Heterogeneous Goods, Strategic Investment, and First Mover Advantages: Real Options Theory and Empirical Study

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Abstract. This study uses Real Options Analysis to receive information regarding market uncertainty. Traditional studies assume that the market is perfectly competitive and homogeneous. However, the automobile market is imperfectly competitive and its goods are heterogeneous. Automobile firms may obtain first mover advantages through irreversible investment when the market is imperfectly competitive. First mover advantages can be regarded as barriers to entry because followers cannot earn profits by entering the market and raising market share. Moreover, traditional surveys exploited the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model to estimate the uncertainty (volatility). In this study, the Kalman Filter is adopted for replacing the GARCH model to improve the weaknesses in the traditional estimation method. In this study, the significant level is 0.05, and the adjusted R2 of Toyota and Honda are 0.87 and 0.58.

Keywords: Real options theory · First mover advantage · Strategic investment Kalman Filter

1 Introduction

It is widely seen the differentiation in society, but what it means in the strategic management? For example, the electric vehicle business can be regarded as the leading industry of the future. We argue that they can be a disruptive innovation toward the automobile industry. This occurrence is similar to how digital cameras affected traditional cameras. For example, a Chinese manufacturer of automobiles and rechargeable batteries, BYD Co. Ltd., is regarded as a high potential automobile manufacturer in the automobile industry. The investment guru Warren E. Buffett has also invested in BYD Co. Ltd. because of their electric vehicle and rechargeable battery technologies.

Electric vehicles and lithium batteries are complementary technologies. Moreover, lithium battery technology is a key component of developing electric vehicles. The optimism regarding the future of the electric vehicle market has prompted most manufacturers in the automobile industry to actively invest in lithium battery R&D. In

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Taiwan, most firms involved in the R&D of lithium battery focus on its material component and their targeted use is in power tools and electric vehicles.

When a firm is deciding on an investment plan, the characteristics of goods are classified as either substitute or complementary goods. For example, EPSON printers require the use their brand of ink cartridges, and APPLE MacBooks require the use of a Macintosh operating system. The electric vehicle market is a high potential market in the future, and electric vehicles and lithium batteries are complementary; thus, manufacturers in the automobile industry are more willing to enter the lithium battery industry. This paper examines the appropriate timing for entering the lithium battery industry to advise automobile manufacturers when they decide to invest.

Traditional methods involve exploiting the Net Present Value (NPV) to evaluate the benefits of entering a market. This method neglects the uncertainty of a market. Because the market is unpredictable, considering the uncertainty is appropriate and may raise the positive value of real options. Moreover, the traditional NPV method overlooks the irreversibility of an investment. These key elements may misestimate the value of an investment.

Several scholars suggested that the real value of an investment involves NPV and the investment's opportunity costs (McDonald and Siegel 1986; Dixit and Pindyck 1994). Moreover, delaying a project in an uncertain market is better than completing a project immediately (Kogut and Kulatilaka 1994; O'Brien et al. 2003; Alessandri et al. 2012). Delaying a project in uncertain markets and during irreversible decision-making situations may lead to positive values in delay options. Firms may delay until new information is released and only then decide to use them (McDonald and Siegel 1986; Dixit and Pindyck 1994; McGrath 1999; Bo et al. 2006; Michailidis 2006). Therefore, the value of deferral options can be regarded as a value of waiting. This characteristic of flexible decision-making is important for management and investment, but is neglected in the traditional NPV method. This study adopts the Real Options Approach (ROA) method that considers the uncertainty, irreversibility, and flexibility characteristics of a project plan to alleviate the shortcomings of the NPV method. For example, Kulatilaka and Perotti (1998) emphasized the value of a strategy under uncertainty in an imperfectly competitive market and exploited growth options to invest strategically. Tong and Reuer (2007) identified the importance of ROA for strategic management: First, ROA requires research to revisit the received wisdom, and offers unique predictions, on firms' decisions for many types of strategic decisions. Second, ROA uniquely posits an asymmetric payoff structure for investments with embedded options by suggesting that real options enable firms to reduce downside risk while accessing upside opportunities. Third, ROA sheds new light on firms' resource allocation processes by informing strategic decision making.

Cottrell and Sick (2001) argued that a pioneer may obtain a first mover advantage that can preclude followers from divvying market shares. Moreover, the irreversible investment of a firm may lead to the benefits of a first mover advantage when the market is imperfectly competitive; that is, the first mover advantage may cause barriers to entry, which may hinder followers from obtaining profits. Although the pioneer advantage may raise monopoly power, several scholars have indicated the presence of advantages for followers. For example, followers may reap benefits from the free-rider effect; that is, followers can save in R&D costs by modeling a pioneer's products

(Schnaars 1994). Moreover, followers can efficiently enter the market by learning from the experiences of a pioneer (Cottrell and Sick 2002). Several empirical studies showed that followers obtain better profits compared to the pioneer in the computer market, motorcycle industry, and electric generator market (Cottrell and Sick 2001).

Cottrell and Sick (2002) further argued that the first mover possesses advantages such as leading technologies and learning curve benefits. Lieberman and Montgomery (Leiberman and Montgomery 1998) indicated that the pioneer may have priority in choosing its suppliers. These pioneer advantages of firms may directly affect costs. Therefore, first mover advantages are important for firms to obtain profits. Whether the first mover advantage affects the profits of automobile firms that desire entering the lithium battery market is important.

Several empirical studies such as the O'Brien et al. (2003) study have traditionally exploited the Generalized Autoregressive Conditional Heteroskedasticit (GARCH) method to estimate volatility (uncertainty). However, the GARCH model cannot effectively estimate volatility. Therefore, Sommacampagna and Sick (2004) used the Kalman Filter to examine the volatility of the ratio of well drilling. Moreover, Welch and Bishop (2006) indicated that the Kalman Filter can effectively estimate uncertainty. This study implements the Kalman Filter to accurately estimate the uncertainty.

Generally, the assumption that a market is perfectly competitive simplifies the issue for discussion. However, the realization of a perfectly competitive market is difficult in practice; thus, this paper assumes that an automobile market is imperfectly competitive.

This study is organized as follows: Sect. 2 shows the theoretical model and propositions, Sect. 3 establishes the research method, Sect. 4 provides an analysis of empirical results, and Sect. 5 is the Conclusion with a discussion of future studies.

2 Theoretical Model

The equilibrium output of the Cournot-Nash model and the values of a firm.

This study assumes that only two firms (firm 1 and 2) exist, which sell heterogeneous goods (Goods 1 and 2) in the automobile market. The inverse demand curves are as follows[1]:

$$p_{11} = \theta_0 - a(q_{11} + q_{21}) - b(q_{12} + \mathrm{q}_{22}) \tag{1}$$

$$p_{21} = \theta_0 - a(q_{11} + q_{21}) - b(q_{12} + \mathrm{q}_{22}) \tag{2}$$

$$p_{12} = \theta_0 - a(q_{12} + q_{22}) - b(q_{11} + \mathrm{q}_{21}) \tag{3}$$

$$p_{22} = \theta_0 - a(q_{12} + q_{22}) - b(q_{11} + \mathrm{q}_{21}) \tag{4}$$

where i = 1, and i = 2 represents firm 1 and 2; j = 1, and j = 2 represents goods 1 (battery) and 2 (vehicle); $p_{i,j}$ and $q_{i,j}$ are prices and quantities; a represents a vertical

[1] We followed Vives (1984) model setting.

differentiation of substitution and follows the law of demand; b represents the level of the differentiation between Goods 1 and 2; 0 < b < 1 represents two substitute goods; b < 0 represents two complementary goods.

Furthermore, this study assumes that θ_0 is the initial quantity of market demand and follows the Geometric Brown Motion (GBM):

$$\frac{d\theta_0}{\theta_0} = \alpha\, dt + \sigma\, dz \tag{5}$$

where α and σ are instantaneous drift and standard deviation, respectively; dz is the incremental Wiener process.

Moreover, this study assumes that there is no variable cost. Therefore, under the Cournot competition of Stage 2 at time t, the maximum profits of the firm i are the following:

$$\text{Max } \pi_{\mathrm{i}}(q_{i,2}, q_{j,2}, \theta) = (\theta_0 - aq_{i,2} - bq_{j,2})q_{i,2}, i \neq j \tag{6}$$

Let V_i represent gross project value and the NPV_i can be calculated as follows:

$$V_i = E\left[\int_0^{\infty} e^{-rt} \cdot \pi_i(\theta)dt\right] = \frac{\pi_i}{n \cdot \delta} \tag{7}$$

and

$$NPV_i = V_i - I \tag{8}$$

where π_i represents the cumulative profit flow at time t, n is defined by the type of market competition, and $\delta = \sigma^2 + 2\alpha - r$ represents the constant equilibrium and risk-adjusted discount rate.

Under the Cournet-Nash competition, the reaction functions of these two equations are as follows:

$$R_i(q_{j2}) = \frac{\theta_0 - bq_{j2}}{2b} \tag{9a}$$

and

$$R_j(q_{i2}) = \frac{\theta_0 - bq_{i2}}{2b} \tag{9b}$$

The Cournot-Nash equilibrium is

$$q*_{1c} = q*_{2c} = \frac{\theta_0}{2a + b} \tag{10}$$

Therefore, under the condition of the duopoly market, the profit of firm i is

$$\pi_{ic} = \frac{a\theta_0^2}{(2a+b)^2},\ i = 1,2 \tag{11}$$

Equation (11) indicates that the two goods are complementary goods when $b < 0$, and the two goods are substitute goods when $0 < b < 1$. Furthermore, the profits of the two firms can be affected by the duopoly market when the two goods are substitute goods. Moreover, under the Cournet-Nash equilibrium, the gross value of the project is

$$V_{ic} = \frac{a\theta_0^2}{\delta'(2a+b)^2},\ i = 1,2 \tag{12}$$

However, under a monopoly, the gross project value is

$$V_{1m} = \frac{\theta_0^2}{4a\delta'} \tag{13}$$

From Eqs. (12) and (13), the results are similar to the outcomes of the Cournot-Nash equilibrium and monopoly. When a decreases, the θ_0 and project value increases.

Competitors are a main consideration for firms that want to enter a market. When a pioneer enters into a new market, a monopoly may result and all the excess profits in the new market may be obtained. However, excess market profits may attract followers.

Following is the situation that occurs when followers enter a market, divvying the market share when a first mover possesses a monopoly.

2.1 The Strategy of Followers

Presuming that θ_0 follows the Geometric Brown Motion (GBM),

$$\frac{d\theta_0}{\theta_0} = \alpha\, dt + \sigma\, dz$$

By using Ito's Lemma, the value of the investment can be expressed as

$$dV = \left(\alpha\theta_0 V' + \frac{1}{2}\sigma^2\theta_0^2 V'' + V_t\right)\vec{d}t + \sigma\theta_0\vec{V}dz \tag{14}$$

The McDonald and Siegel (1986) study indicated that projects are valuable until exercised. Therefore, the present value can be a downward or return to zero. However, maturity is infinite; thus, the value of a project is unrelated to time maturity; thus, $V_t = 0$.

Let $V' = \partial V/\partial\theta_0$, $V'' = \partial^2 V/\partial\theta_0^2$, $V_t = \partial V/\partial t$, and the Bellman equation is followed; thus, Eq. (14) can be expressed as follows:

$$\alpha\theta_0 V' + \frac{1}{2}\sigma^2\theta_0^2 V'' + V_t - rV + \left[\frac{a\theta_0^2}{(2a+b)^2}\right] = 0 \tag{15}$$

Thereafter, the value of the project V_{ic} is

$$V_j(\theta) = A_{ic}\theta_0^{\beta_1} + B_{ic}\theta_0^{\beta_2} + \left[\frac{a\theta_0^2}{(2a+b)^2}\right]\frac{1}{\delta'} \tag{16}$$

where A_{ic} and B_{ic} are endogenous constants, and β_1 and β_2 follow the quadratic form:

$$\frac{1}{2}\sigma^2\beta(\beta-1) + \alpha\beta - \gamma = 0$$

Moreover, β_2 should be greater than 0 to avoid the Bubble solution; thus, β_{ic} is equal to 0. The solutions of β_1 and β_2 are the following:

$$\beta_1 = \frac{1}{2} - \frac{\alpha}{\sigma^2} + \sqrt{\left(\frac{\alpha}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2r}{\sigma^2}} > 0\ (> 0) \tag{17a}$$

$$\beta_2 = \frac{1}{2} - \frac{\alpha}{\sigma^2} + \sqrt{\left(\frac{\alpha}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2r}{\sigma^2}}(< 0) \tag{17b}$$

Assuming that the followers suffer the same barrier to entry, the firm with the monopoly may maintain the sale quantity of their product. Furthermore, Eq. (16) shows the project value of firm j after firm i entered the market. When A_{ic} and B_{ic} are equal to 0 for firm j, the project value of the followers in the duopoly are as follows:

$$V_j(\theta_0) = \left[\frac{a\theta_0^2}{(2a+b)^2}\right]\frac{1}{\delta'} \tag{18}$$

The NPV of the project exercised by firm j is

$$NPV_j(\theta_0) = V_j(\theta_0) - I \tag{19}$$

where I represents the fixed cost of the project.

Moreover, let θ_i be the market demand of followers. When $\theta_i \geq \theta$, the NPV of the implemented project is

$$NPV_j(\theta_i;\theta) = E_\theta\left\{\left[V_j(\theta_i) - I\right]e^{-rt}\right\} \tag{20}$$

where E_{θ_0} is the risk-neutral expectation operator.

then
$$T \equiv T\left(\theta_j;\theta_0\right) = inf(t \geq 0 : \theta \geq 0,\ \theta_0 = \theta)$$

$$E_{\theta_0}[e^{-rt}] = \left(\frac{\theta_0}{\theta_j}\right)^{\beta_1}$$

When $\theta_i^* \geq \theta_0$, firm j (follower) implements the option to gain NPV.

$$NPV_i(\theta_i;\theta_0) = \left[\frac{a\theta_i^2}{(2a+b)^2}\cdot\frac{1}{\delta'} - I\right] \times (\theta/\theta_0)^{\beta_1} \tag{21}$$

The best choice for firm j is to implement its option when $\theta_i > \theta$. Therefore, under the condition of maximum profit and $\theta_i > \theta$, the optimal threshold is

$$\theta_j^* = \frac{\beta_1}{\beta_1 - 2}\cdot\frac{(2a+b)^2}{a\theta_0^2}\cdot\delta'\cdot I \tag{22}$$

where $\delta' = \sigma^2 + 2\alpha - r$.

Proposition 1: $\frac{\partial\theta_j^*}{\partial a} > 0$

The parameter "a" represents the degree of substitution between two goods. The barrier to entry increases as the degree of substitution between two goods increases. High substitution indicates that two goods possess low differentiation. Followers are insignificantly advantaged because of a high substitution degree (or low differentiation); that is, followers need to invest more resources into producing goods to earn profits. When the pioneer's high quality product attracts consumers, followers need to produce higher quality products to compete with the pioneer; thus, the threshold value of entering the market rises.

Proposition 2: $\frac{\partial\theta_j^*}{\partial b} > 0$

The parameter "b" represents the substitution between two goods. A higher degree of substitution (b > 0) indicates a higher threshold of market entry. Conversely, a lower degree of substitution (b < 0) indicates a lower threshold of market entry. When products produced by two firms are complementary, the pioneer may benefit from the entry of followers, which attracts more consumers into the market. Moreover, the degree of complement between two goods indicates that two goods are differential; thus, the threshold of market entry may decrease.

Proposition 3: $\frac{\partial\theta_j^*}{\partial\delta'} > 0$

The threshold of market entry decreases with a lower cost of capital, which may reduce risk. Therefore, the risk-adjusted interest rate may lower the threshold of market entry.

Proposition 4: $\frac{\partial\theta_j^*}{\partial I} > 0$

The threshold of market entry increases with the level of investment. Firms consider their capacity when planning to enter a market. Therefore, a high investment cost increases the threshold of market entry.

Proposition 5: $\frac{\partial \theta_j^*}{\partial \sigma} > 0$

The uncertainty in a market increases the risk-adjusted interest rate. Therefore, the threshold of market entry increases when the market is uncertain.

2.2 Market Entry Strategy of Pioneer

A pioneer can earn profits associated with the monopoly until followers enter the market. The value of the pioneer V_i must satisfy the following quadratic differential equation:

$$\frac{1}{2}\sigma^2\theta_0^2 V_i''(\theta) + V_t + \alpha\theta V_i'(\theta) - rV_i + \left(\frac{\theta_0^2}{4a}\right) = 0 \tag{23}$$

where $V' = \partial V/\partial\theta_0$, $V'' = \partial^2 V/\partial\theta_0^2$, $V_t = \partial V/\partial t$, and $V_t = 0$.

Thereafter, the function of the pioneer's investment value of can be expressed as the following:

$$V_i(\theta) = A_1\theta_0^{\beta_1} + A_2\theta_0^{\beta_2} + \left[\frac{\theta_0^2}{4a}\right] \cdot \frac{1}{\delta'} \tag{24}$$

When potential competitors abandon the market (A_2), Eq. (24) results in 0. The function of the pioneer's investment value can be revised to the following:

$$V_L(\theta) = A_1\theta_0^{\beta_1} + \left[\frac{\theta_0^2}{4a}\right] \cdot \frac{1}{\delta'} \tag{25}$$

Followers enter the market at time t. The market structure transforms the monopoly into an oligopoly. Thereafter, the investment value of the pioneer becomes equal to the outcome of the Cournot-Nash model. Moreover, the value-matching condition indicates that the value of the option becomes equal to the value of investment:

$$V_i\left(\theta_j^*\right) = V_0\left(\theta_j^*\right) \tag{26}$$

Thereafter, the solution of A_1 is obtained to combine Eqs. (25) and (26):

$$A_1 = \frac{1}{\delta'}\left[\frac{\theta_0^{2-\beta_1}(4a+b)(-b)}{(2a+b)^2 - 4a}\right] \tag{27}$$

The NPV of the pioneer's implementation of the option to invest in the project plan is as follows"

$$NPV_i(\theta_i;\theta_0) = \left[A_1\theta_i^{\beta_1} + \frac{\theta^2}{4a}\frac{1}{\delta'} - I\right]\left(\frac{\theta}{\theta_i}\right)^{\beta_1} \tag{28}$$

Moreover, the pioneer (firm i) may choose to enter the market by the threshold of market entry:

$$\theta_i^* = \left(\frac{\beta_1}{\beta_1 - 2}\right)\left(\frac{4a\delta' I}{\theta_0^2}\right)$$

Thereafter, the thresholds of the two firms are indicated as follows.
Pioneer:

$$\theta_i^* = \left(\frac{\beta_1}{\beta_1 - 2}\right)\left(\frac{\delta' I}{\theta_0^2}\right)(4a)$$

Followers:

$$\theta_j^* = \left(\frac{\beta_1}{\beta_1 - 2}\right)\left(\frac{\delta' I}{\theta_0^2}\right)\left[\frac{(2a+b)^2}{a}\right]$$

The equation $4b + \frac{b^2}{a}$ can be obtained by the difference between the pioneer and follower. The two goods are substitutable because 0 < a < 1 and b > 0; that is, the follower's threshold is higher than the pioneer's. Conversely, the two goods are complementary if 0 < a < 1 and b < 0; thus, the follower's threshold is lower than the pioneer's. Moreover, the pioneer cannot obtain the first mover advantage when the two goods are complementary.

2.3 An Interim Summary

Firms will decide to enter a market based on the thresholds at different time points. First, there is no firm in the market because firms are waiting to invest. Thereafter, the pioneer enters the market when the pioneer reaches the threshold; that is, the first mover may obtain several benefits by entering the market. The market is a monopoly at this stage. Thereafter, the follower enters the market because it reaches the threshold; thus, the market structure transforms from a monopoly into an oligopoly.

3 Empirical Research

This study uses the stock prices of the two firms Toyota and Honda to evaluate the value of deferral options that automobile firms can use to invest in the battery market. Toyota is the pioneer and Honda is the follower in this study.

3.1 Research Design

The purpose of this paper is to examine whether the degree of market uncertainty and complement of the electric car and battery affects the stock prices of automobile firms. Thereafter, Toyota's stock price and Honda's stock price are analyzed using the regression model, whereby the stock prices are dependent variables and the market uncertainty and complement of goods are explanatory variables.

During the decision-making process of the investment, the market uncertainty and complement of goods may influence the value of the project. Therefore, the factors of uncertainty and complement are considered in this study.

First, the inverse demand function estimates the degree of complement. Thereafter, the uncertainty of the market is calculated with the Kalman Filter. This study uses the regression model to consider the previously indicated factors and estimate the influence between the two stock prices and two factors. Moreover, the dummy variable D_t is equal to 1 when the uncertainty is higher than the threshold. Conversely, the dummy variable is equal to 0.

3.2 Empirical Model

The regression function of the pioneer (Toyota) is

$$S_{Lt} = \gamma_0 \ + \ \mathrm{b_{Lt}} + \gamma_1 \mathrm{D_{Lt}} \theta_{\mathrm{L}}{}^{*} + \gamma_2 \sigma_{Lt}^2 + \gamma_3 IR_t + + \varepsilon_{Lt}, \quad \varepsilon_{Lt} \overset{iid}{\sim} N\left(0, \sigma_L^2\right) \tag{29}$$

The regression function of the follower (Honda) is

$$S_{Ft} = \beta_0 \ + \ \mathrm{b_{Ft}} + \beta_1 \mathrm{D_{Ft}} \theta_{\mathrm{F}}{}^{*} + \beta_2 \sigma_{Ft}^2 + \beta_3 IR_t + \varepsilon_{Ft}, \quad \varepsilon_{Ft} \overset{iid}{\sim} N(0, \sigma_F) \tag{30}$$

where S_{Lt} and S_{Ft} are the stock prices of Toyota and Honda; b is the complementary of goods; D_t is the dummy variable; σ_{Lt}^2 and σ_{Ft}^2 are the volatilities of these two firms' profits; θ_{Lt} and θ_{Ft} are the variables of thresholds; IR_t is the interest rate; and ε_t is the error term.

3.3 Calculation of the Degree of Complement

The inverse demand functions of Toyota and Honda can derive the following functions:

$$CP_{Lt} = a_1 + a_2 \cdot CS_{Lt} + a_3 \cdot BS_{Lt} + a_4 \cdot BS_{Ft} + \varepsilon_{Lt}, \quad \varepsilon_{Lt} \overset{iid}{\sim} N\left(0, \sigma_L^2\right) \tag{31}$$

$$CP_{Ft} = b_1 + b_2 \cdot CS_{Ft} + b_3 \cdot BS_{Ft} + b_4 \cdot BS_{Lt} + \varepsilon_{Lt}, \quad \varepsilon_{Ft} \overset{iid}{\sim} N\left(0, \sigma_F^2\right) \tag{32}$$

where CP is the price of automobile vehicle[2]; CS is the car quantity (Toyota and Honda); BS is the battery quantity; a1 and b1 are constants; a2 and b2 are the

[2] In this study, prices of cars are the standard cars of 2000 c.c. in automobile market.

coefficients of vehicle quantity; a3 and b3 are the coefficients of battery quantity; and a4 and b4 are the effects between own vehicle and competition's battery.

Moreover, the law of demand indicates that a_2 and b_2 are negative; that is, the quantities of demand decrease when the price increases. Furthermore, $a3$ and $b3$ are negative, which indicates that the electric cars and battery are complementary goods. When the price of a car increases, the quantity of demand decreases; thus, the demand of batteries decrease because of the relationship to complementary goods. The car's price and the battery's price are negative.

3.4 Estimation of Volatility

This study uses the Kalman Filter to estimate the volatility of firms' profits. The Kalman Filter includes the State equation and Observation equation, which are the dynamic model and recursive processes for estimating volatility.

The following are the advantages of using the Kalman Filter: 1) the Kalman Filter provides a recursive process to estimate the state of the past, present, and future, 2) the model can estimate the state of the past, present, and future under uncertainty, and 3) the optimal value of estimation can be identified by providing a sample.

3.5 Choice of Control Variable

Four aspects that can influence stock price are examined: the viewpoints of macroeconomics, industry, corporate, and others that were implemented in past surveys. First, the macroeconomic variables include the income, inflation rate, interest rate, money supply, exchange rate, and commodity price. Second, the industrial variables include the seasonal factor, market concentration rate, degree of competition, and technological innovation. Third, the corporate variables include the change of management, decision-maker, earning, risk premiums, and dividend. Finally, several other variables are included such as corporate behavior, psychology, non-fundamental elements, and lag (Culter et al. 1989; Lee 1998; Olsen 1998; Madsen and Davis 2006). The interest rate is implemented as a control variable in this study.

4 Empirical Results

4.1 Sample Collection

This work includes the sales quantities by Toyota and Honda, quantities of Japanese batteries, price of Japanese automobile vehicles, sales figures of Toyota and Honda, and Japanese interest rates. The sample period is from Q2 2004 to Q4 2007. These samples are figures were collected from the financial reports of Toyota and Honda, Japan Automobile Manufacturers Association (JAMA), Battery Association of Japan (BAJ), and Bank of Japan (BOJ).

4.2 Descriptive Statistics

4.2.1 Estimation of Substitution and Variance

1. Price of automobile vehicle (CP)

This study uses Japan's 2000 c.c. vehicle to represent the prices of Toyota and Japan, because the electric vehicle and hybrid vehicle possess a high price level. In this study, the mean of the price index of an automobile vehicle is 99.4 and the maximum is 100.1.

2. Quantities of automobile vehicle (CS)

The quantities of sales are collected by Toyota and Honda. Our JAMA-based samples are the sales quantities of Toyota's and Honda's 2000 c.c. vehicles. In Japan, the mean of sales quantities by Toyota are 127,996, the maximum is 157,790 (2006 Q1), and the minimum is 127,996 (Q2 2007). Conversely, the mean of the sales quantities by Honda are 35,968, the maximum is 62,325 (Q2 2004), and the minimum is 25,980 (Q3 2007).

The theoretical expectation is that the sales quantities of Toyota and Honda are negative toward the index of car price; that is, the law of demand is satisfied.

3. Quantities of battery (BS)

The samples were collected by the BAJ. The mean of the battery is 6472 and the maximum is 7610. The theoretical expectation is that the quantities of battery sales and quantities of car sales are positive; that is, batteries and vehicles are substitute goods.

4. Sales of firms (SV)

The information regarding Toyota's sales was revealed in the quarter after 2008 because of Japan's accounting principles. Data before 2008 are available in annual or half-year figures. For collecting the data before 2008 for this study, the quantity of car sales is used to estimate Toyota's sales by ratio, which shows the relationship between Toyota's sales and the quantity of national car sales in the Japanese automobile market. Furthermore, the Kalman Filter is used to estimate the variance in sales of Toyota and Honda. The results indicate that the mean return of Toyota is 4% and the maximum return of Toyota is 5%. Conversely, the mean return of Honda is 11% and the maximum return of Honda is 13%.

Regression function: effect between stock price

5. Stock price (S_t)

This study examines the stock prices of Toyota and Honda from the Tokyo Stock Exchange, which are code 7203 and code 7237. The average stock price of Toyota is 5692 Japanese Yen and the maximum stock price is 7840 Japanese Yen during our sample period. Conversely, the average stock price of Honda is 5017 Japanese Yen and the maximum stock price is 6950 Japanese Yen during our sample period.

In this empirical study, the stock prices represent the value of deferral options. If the firm undergoes a budget constraint, this indicates that the firm forgoes the right to delay its option. However, traditional wisdoms regarding uncertain markets suggest that firms delay their option until new information is received. The increase in stock price reflects the potential growth of a firm that investors believe in. Furthermore, the value of the deferral option may increase when a market becomes more uncertain; that is, the time value of a project represents the potentially positive value of new information that investors are waiting for.

6. Complementary (a)

The complementary (a) may be derived using the inverse demand function. A theoretical expectation is that the relationship between complements and stock price are positive. In this study, because the electric car and battery are complementary, firms may expand their product lines by producing cars, electric cars, hybrid cars, and batteries. This widening of product lines of one firm may increase its stock price.

Moreover, when the degree of complement increases, the pioneer obtains advantages from combining complementary goods. These advantages increase the threshold of entering the market for followers.

7. Variance (σ^2)

The variance is calculated using the sales data and represent the market uncertainty. Regarding deferral options, a positive relationship is present with the stock price and investing uncertainty. In an uncertain market, this may increase the potential benefits for investors. Moreover, the value of waiting may be beneficial with the increase in uncertainty, which may be reflected in stock prices.

8. Threshold (M_{it})

The η_L and η_F are the impact of the threshold on stock price when dummy variables are equal to 1. These are positive values that are consistent with the results and the comparative static analysis theory. A higher threshold represents a high difficulty for followers in entering the market and a better performance of stock price for the pioneer. Bo et al. (2006) suggested that the threshold must be greater than 1 to consider the market uncertainty. This factor may exist in the value of deferral options.

9. Interest rate (IR)

The data regarding interest rates were collected from the benchmark interest rate of the BOJ. The average interest rate is 0.21% and the maximum interest rate is 0.5%. Economic theories indicate that the relationship between the interest rate and stock price is negative.

4.3 Analysis of Empirical Results

4.3.1 Result of Complementary

This study estimates the complement of regression for Eqs. (31) and (32) by using the rolling window method: the coefficient of car sale and battery; a_2 and a_3, respectively. The results indicate that the relationship between the car sales quantity and car price are influenced by the law of demand ($a_2 < 0$). Moreover, a_3 is insignificant, and the results indicate that the complement of goods does not influence the car price. Furthermore, car price affects the battery sales quantity.

4.3.2 Estimation of Volatility

After transferring the profits of Toyota and Honda toward the ratio of profit, the Kalman Filter approach is implemented to estimate the volatility. Thereafter, a series of volatility are obtained by using the rolling window method.

4.3.3 Analysis of Regression Model of Stock Price

$$S_{Lt} = \gamma_0 \mathrm{b_{Lt}} + \gamma_1 \mathrm{D_{Lt}} \theta_L{}^* + \gamma_2 \sigma_{Lt}^2 + \gamma_3 IR_t + + \varepsilon_{Lt}, \quad \varepsilon_{Lt} \overset{iid}{\sim} N\left(0, \sigma_L^2\right) \tag{33}$$

$$S_{Ft} = \beta_0 \mathrm{b_{Ft}} + \beta_1 \mathrm{D_{Ft}} \theta_F{}^* + \beta_2 \sigma_{Ft}^2 + \beta_3 IR_t + \varepsilon_{Ft}, \quad \varepsilon_{Ft} \overset{iid}{\sim} N(0, \sigma_F) \tag{34}$$

Integrating the complementary, uncertainty, threshold, and control variable into Eqs. (33) and (34), the degree of influence is calculated between every variable and stock price.

The results indicate that market uncertainty does not affect the stock prices of Toyota and Honda. Moreover, the estimated results regarding the complement degree indicate that they significantly affected Toyota's stock price. Conversely, Honda's stock price was not affected by the complement degree between the electric car and lithium battery. The estimation of the threshold of market entry indicated that it did not influence the stock prices of Toyota and Honda. Furthermore, the results regarding interest rates indicated that they may have negatively influenced the stock prices of both Toyota and Honda. These results are in accordance with investment theories. In this study, the significant level is 0.05, and the adjusted R2 of Toyota and Honda are 0.87 and 0.58, respectively (Table 1).

These results indicate that the pioneer cannot profit from market uncertainty; thus, the existence of first mover advantages for the pioneer (Toyota) is determined in the following section.

4.3.4 First Mover Advantages

According to Gal-Or (1985), compared to stock price of Honda, Toyota's stock price has a relatively weak performance from Q1 1999 to Q4 2005. The booming electric car market prompts the positive performance in Toyota' stock price. Moreover, Toyota's stock price surpassed Honda's in 2006 (Fig. 1).

Table 1. Results of regression model of the Toyota's and Honda's stock price

RHS variables	Coefficient (Toyota)	Coefficient (Honda)
C	8.912***	8.19
σ^2	−2.151	4.48
IR	1.238***	−0.66**
compl	−2783.95***	301.86
Dummy threshold	0.02	−0.03
Adjusted R^2	0.87	0.58
Prob(*F*)	0.000001	0.003

Note: **$\alpha = 0.1$; ***$\alpha = 0.05$; Sample period: Q4 2004–Q4 2007; Dependent variable: stock price

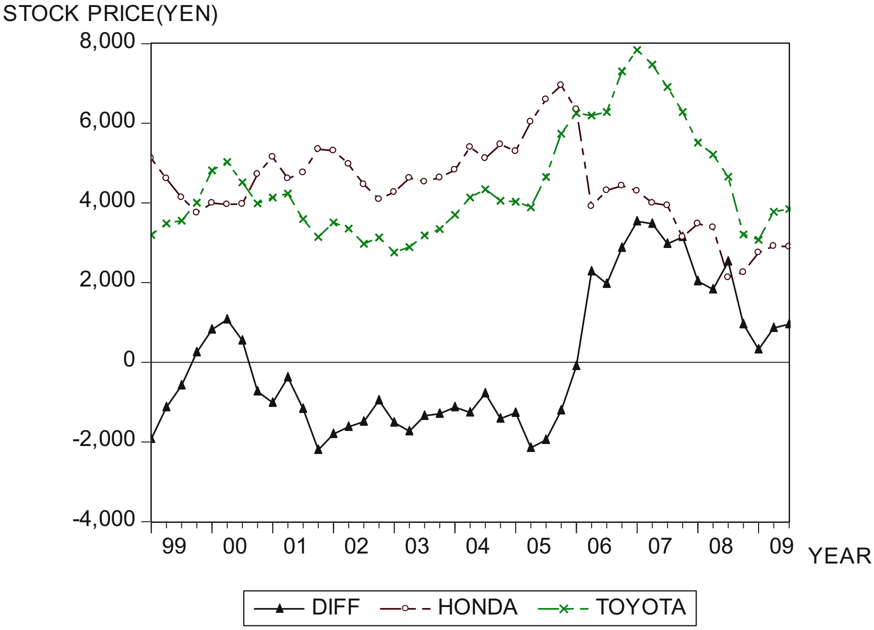

Fig. 1. The time series of Toyota's and Honda's stock price

Moreover, Table 2 shows that the t value is significant under the 95% confident level; that is, Toyota obtained first mover advantages through the R&D of lithium batteries, which are reflected in the firm's stock price.

Table 2. T test of stock price

	Toyota	Honda
Mean	4447.25	4440.59
Variance	1851662.551	1122319.793
Number of observation	43	43
t test	0.025070498	

5 Conclusion and Suggestion

This study examines the relationship between electric cars and lithium batteries, and their influences on the profits of electric car firms that enter into the lithium battery market. The empirical results indicate that Toyota's complementary goods are insignificant. Conversely, Honda's complementary goods are significant. Therefore, discussing the complementary nature between traditional automobiles and batteries is important. The managerial implication is that as complementary companies increase and produce goods, the demand and profits of industry rise, also.

From strategic perspective, we ought to encourage that firms produce complementary goods rather than substitute them under competition. Furthermore, this study used stock prices as the values of deferral options. The empirical results for Toyota indicate that market uncertainty and interest rate are two elements that influence their project plans. Conversely, the empirical results for Honda indicate that three variables are significant to their project plans: complement degrees, dummy variable of threshold, and interest rates. Therefore, these three variables are important for Honda when considering deferring their investment in batteries.

Moreover, the sample was reduced to 15 because of the rolling window method; thus, this study advises that the sample period be increased in the future when adopting the rolling window to receive more reliable results. An increased sample period may improve the significance and power of explanation. Moreover, this study uses the car price index to replace the car prices of Toyota and Honda. Future studies can use actual car prices employ more accurate analyses. Furthermore, Toyota's and Honda's actual sales data of batteries provided by the BAJ can improve the reliability and reality for analyses.

Appendix 1: Process of Theoretical Model Calculation

Proposition 1: $\frac{\partial \theta_j^*}{\partial a} > 0$

$$\theta_{ic}^* = \frac{\beta_1}{\beta_1 - 2} \cdot \frac{(2\mathrm{a} + \mathrm{b})^2}{\mathrm{a} \cdot \theta^2} \cdot \delta \cdot' I$$

Let

$$\begin{aligned}\frac{\partial \theta_j^*}{\partial a} &= B \cdot \delta' \cdot I \cdot 2(2a+b)(2)(a^{-1}\theta^{-2}) + B \cdot \delta' \cdot I \cdot (2a+b)^2(-1)(a^{-2}\theta^{-2}) \\ &= B \cdot \delta' \cdot I \cdot (a^{-1}\theta^{-2})\left[4(2a+b) + (-1)(2a+b)^2 \cdot a^{-1}\right] \\ &= \left(\frac{B \cdot \delta' \cdot I}{a\theta^2}\right) \cdot \left[4 - \frac{(2a+b)^2}{a}\right] > 0\end{aligned}$$

Appendix 2: Process of Kalman Filter Estimation

The dynamic model is used in the Kalman Filter to estimate uncertainty. The recursive processes comprise the following steps. The State equation is the dynamic process and the Observation equation is used to calculate the solution.

State equation:

$$\xi_{t+1} = F\xi_t + v_{t+1} \tag{A.1}$$

Observation equation:

$$y_t = A^{'}x_t + H^{'}\xi_t + w_t \tag{A.2}$$

where A', H', and F are known; x_t is an exogenous variable, ξ_t is the variable of the impact of behavior. In the dynamic process, ξ_t is given as a starting value. The value of y_t can be calculated by implementing these variables and starting value.

Thereafter, the systematic matrix is exploited to consider the uncertainty factor Q:

$$E\left(v_t, v_t^{'}\right) = \begin{cases} Q, \ t = \tau \\ \quad 0 \end{cases}$$

$$E\left(\omega_t, \omega_t^{'}\right) = \begin{cases} R, \ t = \tau \\ \quad 0 \end{cases}$$

where Q and R are the $(r \times r)$ and $(n \times n)$ matrix. Covariance is present when $t = \tau$ Moreover, if $t \neq \tau$, the co-variances are 0.

The calculation steps of the Kalman Filter are the following: 1) implementing the recursive process; 2) calculating the y_t; and 3) renewing the value. The recursive process involves providing the starting value of ξ_1 and using ξ_1 in the Observation equation to obtain y_t, and using the ξ_1 in the State equation to obtain ξ_2.

The Kalman Filter is used to calculate estimates. The Kalman Filter obtains the value of estimates and the uncertainty of estimates with the original value, and can be used to calculate the weight average expected value.

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