent and real option concepts, the proposed procedure could be applied to solve the timing decision problem of a technology innovation investment project with inherent uncertainty and irreversible cost.

The expected net operating cash inflow of a technology innovation investment project is estimated as the sum of the opportunity cost of capital of the project and the economic rent as follows:

\[
CF_t = I \cdot k + ER_t
\]

\(CF_t\) : the expected net operating cash flow
\(I\) : the investment cash outflow
k: the opportunity cost of capital
ER: the expected economic rent

The term \( (t \cdot k) \) reflects the (yearly) opportunity cost of capital invested in a project. Under rivalry, the economic rent would exist if the firm has a competitive advantage in realizing the project. Barriers to entry or a distinct competitive advantage over existing competitors (e.g., economies of scale and scope, absolute cost advantages or product differentiation) are the real source of economic rents. The firm therefore needs to identify those markets in which it has a temporary or permanent competitive advantage, and concentrate investment in these areas. According to Equation (1), we assume that (i) the financial market is efficient; and (ii) the project has an infinite physical life. In perfect competition, the expected economic rents of the technology innovation investment project are expected to decline exponentially, as follows:

\[
ER_t = ER_0 \cdot e^{-xt} \quad t = 1,2,3,\cdots
\]  

(2)

where \( ER_0 \) is the initial value of the economic rent. The yearly change rate of economic rent \( (x) \) is assumed to decline exponentially to simplify the discussion. Because of the recurrent role played in influencing the strategic alternative for the competing firms, innovative technology is one of the main ways to achieve competitive advantage. Economic rents occur only if comparative competitive advantage exists. A hi-tech firm can capture the economic rents (the above-normal return) if the position with strategic benefit of innovative activities has been implemented. Since the expected economic rents induced by innovative technology declines usually over time, any postpone for carrying out the innovative technology project may erode the value of the project.

Simply combine equation (1) and (2), it follows that the expected net operating cash inflows could be represented as

\[
CF_t = I \cdot k + ER_0 \cdot e^{-xt} \quad t = 1,2,3,\cdots
\]  

(3)

The project value is discounted by the opportunity cost of capital: \( (k) \) of the technology innovation project. Thus, the project present value (represented by \( V_0 \)) is as follows:

\[
V_0 = \sum_{i=1}^{\infty} \left( \frac{I \cdot k + ER_i}{(1+k)^t} \right) = \sum_{i=1}^{\infty} \left( \frac{I \cdot k + ER_0 \cdot e^{-xt}}{(1+k)^t} \right) \quad t = 1,2,3,\cdots
\]  

(4)

Under perfect competition, the expected net operational cash inflows will change over time until the project earns just the opportunity cost of capital and their expected net present value will just be zero. A pioneer investment project of adopting new technology may produce only temporary economic rents. Eventually, however, potential competitors will catch up and enter the industry sooner or later. The firm will invest in a pilot project just to get an early foothold in the market; however, if the market opens up and creates expansion opportunities, the firm will increase capacity significantly by investing in a follow-up project. This pioneering strategy involves high risk, but also involves low competition in the early stage of the market leading to substantial expected economic rents. The timing of a project will be influenced by the development of market demand and the behavior of the competitor.

So far, the optimal timing issue is rather trivial in equation (4), if there is no cost to deferring the new technology adoption, a high-tech firm would not undertake the deferrable investment project until the last moment. The cost of deferring the project plays a role here similar to the role played by the dividend to an American call option (Lee, 1988). It creates a wedge between the present value of the project to be is implemented new (represented by \( V_0 \)) or deferred to time \( t \) (represented by \( V_t \)) when the expected demand turns favorable under uncertainty. Base on this analogy, the option to defer investment in the technology innovation investment project is similar to a call option with a changing dividend payout ratio (Scarrow, 1993). Use \( \delta_{s} \) to represent the dividend payout ratio at time \( t \) with shift magnitude \( m_s \), assume that the technology innovation investment project value will have a single up or down shift state \( (s) \) with the magnitude \( m_s \) (represented by \( m_u \) or \( m_d \) as the upward magnitude \( (u) \) or downward magnitude \( (d) \), respectively) and the possibility \( p \) (represented by upward possibility \( p \) and downward possibility \( (1-p) \)), the cash flows could be calculated backward using the multiplicative binomial process over discrete periods. It follows that:

\[
\delta_{t,s} = \frac{CF_{t,s}}{V_{t-1,s} \cdot m_s}, \quad s = d \text{ or } u
\]  

(5)

\[
CF_{t,s} = I \cdot k + (1-\frac{1}{(1+k)^t})e^{-xt}(V_{t-1,s} \cdot m_s - (1+k) \cdot I)
\]  

(6)

Notice that \( CF_{t,s} \) reflects the net operating cash inflow during the deferment period. In
equation (6), the term \((I \cdot k)\) is the yearly opportunity cost of capital, and the term \((1 - \frac{1}{1 + k}) e^{-x} ) (V_{t-1,s} \cdot m_s - (1 + k) \cdot I)\) is the economic rents for each state of nature. Note that when the industry settles into competitive long-run equilibrium, the net present value of the project becomes zero \((V_{t-1,s} \cdot m_s) / (1 + k) = I\), and \(\delta_s\) equals \((i / (1 + i))\) as with constant expected cash inflows. Bases on the binomial option pricing approach, when the market demand or technology development process turns out to be favorable to defer investment, the value of the deferred project is increased by a factor of \(m_u \cdot (1 - \delta_{t,u})\) at time \(t\). On the other hand, the project value will decrease by a factor of \(m_d \cdot (1 - \delta_{t,d})\) at time \(t\). The binomial option pricing approach of Cox, Ross, and Rubinstein (1979) could be applied to derive parameters \(m_u\), \(m_d\), and \(p\) as follows:

\[
m_u = e^{\frac{r}{\sqrt{N}}},
\]

\[
m_d = \frac{1}{m_u},
\]

\[
p = \frac{r/N - m_d}{m_u - m_d}.
\]

Working backwards induction process could derive the current value. The decision analysis criteria of American call option with early exercise conditions are drawn in the decision tree (see Figure 1). The general option pricing formulas of the decision tree at time \(t\) are demonstrated in the following equations:

\[
V_{t,d_j} = V_{t-1,d_j} (1 - \delta_{t,d_j}) m_d; \quad C_{t,d_j} = \text{Max}(0, V_{t,d_j} - I, (pC_{t+1,u_{j+1}} + (1 - p)C_{t+1,d_{j+1}}) / r)....(7)
\]

\[
V_{t,u_j} = V_{t-1,u_j} (1 - \delta_{t,u_j}) m_u; \quad C_{t,u_j} = \text{Max}(0, V_{t,u_j} - I, (pC_{t+1,u_{j+1}} + (1 - p)C_{t+1,d_{j+1}}) / r)....(8)
\]

At time \(t\), if the situation turns favorably, the option value of the project will increase to \(C_{t,u_j}\). On the contrary, the project option value will decrease to \(C_{t,d_j}\). The \(u_j\) and \(d_j\), \(j = 1, \ldots, 2^t\) mean the deferred project at time \(t\) with \(2^t\) kinds of option values with upward \((m_u)\) and downward \((m_d)\) shift. Thus, there are three investment-timing alternatives at time \(t\). The project will not be worth to take if the option value equal to zero, i.e., the project should be abandoned. If the project option value is equal to \((V_{t,S} - I)\) the decision is to invest now. The project should be postponed for further information under other condition.
at time $t_0$

$V_0$

$C_0 = \max\{0, \text{abandon}\}$

$V_0 - I, \text{ invest}$

($p \cdot C_{i_0} + (1 - p) \cdot C_{i_d})/r, \text{ (defer)}$

at time $t_1$

$V_{i_0} = V_0 \cdot (1 - \delta_{i_0}) \cdot u$

$C_{i_0} = \max\{0, \text{abandon}\}$

$V_{i_0} - I, \text{ invest}$

($p \cdot C_{i_0} + (1 - p) \cdot C_{i_d})/r, \text{ (defer)}$

at time $t_2$

$V_{i_1} = V_{i_0} \cdot (1 - \delta_{i_1}) \cdot u$

$C_{i_1} = \max\{0, \text{abandon}\}$

$V_{i_1} - I, \text{ invest}$

($p \cdot C_{i_0} + (1 - p) \cdot C_{i_d})/r, \text{ (defer)}$

at time $t_3$

$V_{i_2} = V_{i_1} \cdot (1 - \delta_{i_2}) \cdot u$

$C_{i_2} = \max\{0, \text{abandon}\}$

$V_{i_2} - I, \text{ invest}$

($p \cdot C_{i_0} + (1 - p) \cdot C_{i_d})/r, \text{ (defer)}$

Figure 1: The investment Timing Decision Tree for Technology Innovation Project

(For simplified to demonstrate the timing decision tree approach, we assumed the investor can defer the project from now ($t_0$) to $t_1$, $t_2$, $t_3$ or $t_4$)

at time $t_4$

$V_{i_4} = V_{i_3} \cdot (1 - \delta_{i_4}) \cdot u$

$C_{i_4} = \max\{0, V_{i_4} - I\}$

$V_{i_4} = V_{i_3} \cdot (1 - \delta_{i_4}) \cdot d$

$C_{i_4} = \max\{0, V_{i_4} - I\}$

$V_{i_4} = V_{i_3} \cdot (1 - \delta_{i_4}) \cdot u$

$C_{i_4} = \max\{0, V_{i_4} - I\}$

$V_{i_4} = V_{i_3} \cdot (1 - \delta_{i_4}) \cdot d$

$C_{i_4} = \max\{0, V_{i_4} - I\}$
DEMONSTRATION WITH NUMERICAL EXAMPLE

In today’s hyper-competitive marketplace, many products like those that memory chips and TFT-LCD TVs are characterized by short life cycles and rapidly-declining sales prices. Furthermore, a new wave of competition lies ahead in the global TFT-LCD panel industry, as all of the top-five players in the arena were ready to jump into construction of 8th-generation (8G) production lines in order to embrace the lucrative business opportunities generated by the large-screen LCD TVs. As the new-generation TFT-LCD plants require a higher investment threshold (the capital investment requirement will cost billions of US dollars), the relatively small panel manufacturers may be squeezed out of the industry. It is wished that an early foothold in the large-screen LCD TVs market could be achieved. Although capital intensive and high uncertainties are inhered in this hi-tech investment project, the competitive advantage leading to substantial expected economic rents is expected.

We utilized a simple numerical example with an investment project about a new-generation TFT-LCD panel production line to illustrate the proposed procedure, the firm, a global top-five TFT-LCD panel company in Taiwan, has planned to invest the eighth-generation (8G) production lines to upgrade the technology position. Together with the current 7th generation line, the start of what is considered to be the world’s most advanced (8th generation) line will enable to expand production of large screen LCD panels for 50 inch class LCD TVs, of which demand is expected to see a significant increase, as well as to acquire a stable supply to meet demands. It is expected that the firm’s 7th generation line and its new 8th-generation line (For 8th generation, approx. 2,200mm×2,500mm, the number of LCD panels obtained from one glass substrate: 6 panels for 50 inch class TV, or 8 panels for 46 inch TV) will enable it to keep its place as the largest panel manufacturer in Taiwan. Nevertheless, the first 8G production line investment project in Taiwan was announced in the beginning of 2006; however, there is no 8G production line constructed in the end of 2007. Considering the mainstream sizes of LCD TVs in the global market, which keep getting bigger even as TV prices continue going down. These imply that the amount of revenue generated may be decreasing because of completing a product as its adoption timing is delayed. In such an environment, there is a decided preference for the maximization of product revenues under the innovative technology adoption timing as an important objective. Further, it was reported that the total amount of the firm’s investment in the line would be US$2.4 billion dollars. Although the production capacity of the 8th-generation line was not mentioned in detail, considering its total investment amount of US$2.4 billion dollars, a production capacity of about 40,000 pieces a month is expected. Using the predicted data of the capital expenditure and the net operating cash inflow for this project, the proposed procedure is adopted and the results are interpreted with some additional assumptions.

It is assumed that risk-free rate is 2.8% per annual and the cost of debt (K_D) is 4.52% that is the average value of the firm’s interest rates of long-term debts. The opportunity cost of capital is measured by the weighted average cost of capital approach. The cost of equity (K_S) is 11.92% that is determined by CAPM approach with the field study of the firm’s stocks transaction data in Taiwan stock market. According to market value perspective, the capital structure of the firm is: (Debt : Equity = 39.68% : 60.32%). Thus, the WACC of the technology innovation project is about 8.53% as calculated:

\[
\text{WACC} = 0.3968 \times K_D \times (1-25\%) + 0.6032 \times K_S = 8.53\%
\]

We employed the predicted data of the capital expenditure and the net operating cash inflow for this project (summarized in Table 1) to evaluate the initial value of the economic rent (ER_0) and the yearly change rate of economic rent (x) by fitting the equation (3) into an exponential model:

\[
CF_t = I \cdot k + ER_t = I \cdot k + ER_0 \cdot e^{-xt} , t = 1,2,3,\ldots
\]

Due to the firm announced the 8th generation TFT-LCD investment project in the beginning of 2006, and the historical market prices of large screen LCD TV (only 42"LCD TV) have been quoted since August 2006. For demonstrating the investment decision is investing, defer or abandon the technology innovation project by this real option approach, we assumed the investment decision-making analysis in 2007 and the operating cash flow in 2007 for presenting the ER_0. Thus, the estimation result by using the data in Table 1 is:

\[
ER_t = ER_0 \cdot e^{-xt} = 315117735 \cdot e^{-0.2663t} , t = 1,2,3,\ldots,
\]

where \(ER_0 = 315,117,735\) and the economic rent declines exponentially at a 26.63% annual rate (R² of the model is 0.8796). The expected capital budgets generated by this approach were summarized in Table 2. We assume the time horizon of the innovative project is 12 years, because this project has to last for 12 year then will be a valuable project under NPV investment criteria. It means that the project maybe not worthwhile for the firm to invest according to the traditional capital budgeting
criteria, because LCD TVs are characterized by short life cycles (about 18 months) and rapidly-declining sales prices. However, this firm has to invest this technology innovation project to get a sound competitive basis for future development. There must be some inherent “strategic value” for this firm to derive from a negative-NPV project. The proposed procedure will provide an analytical tool to evaluate this technology innovation projects.

<table>
<thead>
<tr>
<th>Date</th>
<th>42”LCD TV Quote A</th>
<th>Monthly Capacity B (pieces)</th>
<th>Monthly Sales C</th>
<th>Net Cash flow from Operating D</th>
<th>I*k/12 E</th>
<th>The Monthly Expected Economic Rent (ER) F</th>
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Note: A.: 42”LCD TV Quotes of historical market price. There were no quotes about the large LCD screens which are larger than 42” before 2008.
B.: The monthly production capacity of about 40,000 pieces is expected.
C.: Assume one 8G TFT-LCD glass substrate 8 panels for 42 inch TV, the expected monthly sales of the project: C=A*B*8.
D.: Assume the margin large screen LCD TV will be 30% (more than the others products), and the administration expenses is 6%, thus, D=C*(30%-6%)
E.: the monthly opportunity cost of capital invested in the project= (I*k)/12, I =US$2,400,000,000, k =8.5341%
F.: the monthly expected economic rent of the project: F=D-E.
Following Luehrman’s “take an educated guess” approach (Luehrman, 1998), \( \sigma \) is estimated. We consider the volatility of the total risk of Taiwan electric industry in this example. The hi-tech firms may refer to the similar project or related industry to reveal the volatility of technology innovation project. The total risk of Taiwan electric industries was about \( \sigma = 0.2 \) from 2006 to 2007. Considering the high uncertainty inherited in the technology innovation project, the scenario analysis considers different values for \( \sigma \) (0.2 and 0.4) for capital budgeting decision under uncertainty with this real option approach (the results have shown in Figures 2 and 3).

**Table 2: The Estimated Cash Flows of the 8G TFT-LCD Panel Production Line Investment Project**

<table>
<thead>
<tr>
<th>Time</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>( I^*k )</td>
<td>204,818,265</td>
<td>204,818,265</td>
<td>204,818,265</td>
<td>204,818,265</td>
<td>204,818,265</td>
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<td>204,818,265</td>
<td>204,818,265</td>
<td>204,818,265</td>
</tr>
<tr>
<td>( ER_t )</td>
<td>315,117,735</td>
<td>241,446,117</td>
<td>184,998,244</td>
<td>141,747,362</td>
<td>108,608,137</td>
<td>83,216,557</td>
<td>63,761,294</td>
<td>48,854,492</td>
<td>37,432,763</td>
<td>28,681,328</td>
<td>21,975,899</td>
<td>16,838,136</td>
<td></td>
</tr>
<tr>
<td>( CF_t )</td>
<td>2,400,000,000</td>
<td>519,936,000</td>
<td>446,264,382</td>
<td>389,815,509</td>
<td>346,565,627</td>
<td>313,426,402</td>
<td>288,034,822</td>
<td>268,579,559</td>
<td>253,672,757</td>
<td>242,251,028</td>
<td>233,499,593</td>
<td>226,794,364</td>
<td>221,656,401</td>
</tr>
</tbody>
</table>

**NPV:** 68,181,299 \( (k: \text{WACC}=8.5341\%) \)

**IRR:** 9.2544%

**Figure 2:** The investment Timing Decision Tree for Technology Innovation Project with \( \sigma = 0.2 \)
According to the above results, the real option values of the project are significant and the optimal investment timing for the innovative 8G TFT-LCD panel production line project is to defer for about 1-2 years. The investment strategy of the 8G TFT-LCD panel production line consists of mapping the information set about its own financial condition, technology developing process, management and learning abilities, and the market demand volatility, that is the project total risk which is measured by $\sigma$, to decide the acceptable level of the project uncertainty. If the firm is confident with its own ability and future development of the project, there is relatively larger embedded value under uncertainty, that is, the firm could evaluate the project option value with higher $\sigma$ to evaluate the adequate investment timing. However, if the firm has a weak position in technology/market, it may be better to defer the project until the technology/market develops maturely in the future to start the project.

CONCLUSION

The focus of this work is the economic rents, i.e., the excess profit over the opportunity cost of capital. Economic rents occur only if comparative competitive advantage exists. Because of the recurrent role played in influencing the strategic alternative for the competing firms, innovative technology is one of the main ways to achieve competitive advantage. A hi-tech firm can capture the economic rents (the above-normal return) if the position with strategic benefit of innovative activities has been implemented under uncertain technology development progress, uncertain market demand, and irreversible cost. An approach to evaluate the technology innovation project with the option pricing technique is proposed in this work, to simulate the uncertainty of the project using the volatility (standard deviation) of the project value. We have also considered that the expected economic rents induced by innovative technology usually declines over time and postpone for carrying out the innovative technology may erode the value of the project. The appropriate investment timing will make a substantial influence on the competitive advantage induced by innovative technology. The value of the technology innovation project as well as the optimal timing could be derived. With the advantage of option pricing approach, decision makers can evaluate the project value and decide the investment timing using different degree of uncertainty.

The results not only extend the advantage of keeping the future uncertainty simple but also provide the decision maker references for different level of uncertainty. If the hi-tech firm is confident in its own management ability as well as future technology development process of the
project, this firm will be more talent to take higher uncertainty. Larger standard deviation could be applied in deriving the project value and determining optimal timing. On the other hands, if the hi-tech firm is reluctant to take higher uncertainty, smaller standard deviation could be employed to evaluate the project value. Taking this real option approach to evaluate technology innovation project will complement the disadvantage of DCF method. Under the uncertain environment, our procedure could be applied to facilitate the decision of the innovative project investment timing.

REFERENCES