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Application of Timing Option to Founding Investment of Biotech Start-ups

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Abstract

In the field of life sciences, biotech start-ups are expected to follow a more rapid commercialization process than that experienced by big pharmaceutical companies. There are about 300 public companies out of 1500 biotech start-ups in the United States, but only 23 public companies out of about 500 biotech start-ups in Japan. Why is there such a big numerical difference between the two countries? As a key term, a timing option is defined as a deferrable right—like a call option—to start any given project as a real option. It is considered as a useful tool when determining the optimal timing for risky, but promising biopharmaceutical projects given the trade-off of irreversible investments as a sunk cost. The objectives of this paper include determining the characteristics of the optimal timing for start-ups, understanding the model structures, and forecasting the optimal timing.

Introduction

About 25% of recently approved new medicines by the National Institutes of Health in the United States are biopharmaceuticals (Nikkei Biotech, 2008; PhRMA, 2008). Drug-discovery biotech start-ups are expected to refill the gap, between basic research and clinical development, through a more rapid commercialization process than that experienced by big pharmaceutical companies; however, their bankruptcy rate is high due to resource limitations (Pisano, 2006; Kenney, 1986; National Science Board, 2008) For example, while there are about 1500 biotech start-ups and about 300 public biotech companies in the United States, only a few dozen are profitable (Burrill and Company, 2007). In addition, while there are about 500 biotech start-ups in Japan, the proportion of drug-discovery biotech start-ups is low, and the number of public companies in the industry is only 23—it is just the dawn of the industry in Japan (Venture Enterprise Center, 2008; Japan Bio-industry Association, 2008).

How is it basically possible to repeatedly invest huge amounts and irreversible sunk costs and time in new, risky, and long-term projects, and realize a final return? Why, in the meantime, is the number of biotech start-ups being founded relatively low in Japan, while in the United States new companies are constantly being founded despite the majority being awash in red ink?

For these research questions, this paper applies the discipline of real options analysis. Real options analysis is the application of the concept and techniques used for financial derivatives to real assets. Real options analysis can be used to evaluate the economic validity of the innovative, promising, but high-risk project (Fujiwara, 2008a; Fujiwara, 2008b; Copeland, 2001; Smit, 2004; Trigeorgis, 1996). Above all, this paper examines the characteristics and functions of the timing option. This is because the timing option is an option to defer until uncertainty levels fall, and can be applied to an investment with irreversible, sunk costs.

Based on the above research questions and methodology, this article examines basic timing-option models that enable one to intermittently invest in new emerging projects, and it looks at the characteristics and functions of models that assume underlying assets being of deterministic or stochastic behavior.

The Symbiotic System of Biotech Start-ups and the Timing Option

Here we consider the effectiveness of real options in the survival of biotech start-ups. For this reason, we examine the modeling of a symbiotic system for biotech start-ups, and explore a suitable relationship between the model and real options. Above all, regarding the optimal timing of the decision to go ahead with a start-up, a basic model of the timing option is examined.

Japan's Manufacturing Industrial Structure. From data obtained in 2006, the year before the global financial crisis, we can see that Aichi prefecture's automobile industry is Japan's main manufacturing cluster (Fig. 1). Until some years ago, there were sub-main manufacturing clusters centered around Kanagawa's electronic industry and Tokyo's publishing industry. However, in the case of Aichi prefecture, Toyota city's weight of the added value of the transportation industry has ranged from about 40 to 60%. Previously, up to 1976, prefecture's main industry had been textiles.

Although such a polar concentration of one industry seems efficient for a supply chain, a next generation of industries is necessary through technological transfer, or the commercialization of science research, to prevent such high volatility and systematic shock that comes with a financial crisis. The biopharmaceutical industry seems one such candidate among high-tech industries that can exploit the commercialization of basic research at universities throughout the country.

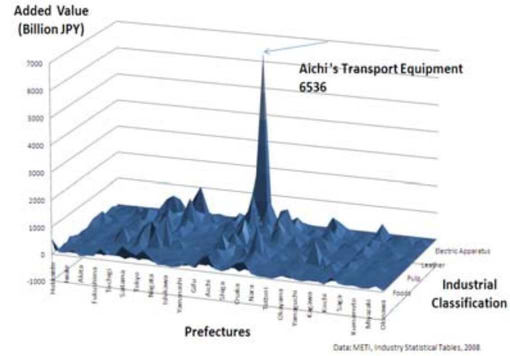

Fig 1: 2006 Japan's manufacturing industrial structure

A symbiotic system of biotech start-ups. The number of biotech start-ups has shown an upward trend until recently, and this is in line with plans by the Japanese government to create 1000 start-ups across all industries by 2010. For example, while the number of biotech start-ups had smoothly increased from 102 companies in 1994 to 586 companies in 2006, it slightly decreased to 577 companies in 2007 (Japan Bio-industry Association, 2008).

Why, basically, can so many deficit biotech start-ups survive in the United States? Can similar results be expected here even if it is recognized that Japan's symbiotic system of biotech start-ups is immature? The answers lie in that biotech start-ups have a comparative advantage in the more rapid commercialization of innovative technology— even in niche markets—than do blockbuster, drug-oriented large pharmaceutical firms.

The symbiotic system of biotech start-ups conceptualized in Fig. 2 is a model based on the functions of founding, selection, and circulation. Hence even a risky investment, which includes the majority of deficit companies, can be attractive if both the criteria of sorting precision and improving potential are high at the development stages for a promising portfolio. In addition, it is also necessary to found a company at an appropriate time, and to circulate information, money, and human resources for a possible re-founding through a sorting process of product ideas, business failure, Mergers and Acquisitions (M&A), Initial Public Offering (IPO), and new drugs on the market.

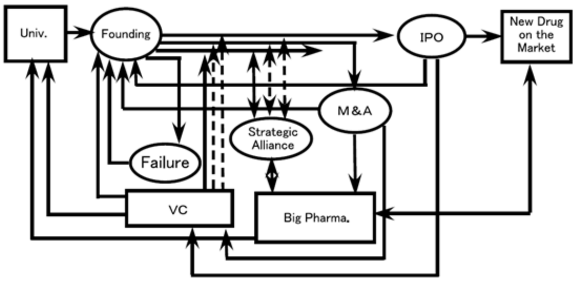

Fig.2: Symbiotic system of biotech start-ups: a model of founding, selection, and circulation

However, in the case of the San Francisco Bay Area, what sort of decision-making criterion has already enabled, as a trigger, many of the founding investments in the biotech drug-discovery start-ups, facing such severe survival conditions, even if there already exist an excellent symbiotic system? In other words, what kinds of characteristics are necessary for theoretical models and managerial techniques, to evaluate the optimal timing of investment decisions for the long term and large amount of irreversible sunk costs, for uncertain profits? We examine this problem next.

In order to patiently commercialize innovative but risky projects such as biotech start-ups, it is necessary to evaluate their potential survival value, even that of deficit companies. At the same time, it is also necessary to timely begin a series of new projects without flinching even when facing the death-valley, initial negative cash-flow, curve. In other words, the optimal timing of founding a start-up is vital to the circular model of resources in the symbiotic system working together with development / sorting and leading to the investment exit.

In addition, if this symbiotic circular resource system for breakthrough innovation were to be established—even in Japan—an increase of start-ups can be expected due to a reasonable enduring of deficits while aiming at radical innovation, in addition to an existing incremental improvement system.

In the following sections, we examine the crucial component of optimal timing, based as a timing option to defer investment until uncertainty sufficiently decreases. This is for an investment of irreversible sunk costs in promising but risky projects.

A basic model of the timing option. In order to optimize the trade-off between the irreversible investment as a sunk cost and uncertain future profits, we examine both the potential and the challenges of the concept and techniques of the timing option in development decisions. In other words, a possible reduction of numerical gap between Japan and US biotech start-ups is examined from an index viewpoint of optimal investment timing.

Research question of the timing option. What kind of decision-making criteria has already enabled much more investment in the United States compared to Japan, with regard toward the founding of drug discovery start-ups in severe survival conditions, even taking into consideration the existence of a symbiotic system of sorting/resources circulation such as that found in the San Francisco Bay Area? In other words, what type of concept is needed for a theoretical model and managerial decision-making techniques to foster the optimal timing of an investment that is long term and includes a large amount of irreversible sunk costs for uncertain profits?

Research framework. As a definition important to the main concept, we look at the timing option defined as a deferrable right—like a call option—to start any given project as a real option. Generally, if an American call option should not be exercised until its maturity, it is equivalent to a European call option. However, the exercise of an American call option is possible even before maturity, only if the underlying asset has a dividend. For the purposes of this research, we will assume all business chances as the perpetual American call options. Next, we examine the decision-making techniques able to overcome the numerical difference between Japan and US biotech start-ups under the concept of a theoretical application that involves the exercise and timing of the perpetual America call options for the underlying asset with a dividend, related to the speed of managerial decision making.

A basic model. The basic model here is based on the precedent studies of McDonald & Siegel (1986), Dixit and Pindyck (1994), and Mun (2002). One objective of the model is to develop a method by which to solve the optimal timing of investing sunk costs *I* in the project with a value *V*. Basically, all investment opportunities of a company can be assumed as the perpetual American call options. Hence, the investment decision is equal to the problem of either the exercise timing of a perpetual American call option or the valuation of an option to defer.

First of all, let the value of the investment opportunity, or the option to defer, be represented by $F(V)$. Hence, the maximization criterion of the expected present value of the investment is,

$$F(V) = \max E[(V_T - I)e^{-\rho T}], \qquad (1)$$

where T denotes the investment timing and ρ is the discount rate. As a basic premise, when μ is the growth rate, the dividend rate δ is assumed to be $\delta = \rho - \mu > 0$ in order to enable the exercise of American call options. The discount rate is CAPM (Capital Asset Pricing Model), which is comprised of the sum of the dividend rate and the capital gain rate. The dividend rate refers to the opportunity cost that has occurred from the non-existence of the underlying assets from the initial time point.

In following sections, this basic model is expanded by separating the behavior of underlying assets into the deterministic and the stochastic conditions.

The Optimal Investment Criterion in the Deterministic Condition

A model of the optimal investment criterion. When the present value is V_0, the project value at time point *t* is $V(t) = V_0 e^{\mu t}$. Then the value of the investment opportunity at the time point T is:

$$F(V) = \max E[(V_0 e^{\mu T} - I)e^{-\rho T}] \qquad (2)$$

If $\mu \leq 0$, since *V(t)* deteriorates with time, it is worthless to defer, so $F(V) = \max[V_0 - I, 0]$. On the other hand, if $0 < \mu < \rho$, since $F(V) = \max E[V_0 e^{-(\rho-\mu)T} - Ie^{-\rho T}]$, by differentiating *F (V)* with respect to *T*, the optimization condition is:

$$\frac{dF(V)}{dT} = -(\rho - \mu)V_0 e^{-(\rho-\mu)T} + \rho I e^{-\rho T} = 0. \qquad (3)$$

Hence, the optimal investment timing is:

$$T^* = \max\left\{\frac{1}{\mu} ln\left[\left(\frac{\rho}{\rho-\mu}\right)\frac{I}{V_0}\right]\right\}. \qquad (4)$$

From the boundary conditions of $\lim_{\mu\to\rho} T^* = \infty$ and $\lim_{\mu\to 0} T^* = 0$ within $0 < \mu < \rho$, it is necessary to find equilibrium between the reduction effect of the sunk cost and the increase of the opportunity cost δ due to the isolating from growth of the project value from deferring the investment. When $T^* = 0$ in equation (4) for deciding the exercise timing of an option to defer, the trigger price V^* of the project is:

$$V_0{}^{\mu T^*} = V^* = \left(\frac{\rho}{\rho-\mu}\right) I > I. \tag{5}$$

By substituting equation (4) into (2), the optional value is:

$$F(V) = \begin{cases} \left[\left(\dfrac{\rho-\mu}{\rho}\right)\dfrac{V}{I}\right]^{\rho/\mu}\left(\dfrac{\rho}{\rho-\mu}\right) I & for\, V \le V^*, \\ V - I & for\, V > V^*. \end{cases} \tag{6}$$

According to equation (6), the option value can be specified by either the curve of the summation with the intrinsic and the time values if the project value is equal and less than the trigger value (critical value), or by the curve of only the intrinsic value if the project value is larger than the trigger value.

Numerical calculation example. When $\sigma = 0$ as a deterministic situation and T^* is a given time point in equation (4), the relationship between the profit index *V/I* and the opportunity cost δ becomes of inverse proportions (see Fig. 3). Furthermore, when $\rho = 0.1$, as opportunity cost δ becomes larger and approaches $\rho = 0.1$, the optimal investment criterion V^* approaches the investment *I*, and, hence, the optimal exercise timing becomes earlier (Fig. 4).

Therefore, at first, when the behavior of the underlying assets can be explained by a deterministic model, the relationship becomes a trade-off between the profit index (V/I), as a

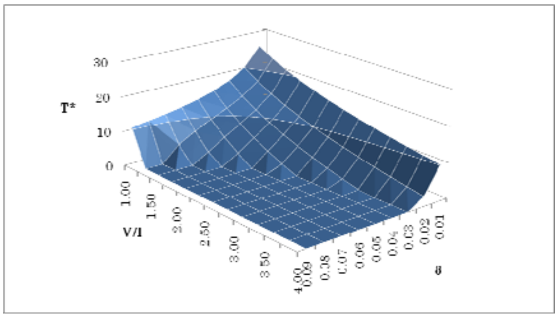

Fig. 3: Optimal time with both profit index and opportunity cost (σ = 0)

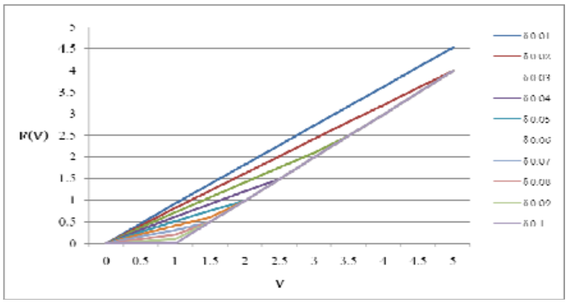

Fig. 4: Opportunity cost and critical value (σ=0, ρ=0.1, i=1, 0<δ≦0.1)

ratio of project value for investment, and the opportunity cost δ, at a given level of investment timing.

Thus, the investment threshold declines. Hence, when the behavior of the underlying asset can be predicted deterministically, the optimal timing point can be calculated by both the opportunity cost and the profit index. And the critical value as the optimal investment criterion depends mainly on the opportunity cost.

The Optimal Investment Criterion in the Stochastic Condition

When the project risk is $\sigma > 0$, investment timing is equated with the decision of the optimal time point of the investment *I* in order to get the asset of value *V*. However, it is not possible to calculate the optimal time point T^*, which is different from the deterministic condition. Hence, after setting the critical value V* as the trigger price, such as $V \geqq V^*$, the timing decision is made by observing the state variable V. When the uncertainty of the underlying assets is modeled, there exist mainly, for instance, the Geometric Brownian Motion (GBM) as a basic model, the Mean Reversion process for the long-term average value of a project for the whole industry, and the Jump process for the sudden loss of the project value from the precedent development completion by a potential rival or the project failure from the toxic result at the clinical trial.

A case of the GBM model of the underlying assets.

A theoretical model. If you assume the uncertainty of the underlying asset V as a GBM with the drift parameter μ, the volatility σ, and the Weiner process dz, the random walk equation is:

$$dV = \mu\, V\, dt + \sigma\, V\, dz. \qquad (7)$$

The value $F(V)$ of an option to defer as an investment opportunity has, by reflecting the time value and the intrinsic value, the boundary conditions as follows:

$$F(0) = 0, \qquad (8)$$
$$F(V^*) = V^* - I, \qquad (9)$$
$$F'(V^*) = 1. \qquad (10)$$

For the exercise timing of an option to defer, it is a premise that the critical value V^* of a project is the summation of the exercise cost I and the option value $F(V^*)$ as the opportunity cost of an investment without deferring. Hence, it can be said that for V, under the condition of $F(V) > V - I$, it is too early for the exercise, and for V under the condition of $F(V) \leq V - I$, it is the optimal timing.
Both the methods of Dynamic Programming (DP) and Contingent Claims Analysis (CCA) can be proved to reach the same solution. In the case of DP, the assumption is that the return of the investment opportunity F with interest ρ and time increment dt is equal to the expected variation of asset value of the investment opportunity:

$$\rho F dt = E[dF]. \qquad (11)$$

On the other hand, with CCA, total return of the risk-free dynamic portfolio consists of the investment option $F(V)$ and the F′(V) unit of short position of the asset, which, in need of the unit time maintenance cost $\delta V F'(V)$, is

$$dF - F'(V)dV - \delta V F'(V)\, dt. \qquad (12)$$

From each assumption, applying Ito's lemma, the differential equation is:

$$\frac{1}{2}\sigma^2 V^2 F''(V) + (\rho - \delta) V F'(V) - \rho F = 0. \qquad (13)$$

If one solves this equation under the above three boundary conditions, the value of an option to defer is:

$$F(V) = A V^{\beta_1}. \qquad (14)$$

Hence, the critical value is:

$$V^* = \frac{\beta_1}{\beta_1 - 1}, \qquad (15)$$

where,

$$\beta_1 = \frac{1}{2} - \frac{\rho - \delta}{\sigma^2} + \sqrt{\left[\frac{\rho - \delta}{\sigma^2} - \frac{1}{2}\right] + \frac{2\rho}{\sigma^2}}. \qquad (16)$$

$$A = \frac{V^* - I}{(V^*)^{\beta_1}} = \frac{(\beta_1 - 1)^{\beta_1 - 1}}{\beta_1{}^{\beta_1} I^{\beta_1 - 1}}. \qquad (17)$$

A characteristic of the optimal criterion. A critical value V^* of an investment decision is the project value at the tangency point between an intrinsic-value curve and a time-value curve, and this becomes larger with an increase in risk σ (see Fig. 5). As a difference between an option value and an intrinsic value, the time value $[F(V) - (V - I) \geq 0]$ enlarges with the increase of risk, and this makes the level of the profit index, $V/I = 1$, a peak (see Fig. 6). For a given critical value V^*, there is a trade-off between the largeness of risk σ and the smallness of opportunity cost δ (see Fig. 7). And for a given risk σ, the critical value V^*

declines with the increase of opportunity cost δ; this makes the exercise timing becomes earlier (Fig. 8).

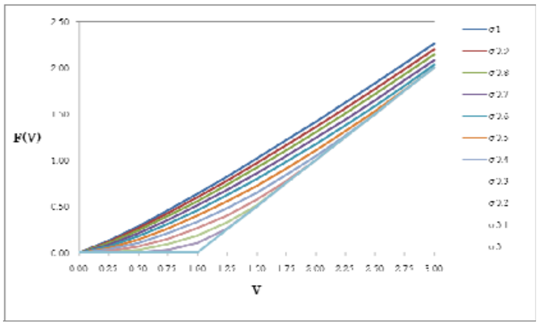

Fig 5: Option value and risk (ρ=0.1, i=1)

Thus, at first, if risk is small, it is a time value in optional value contracts. Also, it is considered a critical value approach to an investment as an exercise price when the optional value is equal to the Net Present Value (NPV). In this case, the additional time value to an intrinsic value becomes zero. Next, the size of a time value, in the design or exercise of a real option, increases with the largeness of risk around the grey zone, where the NPV is close to zero or the profit index = 1 (since the project value is equal to the investment). That is, real options can work most effectively, and the relation of real options with parameters is significantly efficient, in transforming the NPV into the ENPV (Expanded NPV). Thirdly, critical value as a criterion of investment timing can be determined as a trade-off

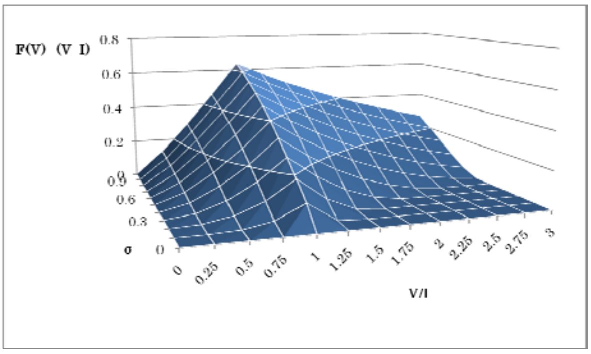

Fig. 6: Option value with profit index and risk (ρ=0.1)

between the largeness of risk and the smallness of opportunity cost. Finally, a related matter, if the risk is constant and the opportunity cost increases, the critical value declines. In this case, the timing is likely to come earlier. In addition, it is possible to specify the critical value from the parameters of curves.

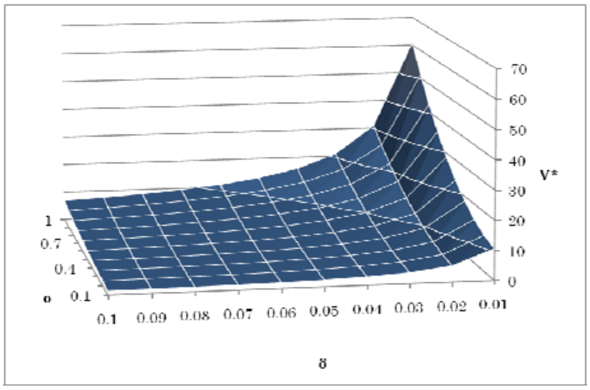

Fig. 7: Critical value of risk and opportunity cost (ρ=0.1)

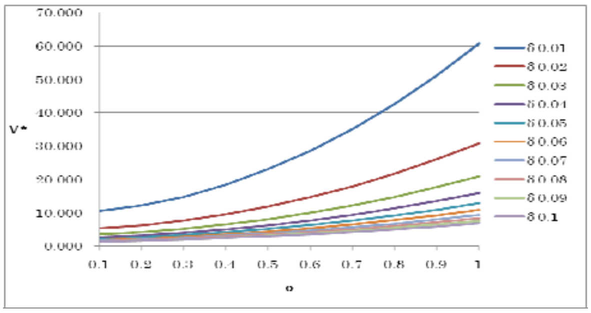

Fig. 8: Critical value with risk and opportunity cost (i=1, ρ=0.1)

Since it is impossible to calculate the optimal timing based on the stochastic assumption of the underlying assets, stochastic optimal timing is forecasted by replicating a time point within the project value (as a state variable) with one equal or bigger than the critical value as $V \geq V^*$.

Simulation. Here, the measurement of the optimal timing of an investment is examined using a simulation of the numerical computation of the time point when the project value, as a state variable, becomes equal or larger than the critical value. This is a modeling of the volatility risk of the underlying asset using GBM.

For instance, when annual interest is $\rho = 0.2$, growth rate $\mu = 0.05$, risk $\sigma = 0.6$, and investment $I = 1$, the simulation result of the calculation $V^* = 2.425$ shows that the optimal investment timing falls on the 371st day (250 annual working days) (see Fig. 9). In the graph, at a time point when $NPV(= V - I)$ is equal to the optional value F(V), the opportunity loss of an investment can be considered to be zero as the time value within an option value.

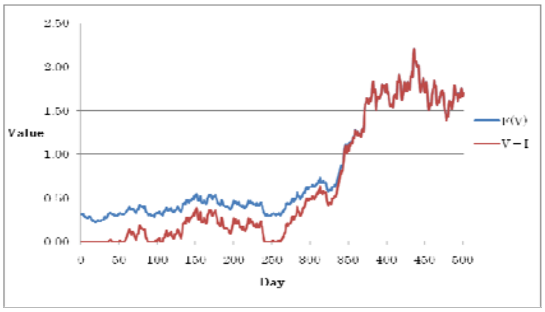

Fig. 9: A case of GBM simulation on timing option (ρ=0.2, μ = 0.05, σ = 0.6, i=1, t=371)

A case of the jump diffusion model of the underlying assets.

A theoretical model. Here we expand the GBM model as a basic model of an underlying asset's behavior into the Jump Diffusion Model by adding the Poisson Jump process. As an example, let the immediate value change of a project that is deferring but facing the risk of precedent development and market monopoly by a potential rival or the risk of toxic failure in a clinical trial be represented as

$$dV = \mu V dt + \sigma V dz - V dq, \quad (18)$$

where dq is an increment of the Poisson process with the average arrival rate λ, and an adjustment of dV by $-\phi V$ with the probability λdt ($0 \leq \phi \leq 1$). According to Merton's proof (Merton, 1990), it becomes possible to add dq to random walk equation (7) and convert it into (18). Hence:

$$dq = \begin{cases} -\phi & \text{with probability } \lambda dt, \\ 0 & \text{with probability } 1 - \lambda dt. \end{cases} \quad (19)$$

F(V), A, and V* each have the same equation, as with the case of GBM, but when $\phi = 1$, the question of β_1 becomes

$$\beta_1 = \frac{1}{2} - \frac{\rho - \delta}{\sigma^2} + \sqrt{\left[\frac{\rho - \delta}{\sigma^2} - \frac{1}{2}\right] + \frac{2(\rho + \lambda)}{\sigma^2}}. \quad (20)$$

Because of the fact that when $\phi = 1$, the decline rate $-\phi$ of a project value makes the project value equal to zero using $V - V$ from equation (18) , there is a decrease in the opportunity cost of the immediate investment without deferring—there is a decline in the critical value as a trigger price, and this has the effect of hastening the investment. Thus, in an option to defer with the hope of a decrease in uncertainty, the jump diffusion process assumes the trade-off between the decrease in uncertainty and the risk of a sudden precedent development by a potential rival or the risk of toxic failure of clinical trial by adding the Jump process into the basic GBM model of the underlying assets.

Hence, it is necessary to replicate the optimal timing with a simulation that takes into effect a stochastic balance between the effect of an uncertainty reduction by deferring an investment and the risk to completely and suddenly lose the value of a project.

Simulation. With a simulation based on a numerical calculation, it is possible to test the validity of a decision on the optimal investment timing by comparing a state variable of project value with its critical value. For example, from the results of a simulation that includes the parameters of volatility σ = 0.7, drift μ = 0.5, discount rate $\rho = 0.2$, investment I = 1, average arrival rate λ = 0.1, and change rate of the Poisson process ϕ = 1, we arrive at a conclusion that gives us the 70th day (per 250 annual operating days) for optimal investment timing (Fig. 10).

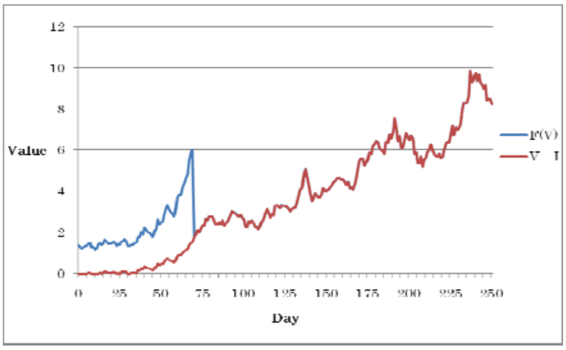

Fig. 10: A case of jump-diffusion simulation on timing option (σ=0.7, μ=0.5, ρ=0.2, i=1, λ=0.1, ϕ=1, t=70)

When it is possible to model the stochastic behavior of an underlying asset using the GBM, the critical value representing the optimal investment criterion is identified by both the risk and the opportunity cost. In addition, if the behavior of an underlying asset is modeled by the jump diffusion process through not only the GBM—based on the lognormal distribution—but also using the Poisson jump process , we are able to calculate a similar optimal investment criterion. Hence, by observing the occasion when the project value, as a state random variable, becomes equal or larger than the optimal investment criterion, it is possible to use this information for forecasting as a replication of the optimal timing.

Thus, in the future, even if a prediction of the optimal timing becomes possible, it still seems necessary to make predictions that conform with a forward-looking process that goes beyond starting a project that relies only on existing spot forecasting, and, furthermore, to focus on only the most profitable opportunity while forecasting.

Conclusion

The reason why a lot of deficit companies facing the death-valley curve can exist in the United States depends on a rational decision making process based on whether the return as a whole is larger than the investment. There are also symbiotic systems to support, incubate, and circulate resources for the founding of biotech start-ups, as in the San Francisco Bay Area and La Jolla. Furthermore, the timing option is applicable to the decision to found a start-up as an irreversible investment of a huge amount of sunk costs into a long-term and high-risk project. It is also applicable in helping to reduce the numerical difference of biotech start-ups between Japan and the United States.

With a timing option, as the optimal investment criterion, the trigger price (a critical value) V^* is the summation of the value of the option to defer (as the opportunity cost of immediate investment without deferring) and the value of an investment that is suitable for the state variable *V* (as a project value to overcome it), instead of the NPV. When the behavior of a project value is assumed as a deterministic model, the critical value becomes smaller with the largeness of the profit index V/I and the largeness of the opportunity cost δ, in which, the optimal timing T^* becomes earlier. In addition, at any given optimal timing T^*, there is the trade-off between the profit index *V/I* and the opportunity cost δ. When the risk behavior of a project value can be modeled using the GBM, the timing of a critical value becomes earlier with the smallness of risk σ and the largeness of opportunity cost δ. And at any given critical value V^*, there is the trade-off relationship between the smallness of volatility σ and the largeness of opportunity cost δ. Basically, optimal timing is forecasted by the replication of the possibility of whether the value of the option to defer *F(V*)* in a simulation becomes equal to NPV with the option exercise ($F(V^*) \leq V^* - I$).

The models and simulation techniques examined here may contribute to the forecasting of the optimal timing of founding start-ups, and to the improvement of Japanese management style, which is generally regarded as making slow, prudent decision, by calling attention to the importance of opportunity loss in addition to the value of the option to defer the projects of biotech start-ups. However, an estimate based on the probability distribution using multiple trials also seems to be necessary, instead of relying only on simulation as the one scenario for timing forecasting.

And in the future, there may still be challenges in expanding the biotech start-up model. It will depend on characteristics such as intellectual property, the switching options of market entrance/withdrawal, the learning effect, and the decay of competitiveness due to obsolescence.

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