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Applying a Two-Stage Option Games Method to Investment Decisions of Business Startups: Case Study of a Smart House Startup in Indonesia

Ida Sri Wardani[*]**, Takao Fujiwara**[**]

Abstract In this paper, we present a case study of a new emerging business startup involved in smart house appliances. The irreversible investment concept and real-option theory are introduced as the fundamentals of the model. By using games theory we show that the startup's actions can trigger reactions from other firms. The first part covers initial the research and development stage, while the second part covers production and commercialization. The findings of this study suggest that, given a certain amount of initial investment, an open and shared innovation may lead to hurting a firm's investment while strengthening the competitors' position in the market. However, given the sensitivity analysis, when volatility and demand grow favorably, sharing R&D investment is not a bad option for a new player to adjust its position in the market while still maintaining positive returns.

Keywords Real options approach, game theory, flexibility, two-stage game, smart house company

I. Introduction

As technology improves and hardware prices decrease, new businesses are emerging and become more accessible to everyone. As the Internet of Things technology is embedded in an ever-larger array of household product categories, Smart Home has the potential to be one of the biggest tech adoption revolutions (Chan et al., 2009). The Smart Home concept has caught the attention of researchers and business players, attracted by the opportunities offered specifically by ICT-related technologies. Interest from industry is diverse. Energy providers see opportunities for ICT-enabled smart energy management. Hardware providers see opportunities for the house to become an entertainment experience center. Security providers see distant surveillance, control and safety equipment as options for new business. Although houses contain ever more smart devices, the concept of smart houses is seldom

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[*] Toyohashi University of Technology; ida.wardani90@gmail.com
[**] fujiwara@las.tut.ac.jp

realized on a large scale and almost never leads to an integration of applications in the commercial market (Solaimani et al., 2010).

However, in recent years, new startups have emerged all over the world. As technology becomes further integrated into our everyday lives, smart home startups are creating a range of products and services aimed at making homes safer, more efficient, and more connected than ever before. This rapid growth also triggers interest from large companies to participate in the smart home market. While new and small startup firms are rapidly increasing, bigger firms tend to join the market when the products are already well received. Firms are expected to be more flexible and responsive to market changes. The flexibility, which can allow management to adjust the amount, rate, timing or scale of investment, will provide a significant competitive advantage in the current market.

Small and innovative firms also face the traditional problem of investment decisions and valuations, which plays a significant role in business financing and is also an important prerequisite for the success of a business operation (Song, 2010). Currently, real options analysis (ROA) has emerged to replace the traditional discount cash flow method (net present value-NPV). ROA is able to capture management's flexibility to adapt and revise later decisions in response to unexpected market development (Copeland and Antikarov, 2003). But it depends on the manager's capability to flexibly take real managerial actions, which is sometimes quite troublesome in large enterprises.

The speed to react and respond to recent market changes provide a heads-up for firms that want to gain customers' preference. This feature is one of the advantages of small and new startups. The smaller organization structure allows management to react and make business decision promptly. When a startup owner sees an opportunity to challenge or to expand the business, he/she can do it without discussing with a board of directors or stockholders. This feature also allows startups to enter new businesses rapidly, although it can be risky in a promising market.

The approaches used in ROA have been extensively studied in recent years and have been applied to many types of business, such as energy (Fernandes et al., 2011), public infrastructure (Cheah and Liu, 2006; Hyuk Lee, 2011; Ha and Fujiwara, 2015), information technology (Dimakopoulou et al., 2014) and biotechnology (Fujiwara, 2014). However, the main disadvantage of ROA is that it cannot take into account additional investments between an investor and its competitors (Suttinon et al., 2011). The investment decision of a policy maker also has an effect on the market. This means that the value of investment is uncertain not only with regard to demand and price, but also as it relates to additional investment made by an investor and its competitors.

To address this shortcoming, the option games approach that combines real options (with demand and price uncertainties) and game theory (with a competitor's decision perspective) has been presented as a hybrid investment valuation tool for analysis of the value of flexibility and commitment (Smit and Trigeorgis, 2009). In the earlier years, Panayi and Trigeorgis (1998) proposed multi-stage real options applications that have strategic importance beyond those captured by standard DCF valuation approaches. Later on, Dongping Yu (2009) provided an application of game theoretic approach to real options to discuss the strategic decision rules in corporate R&D investment under uncertainty and competition, with three uncertainties in terms of income, cost and technology considered. The development of option games has become a popular topic in the field of decision-making analysis. Such approach has been implemented in various models, such as real option game models based on stochastic variables (Azevedo and Paxson, 2014) and option games on one-stage strategic model (Aye and Fujiwara, 2014). From the previous reviews, it is certain that option games approach is a new valuation tool that combines real option and game theory so as to value flexibility and commitment.

In the previous studies, most real options and game theory applications are applied to stable and well-established businesses. The option games approach is clearly suited to companies in capital-intensive, oligopolistic markets facing considerable demand volatility. However, there are fewer studies that focus on new business that start in small yet growing markets. With aggressive technological development and growing interest in startup companies, we believe that market dynamics for new technologies are worth exploring. Therefore, the goal of this study is to analyze the dynamics of business competition in new or relatively unknown sectors entered by small firms or startup companies. As the market grows, big firms usually enter and improve the market flows through price and/or quantity competition. The objective of this paper is to assess the value of startups' investment by means of a tool that integrates real options valuation with game theory. It will seek to answer questions such as whether it is feasible for a new business to make an early investment, and how the action of a bigger competitor will affect the firm's investment decision in the long term. This proposed option game enable a more complete assessment of options in demand and future price with interactive competitors' moves in the market. The case study was selected from among new firms in Indonesia present in the technology-based market that focus on developing smart house technology for residential areas of major cities in developing countries.

II. Methodology

In our previous paper, we analyzed a new startup company called SED (system of electronic devices), which is also the name of its main product. The idea behind this company product is to allow homeowners to manage and monitor electricity usage easily using electronic interfaces. It is designed to meet major housing residential needs in Indonesia, which comprise low- to medium-economy housing type. As the market grows, firms have to keep up with customer demands and also consider competitors' action. Therefore, even in the initial stage, a new startup business also has to deal with the issue whether to invest in R&D or not.

1. Discounted Cash Flow

Business owners realize that the value of money changes according to time. This is the main concept of discounted cash flow method evaluation. Decision makers can decide whether an investment is worth doing by comparing the value of an investment with a base measure. The most popular and frequently used measure is the net present value (NPV) technique, which compares the value of an investment over the project's lifetime to its initial value in time period 0. Another commonly used technique is internal rate of return, which compares the rate of return of a project to the designated rate that is decided by management. The NPV technique is the most widely used decision-making tool for various investment projects. This traditional approach is known to be quite useful in many projects, but not in the case of highly volatile and uncertain investments. It is unreasonable to imagine that market conditions remain constant during the lifetime of a project, especially in a high risk and high return project. Using NPV technique, a project is deemed acceptable when NPV is positive. This is the main weak point of DCF - it does not include uncertainty about the future nor the volatility during the project lifetime.

2. Real Options Analysis

Real option analysis (RO) was developed by valuing flexibility. It was first applied in the financial sector to overcome the shortcoming of NPV. The main objective is to identify uncertainty and create flexibility. The RO enables policy makers to consider when it is suitable to initiate or continue a project. The binomial approach is one of the most powerful tools currently available because it can create a decision tree based on demand, price, and other parameters for each time period. The resulting chart shows possible decision values with occurrence probabilities at each point. The value of the various possible outcomes is then integrated to yield the final expected value of the project. Based on the result in our previous study, real options have been proven to help new businesses to survive the Death Valley Curve during the earlier period. Market changes demand business owners to response promptly, whether it is to defer, expand or stop an investment at a particular time. This flexibility can be developed effectively using the real option approach.

3. Option Games

The basic setup is a two-stage game with player A and B, in which player A is the startup and player B is the big company that usually enters the market at a latter stage. In the first stage (basic research), the initial investment is made only by Player A as the pioneer that has the proprietary right to invest or not. In the second stage, the two players will engage in endogenous competition between themselves for the commercialization of R&D investment. As for the game's methodology, the procedure essentially consists of comparing both the value of flexibility through real options and the value of commitment through game theory in a game tree, and then utilizes both to optimize the strategic decision through backward induction. An early stage investment will give a competitive advantage of cheaper production cost during the next stage's commercialization. In this study, the analysis will be limited to no investment (scenario 1) and shared investment by both firms (scenario 2) following Cournot's quantity competition framework.

To demonstrate the applicability of the proposed method, actual data is generated from the case study. The unique smart house-based business was chosen because it represents a niche market that is occupied by most technology-based businesses. The illustration of this case study is as follows: firm A can decide to make an initial R&D investment during the first stage that will result in a deterministic operating cost advantage during the second stage. The first-stage initial investment and the second-stage commerciali-zation investment total IDR100 million. When they engage in endogenous competition during the latter stage, either firm A or firm B can invest in commercialization projects, depending on movement in subsequent random demand compared to its initial demand $\theta = 15$. Volatility is estimated using discounted cash flow and utilizing Monte-carlo simulation, thus $\sigma = 14\%$. Binomial parameters up and down moves of $u = 1.15$ and $d = 1/u = 0.87$. The risk-adjusted discount rate, k is 17% while risk-free rate is 7.5%. Risk-neutral probabilities are also used in this approach. They are probabilities of future outcomes adjusted for risk, which are then used to compute expected asset values. The benefit of this risk-neutral pricing approach is that once the risk-neutral probabilities are calculated, they can be used to price every asset based on its expected payoff. If constant asset payout yield for perpetual project is:

$$\delta = \frac{k}{1+k}$$

risk-neutral probability is

$$p = \frac{(1+r-\delta)-d}{u-d} = 0.214$$

where u=exp$\sqrt{\sigma\Delta t}$ and d=1/u.

As firm A chooses not to make its basic R&D investment, the two firms would have the symmetric second-stage operating costs based on first-stage old technology, cA = cB = 3. The illustration of the base case is shown in Figure 1 below. The details of the figure are as follows:

A or B (□) represents a decision to invest (I) or defer (D). (○) represents the state of market demand up (u) and down (d) moves.

The combination of competitive decisions (A or B) and market demand moves (θ) may result in one of the following market structure game outcomes:

C: Cournot Nash quantity / price competition equilibrium outcome
S: Stackelberg leader (S_L) / follower (S_F) outcome
M: Monopolist outcome
A: Abandon (0 value)
D: Defer / stay flexible (option value)

Calculation is done as follows:
general equation for Cournot-Nash equilibrium (C) is:

$$NPV_i(C) = \frac{(\theta_t - 2c_i + c_j)^2}{9k} - I_1$$

In the base case of the second period, when demand is up and both A and B select D (Defer) first and I (Invest) next, and C is attained by 32.7.
General equation of monopoly (M) is:

$$NPV_i(M) = \frac{(\theta_t - c_i)^2}{4k} - I_1$$

general equation of the Stackelberg leader equilibrium is:

$$NPV_i(S_L) = \frac{(\theta_t - 2c_i + c_j)^2}{8k} - I_1$$

general equation of the Stackelberg follower equilibrium is:

$$NPV_i(S_F) = \frac{\left(\theta_t - 3c_i + 2c_j\right)^2}{16k} - I_1$$

For the alternate demand of up and down and for the downside demand, we were able to find all equilibrium results under all market structures of Cournot Nash equilibrium (C), Stackelberg leader (S_L) and follower (S_F), monopoly (M) and abandon (A) by using above same fashion formulas. At first period the general equation of the monopoly (M) is

$$NPV_i(M) = \frac{pV_u + (1-p)V_d}{1 + r_f} - I_1 + \frac{\pi M}{1 + K}$$

while monopolist profit for 1 period is defined by:

$$\pi M = \frac{(\theta_t - c_i)^2}{4}$$

As for the general equation of deferment (D) is:

$$NPV_i(D) = \frac{pNPV_u + (1-p)NPV_d}{1 + r_f}$$

Once we calculated the value at each node from the bottom-up, we are able to value the expected equilibrium value at the first stage (t = 0):

$$PV_i * = \frac{pPV_u + (1-p)PV_d}{1 + r_f}$$

The base case value of no R&D investment is symmetric for both firms, in which it is (5.7, 5.7) for firm (A, B). The diagram for base case of no investment in the initial stage is illustrated below in Figure 2.

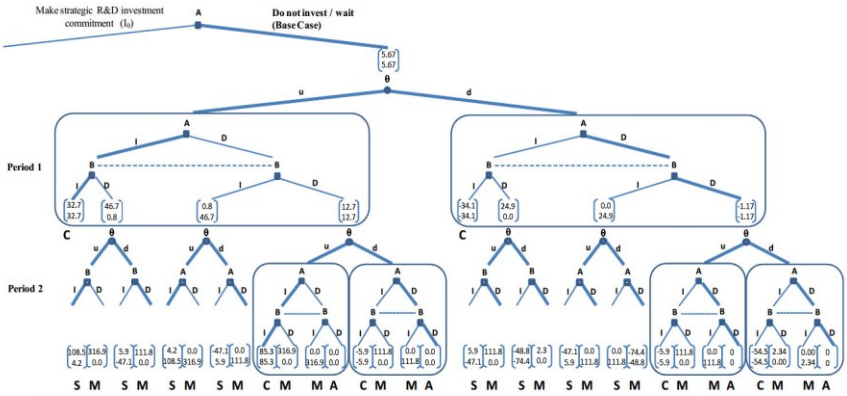

Figure 1 Base case: two-stage game with no investment in 1st stage

Under the shared investment strategy, the operating costs are symmetric for both firms. There is no means to benefit from initial investment, and pioneering firm A shares development findings with rival firm B. Because of more cost-effective technology utilized by firm A, they can exploit the reduction in their costs, therefore the operating cost will be equal to zero. And the valuation method for all results is the same as for the base case. Figure 3 illustrates the symmetric shared case, and all valuation equilibrium results can be seen in it.

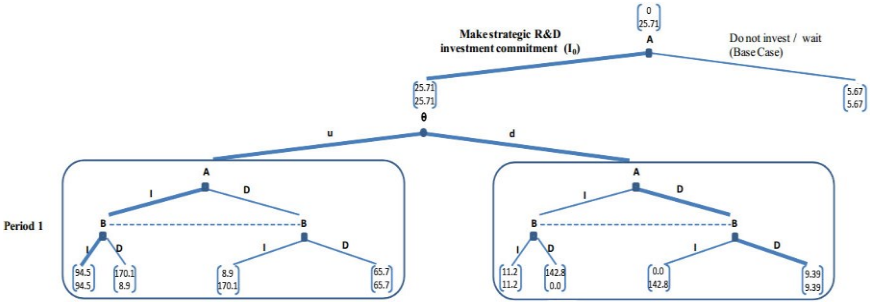

Figure 2 Shared investment between firms

III. Result

The base case value is symmetric for both firms when neither invests in R&D, which is valued at IDR 5.67 million. In the shared case, the pioneer company shares the development finding thus reducing both companies' production cost to zero. As seen in Figure 3, if firm A insists on investing in

R&D its NPV will be less than zero, whereas firm B's NPV remains positive. The open market R&D expenditure strengthens the competitor's strategic position and enhances its incentive to respond aggressively in the future. As a consequence of this strategy, pioneer firm A moves into a disadvantageous position compared with its base case of no investment. Firm A should not invest in R&D, but should rather retain a flexible wait-and-see position, attaining the base case equilibrium values of (5.7, 5.7). Investing in R&D may create a strategic disadvantage for firm A by taking on the cost of creating valuable investment opportunities for competition or by enhancing the competitor's ability and incentive to respond aggressively in the future. We performed a numerical simulation by alternating demand and volatility rates, shown in Figure 3. The calculation indicates that when demand goes lower than 14, the payoff will be negative for both firms. It indicates that firms need to monitor the changes in market before proceeding to the next stage and consider what is the best action that will provide better payoff.

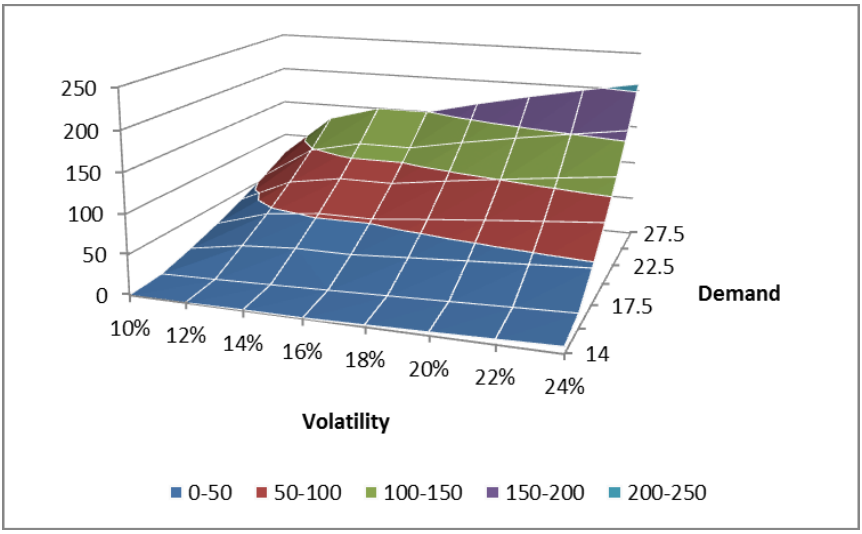

Figure 3 Base case payoff considering changes on demand and volatility

When there is no means to change an investment benefit, and when a pioneering company with initial R&D investment shares development findings with a rival company, the pioneering company's position becomes disadvantageous since it will receive less NPV than its competitor. This happens because startups do not have any competitive advantage and cannot deter a competitor from entering the market. However, by changing volatility and demand value, it is possible to attain the same level of a base case, which is shown in Figure 4. The rise of volatility will increase payoff for each firm, but at the same time it also raises market uncertainty.

By changing θ and volatility rate, we perform a sensitivity analysis for firm A's NPV valuation in the shared investment case. It suggests the basic option theory, which says that the higher the volatility, the higher the options value will be. In this case, the option value is represented by the value of expanded NPV of firm A. In summary, although the strategic sharing of R&D findings can appear to produce disadvantageous results, it also has an opportunity to enhance the firm's NPV rather than the base case. It is also possible for the pioneer to design a policy to collect profits from a free riding competitor who is enjoying profits without committing initial investment. The other insight gained from this study is that demand and volatility act as a significant variable in determining the firm's payoff. Determining demand target relates strongly to the firm's commitment in making the first investment to create a new technology and to commercialize its product, while volatility can be associated with the state of the market, which is quite difficult to predict accurately.

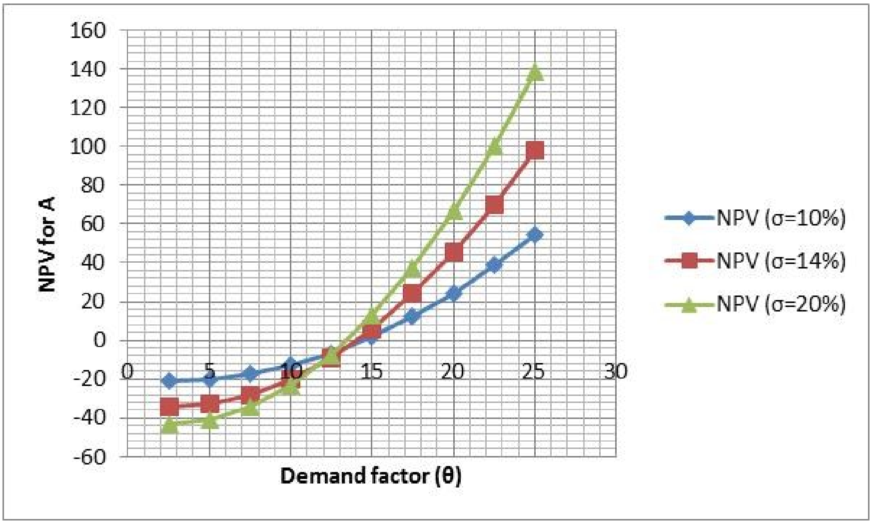

Figure 4 The changing behavior of A's NPV with the shifts of θ and σ (shared investment)

IV. Conclusion

Using the case study's real data as guidelines to increase efficiency in investment decision-making, our research shows that it is advisable for rival firms to strategically share R&D findings during the commercialization stage, to pursue a wait-and-see approach under market uncertainties, and to make efforts to meet large demands in the context of changing volatility. This approach may enable the firms cooperating on projects to take full advantage of the flexibility value of immediate substantial investment, thus avoiding the competitive pressures of a race to preempt the market with innovation. Moreover, strategic interactions among rival firms clearly influence positively the value of the sequential investment plan of startups under technological or demand uncertainty conditions.

In case of high volatility and high demand, a new entrant startup will face a disadvantage positioning against its competitor when it chooses a shared investment strategy. However, aside from the calculation result itself, sharing a strategy can be used as a course to trigger innovations and more advanced development in the respective technologies. In a broader point of view, shared investment may hurt a startup in the short term, but it may establish a more innovative technological offer. The downside effect is that the pioneer firm will suffer lower payoff than its competitor, but in the near future, the pioneer firm is also able to establish a position in the market and gain customer trust.

In view of all the parameters above, it becomes possible for a startup to maximize NPV on the basis of the Option-Games Analysis. Furthermore, in the new dynamic, competitive, global world, it is necessary to decide when is the optimal time for a startup to switch its investment strategy from non-investing to sharing a proprietary strategy to overcome the Death Valley Curve, to deter a rival company from entering its market and to maximize its own NPV. Volatility values play a significant role in determining the payoff of the firms. In this study, we performed a numerical simulation to forecast the firms' payoff under different values. In reality, however, volatility varies according to timing and the surrounding environment. Thus, future studies ought to focus on estimating better volatility value during the two-stage of the game.

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