行政院國家科學委員會補助國內研究生出席國際學術會議報告

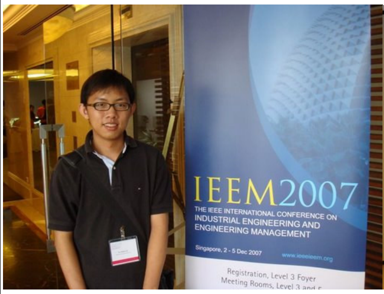
96 年 12 月 14 日

報告人姓名	劉得賢	就讀校院（科系所）	國立東華大學國際企業學系碩士班研究生
會議時間地點	2007/12/02~2007/12/05 新加坡	本會核定補助文號	NSC-96-2922-I-259-018
會議名稱	（中文）2007 年 IEEE 工業工程與工程管理國際研討會 （英文）IEEE The International Conference on Industrial Engineering and Engineering Management (IEEM2007)		
發表論文題目	（中文）運用實質選擇權建構最適多階段收購模型 （英文）Appling the Real Options Approach to an Optimal Multi-stage Acquisition Model		

報告內容應包括下列各項：

一、參加會議經過

於2007年12月1日搭乘長榮航空公司BR0225次班機抵達新加坡璋宜機場，並於當日先行與會議舉辦單位進行簡單的聯絡，當日住宿於YORK HOTEL；12月2日當天中午前往IEEM 2007會議場地「**Furama River Front**」進行報到並參與簡單的會議開場儀式，結束後進行簡單的新加坡文化考察，參觀小印度區與牛車水，當日住宿於YORK HOTEL；12月3日至會場進行論文報告並與新加坡及國際學者進行意見交換，而報告場次與主持人為DA (3) 15:30 - 17:30, 3 Dec 2007 - Monday / Jiuping XU, Felix WRIGGERS，當日住宿於YORK HOTEL;12月4日搭乘長榮航空公司BR0226次班機返台。




二、與會心得

雖然在參加此次國際研討會前在國內已有三次的與會經驗，但是出國報告後，在會議中看到許多來自世界各地的優秀學者，並且從中了解到目前國際上主要的研究議題以及文化差異所造成的研究方向的差異，使我了解與體認到其實一個研究議題在不同的角度切入，將會有非常不同的研究發現，這些是在國內參加研討會時較沒有辦法發現到的，另外，這次的國際會議對我來說也是非常重要的一次學習經驗，這也是我一直以來較缺乏的，從中學習到如何與國際學者應對，並且使自己的膽識增加不少，透過這次的國際研討會讓我獲得的不只是學術上的知識而已，更重要的事是自我心態上的改變，並且國際經驗的累積更是無價，我相信透過這種國際學術上的交流，這次的研討會對我的研究與國際視野的開拓上將有非常大的突破，當然非常感謝國科會能夠持續的對國內研究生出席國際學術會議進行補助，也因為有了國科會大力的相助，才使得身為研究生的我能夠順利的完成這次的國際會議報告，在此致上十二萬分的謝意。

三、考察參觀活動(無是項活動者省略)

在這次的會議空檔時間，有進行簡單的文化與商業活動的參觀活動，例如:參觀了小印度區與牛車水…等文化特色顯明的文化區，希望新加坡民族多元的特性，增加自己對各種民族文化的了解，以減少文化差異所帶來的誤解，當然也有去新加坡的行政區與金融區，希望透過這樣的參觀活動去了解新加坡的商業活動。

四、建議

若能夠持續鼓勵國內研究生出席國際學術會議以及增加補助次數，透過增加學者出國發表論文並帶回新的研究知識的方式，相信國內學術研究應能與國際接軌，使得國內的研究競爭力得以維持。

五、攜回資料名稱及內容

Proceedings of the 2007 IEEE International Conference on Industrial Engineering and Engineering Management 光碟片一份及會議議程與論文摘要集一本。

六、其他

出席國際學術會議心得報告

計畫編號	96-2416-H-259-009-MY2
計畫名稱	一般化生產專案投(撤)資均衡策略:多準則決策評估之應用
出國人員姓名 服務機關及職稱	林達榮/國立東華大學國際企業學系/副教授
會議時間地點	會議時間:2008/12/08-2008/12/11　地點:新加坡
會議名稱	International Conference on Industrial Engineering and Engineering Management (IEEM2008)
發表論文題目	1. The Determinant of the Strategic Value with Human Resource Management on Transnational Enterprises 2. The Optimal Pollution Technical Standard Model with the Environment Economy 3. The Market Entry/Exit Model on the Free Internet Service Firm

一、參加會議經過

1. 2008/12/08-2007/12/11 期間出席 IEEM2008 國際研討會
2. 2008/12/08 下午搭乘華航班機出席新加坡研討會
3. 2008/12/09 上午 8:30 報到時間/領取會議相關資料
4. 2008/12/09 上午 9:00-下午 5:00 海報論文張貼與展覽:
   (1) The Determinant of the Strategic Value with Human Resource Management on Transnational Enterprises
   (2)The Optimal Pollution Technical Standard Model with the Environment Economy
5. 2008/12/10 上午 9:00-下午 5:00 海報論文張貼與展覽: The Market Entry/Exit Model on the Free Internet Service Firm
6. 2008/12/11 上午搭乘華航班機回國

二、與會心得

1. 此次 IEEM2008 國際研討會為 IEEE 旗下所轄之國立新加坡大學主辦具有 IE index 之研討會，本人非常榮幸再獲邀擔任 program committee 委員，並擔任 15 篇論文審稿及參與最佳論文之決選委員。
2. 此次三篇論文獲選參加研討會,均為國科會專題直接關連性論文或計畫經費援助所呈現之成果。與會最主要能將目前執行國科會計畫案內容彙並提供後續計畫進行及修改之參考。
3. 除參與國際研討會外,同時針對碩士班研究生(三位協同出席)在從事國際化學術活動增廣見聞，相信 未來在個人學術研究交流與學生國際觀均有助益。

The Determinant of the Strategic Value with Human Resource Management on Transnational Enterprises

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Abstract - **This study utilizes the real options approach to construct the model of entering the international manpower market in order to effectively evaluate the potential value and obtain the optimal foreign exchange rate under the uncertain situation. That is, building the decision rule and threshold for entering the international manpower market can help evaluate the influence of hiring domestic or foreign manpower on the enterprise value.**

Keywords - **Human resource management, multi-national enterprise, decision-making, real options.**

I. INTRODUCTION

According to enterprise internationalization, the demand of multinational human resources has been increasing; choosing domestic manpower assignment and foreign professional manpower is the most important target that must consider an enterprise's cost and profit in utilizing human resources. In addition, the monetary value is an external factor that will cause the fluctuation of exchange rate. Therefore, this study utilizes the model of hiring multinational foreign labor market (entering and exiting) to satisfy the multinational human resource demand; how to choose the optimal threshold to hire domestic or foreign manpower is the main research purpose.

Most studies of human resources employ qualitative research to evaluate how to make the decision about expatriation, such as the influence of culture, but less studies use the quantitative research approach to evaluate the decision-making value of expatriating in human resources. This study utilizes the real options approach (ROA) to construct the mathematical model of entering the international manpower market. The decision variable is foreign exchange rate which follows geometric Brownian motion (GBM). The intangible value of potential choosing value is an important factor in consideration of HR cost which is ignored by the traditional net present value (NPV) method. The traditional NPV method usually calculates the NPV to evaluate the enterprise value under the certain and static situation, but ignores the flexibility of enterprise value. The biggest difference between the NPV method and the ROA is that [1] pointed out profit is produced by the cash flows of investment, which not only includes the present value of real assets of investment, bust also considers the option value generated by the investment opportunity. Reference [2] proposed that the traditional NPV method ignores or is unable to measure the difference result generated by the actual value and anticipative appraisal result, and the decision-maker is short of adjustability ability because the NPV method ignores the flexibility of management value. Hence, the ROA is more suitable to evaluate the enterprise value in the dynamic situation than the NPV method. Using the ROA to evaluate the intangible value will obtain the actual value of the optimal allocation in the model of human resources.

Furthermore, the visible manpower cost incurred by actual assignment or local hiring will influence the enterprise value. How to obtain the optimal foreign exchange rate, so as to evaluate the enterprise value and decide the strategy for entering or exiting from the international manpower hiring market. That is, how to achieve the maximum value of utilizing the multinational human resources is the main focus in this paper.

Reference [3] showed the demand of managing the international assignment is the major consideration within the strategic international human resource management (IHRM) theory and most frequently considered within the long-term employment choice between parent-country expatriates or host-country nationals. Reference [4] pointed out within the strategic context of IHRM, a significant aspect of research has focused on the management of expatriate assignments and more recently on the issue for the inpatriates who may move from subsidiary organizations to corporate headquarters.

Reference [5] noted that in rethinking strategic investments, managers must try to view their markets in terms of the source, trend, and evolution of uncertainty in order to determine the degree of exposure for their investments and then respond by positioning the investments to best take advantage of uncertainty. Reference [6] introduced the ROA under the investment uncertainty related to real assets and suggested that the options created on these assets will reduce the risk of the loss of value and increase future opportunities for returns. Reference [7] used the ROA to estimate the value of flexibility and determine the optimal strategy of managing the flexibility under the uncertain of exchange rate.

Reference [8] proposed a firm's human resources as an asset that can provide value and competitive advantages; the HRM field has tended to ignore the fact that assets have associated uncertainties and risks.

According to the above literature, the article will utilize the ROA to evaluate the multinational manpower assignment strategy and produce the optimal assignment foreign exchange rate to evaluate the decision-making in the multinational manpower assignment strategy.

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II. THE MODEL

The transnational enterprise makes the decision on hiring the manpower of the overseas subsidiary company, which brings the potential strategy value of hiring domestic employees or foreign professional manpower; the synthetic value causes the enterprise to achieve the minimum cost and total maximum revenue. It assumes that the transnational enterprise assigns professional manpower to the overseas subsidiary company, considers the cost of hiring the domestic and foreign professional manpower on the exchange rate level of domestic and foreign countries (that is, considers the value on hiring the domestic and foreign professional manpower), and finds the threshold of the optimal foreign exchange rate of expatriating and outsourcing to effectively evaluate the optimal decision-making model of the transnational human resource management.

The transnational enterprise will enlarge the operation scale of overseas subsidiary company, so it must supply the lack of N manpower per unit of time; the host company can expatriate n ($0 \le n \le N$) manpower per unit of time, or the overseas subsidiary company can locally outsource ($N-n$) manpower per unit of time. In other words, the manpower demand of overseas subsidiary company per unit of time can be offered by expatriating and outsourcing. Simultaneously, it assumes that the enterprise can possibly satisfy $\overline{n}$ manpower per unit of time. The host company's expatriate cost of unit time is $C_d\left(n(t)\right) = h_d n + h_p n^2$, where h_d is the increasing manpower cost of expatriating a person, h_p is the decreasing average revenue of expatriating a person, and both are the known fixed constants. Suppose $\pi_f\left(n^*(t)\right) = \left(N-n\right)w_f + n w_d$ is the unit of time benefit of expatriating and outsourcing in the host company, where w_f is the revenue of locally hiring a person, w_d is the average revenue of a person that the parent company expatriates, and both w_f and w_d are the known fixed constants. The revenue and cost are priced by the host company's currency and the change of exchange rate can influence the monetary value. Assume the foreign exchange rate level is governed by the following GBM:

$$\frac{dR_t}{R_t} = \alpha dt + \sigma dW_t \, , R_0 = R. \tag{1}$$

where α is the growth rate of foreign exchange rate, σ is the volatility rate of the growth of exchange rate, dW_t is governed by the following standard Wiener process, and $dW_t \sim N\left(0, dt\right)$.

Fig.1 illustrates the relationship between model value functions and decision variables.

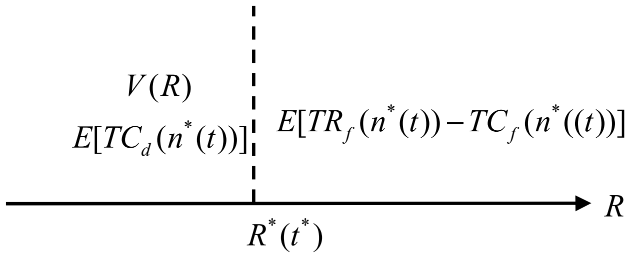

Fig.1 The hiring model of international professional labor

At the left side of the optimal expatriating foreign exchange rate R^* (time t is between 0 and t^*), $E\left[TC_d\left(n^*(t)\right)\right]$ represents the operating cash flow of the parent company's expatriating and $V(R)$ is the potential enterprise value of expatriating. It can be derived by $V(R) = AR^{\beta}$, where A is the scale coefficient of the potential enterprise value of expatriating (see Dixit and Pindyck (1994)). The right side of the optimal expatriating foreign exchange rate R^* (time t is lower than t^*) represents the expatriate manpower of the host company and locally outsourcing manpower assigned to the overseas subsidiary company at unit of time. $E\left[TR_f\left(n^*(t)\right) - TC_f\left(n^*(t)\right)\right]$ represents the expected operating cash flow of the overseas subsidiary company, where $TC_d\left(n^*(t)\right)$ is the present value of expatriating total cost in the host company, $TR_f\left(n^*(t)\right)$ is the present value of expatriating and outsourcing total revenue in the overseas subsidiary company, and $TC_f\left(n^*(t)\right)$ is the present value of outsourcing total cost in the overseas subsidiary company.

The optimal expatriating population $n^*(t)$ in the host company can be written as the objective function:

$$\begin{aligned} &\max E\left\{\pi\left(n^*(t)\right)R - C_d\left(n^*(t)\right)\right\} \\ &s.t. \quad 0 \le n^*(t) \le \overline{n} \end{aligned} \tag{2}$$

Differentiating (2) with respect to n , we can find the optimal expatriating population at unit of time $n^*(t)$ as follows:

$$n^*(t) = \frac{\left(-w_f + w_d + h_f\right)Re^{\alpha\tau} - h_d}{2h_p} \equiv w_o e^{\alpha\tau} - w_1. \tag{3}$$

where $w_o = \dfrac{\left(-w_f + w_d + h_f\right)R}{2h_p}$, $w_1 = \dfrac{h_d}{2h_p}$, and both are constants.

According to the optimal expatriating population $n^*(t)$ at unit of time, the expatriate cost function of the parent company is

$C_d\left(n^*(t)\right)=h_d n^*(t)+h_p(n^*(t))^2 = Be^{2\alpha\tau}+Ce^{\alpha\tau}+D$,

where $B=\left(w_0{}^2 h_p\right)$, $C=\left(h_d w_o - 2w_0 w_1 h_p\right)$, $D=\left(w_1{}^2 h_p - w_1 h_d\right)$, and all of them are constants. The revenue function of hiring expatriate manpower and locally outsourcing in the overseas subsidiary company is $\pi_f\left(n^*(t)\right)=\left(N-n^*(t)\right)w_f + n^*(t)w_d = Ee^{\alpha\tau}+G$, where $E=\left(w_d - w_f\right)w_0$, $G=\left(Nw_f + w_1 w_f - w_1 w_d\right)$, and both are constants. The outsourcing cost function of the overseas subsidiary company is $C_f\left(n^*(t)\right)=\left(N-n^*(t)\right)h_f = He^{\alpha\tau}+I$, where $H=\left(-w_0\right)$, $I=\left(w_1+N\right)$, and both are constants.

Considering the situation of cash flows, the present value of expatriating total cost in the parent company is:

$$\begin{aligned} TC_d\left(n^*(t)\right) &= \int_0^{t^*} e^{r_d(t^*-t)}\left(Be^{2\alpha\tau}+Ce^{\alpha\tau}+D\right)dt + F \\ &= c_1 e^{a_1 t^*} + c_2 e^{a_2 t^*} + c_3 e^{a_3 t^*} - c_1 - c_2 - c_3 + F. \end{aligned} \tag{4}$$

where t^* is the time point of expatriate manpower in the parent company; $c_1=\dfrac{B}{a_1}$, $c_2=\dfrac{C}{a_2}$, $c_3=\dfrac{D}{a_3}$; $a_1=\left(r_d+2\alpha\right)$, $a_2=\left(r_d+\alpha\right)$, $a_3=r_d$; F is the fixed cost of expatriating manpower. Similarly, considering the situation of cash flows, the present values of operating total revenue $TR_f\left(n^*(t)\right)$ and total cost $TC_f\left(n^*(t)\right)$ in the overseas subsidiary company are as follows:

$$\begin{aligned} TR_f\left(n^*(t)\right) &= \int_{t^*}^{\infty} e^{-r_f(t-t^*)}\left(Ee^{\alpha\tau}+G\right)dt \\ &= Ee^{\left(-r_f+\alpha\right)t+r_f t^*} + Ge^{\left(-r_f\right)t+r_f t^*}. \end{aligned} \tag{5}$$

$$\begin{aligned} TC_f\left(n^*(t)\right) &= \int_{t^*}^{\infty} e^{-r_f(t-t^*)}\left(He^{\alpha\tau}+I\right)dt \\ &= He^{\left(-r_f+\alpha\right)t+rft^*} + Ie^{\left(-r_f\right)t^*+r_f t^*}. \end{aligned} \tag{6}$$

Similarly, considering the situation of cash flow, the present value of operating cash flow in the overseas subsidiary company is as follows:

$$\begin{aligned} & E\left[TR_f\left(n^*(t)\right) - TC_f\left(n^*(t)\right)\right] \\ &= -c_4 e^{(a_4+r_f)t^*} - c_5 e^{(a_5+r_f)t^*}. \end{aligned} \tag{7}$$

where $c_4=\dfrac{J}{a_4}$; $c_5=\dfrac{K}{a_5}$; $a_4=\left(-r_f+\alpha\right)$; $a_5=\left(-r_f\right)$.

All above are yielded from the relationship of value and cost functions by the definition of cash flow. In addition, the allocation of human resources has the potential value $V(R)$ of the parent company under the risk-neutral condition to measure the enterprise value. The measurement model shows:

$$r_d V\left(R\right) = E\left[dV(R)\right]. \tag{8}$$

where r_d represents the risk premium of choosing the expatriate strategy and $E\left[dV(R)\right]$ is the capital gains of the expected potential expatriating. By using Ito' s Lemma to figure out the second differential equation of the enterprise value of potential expatriating $V\left(R\right)$, the following result can be obtained:

$$\frac{1}{2}\sigma^2 R^2 V''\left(R\right) + \alpha R V'\left(R\right) - r_d V\left(R\right) = 0. \tag{9}$$

where $V(R)=AR^\beta$, $V''\left(R\right)$ is the second-order differential of R, and $V'\left(R\right)$ is the first-order differential of R. General solution is:

$$V(R) = AR^\beta. \tag{10}$$

where $\beta = \dfrac{\left(\frac{1}{2}\sigma^2-\alpha\right)+\sqrt{\left(\alpha-\frac{1}{2}\sigma^2\right)^2+2\sigma^2 r_d}}{\sigma^2} > 1$ and AR^β is the potential strategy value when the parent company expatriates manpower to the overseas subsidiary company.

III. THE THRESHOLD OF DECISION-MAKING

Following the initial condition of equivalence (value-matching condition) of Dixit and Pindyck (1994), the host company' s total expected enterprise value of potential expatriating equals the expected total revenue in the overseas subsidiary company at threshold $n^*(t^*)$. Note that:

$$\begin{aligned} & E\left[A(R^*)^\beta\right] - E\left[\int_0^{t^*} e^{r_d(t^*-t)} C_d\left(n^*(t)\right)dt\right] + F \\ &= E\left[\int_{t^*}^{\infty} e^{-r_f(t-t^*)}\left(\pi_f\left(n^*(t)\right) - C_f\left(n^*(t)\right)\right)dt\right]. \end{aligned} \tag{11}$$

Furthermore, by using the smooth-pasting condition to carry on the first-order differential, we can obtain the following result:

$$\begin{aligned} & b_1 AR^\beta e^{b_1 t^*} - c_1 d_1 e^{d_1 t^*} - c_2 d_2 e^{d_2 t^*} - c_3 d_3 e^{d_3 t^*} \\ & + c_4 d_4 e^{d_4 t^*} + c_5 d_5 e^{d_5 t^*} - d_6 L e^{d_6 t^*} = 0. \end{aligned} \tag{12}$$

where $d_1=r_d+a_1$; $d_2=r_d+a_2$; $d_3=r_d+a_3$; $d_4=r_f+a_4$; $d_5=r_d+a_5$; $d_6=r_d$; $L=c_1+c_2+c_3$.

Finally, using the value-matching and smooth-pasting conditions can obtain the function to count the threshold when the transnational enterprise enters the international manpower market:

$$\begin{cases} AR^{\beta}e^{b_1t^*} = c_1e^{d_1t^*} + c_2e^{d_2t^*} + c_3e^{d_3t^*} - c_4e^{d_4t^*} - c_5e^{d_5t^*} \\ \quad + Le^{d6t^*} - F. \\ b_1AR^{\beta}e^{b_1t^*} = c_1d_1e^{d_1t^*} + c_2d_2e^{d2t^*} + c_3d_3e^{d_3t^*} - c_4d_4e^{d_4t^*} \\ \quad -c_5d_5e^{d_5t^*} + d_6Le^{d6t^*}. \end{cases} \tag{13}$$

Cancelling two types of (13) can derive (14) as follows:

$$\begin{aligned}(1-b_1)AR^{\beta}e^{b_1t^*} &= (c_1-f_1)e^{d_1t^*} + (c_2-f_2)e^{d_2t^*} \\ &+ (c_3-f_3)e^{d_3t^*} - (c_4-f_4)e^{d_4t^*} \\ &- (c_5-f_5)e^{d_5t^*} + (1-d_6)Le^{d_6t^*} - F.\end{aligned} \tag{14}$$

where

$f_1 = c_1d_1$; $f_2 = c_2d_2$; $f_3 = c_3d_3$; $f_4 = c_4d_4$; $f_5 = c_5d_5$. Arranging (14) can result in (15) as follows:

$$\begin{aligned}A &= g_1e^{h_1t^*} + g_2e^{h_2t^*} + g_3e^{h_3t^*} - g_4e^{h_4t^*} \\ &- g_5e^{h_5t^*} + g_6e^{h_6t^*} + g_7e^{h_7t^*}.\end{aligned} \tag{15}$$

where $g_1 \equiv \frac{(c_1-f_1)}{(1-b_1)R^{\beta}}$; $g_2 \equiv \frac{(c_2-f_2)}{(1-b_1)R^{\beta}}$; $g_3 \equiv \frac{(c_3-f_3)}{(1-b_1)R^{\beta}}$; $g_4 \equiv \frac{(c_4-f_4)}{(1-b_1)R^{\beta}}$; $g_5 \equiv \frac{(c_5-f_5)}{(1-b_1)R^{\beta}}$; $g_6 \equiv \frac{(1-d_6)L}{(1-b_1)R^{\beta}}$; $g_7 = \frac{F}{(1-b_1)R^{\beta}}$; $h_1 = (d_1-b_1)$; $h_2 = (d_2-b_1)$; $h_3 = (d_3-b_1)$; $h_4 = (d_4-b_1)$; $h_5 = (d_5-b_1)$; $h_6 = (d_6-b_1)$; $h_7 = (-b_1)$.

Incorporating (15) into (12) yields:

$$\begin{aligned}&k_1e^{d_1t^*} + k_2e^{d_2t^*} + k_3e^{d_3t^*} - k_4e^{d_4t^*} \\ &-k_5e^{d_5t^*} + k_6e^{d_6t^*} - k_7 = 0.\end{aligned} \tag{16}$$

where $k_1 \equiv \frac{b_1(c_1-f_1)}{(1-b_1)} - f_1$; $k_2 \equiv \frac{b_1(c_2-f_2)}{(1-b_1)} - f_2$; $k_3 \equiv \frac{b_1(c_3-f_3)}{(1-b_1)} - f_3$; $k_4 \equiv \frac{b_1(c_4-f_4)}{(1-b_1)} - f_4$; $k_5 \equiv \frac{b_1(c_5-f_5)}{(1-b_1)} - f_5$; $k_6 \equiv \frac{b_1L(1-d_6)}{(1-b_1)} - f_6$; $k_7 \equiv \frac{b_1F}{(1-b_1)}$.

Finally, combining (3), (15), (16) can obtain the optimal foreign exchange rate R^* , the optimal point in time t^* , and the optimal expatriate population $n^*(t^*)$ under the optimal point in time.

IV. NUMERICAL EXAMPLE ANALYSIS

This section addresses how related parameters influence the optimal expatriate threshold, R^*, and decide the strategy for entering or exiting from the international manpower hiring market.

It simulates the decision value of entering or exiting from the international manpower hiring market with the proposed model mentioned in the previous section. Additionally, it independently incorporates the above parameters into the international manpower market model built in the previous paragraph, and then utilizes MATHLAB software to determine the analytical solution. Consequently, the paper gets the approximate optimal decision timing of real expatriate and finds out some numerical solutions that we arrange below.

Numerical analysis is conducted by using the following base case parameters. We assume that the growth of foreign exchange rate α =0.016 and the volatility of the growth of foreign exchange rate σ =2 monthly. We estimate the increasing manpower cost of expatriating a person h_d = 4.5 thousand (NT\$) and the decreasing average revenue of expatriating a person h_p = 5 thousand (NT\$) monthly. The average cost of locally hiring a person h_f = 7 hundred (USD), the average revenue of locally hiring a person w_f =12 hundred (USD), and the average revenue of expatriating a person by parent company w_d =19 hundred (USD) monthly. The fixed cost of expatriate manpower per month is 1000000 (NT\$). The demanded manpower in the foreign subsidiary company N=1200. The investigation assumes the risk premiums of choosing the expatriate strategy (r_d) and outsourcing strategy (r_f) are 0.027 and 0.046 respectively. The foreign exchange rate R_0 = 30.58, which is obtained from Taiwanese banks.

Based on the basic numerical example, first we can find the optimal expatriating population n^*=989 we obtain in (3), which means the parent company can expatriate 989 employees to accord with the manpower demand of the overseas subsidiary company. And the overseas subsidiary company must hire 211 locally manpower. Thus, β =1.0217 is calculated from (9). And the enterprise value of potential expatriating V(R) = 306.334, which is obtained from (10).

The expatriate threshold of foreign exchange rate for the transnational enterprises is 28.582 at the optimal point time t^*=3.9741 which is calculated from (16). That is, as soon as the foreign exchange rate will reach 28.528 in 3.9741 months, the transnational enterprises will choose to expatriate manpower to the international manpower market.

V. CONCLUSION

This study utilizes the mathematical model to do analysis for managers when they use the optimal foreign exchange rate to choose the timing of decision-making in hiring the domestic or foreign professional manpower in the application of human resources. And it can help multinational enterprises to obtain the optimal foreign exchange rate to evaluate the influence of enterprise value and decide entering or exiting from the international manpower hiring market to achieve the maximum value of utilizing human resources in multinational enterprises.

In conclusion, we consider the effect of the potential human resource strategy on the enterprise value and offer the reference of evaluation for entering or exiting from the international manpower market. Managers can also utilize this result to hire manpower, and make the optimal allocation in human resources that can achieve the object of minimum operation cost in the future.

ACKNOWLEDGMENT

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The Optimal Pollution Technical Standard Model with the Environment Economy

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Abstract - **This study attempts to analyze what kind of environmental pollution technical standard to transform the new technology will have the maximum economic efficiency, and to decide when it is the best timing for transforming the environmental pollution processing technical standards.**

Keywords - **Environment economy, decision-making, technical standards, real options**

I. INTRODUCTION

This study utilizes the real options approach (ROA) to decide the optimal pollution technical standard. This work introduces the real and potential firm values to measure the strategic value and tries to construct a decision-making model under the viewpoint of the environment economy. The environmental pollution processing technical standards obey the geometry Brownian motion (GBM), and the total cost may be divided into the production cost and the pollution cost. Under this premise, it attempts to analyze what kind of environmental pollution technical standard to transform the new technology will have the maximum economic efficiency.

Reference [1] pointed out that under economic and environmental uncertainty, the ROA is utilized to construct a continuous time model and find the optimal investment environment. This study differs from other traditional cost-benefit analyses by extending to Pindyck model (2002) and trying to find the optimal investment timing and threshold. Reference [2] applied the ROA to analyze the investment cost, number of customers, price policy, and risk attitude to measure a firm's earnings under uncertainty. Reference [3] treated considerately economic, technical, and uncertain risks to construct a dynamic model for helping a firm choose the optimal investment timing and technology adoption.

Reference [4] tried to find the optimal timing of the present technology and future upgrade technology for the objective function with the maximum profit. Reference [5] assumed that the present technology has a upgrade possibility in the future. In consideration of the first-mover advantage and the transfer cost and risk, this study will find out the effect from a firm's upgrading its technology and search the optimal transfer technology and timing to switch. Reference [6] assumed that technology follows Poisson process and earnings follow spread process, and introduced the ROA to choose the optimal investment timing. Reference [7] examined the effects of investment mode strategy and expatriate strategy during times of economic crisis. They found that in an environment of economic crisis, the greater utilization of expatriates is more likely to enhance the survival.

Reference [8] discussed the relationship between environmental and economic performance and the influences of corporate strategies with regard to sustainability and the environment in the European paper industry. Reference [9] showed that subsidies to the input into pollution abatement are inefficient when a Pigouvian pollution tax is available. And the equilibrium subsidy rate is shown to depend on the subsidy elasticity of pollution abatement and lobby group membership. Reference [10] showed that the impact of a policy change on the investment behavior of the firm is studied in an incomplete information setting. This paper derives the optimal investment rule maximizing the value of the firm and shows that the impact of the trigger value uncertainty on the optimal investment threshold is non-monotonic.

II. METHODOLOGY

Under the environment economy, this study focuses on what kind of environmental pollution technical standard to transform the new technology will have the maximum economic efficiency. It hypothesizes that the total cost can be divided into the production cost and the pollution cost. When the technical standards change, a firm can choose equipment upgrade or industry exit to reduce the cost. This study utilizes the ROA to construct a strategy of the optimal timing for equipment upgrade or industry exodus. The environmental pollution processing technical standards follow the GBM:

$$\frac{dS_t}{S_t} = \alpha dt + \sigma dw_t \,; \quad S_0 = S \tag{1}$$

where w_t is a standard Wiener process, α is the average growth rate of the technology ratio, and σ is the variance growth rate of the technology ratio. Fig. 1 illustrates the business normal entry model. Fig. 2 illustrates the business special entry model. We utilize the two models to find the optimal transfer point.

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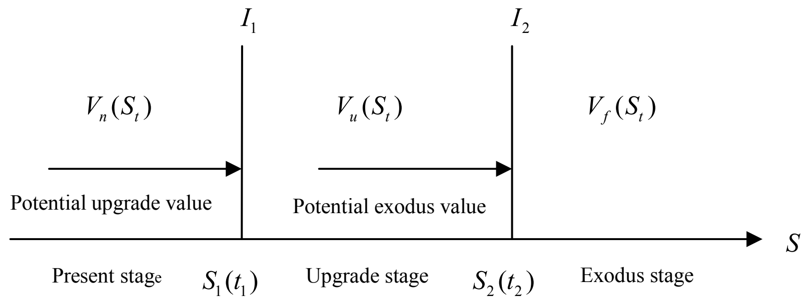

Fig. 1: Entering model

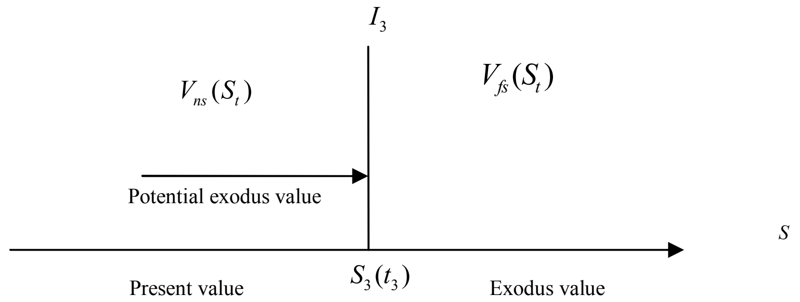

Figure 2:Entering model (Special case)

In the normal case, the firm value at the present stage, $V_n(S_t)$, is combined with cash flows and potential values. Cash flows show the firm's total cost at the present stage and potential values express the firm's option to upgrade equipment or not. If the technology standards achieve S_1 , the firm will have a value of equipment upgrade. Conversely, if the technology standards do not hit S_1, the firm will continue operating at the same stage.

The firm value at the upgrade stage, $V_u(S_t)$, is combined with cash flows and potential values. Cash flows show the firm's total cost at the upgrade stage and potential values express the firm's option to exit from the industry or not. If the technology standards achieve S_2, the firm will have a value of industry exit. Conversely, if the technology standards do not achieve S_2, the firm will stay at the same stage.

In the special case, the firm value at the present stage, $V_{ns}(S_t)$, is combined with cash flows and potential values. If the technology standards achieve S_3 , the firm will have a value of industry exit. Conversely, if the technology standards do not achieve S_3 , the firm will stay at the same stage.

$TC_i(Q)$ is the total cost when the firm produces Q unit, and $TC_i(Q) = (C_i + P_i)Q$. $C_i = a_i s^2 + b_i$ is the unit product cost and $P_i = c_i s^2 + d_i$ is the unit pollution cost. a_i , b_i , c_i , d_i are fixed parameters. $i = n$ means the present stage, $i = u$ means the upgrade stage, $i = f$ means the exit stage, $i = ns$ means the special present stage, and $i = nf$ means the special exit stage. It assumes that the product cost and pollution cost will decrease progressively when the technology improves. When the firm chooses upgrade equipment, industry exit, or direct exit, fixed cost I_1, I_2, I_3 will be charged.

Reference [11] showed the potential values are $A_i S_t^{\beta_i}$ and the calculating result is as follows:

$$E[dV_n(S_t)] = E[V_{ns}(S_t) \cdot dS_t + \frac{1}{2} \cdot V_{nss}(S_t) \cdot (dS_t)^2]$$
$$= (\frac{1}{2}\sigma^2 S_t^2 V_{nss}(S_t) + \alpha S_t V_{ns}(S_t))dt \qquad (2)$$

where $V(S_t)$ is the firm value, and the first-order and second-order differential equations of $V(S_t)$ are represented by $V_{ns}(S_t)$ and $V_{nss}(S_t)$ respectively. Then calculating the coefficient β_i by using the risk neutral condition, the below equation is satisfied:

$$\frac{1}{2} \cdot \sigma^2 \cdot \beta_i^2 + (\alpha - \frac{1}{2}\sigma^2)\beta_i - r = 0 \qquad (3)$$

It means $\beta_i = \frac{(\frac{1}{2}\sigma^2-\alpha)\pm\sqrt{(\alpha-\frac{1}{2}\sigma^2)+2\sigma^2 r_i}}{\sigma^2} > 1.$

(a) Normal case

1. Firm value at the present stage

Under the present technology standard, the expected total firm value $V_n(S_t)$ is showed as follows:

$$E\left[dV_n(S_t)\right]= -E\left[\int_0^t e^{r(t-s)} -TC_n(S_s)Qds\right]+A_nE[S_t]^{\beta_n} \quad (4)$$

where $-E\left[\int_0^t e^{r(t-s)} -TC_n(S_s)Qds\right]$ is the expected total cost at the present stage and $A_nE[S_t]^{\beta_n}$ is the potential strategic value of equipment upgrade.

2. Firm value at the upgrade stage

When the firm adopts technology upgrade, the expected firm value $V_u(S_t)$ is showed as follows:

$$E\left[dV_u(S_t)\right]= -E\left[\int_{t_1}^t e^{r(t-s)} -TC_u(S_s)Qds\right]+A_uE[S_t]^{\beta_u} \quad (5)$$

where $-E\left[\int_{t_1}^t e^{r(t-s)} -TC_u(S_s)Qds\right]$ is the expected total cost at the upgrade stage and $A_uE[S_t]^{\beta_u}$ is the potential strategic value of industry exit.

3. Firm value when transferring to the foreign stage

When the firm transfers to the foreign stage, the expected firm value $V_f(S_t)$ is showed as follows:

$$E\left[dV_f(S_t)\right]= -E\left[\int_{t_2}^t e^{r(s-t_2)} -TC_f(S_s)Qds\right] \quad (6)$$

where $-E\left[\int_{t_2}^t e^{r(s-t_2)} -TC_f(S_s)Qds\right]$ is the expected total cost when the firm transfers to the foreign stage.

(b) Special case

1. Firm value at the present stage

Under the present technology standard, the expected total firm value $V_{ns}(S_t)$ is showed as follows:

$$E\left[dV_{ns}(S_t)\right]= -E\left[\int_0^t e^{r(t-s)} -TC_{ns}(S_s)Qds\right]+A_{ns}E[S_t]^{\beta_{ns}} \quad (7)$$

where $-E\left[\int_0^t e^{r(t-s)} -TC_{ns}(S_s)Qds\right]$ is the expected total cost at the present stage and $A_{ns}E[S_t]^{\beta_{ns}}$ is the potential strategic value of industry exit.

2. Firm value at the exit stage

When the firm is located at the industry exit stage, the expected firm value $V_{fs}(S_t)$ is showed as follows:

$$E\left[dV_{fs}(S_t)\right]= -E\left[\int_{t_3}^t e^{r(s-t_3)} -TC_{fs}(S_s)Qds\right] \quad (8)$$

where $-E\left[\int_{t_3}^t e^{r(s-t_3)} -TC_{fs}(S_s)Qds\right]$ is the expected total cost at the exit stage.

III. The Optimal Decision and Thresholds

This study follows the value-matching condition and smooth-pasting condition introduced by the textbook of Dixit and Pindyck (1994), and tries to find the optimal technology transfer threshold S_1, S_2, S_3 and potential value parameter A_n, A_u, A_{ns}. Please see reference [12] for more detailed explanation.

1 .Value-matching condition

When the technology standards achieve S_1, the total value plus the fixed charge I_1 at the present stage is equal to the total value at the upgrade stage. It is showed as follows:

$$E\left[dV_n(S_1)\right]+I_1 = E\left[dV_u(S_1)\right] \quad (9)$$

When the technology standards achieve S_2, the total value plus the fixed charge I_2 at the upgrade stage is equal to the total value at the foreign stage. It is showed as follows:

$$E\left[dV_u(S_2)\right]+I_2 = E\left[dV_f(S_2)\right] \quad (10)$$

When the technology standards achieve S_3, the total value plus the fixed charge I_3 at the special present stage is equal to the total value at the special foreign stage. It is showed as follows:

$$E\left[dV_{ns}(S_3)\right]+I_3 = E\left[dV_{fs}(S_3)\right] \quad (11)$$

Calculating Eqn. (9), (10), and (11), we can find out three value-matching conditions as follows:

$$\begin{aligned}&-E\left[\int_0^{t_1} e^{r(t_1-t)}TC_n(S_t)Qdt \mid t=t_1; S_{t_1}=S_1\right] \\ &+A_nE(S_1)^{\beta_n}+I_1 \\ &= -E\left[\int_{t_1}^{t_2} e^{-r(t-t_1)}TC_u(S_t)Qdt \mid t=t_2; S_{t_2}=S_2\right] \\ &+A_u(S_1)^{\beta_u}\end{aligned} \quad (12)$$

and

$$\begin{aligned}&-E\left[\int_{t_1}^{t_2} e^{r(t_2-t)}TC_u(S_t)Qdt \mid t=t_1; S_{t_1}=S_1\right] \\ &+A_uE(S_2)^{\beta_u}+I_2 \\ &= E\left[\int_{t_2}^{\infty} e^{-r(t-t_2)}TC_f(S_t)Qdt \mid t=t_2; S_{t_2}=S_2\right]\end{aligned} \quad (13)$$

and

$$
\begin{aligned}
&-E\left[\int_{t_0}^{t_2} e^{r(t_3-t)} TC_{ns}(S_t) Q dt \mid t=t_3; S_{t_3}=S_3\right] \\
&+A_{ns} E(S_3)^{\beta_{ns}} + I_3 \qquad (14) \\
&= E\left[\int_{t_3}^{\infty} e^{-r(t-t_3)} TC_{fs}(S_t) Q dt \mid t=t_3; S_{t_3}=S_3\right]
\end{aligned}
$$

Equation(12) can be rewrite to ：

$$X_a e^{(3\alpha+\sigma^2)t_1} - X_b e^{r_1 t_1} + X_c e^{\alpha t_1} - X_d e^{r_2 t_1} + A_n S^{\beta_1} e^{\alpha\beta_1 t_1} = 0 \qquad (15)$$

where $X_1 \equiv \dfrac{-(a_n + c_n)s^2 Q}{(3\alpha+\sigma^2-r_1)}$, $X_2 \equiv \dfrac{-(b_n + d_n)Q}{(\alpha - r_1)}$,

$X_3 \equiv \dfrac{-(a_u + c_u)s^2 Q}{(3\alpha+\sigma^2-r_2)}$, $X_4 \equiv \dfrac{-(b_u + d_u)Q}{(\alpha - r_2)}$;

and

$$
\begin{aligned}
X_a &= (X_1 + X_3), \\
X_b &= (X_1 + X_2), \\
X_c &= (X_2 + X_4), \\
X_d &= \left(X_3 e^{(3\alpha+\sigma-r_2)t_2} + X_4 e^{(\alpha-r_2)t_2}\right)
\end{aligned}
$$

Equation(13) can be rewrite to ：

$$Y_a e^{(3\alpha+\sigma^2)t_2} - Y_b e^{r_2 t_2} + Y_c e^{\alpha t_2} + A_u S^{\alpha\beta_u t_2} = 0 \qquad (16)$$

where $Y_1 \equiv \dfrac{-(a_u + c_u)s^2 Q}{(3\alpha+\sigma^2-r_2)}$, $Y_2 \equiv \dfrac{-(b_u + d_u)Q}{(\alpha - r_2)}$,

$Y_3 \equiv \dfrac{-(a_f + c_f)s^2 Q}{(3\alpha+\sigma^2-r_3)}$, $Y_4 \equiv \dfrac{-(b_f + d_f)Q}{(\alpha - r_3)}$;

and

$$
\begin{aligned}
Y_a &= (Y_1 + Y_3), \\
Y_b &= \left(Y_1 e^{(3\alpha+\sigma^2-r_2)t_1} + Y_2 e^{(\alpha-r_2)t_1}\right), \\
Y_c &= (Y_2 + Y_4),
\end{aligned}
$$

Equation(14) can be rewrite to ：

$$Z_a e^{(3\alpha+\sigma^2)t_3} - Z_b e^{r_1 t_3} + Z_c e^{\alpha t_3} + A_{ns} S^{\beta_3} e^{\alpha\beta_3 t_3} = 0 \qquad (17)$$

where $Z_1 \equiv \dfrac{-(a_{ns} + c_{ns})s^2 Q}{(3\alpha+\sigma^2-r_1)}$, $Z_2 \equiv \dfrac{-(b_{ns} + d_{ns})Q}{(\alpha - r_1)}$,

$Z_3 \equiv \dfrac{-(a_{fs} + c_{fs})s^2 Q}{(3\alpha+\sigma^2-r_3)}$, $Z_4 \equiv \dfrac{-(b_{fs} + d_{fs})Q}{(\alpha - r_3)}$,

and

$$
\begin{aligned}
Z_a &= (Z_1 + Z_3), \\
Z_b &= (Z_1 + Z_2), \\
Z_c &= (Z_2 + Z_4)
\end{aligned}
$$

2. Smooth-pasting condition

First-order differential (15), (16), and (17) are shown as follows:

$$
\begin{aligned}
&(3\alpha+\sigma^2) X_a e^{(3\alpha+\sigma^2)t_1} - r_1 X_b e^{r_1 t_1} + \alpha X_c e^{\alpha t_1} \\
&- r_2 X_d e^{r_2 t_1} + \alpha\beta_1 A_n S^{\beta_1} e^{\alpha\beta_1 t_1} = 0
\end{aligned} \qquad (18)
$$

and

$$
\begin{aligned}
&(3\alpha+\sigma^2) Y_a e^{(3\alpha+\sigma^2)t_2} - r_2 Y_b e^{r_2 t_2} \\
&+ \alpha Y_c e^{\alpha t_2} + \alpha\beta_u A_u S^{\alpha\beta_u t_2} = 0
\end{aligned} \qquad (19)
$$

and

$$
\begin{aligned}
&(3\alpha+\sigma^2) Z_a e^{(3\alpha+\sigma^2)t_3} - r_1 Z_b e^{r_1 t_3} \\
&+ \alpha Z_c e^{\alpha t_3} + \alpha\beta_3 A_{ns} S^{\beta_3} e^{\alpha\beta_3 t_3} = 0
\end{aligned} \qquad (20)
$$

All the thresholds S_1, S_2, S_3 and potential value parameters A_n, A_u, A_{ns} by nonlinear stochastic equations which are composed of formula (15)-(20) can be found numerical solution hereafter.

IV. CONCLUSION

Recently, the issue about the environment economy and pollution prevention becomes more and more important. Hence, the firm faces a problem how to make a choice between reducing the product cost and reducing the pollution cost. Under the environment economy, the firm needs to measure the pollution and consider how to reduce it. As the technology improves, more and more pollution prevention methods appear. If the firm chooses the new technology, it will increase the product cost. So under the environment economy, the firm needs to focus on what kind of environmental pollution technical standard to transform the new technology will have the maximum economic efficiency.

This study utilizes a real option approach to constructs a mathematical decision-making model of the optimal pollution technical standard. Using this proposed model, it can find the optimal decision threshold. The research result can serve as the reference for the firm when facing to choose the optimal technology threshold under the environment economy.

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The Market Entry/Exit Model on the Free Internet Service Firm

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Abstract - **This study utilizes the real options approach to construct the investing (disinvesting) decision model on free internet service. Two firm values of the internet service industry include the cash flows from the usage of free software and the potential value of entering (exiting from) the market so as to evaluate the firm value.**

Keywords - **e-commerce, internet service, decision-making, real options**

I. INTRODUCTION

The Internet is the most unbounded tool now, and the Internet service firms are competitive drastically. The Internet service firms can get a lot of advertising revenues if they are the market dominators. Any firm wants to be the hugest one in the market. They can expand their scale by many different ways such as marketing, increasing research and development, or increasing capital. But in the long term, the most effective way is to increase the page views, and users will get adapted to their Internet services. Also through the Internet spread, firms will get increasing margin revenues. So the Internet service firms are for the sake of growing, they will attempt to improve their page views.

The Internet services firms (Google, Yahoo, etc.) provide free services, and try to increase their homepage views. Nevertheless, regardless of providing free spaces, researching new software, or building the network, there are charged a lot fixed and variable costs. The main purpose is to raise the potential user and to get the additional values of free services usage. This study utilizes the real options approach (ROA) to construct the mathematical decision-making model of investing (disinvesting) in free Internet service. In this proposed model, Internet service firm has an option to invest (disinvest) in free software market, and the usage ratio evolves over time according to the following geometric Brownian motion (GBM). The costs of the Internet services firm assumes to be affect on researching software, structuring the internet spaces, and providing anti-virus. And the revenues are gained by advertisers' trust that they choose to promote in the Internet. This study attempts to evaluate the optimal usage rate from the maximum profit of objective function concerning for internet services firm's operating costs and revenues function. Furthermore, it also gives advices that internet service firm makes the best timing for when to enter or exit the free internet service market.

Reference [1] used an option value model to examine the factors affecting an agribusiness firm's decision whether and how much to invest in an emerging market under demand uncertainty. Demand uncertainty and investment irreversibility make investment less desirable than the net present value (NPV) rule indicates. The inactive firm is more reluctant to enter the market when it takes into account demand uncertainty because it preserves the opportunity of making a better investment later. This paper results have implications for agribusiness decision- making to understand and respond to uncertainty.

Reference [2] presented a decision model using the real options approach for evaluating the entry or exit of the internet securities trading business in the face of both technological and economic uncertainties. The authors considered the effect of uncertainty and the added profits after establishing an electronic securities trading system to determine the optimal threshold for implementing the entry/exit project. Meanwhile, they presented the differences between the ROA and the NPV method and proved the accuracy of the ROA model. Reference [3] developed an economic model that explains the decision-making problem under the uncertainty of an industrial firm that wants to invest in a process technology. This study accounts for the risk and uncertainty inherent in the volatile energy prices that can greatly affect the valuation of the investment project. The dynamic stochastic model presented allows the authors to determine the optimal technology choice and investment timing.

Reference [4] presents that the discounted cash flow is the main tool for valuing projects and companies. Real options techniques can augment valuation. And using the case of Netscape demonstrates this. It provides an approximate valuation. In this study, they prefer equity valuation using various methodologies, including real options where appropriate, to arrive at a range of values. Reference [5] investigates three complementary measures of portal use: frequency of use, length of visits, and repeat use. To examine these three measures of use, they first classify the services provided by portals into three categories: search, information, and personal services. These three different functions affect portal use. Finally, this article results show strong repeat use for personal services followed by information services and search function. Both information and personal services tend to extend the length of portal visits. But they also find that search function availability drives more traffic to portals than information or personal services do.

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In this article, it introduces the ROA to evaluate the internet service firms' investment of free software. The authors combine the generated cash flows in finance and the potential value comes from the firms' option spaces. Final this study constructs a model to assess the optimal entering/exiting timing.

II. THE MODEL

This article deals with three stages in which the internet service firms invest in the free software. Supplying the free software to the public is a huge cost to the internet service firms in the short-run. The internet service firms can't acquire the revenues without spending much money investing in, building, and preserving the free software. Their main consideration is the increasing follow-up page view. If the use ratio of free software achieves a respectable level $U(t)$, the firms can increase page view through supplying the free software and it can also make the advertising agency feel confident of using the internet promotion. It will be the main revenue source to the internet service firms. Meanwhile, the firms can invest in the free software further. However, If the use ratio is not enough, the firms can't make the advertising agency use the internet advertisement and acquire sufficient revenues; then, they can choose to exit from the free software market. Assume the internet services firms have the potential value of entering next stage - investing in the free software, and also the potential value of exiting from the market now. Even if entering (exiting from) the market, the firms still can observe the market. If there is an opportunity, they can enter the market again to serve free services to grow their page views. Also, they can exit from the market if there is a threat. Each stage in the model is repeating behavior. The firms can depend on the use ratio to decide what to do.

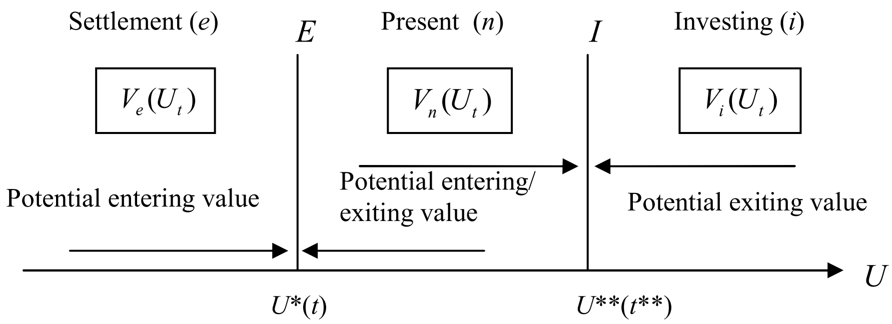

Fig 1: Internet services firms' free software supply and the thresholds to enter/exit model.

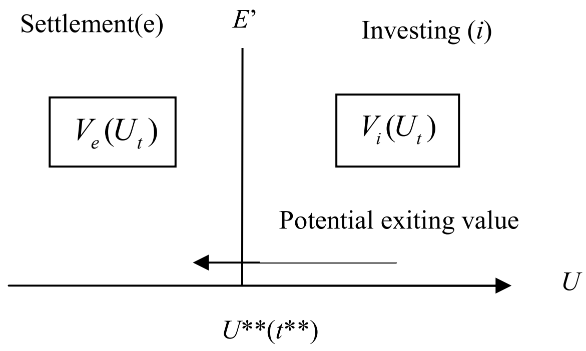

Fig 2: The special case that firms exit market directly from investing stage to settlement stage.

It constructs a decision-making model of investing (disinvesting) in the free internet service, finding out the optimal investing U^{**} and the disinvesting U^{*}. In this model, the firms have an option to invest (disinvest) in the free software market, and the use ratio, $U(t)$, evolves over time according to the following geometric Brownian motion:

$$\frac{dU_t}{U_t} = \alpha dt + \sigma dW_t, \; U_0 = U \qquad (1)$$

where W_t is a standard Wiener process, α is the average grow rate of the use ratio, and σ is the variance growth rate of the use ratio. The firm value at the present stage, $V_n(U_t)$, is combined with the cash flows and potential values of entering and exiting from the market.

Cash flows show the firms generate cash receipts and payments. Potential values express the firms' options to invest or disinvest in the free software. If the usage ratio achieves the threshold U^{**}, the firms can go to the further step. Conversely, if the use ratio falls in the threshold U^{*}, the firms will suffer the loss and have to settle their investment. Using Reference [6], the potential values are $A_{n1}U^{\beta_{n1}} + A_{n2}U^{\beta_{n2}}$ there and the calculating result is as follows:

$$E[dV(U_t)] = (\frac{1}{2}\sigma^2 U_t^2 V_{UU}(U_t) + \alpha U_t V_U(U_t))dt \qquad (2)$$

where $V(U_t)$ means business values and $V(U_t)$'s first-order and second-order differentials are represented by $V_U(U_t)$ and $V_{UU}(U_t)$ respectively. After calculating the coefficient β_n by using the risk neutral condition, the following equation is satisfied:

$$\frac{1}{2}\cdot\sigma^2\cdot\beta_n{}^2 + (\alpha - \frac{1}{2}\sigma^2)\beta_n - r = 0 \qquad (3)$$

It means $\beta_n = \dfrac{(\frac{1}{2}\sigma^2 - \alpha) \pm \sqrt{(\alpha - \frac{1}{2}\sigma^2) + 2\sigma^2 r_1}}{\sigma^2}$.

The firms have the potential values of entering and exiting meanwhile. The scale of coefficient is $A_{n1}>0$, $\beta_{n1}>1$ when the firms derive the potential entry value. The scale of coefficient is $A_{n2}<0$, $\beta_{n2}<0$ when the firms produce the potential exit value Reference [1]. $\pi_n(U_t)$ is the cash flows of the internet service firms at the present stage, by definition, $\pi_n(U_t) = [R_n(U_t) - CO_n(U_t)]\times Q_t$. The firms' revenue function is $R_n(U_t) = c_n U_t^2 + d_n U_t + e_n$, where e_n is the fixed revenue and $e_n>0$. The firms' revenues increase from higher free software use ratio and the marginal revenue is increasing, $c_n>0$, and $d_n<0$. The firms' cost function is $CO_n(U_t) = a_n U_t + b_n$, where b_n is the firms' fixed equipment cost and $b_n>0$. Also, the variable cost, a_n, grows from higher usage ratio and $a_n>0$. Q_t represents the quantity of the firms' free software supply. The revenue and cost functions are summed up to $\pi_n(U_t) = [c_n U_t^2 + (d_n - a_n)U_t + (e_n - b_n)]\times Q_t$. Entering the market requires investing in researching and supporting the free software, *I*, and exiting from the market can take back settlement value, *E*. The definitions of A_{n1}, A_{n2}, α, and σ are as mentioned above. r_1 is the risk premium of investing at the present stage. The restrictions of β_{n1}, β_{n2} are as follows:

$$\beta_{n1} = \frac{(\frac{1}{2}\sigma^2 - \alpha) + \sqrt{(\alpha - \frac{1}{2}\sigma^2) + 2\sigma^2 r_1}}{\sigma^2} > 1 \quad ;$$

$$\beta_{n2} = \frac{(\frac{1}{2}\sigma^2 - \alpha) - \sqrt{(\alpha - \frac{1}{2}\sigma^2) + 2\sigma^2 r_1}}{\sigma^2} < 0 .$$

To sum up the present stage, the whole firm value is as follows:

$$E[dV_n(U_t)] = E\left[\int_{t^*}^{t^{**}} e^{-r_1(s-t^*)}\pi_n ds\right] + E[A_{n1}U_t^{\beta_{n1}}] + E[A_{n2}U_t^{\beta_{n2}}] \qquad (4)$$

If the firms choose to invest in the free services, they need to invest in the expense, *I*. At the investing stage, the firms have the new formula of cash flows, $\pi_i(U_t) = [R_i(U_t) - CO_i(U_t)]\times Q_t$, and revenue function $R_i(U_t)$ and cost function $C_i(U_t)$ as follows: $R_i(U_t) = c_i U_t^2 + d_i U_t + e_i$, $C_i(U_t) = a_i U_t + b_i$, e_i is the fixed revenue and $e_i>0$; $c_i>0$, $d_i<0$, $c_i > c_n$ are due to the increasing revenues from higher usage ratio and the increasing marginal revenues. $CO_i(U_t) = a_i U_t + b_i$, where b_i is the firms' fixed cost and $b_i>0$, and a_i is the variable cost which grows along with the increasing usage ratio.

The firms will provide much better service to consumers after investing in their free software, and their variable costs will be higher than before as well ($a_i > a_n$). Also their fixed costs will be higher than before ($b_i > b_n$). $\pi_i(U_t) = [c_i U_t^2 + (d_i - a_i)U_t + (e_i - b_i)]\times Q_t$.

The firms can exit from the market if the result is not as they expect, so the firms have the potential value of exiting, $A_i U_t^{\beta_i}$. $A_i U_t^{\beta_i}$ is the potential exiting value. A_i, α, and σ are as mentioned in last paragraph. r_2 is the risk premium of the investing stage. The calculation of β_i is as follows:

$$\beta_i = \frac{(\frac{1}{2}\sigma^2 - \alpha) - \sqrt{(\alpha - \frac{1}{2}\sigma^2) + 2\sigma^2 r_2}}{\sigma^2} < 0 .$$

To sum up the investing stage, the entire firm value is as follows:

$$E[dV_i(U_t)] = E[\int_{t^{**}}^{\infty} e^{-r_2(s-t^{**})}\pi_i ds] + E[A_i U_t^{\beta_i}] \qquad (5)$$

If the internet service firms provide the free software and the use ratio does not increase as the firms expect, it will not achieve the economy of scale. If the use ratio goes downs to the threshold U^*, their supply of free service can not enhance the firm value. The firms should settle their investment and take back the settlement value, *E* (*E*>0). $\pi_e(U_t) = [R_e(U_t) - CO_e(U_t)]\times Q_t$ and $R_e(U_t) = c_e U_t + d_e$, where c_e is the fixed revenue and

c_e >0 ; d_e is the variable revenue and d_e >0. $CO_e(U_t) = a_e U_t + b_e$, where b_e is the fixed cost and b_e >0; a_e is the variable cost and a_e >0. $\pi_e(U_t) = [(c_e - a_e)U_t + (d_e - b_e)] \times Q_t$.

The three stages are repeating behavior. The firms can enter the market again if there is an opportunity and the firms have the potential entering value, $A_e U_t^{\beta_e}$. A_e , α , and σ are as mentioned in last paragraph. r_3 is the risk premium of the settlement stage. The calculation of β_e is as follows:

$$\beta_e = \frac{(\frac{1}{2}\sigma^2 - \alpha) + \sqrt{(\alpha - \frac{1}{2}\sigma^2) + 2\sigma^2 r_3}}{\sigma^2} > 1 .$$

To sum up the settlement stage, the whole firm value is as follows:

$$E[dV_e(U_t)] = E[\int_0^{t^*} e^{-r_3(s-t^*)}\pi_e ds] + E[A_e(U_t)^{\beta_e}] \quad (6)$$

The internet service firms can find out the potential value of entering or exiting at each stage of thresholds, U^* and U^{**} . The value-matching condition and smooth-pasting condition are introduced by Reference [7].

(a.1) Value-matching condition of present and investing stages:

$$E\left[\int_{t^*}^{t^{**}} e^{r_1(t^{**}-t)}\pi_n dt\right] + E[A_{n_1}(U^{**})^{\beta_{n1}}] + E[A_{n_2}(U^{**})^{\beta_{n2}}] + I = E\left[\int_{t^{**}}^{\infty} e^{-r_2(t-t^{**})}\pi_i dt\right] + E[A_i(U^{**})^{\beta_i}] \quad (7)$$

where $A_1 \equiv A_{n_1}U_0^{\beta_{n1}}$, $A_2 \equiv A_{n_2}U_0^{\beta_{n2}}$, $A_3 \equiv A_i U_0^{\beta_i}$,

$A_4 \equiv A_e U_0^{\beta_e}$, $X_1 \equiv \dfrac{c_n \cdot Q_0 \cdot U_0^2}{-(r_1 - 3\alpha - \sigma^2)}$,

$X_2 \equiv \dfrac{(d_n - a_n)\cdot Q_0 \cdot U_0}{-(r_1 - 2\alpha)}$, $X_3 \equiv \dfrac{(e_n - b_n)\cdot Q_0}{-(r_1 - \alpha)}$,

$Y_1 \equiv \dfrac{(c_e - a_e)\cdot Q_0 \cdot U_0}{-(r_3 - 2\alpha)}$, $Y_2 \equiv \dfrac{(d_e - b_e)\cdot Q_0}{-(r_3 - \alpha)}$,

$Z_1 \equiv \dfrac{c_i \cdot Q_0 \cdot U_0^2}{-(r_2 - 3\alpha - \sigma^2)}$, $Z_2 \equiv \dfrac{(d_i - a_i)\cdot Q_0 \cdot U_0}{-(r_2 - 2\alpha)}$,

$Z_3 \equiv \dfrac{(e_i - b_i)\cdot Q_0}{-(r_2 - \alpha)}$, $\beta_{11} \equiv \exp[(\alpha - \frac{1}{2}\sigma^2)\beta_e + \frac{1}{2}\sigma^2\beta_e^2]$,

$\beta_{21} \equiv \exp[(\alpha - \frac{1}{2}\sigma^2)\beta_{n1} + \frac{1}{2}\sigma^2\beta_{n1}^2]$,

$\beta_{22} \equiv \exp[(\alpha - \frac{1}{2}\sigma^2)\beta_{n2} + \frac{1}{2}\sigma^2\beta_{n2}^2]$,

$\beta_{31} \equiv \exp[(\alpha - \frac{1}{2}\sigma^2)\beta_i + \frac{1}{2}\sigma^2\beta_i^2]$, $X_4 = X_1 + Z_1$,

$X_5 = X_2 + Z_2$, $X_6 = X_3 + Z_3$,

$3\alpha + \sigma^2 = \bar{\alpha}$, $X_7^{(t)} = [X_1 e^{(3\alpha+\sigma^2-r_1)t^*} + X_2 e^{-(r_1-2\alpha)t^*} + X_3 e^{-(r_1-\alpha)t^*}]$. Equation (7) can be rewritten to:

$$X_4 e^{\bar{\alpha}t^{**}} + X_5 e^{2\alpha t^{**}} + X_6 e^{\alpha t^{**}} - X_7^{(t^*)} e^{r_1 t^{**}} + A_1 e^{\beta_{21}t^{**}} + A_2 e^{\beta_{22}t^{**}} - A_3 e^{\beta_{31}t^{**}} + I = 0 \quad (8)$$

(a.2) Smooth-pasting condition of present and investing stages: It means the first-order differentials are equal at the two stages.

$$\bar{\alpha} X_4 e^{\bar{\alpha}t^{**}} + 2\alpha X_5 e^{2\alpha t^{**}} + \alpha X_6 e^{\alpha t^{**}} - r_1 X_7^{(t^*)} e^{rt^{**}} + \beta_{21} A_1 e^{\beta_{21}t^{**}} + \beta_{22} A_2 e^{\beta_{22}t^{**}} - \beta_{31} A_3 e^{\beta_{31}t^{**}} = 0 \quad (9)$$

(b.1) Value-matching condition of present and settlement stages:

$$E\left[\int_{t^*}^{t^{**}} e^{-r_1(t-t^*)}\pi_n dt\right] + E[A_{n_1}(U^*)^{\beta_{n1}}] + E[A_{n_2}(U^*)^{\beta_{n2}}] + E = E\left[\int_0^{t^*} e^{r_3(t^*-t)}\pi_e dt\right] + E[A_e(U^*)^{\beta_e}] \quad (10)$$

where $Y_3 = X_2 + Y_1$, $Y_4 = X_3 + Y_2$, $Y_5 = Y_1 + Y_2$, $Y_6^{(t^{**})} = [X_1 e^{\bar{\alpha}t^{**}} + X_2 e^{-(r_1-2\alpha)t^{**}} + X_3 e^{-(r_1-\alpha)t^{**}}]\cdot e^{r_1 t^*}$ Equation (10) can be rewritten to:

$$-X_1 e^{\bar{\alpha}t^*} - Y_3 e^{2\alpha t^*} - Y_4 e^{\alpha t^*} + Y_5 e^{r_3 t^*} + Y_6^{(t^{**})} e^{r_1 t^*} + A_1 e^{\beta_{21}t^*} + A_2 e^{\beta_{22}t^*} - A_4 e^{\beta_{11}t^*} + E = 0 \quad (11)$$

(b.2) Smooth-pasting condition of present and settlement stages:

$$-\bar{\alpha} X_1 e^{\bar{\alpha}t^*} - 2\alpha \cdot Y_3 e^{2\alpha t^*} - \alpha \cdot Y_4 e^{\alpha t^*} + r_3 \cdot Y_5 e^{r_3 t^*} + r_1 \cdot Y_6^{(t^{**})} e^{r_1 t^*} + \beta_{21}\cdot A_1 e^{\beta_{21}t^*} + \beta_{22}\cdot A_2 e^{\beta_{22}t^*} - \beta_{11}\cdot A_4 e^{\beta_{11}t^*} = 0 \quad (12)$$

(c.1) Special case: Value-matching condition of investing and settlement stages:

$$E\left[\int_0^{t^{**}} e^{r_3(t^{**}-t)}\pi_e dt\right] = E\left[\int_{t^{**}}^{\infty} e^{-r_2(t-t^{**})}\pi_i dt\right] + E[A_i(U^{**})^{\beta_i}] + E' \quad (13)$$

where $Z_4 = Y_1 + Z_2$, $Z_5 = Y_2 + Z_3$, and $Z_6 = Y_1 + Y_2$.

Equation (13) can be rewritten to:

$$Z_1 e^{\bar{\alpha}t^{**}} + Z_4 e^{2\alpha t^{**}} + Z_5 e^{\alpha t^{**}} - Z_6 e^{r_3 t^{**}} - A_3 e^{\beta_{31}t^{**}} - E' = 0 \quad (14)$$

(c.2) Special case: Smooth-pasting condition of investing and settlement stages:

出席國際學術會議心得報告

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會議時間地點	會議時間:2009/12/08-2009/12/11　地點:香港
會議名稱	IEEE2009 The International Conference on Industrial Engineering and Engineering Management (EI index)
發表論文題目	The Analysis of Decision-making of Investing in the Bi-national Marketing Channel with Game Options

一、參加會議經過

1. 2009/12/08-2009/12/11 期間出席 IEEM2009 國際研討會
2. 2009/12/08 上午搭乘港龍航空班機出席香港研討會
3. 2009/12/08 上午 10:30 報到時間/領取會議相關資料
4. 2009/12/09 上午 9:00-下午 5:00 口頭報告及參與其他場次:
   The Analysis of Decision-making of Investing in the Bi-national Marketing Channel with Game Options
5. 2009/12/10 上午 9:00-下午 5:00 海報論文展覽
6. 2009/12/11 下午搭乘國泰航空班機回國

二、與會心得

1. 此次論文獲選參加研討會為國科會專題直接關連性論文或計畫經費援助所呈現之成果。與會最主要能將目前執行國科會計畫案內容彙並提供後續計畫進行及修改之參考。
2. 聆聽超過十篇論文發表，使個人得到許多新的研究方法及研究議題之啟發，相信這些寶貴的經驗，能為做今後在學術研究上獲得改善及方法之精進，提供借鏡與參考。
3. 除參與國際研討會外，同時針對碩士班研究生在從事國際化學術活動增廣見聞，相信未來在個人學術研究交流與國際觀均有助益。

The Analysis of Decision-making of Investing in the Bi-national Marketing Channel with Game Options

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Abstract — **This study uses the mathematical model of game options to analyze when the distributors of the two countries choose to invest in the domestic or international marketing channel, they will consider competitors' behavior and invest in the marketing channels of the two countries based on the optimal time point. The results will provide distributors with the references of evaluating the influence of the potential channel value on the firm value and deciding whether to enter the international marketing market when they want to invest in the multi-national marketing channel in the future.**

Keywords - **marketing channel, decision-making, game options, geometric Brownian motion**

I. INTRODUCTION

The selection and operation of marketing channels represent the interactive links between producers and consumers. The world's richest man Bill Gates said: "Those who control channels will be winners in the 21st century." For example, 7-ELEVEN's vertical integration of channels creates the high growth rate of sales and makes it become Taiwan's no. 1 retailer. The paper aims to use the game options in consideration of competitors' reactions to construct a mathematical model for the payoffs generated from distributors' investing in the home country or host country, and introduces the assessment of the potential channel value to reflect the investment value of financial payoffs.

Reference [1] pointed out that international marketing means a company sells products or services to the customers or users more than a country and attempts to use effective international commercial activities to obtain more profits from the international market. Unquestionably, distributors choose to invest in the international marketing channel in order to create international business opportunities because they want to expand the need of the market, economy of scale, technology, and products. Thus, the paper wants to explore how to measure the future expected revenues and corresponding investment threshold when distributors undertake the decision-making of investing in the international marketing channel. Reference [2] put forward when distributors face an uncertain environment and irreversible investment, if they are willing to spend time obtaining more information before deciding whether to invest, this waiting value will be the same as the waiting value or time value of options and this decision-making rule will find out not only the optimal but also the second best time point for investment correctly.

Reference [3] explained that under the fluctuations of exchange rates, the issues like entry investment, capital increase for production, and transfer investment or transfer production which multinational enterprises will face are related to the analysis of decision-making of options. Reference [4] proposed the analysis of five forces and its purpose is to define a high or low degree of market appeal. Five forces are composed of the dimensions that closely affect a company's customer service and profits, and the change of any force is likely to attract the company to exit from or enter the market. Reference [5] constructed a mathematical model of game options to analyze the situation when many enterprises compete for a single investment project. The authors assumed that the value of this project follows the geometric Brownian motion. The research result showed that the optimal investment threshold under the Nash equilibrium will range between the threshold under the full information equilibrium and the threshold under the monopoly market. Reference [6] used the game options to explore the optimal investment decision-making for fully competing enterprises under the circumstances that there exist the incomplete information and first-occupied advantage. The research result showed that the optimal investment threshold for enterprises will range between the threshold under the NPV of zero and the threshold under the monopoly enterprise. Reference [7] used the game options to explore how enterprises' decision-making of investing in the project is affected by the uncertainty of demand, costs, and competitors. The research result showed that aggressive enterprises have the option of exiting from investing, so they are not willing to give up investing under the uncertainty of demand, while conservative enterprises have the option of waiting to invest, so they are not willing to invest under the uncertainty of demand. Reference [8] compared the traditional discounted cash flow modeling with the real options valuation. The authors proposed using a derivative of scenario planning and qualitative real options to evaluate the non-quantifiable factors in a project that will be better under the circumstances that uncertainty increases and forecasting becomes difficult.

Based on the above literature, the paper will use the game options to assess international distributors' decision-making of investing in the international marketing channel and the future expected investment payoffs and corresponding optimal investment threshold.

II. THE MODEL

The model aims to explore how to expect the potential value generated from future payoffs when distributors undertake the decision-making of investing in the international marketing channel, namely how the investment strategy in consideration of competitors' reactions affects the firm value. It is assumed that two countries have their respective distributors who compete for the marketing channels of the two countries, i.e. consider investing in the marketing channels of the two countries (country A and country B). The model wants to find out the expected investment threshold of the two distributors and the optimal time point for investing in the international marketing channel. Assuming the country base of distributor H is country A, the subjective investment opportunity of investing in the marketing channel of country A is p and that of investing in the marketing channel of country B is $1-p$. Assuming the country base of distributor F is country B, the subjective investment opportunity of investing in the marketing channel of country A is q and that of investing in the marketing channel of country B is $1-q$. TABLE I shows the expected payoffs in the marketing channels of the two countries.

TABLE I

The corresponding coefficients for the expected payoffs in the marketing channels of the two countries

		Distributor H	
		The marketing channel of country A (p)	The marketing channel of country B $(1-p)$
Distributor F	The marketing channel of country A (q)	$(\pi_{AA}^{H}, \pi_{AA}^{F})$	$(\pi_{BA}^{H}, \pi_{BA}^{F})$
	The marketing channel of country B $(1-q)$	$(\pi_{AB}^{H}, \pi_{AB}^{F})$	$(\pi_{BB}^{H}, \pi_{BB}^{F})$

π_i^{jk} represents the corresponding coefficients for the expected payoffs in the marketing channels of the two countries, where $i = H、F$ is distributor H or F; $j = A、B$ is country A or B that distributor H invests; $k = A、B$ is country A or B that distributor F invests. By using the payoff equating method (Reference [9]), we can get:

$$p \times [q \times \pi_{AA}^{H} + (1-q) \times \pi_{AB}^{H}] = (1-p) \times [q \times \pi_{BA}^{H} + (1-q) \times \pi_{BA}^{H}] \quad (1)$$

Eqn. (1) shows whichever country distributor H chooses to invest, the expected payoffs generated from investing in country A and B will be the same.

$$q \times [p \times \pi_{AA}^{F} + (1-p) \times \pi_{BA}^{F}] = (1-q) \times [p \times \pi_{AB}^{F} + (1-p) \times \pi_{BB}^{F}] \quad (2)$$

Eqn. (2) shows whichever country distributor F chooses to invest, the expected payoffs generated from investing in country A and B will be the same.

By combining Eqn. (1) with Eqn. (2), p^*, the optimal subjective investment opportunity of distributor H and q^*, the optimal subjective investment opportunity of distributor F can be obtained as follows:

$$p^* = \frac{-E \pm \sqrt{E^2 - 4N\Pi}}{2N} \quad (3)$$

only the positive root is chosen,

$$N \equiv \pi_{AA}^{H}(\pi_{AB}^{F} - \pi_{BB}^{F}) + \pi_{AB}^{H}(\pi_{AA}^{F} - \pi_{BA}^{F}) + \pi_{BA}^{H}(\pi_{AB}^{F} - \pi_{BB}^{F}) + \pi_{BB}^{H}(\pi_{AA}^{F} - \pi_{BB}^{F});$$

$$E \equiv \pi_{BB}^{F}[(\pi_{AA}^{H} + \pi_{BA}^{H}) + (\pi_{BA}^{H} - \pi_{BB}^{H})] + \pi_{BB}^{H}[(\pi_{BA}^{F} + \pi_{BB}^{F}) - (\pi_{AA}^{F} + \pi_{AB}^{F})] + \pi_{BA}^{F}(\pi_{AB}^{H} + \pi_{BB}^{H}) - \pi_{AB}^{F}(\pi_{BA}^{H} - \pi_{BB}^{H});$$

$$\Pi = \pi_{BB}^{H}(\pi_{BA}^{H} - \pi_{BB}^{H}) + \pi_{BB}^{H}(\pi_{BA}^{F} + \pi_{BB}^{F}),$$

$$q^* = \frac{p^* \pi_{AB}^{F} + (1-p^*)\pi_{BB}^{F}}{p^*(\pi_{AB}^{F} + \pi_{AA}^{F}) + (1-p^*)(\pi_{BA}^{F} + \pi_{BB}^{F})} \quad (4)$$

It is assumed the strategy of distributor H is to first invest in the marketing channel of the home country (country A), namely there exists the potential strategy value of investing in the marketing channel of country A at the waiting stage. When distributor H invests in the marketing channel of country A, it has to pay C_A^H, the cost of investing in the marketing channel of country A; at this time, the threshold of expected payoffs is E[π_A^H] and the corresponding time point is t_1^* respectively. Meanwhile, distributor H also considers the other strategy of investing in the marketing channel of country B, namely there exists the potential strategy value of investing in the marketing channel of country B. When distributor H invests in the marketing channel of country B, it has to pay C_B^H, the cost of investing in the marketing channel of country B; R_A^H is the residual value generated from distributor H's liquidating the marketing channel of country A and $\frac{1}{2}\pi_A^H$ is distributor H takes half of the payoffs from the marketing channel of country A to country B; at this time, the threshold of expected payoffs is E[π_B^H] and the corresponding time point is t_2^* respectively. It is also assumed the strategy of distributor F to first invest in the marketing channel of the home country (country B), namely there exists the potential strategy value of investing in the marketing channel of country B at the waiting stage. Similarly, it has to pay C_B^F and C_A^F, the cost of investing in the marketing channel of country B and A; R_B^F is the residual value and $\frac{1}{2}\pi_B^F$ is half of the payoffs at the last stage; at this time, the threshold of expected payoffs are E[π_B^F] and E[π_A^F],also the corresponding time point are t_3^* and t_4^* respectively. So we will not repeat here. In addition, the cash flows of the actual payoffs of the two distributors are the overall market payoffs π multiplied by the corresponding coefficients at various stages in TABLE I.

In the waiting stage, distributor H doesn't invest in any country that has the potential strategy value of investing in country A; α_0^H is the average growth (bank rate), r_0^H is the risk factor (discounted rate), and σ_0^H is the volatility of waiting stage. In the country A stage, distributor H decides to invest in country A that has the potential strategy value of investing in country B; α_A^H is the average growth of investment project A, r_A^H is the risk factor of investment project A, and σ_A^H is the volatility of investment project A. In the country B stage, distributor H decides to invest in country B but doesn't have next stage to invest; α_B^H is the average growth of investment project B and r_B^H is the risk factor of investment project B. The relationship among α_0^H, α_A^H, α_B^H is that α_B^H is greater than α_A^H and α_A^H is greater than α_0^H. The relationship among r_0^H, r_A^H, r_B^H is that r_B^H is greater than r_A^H and r_A^H is greater than r_0^H. The relationship between σ_0^H and σ_A^H is that σ_A^H is greater than σ_0^H.

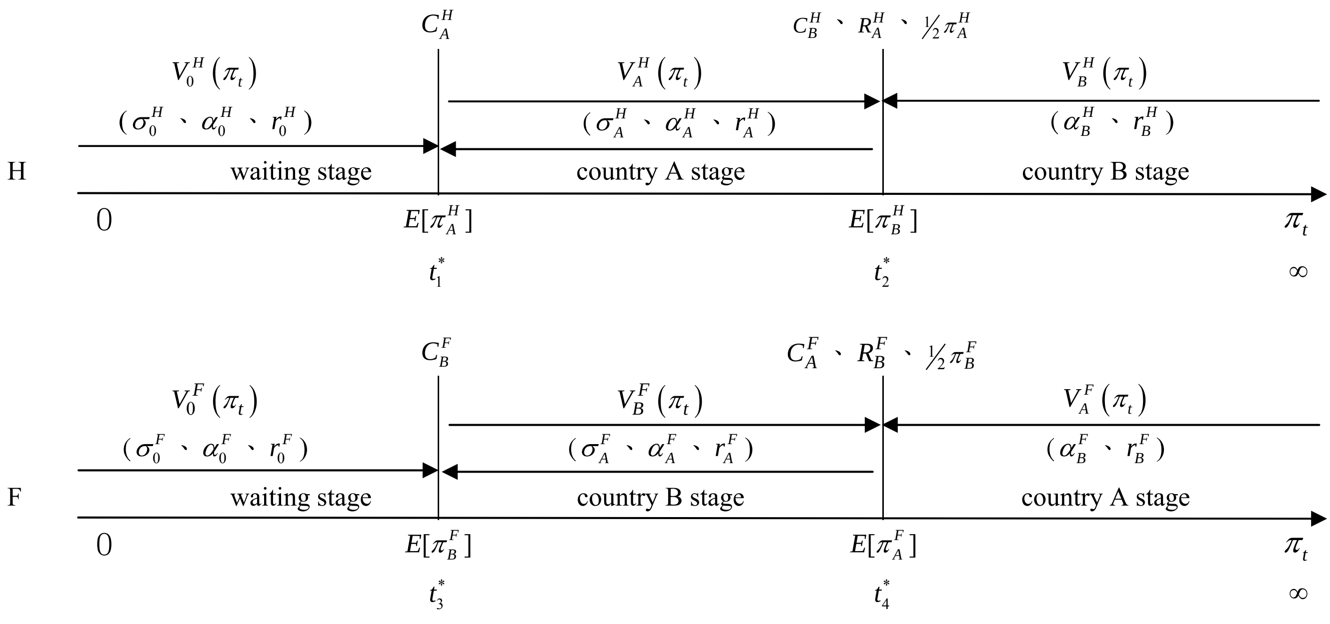

Fig. 1. The model of the two distributors' investing in the marketing channels

Moreover, the overall market payoffs π_t at time t follow the geometric Brownian motion:

$$\frac{d\pi_t}{\pi_t} = \alpha dt + \sigma dw_t \quad ; \pi_0 = \pi \tag{5}$$

where α is the average growth rate of the quantity of payoff , σ is the change of the growth rate of the quantity of payoff, and dw_t is the change of quantity per unit time with zero mean and variation deviation of dt in standard Wiener process.

When distributor H has not invested in the marketing channel of any country yet, the overall firm value is $V_0^H(\pi_t)$ at this stage and the expected value function (by using Ito's Lemma [10]) is as follows:

$$E[dV_0^H(\pi_t)] = E[A_0^H \pi_t^{\beta_0^H}] \qquad (6)$$

Where E[$A_0^H \pi_t^{\beta_0^H}$] is the potential strategy value of investing in the marketing channel of country A when distributor H has not invested in the marketing channel of country A yet, A_0^H is the multiplier effect of potential value, and β_0^H is the scale factor shown as follows:

$$\beta_0^H = \frac{(\tfrac{1}{2}(\sigma_0^H)^2 - \alpha_0^H) + \sqrt{(\alpha_0^H - \tfrac{1}{2}(\sigma_0^H)^2)^2 + 2(\sigma_0^H)^2 r_0^H}}{(\sigma_0^H)^2} > 1 \qquad (7)$$

where r_0^H is the risk factor when distributor H waits to invest in the marketing channel of country A (discounted rate). When the overall market payoffs π reach the threshold of expected payoffs E[π_A^H], distributor H will pay C_A^H (the cost of investing in the marketing channel of country A) in order to invest in the marketing channel of country A. After distributor H invests in the marketing channel of country A, the overall firm value is $V_A^H(\pi_t)$ at this stage and the expected value function at the threshold of expected payoffs is as follows:

$$\begin{aligned} E[V_A^H(\pi_t)] &= E[\int_{t_1^*}^{t_2^*} \pi_t \cdot e^{-r_A^H (t-t_1^*)} dt] \\ &(q^* \times \pi_{AA}^H + (1-q^*) \times \pi_{AA}^H) + E[A_A^H(\pi_t)^{\beta_A^H}] \end{aligned} \qquad (8)$$

where $E[\int_{t_1^*}^{t_2^*} \pi_t \cdot e^{-r_A^H \cdot (t-t_1^*)} dt](q^* \times \pi_{AA}^H + (1-q^*) \times \pi_{AB}^H)$

is the value of the cash flows of expected payoffs generated from distributor H's investing in the marketing channel of country A, i.e. the value of the total profits of sales revenues at this stage, E[$A_A^H(\pi_t)^{\beta_A^H}$]is the potential strategy value of investing in the marketing channel of country B when distributor H has not invested in the marketing channel of country B yet, A_A^H is the multiplier effect, and β_A^H is the scale factor shown as follows:

$$\beta_A^H = \frac{(\tfrac{1}{2}(\sigma_A^H)^2 - \alpha_A^H) + \sqrt{(\alpha_A^H - \tfrac{1}{2}(\sigma_A^H)^2)^2 + 2(\sigma_A^H)^2 r_A^H}}{(\sigma_A^H)^2} > 1 \qquad (9)$$

where r_A^H is the risk factor after distributor H invests in the marketing channel of country A (discounted rate).

When the overall market payoffs π reach the threshold of expected payoffs E[π_B^H], distributor H will pay C_B^H (the cost of investing in the marketing channel of country B) in order to invest in the marketing channel of country B. After distributor H invests in the marketing channel of country B, the overall firm value is $V_B^H(\pi_t)$ at this stage and the expected value function at the threshold of expected payoffs is as follows:

$$\begin{aligned} &E[V_B^H(\pi_t)] = \\ &E[\int_{t_2^*}^{\infty} \pi_t \cdot e^{-r_B^H (t-t_2^*)} dt](q^* \times \pi_{\mathrm{BA}}^H + (1-q^*) \times \pi_{\mathrm{BB}}^H) \end{aligned} \qquad (10)$$

where $E[\int_{t_2^*}^{\infty} \pi_t \cdot e^{-r_B^H (t-t_2^*)} dt](q^* \times \pi_{\mathrm{BA}}^H + (1-q^*) \times \pi_{\mathrm{BB}}^H)$

is the value of the cash flows of expected payoffs generated from distributor H's investing in the marketing channel of country B, i.e. the value of the total profits of sales revenues at this stage. r_B^H is the risk factor after distributor H invests in the marketing channel of country B (discounted rate).

Similarly, we can derive the values generated from distributor F's investments at various stages, so we will not repeat here.

III. INVESTMENT THRESHOLD

By using the value-matching condition advocated by the Reference [11], we can calculate the values generated from distributor H's and F's investing in the marketing channels of country A and B at the various thresholds of expected payoffs as follows:

1. *Distributor H: from the waiting stage to country A stage*

By using Eqn. (6) (the threshold of expected payoffs is E[π_A^H] and the corresponding time point is t_1^*) plus C_A^H, the cost of investing in the marketing channel of country A and Eqn. (8) plus R_A^H, the residual value generated from distributor H's liquidating the marketing channel of country A, we can get the equating relationship at this threshold of expected payoffs as follows:

$$\begin{aligned} &E[A_0^H(\pi_t)^{\beta_0^H}] + C_A^H = E[\int_{t_1^*}^{t_2^*} \pi_t \cdot e^{-r_A^H (t-t_1^*)} dt] \\ &(q^* \times \pi_{AA}^H + (1-q^*) \times \pi_{AB}^H) + E[A_A^H(\pi_t)^{\beta_A^H}] \end{aligned} \qquad (11)$$

By using the moment generation function, we can get the following three equations:

$$E[A_0^H(\pi_t)^{\beta_0^H}] = A_0^H \pi^{\beta_0^H} e^{[\beta_0^H \alpha_0^H + \frac{1}{2}((\beta_0^H)^2 - \beta_0^H)(\sigma_0^H)^2] t_1^*},$$

$$E[A_A^H(\pi_t)^{\beta_A^H}] = A_A^H \pi^{\beta_A^H} e^{[\beta_A^H \alpha_A^H + \frac{1}{2}((\beta_A^H)^2 - \beta_A^H)(\sigma_A^H)^2] t_1^*},$$

and the mean equation of geometric Brownian motion $E[\pi_t] = \pi_0 \cdot e^{\alpha t}$. By incorporating these three equations into Eqn. (11), we can get:

$$\begin{aligned} &A_0^H \pi^{\beta_0^H} e^{B_0^H t_1^*} + C_A^H + \frac{\pi_0 \cdot \Sigma_A^H \cdot e^{(\alpha_A^H + r_A^H) t_1^*}}{(r_A^H)} (e^{-r_A^H t_2^*} - e^{-r_A^H t_1^*}) \\ &- A_A^H \pi^{\beta_A^H} e^{B_A^H t_2^*} = 0 \end{aligned} \qquad (12)$$

where $B_0^H \equiv \beta_0^H \alpha_0^H + \frac{1}{2}((\beta_0^H)^2 - \beta_0^H)(\sigma_0^H)^2$;

$$\sum\nolimits_A^H \equiv q^* \times \pi_{AA}^H + (1-q^*) \times \pi_{AB}^H ;$$

Moreover, by using the smooth-pasting condition advocated by [11], the first differential equation of t_1^* on Eqn. (12) can be obtained as follows:

$$B_0^H A_0^H \pi^{\beta_0^H} e^{B_0^H t_1^*} + \frac{(\alpha_A^H + r_A^H) \cdot \pi_0 \cdot \sum_A^H e^{(\alpha_A^H + r_A^H) t_1^*}}{r_A^H} + (\alpha_A^H + r_A^H) \pi_0 \sum\nolimits_A^H e^{\alpha_A^H t_1^*} = 0 \quad (13)$$

2. *Distributor H: from country A stage to country B stage*

By using Eqn. (8) (the threshold of expected payoffs is $E[\pi_B^H]$ and the corresponding time point is t_2^*) plus C_B^H, the cost of investing in the marketing channel of country B and Eqn. (10), we can get the equating relationship at this threshold of expected payoffs as follows:

$$A_A^H \pi^{\beta_A^H} e^{B_A^H t_2^*} + R_A^H + C_B^H + \frac{1}{2} \pi_A^H + E[\int_{t_1^*}^{t_2^*} \pi_t \cdot e^{r_A^H (t - t_1^*)} dt](q^* \times \pi_{AA}^H + (1-q^*) \times \pi_{AB}^H) \quad (14)$$
$$= E[\int_{t_2^*}^{\infty} \pi_t \cdot e^{-r_B^H (t - t_2^*)} dt](q^* \times \pi_{BA}^H + (1-q^*) \times \pi_{BB}^H)$$

Reorganizing Eqn. (14) can get:

$$A_A^H \cdot \pi^{\beta_A^H} \cdot e^{B_A^H t_2^*} + C_B^H + R_A^H + \frac{1}{2} \pi_A^H + \frac{\pi_0 \cdot \Sigma_A^H \cdot e^{\alpha_A^H t_1^*} \cdot e^{r_A^H t_2^*}}{(-r_A)} (e^{-r_A^H t_2^*} - e^{-r_A^H t_1^*}) - \frac{\pi_0 \cdot \Sigma_F^B \cdot e^{(\alpha_B^H + r_B^H) t_2^*}}{(r_B^H)} e^{(-r_B^H t_2^*)} = 0 \quad (15)$$

where $B_A^H \equiv \beta_A^H \alpha_A^H + \frac{1}{2}((\beta_A^H)^2 - \beta_A^H)(\sigma_A^H)^2$;

$$\sum\nolimits_B^H \equiv q^* \times \pi_{BA}^H + (1-q^*) \times \pi_{BB}^H ;$$

Furthermore, by using the smooth-pasting condition advocated by [10], the first differential equation of t_2^* on Eqn. (15) can be obtained as follows:

$$B_A^H A_A^H \pi^{\beta_A^H} + \pi_0 \cdot \Sigma_A^H \cdot e^{r_A^H t_2^*} - \frac{\alpha_B^H \cdot \pi_0 \cdot \Sigma_F^B \cdot e^{\alpha_B^H t_2^*}}{r_B^H} = 0 \quad (16)$$

Through Eqn. (12), (13), (15), (16), we can obtain distributor H's multiplier effects of potential value A_0^H, A_A^H and thresholds of expected payoffs E[π_A^H], E[π_B^H] or optimal time points t_1^*, t_2^*. Similarly, we can obtain distributor F's multiplier effects of potential value and thresholds of expected payoffs E[π_B^F], E[π_A^F] or optimal time points t_3^*, t_4^*, so we will not repeat here.

IV. CONCLUSION

The paper uses the game options to build a mathematical model in consideration of competitors' investment behavior to decide the expected payoffs and evaluate the optimal time point for investing in the domestic or international marketing channel assuming that there exists the potential entry value but no potential exit value for distributors to invest in the domestic or international marketing channel and the overall market payoffs follow the geometric Brownian motion. The results will provide the references of evaluating the costs and payoffs and the cash flow value generated from the investments and considering competitors' investment strategies and distributors' potential value of changing their strategies in order to measure whether the investments reach the expected payoffs when distributors want to invest in the international marketing channel in the future.

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$$-\bar{\alpha}Z_1e^{\bar{\alpha}t^{**}}+2\alpha\cdot Z_4e^{2\alpha t^{**}}+\alpha\cdot Z_5e^{\alpha t^{**}}$$
$$-r_3\cdot Z_6e^{r_3t^{**}}-\beta_{31}\cdot A_3e^{\beta_{31}t^{**}}=0 \quad . \tag{15}$$

All the thresholds U^*, U^{**}, and related parameters A_{n_1}, A_{n_2}, A_e, and A_i by the nonlinear stochastic equations which are composed of formula (8)-(15) can be found numerical solution hereafter.

III. CONCLUSION

This study utilizes the real options approach to construct the mathematical decision-making model of investing (disinvesting) in the free internet service. Using the realistic and potential business values evaluates the investing project of financial effect. Additionally, this study deals with the optimal use ratio of free software service and provides the firms to measure their expected achievement. In this article, the use ratio assumes to follow geometric Brownian motion. The costs of increasing page views will be affected by researching the free software, building network spaces, providing anti-virus functions, etc. The firms' revenues are arisen from the advertiser's trust and confidence and the advertiser will choose to promote through the internet. This study attempts to construct a model that shows the internet service firms' cost and revenue functions. And it also gives the advices for the firms to decide the best timing of entering or exiting from the market.

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出席國際學術會議心得報告

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發表論文題目	A Decision Analysis for Introducing Corporate Social Responsibility on Science and Technology Industry

一、參加會議經過

1. 2009/12/08-2007/12/11 期間出席IEEM2009 國際研討會
2. 2009/12/08 上午搭乘港龍班機出席香港研討會
3. 2009/12/09 上午8:30 報到時間/領取會議相關資料
4. 2009/12/09 下午15:30-下午17:00 口頭發表論文
5. 2009/12/10 上午 9:00-下午 5:00 參觀海報論文
6. 2009/12/11 下午搭乘國泰班機回國

二、與會心得

1. IEEM2009為IEEE協會下工程管理領域之重要學術研討會，發表論文將收錄於EI index。此次很榮幸能參與此盛會，並且得到來自各地的學術人士最實質的建議。
2. 此次論文獲選參加研討會，均為國科會專題直接關連性論文或計畫經費援助所呈現之成果。與會最主要能將目前執行國科會計畫案內容增進，並提供後續計畫進行及修改之參考。
3. 除參與國際研討會外，同時從事國際化學術活動增廣見聞，相信未來在個人學術研究交流與國際觀均有助益。

A Decision Analysis for Introducing Corporate Social Responsibility on Science and Technology Industry

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Abstract - **In consideration of the development of the technology industry and the issue of global warming caused by the environmental pollution and deterioration, "Corporate Social Responsibility (CSR)" has become the subject of attention. Therefore, this paper will explore how enterprises evaluate the relationship between the additional cost for protecting the environment and the intangible firm value generated from investing in CSR in order to obtain the maximum firm value under the consideration of environmental economics. This paper introduces the utility function to analyze the intangible benefits generated from investing in CSR and uses the real options approach to construct a mathematical model to find out the optimal time point for investing in CSR. The result can provide the reference of decision-making for managers in consideration of the profits under the financial economics and the corporate social responsibility under the environmental economics.**

Keywords - **Corporate social responsibility, technology industry, environmental economics, real options**

I. INTRODUCTION

Since Asia Financial Crisis occurred in 1997, Enron had been malicious bankrupt in December 2001 and many well-known and large enterprises such as Tyco, WorldCom, Xerox, Merck & Co., etc. had been also involved in a series of accounting scandals. Since then, corporate sustainability has been an important subject for many enterprises and corporate social responsibility (CSR) has also evolved into an indispensable element of corporate sustainability. Many norms and initiatives related to CSR are established one after another internationally (For example: The OECD Guidelines for Multinational Enterprise; The UN Global Compact; ILO Conventions; ISO 14000; Accountability 1000; The Global Report ring Imitative; The Global Sullivan Principles; Social Accountability 8000) so that enterprises can feed back the society where they get resources and should find the balance between cooperate growth and social progress when they pursue corporate financial performance (CFP).

Inevitably enterprises aim to maximize the shareholder's equity, but enhancing social performance has also become a factor that enterprises must take into account while people are concerned about CSR nowadays. Therefore, enterprises should not only care about how to maximize the shareholder's equity but also consider the benefits of other stakeholders like employees, consumers, communities, and the environment). However, the issue that enterprises are most concerned about is how the investment of CSR affects their financial performance. The result of the present study shows that the relationship between CSR and CFP is not clear. Reference [1] explained the reason may be because the uses of samples and the methods of measuring the relationship between CSR and CFP are different, [2] showed the researches of valuating CSR are inadequate, [3] showed the research methods are different, and so on.

For the relationship between CSR and CFP, [1] explored 62 data to find that the relationship between them is negative; Reference [4] used almost the same database but in a different combination of categories to conclude that the relationship between them is mostly positive; Reference [3] pointed out that such a moral orientation (CSR) has a positive relationship with CFP. If the relationship between CSR and CFP is explored from an indirect viewpoint, [5] and [6] proposed to explore their relationship from a resource-based view of the firm. This viewpoint considers that the organization can be divided into tangible and intangible assets; Reference [7] showed both assets can enhance the organization's competitive advantage and further affect the organization's strategy decision. Reference [8] and [9] explained the benefit generated from CSR can be regarded as corporate intangible asset and further affect corporate strategy decision. CSR can enhance corporate competitive advantage, improve corporate brand image, and increase corporate popularity. In addition, [6] from the viewpoint of resources, presented CSR can also enhance the organization's performance and competitive advantages that introduced in [10].

Coca-Cola co. had raised USD 60 million for children and youth fund in the past 10 years, which really contributed to social welfare; NIKE had announced "Corporate Social Responsibility Report" and hoped to remove the negative impression on their dealing with environmental and ecological problems and the problem of labor exploitation. In the past few years, there have been at least four large banks using corporate social investment (SRI) to evaluate their social investment strategy. For example, Citicorp's Smith Barney Financial Securities Corporation used the qualitative method to evaluate the issue of the sustainability of 28 industries in its announced research report; Goldman, Sachs & Co. used the quantitative method with 42 evaluation standards

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related to the environment, society, and governance to transform social performance into financial performance in the energy industry and disclosed the concrete results of new legacy assets or new oil field; UBS corp. tried to establish a framework to judge the CSR in each industry and quantitate the value in its SRI report. Merrill Lynch cooperated with World Resource Center to announce a study, which analyzed the investment opportunity within climate change for the auto industry and made some specific recommendations for investment.

In this paper, the benefits generated from investing in CSR (social justice, environmental sustainability, corporate image) will be transformed into the utility function of economics. This paper uses the real options approach to construct a mathematical model to find out the optimal time point for investing in CSR and provide the reference of decision-making for managers in consideration of the profits under the financial economics and the corporate social responsibility under the environmental economics.

II. THE MODEL

In this paper, the utility function $U(E[\pi^*])$ represents the intangible value after enterprises invest in CSR, namely the subjective actual benefit after enterprises invest cost I in CSR. Before investing in CSR, enterprises should consider the potential entering loss, and the benefits generated from investing in CSR and aim to maximize the overall profit to serve as the basis for business decision-making.

This model illustrates the best investment time point for CSR under the subjective utility function. Variable $V_0(\pi_t)$ is the total value at the waiting stage, including the operating cash flows and the potential strategy value of investing in CSR. Variable π_t is the operating revenues at any time point. Variable $V_1(\pi_t)$ represents the total value at the entering stage, including the operating cash flows and the utility $U(E[\pi^*])$. In addition, the risk coefficients (discounted rates) at the waiting stage and entering stage are r_0 and r_1 respectively. Since investing in CSR will raise the operating cost, we assume that $r_1 > r_0$, which accords with the relationship between return and risk.

The decision variable in this model is π_t. Therefore, $\pi^*(t^*)$ is the threshold for the maximum profit. It is assumed the operating revenues π_t follow geometric Brownian motion (GBM).

$$\frac{d\pi_t}{\pi_t} = \alpha \cdot dt + \sigma \cdot dw_t \;;\; \pi_0 = \pi \tag{1}$$

where α is the average growth rate of operating revenues, σ is the volatility growth rate of operating revenues, and dw_t follows the standard Wiener process with mean zero and variance dt, i.e. $dw_t \sim N(0, dt)$.

At the waiting stage, the total value includes the operating cash flows and the potential loss of investing in CSR. The expected value function is showed as follows:

$$E[dV_0(\pi_{t^*}^*)] = E\left[\int_0^{t^*} e^{r_0(t^*-t)}\pi_t dt \mid \pi_0 = \pi\right] - E\left[A\left[\pi_{t^*}^*\right]^\beta\right] - I \tag{2}$$

Where $E[\int_0^{t^*} e^{r_0(t^*-t)}\pi dt]$ is the operating cash flows at the waiting stage, i.e. the total operating revenue at this stage. A is the scale coefficient of potential investment in CSR. $E[A[\pi_{t^*}^*]^\beta]$ is the expected entering lost. Meanwhile, they should invest the capital I in CSR. We can find the potential entering loss by using Ito's Lemma introduced in [11] as follows (please omit the subscript of $V_0(\pi_{t^*}^*)$ and keep $V(\pi_t)$ instead):

$$\begin{aligned} E[dV(\pi_t)] &= E\left[V_\pi(\pi_t) \cdot d\pi_t + \frac{1}{2} \cdot V_{\pi\pi}(\pi_t) \cdot (d\pi_t)^2\right] \\ &= \left(\frac{1}{2} \cdot \sigma^2 \cdot \pi_t^2 \cdot V_{\pi\pi}(\pi_t) + \alpha \cdot \pi_t \cdot V_\pi(\pi_t)\right)dt \end{aligned} \tag{3}$$

Here we use $V_\pi(\pi_t)$ and $V_{\pi\pi}(\pi_t)$ to represent the first-order and second-order differential on π_t of enterprise value $V(\pi_t)$ respectively. By using the risk neutral condition, the coefficient β is calculated to satisfy the equation:

$\frac{1}{2} \cdot \sigma^2 \cdot \beta^2 + (\alpha - \frac{1}{2}\sigma^2)\beta - r_0 = 0$, that is:

$$\beta = \frac{\left(\frac{1}{2}\sigma^2 - \alpha\right) \pm \sqrt{\left(\alpha - \frac{1}{2}\sigma^2\right)^2 + 2\sigma^2 r_0}}{\sigma^2} \tag{4}$$

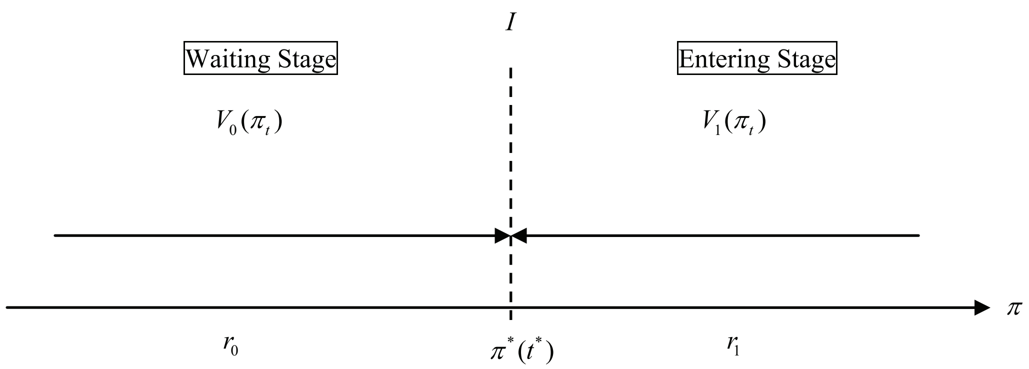

Fig. 1: Investment decision-making model for corporate social responsibility.

This paper assumes that only the potential entering loss but not the potential exiting value exists at the waiting stage. So we only choose the positive root $\beta > 1$ (please see the explanation of [12] for details).

When enterprises evaluate that the operating revenue of investing in CSR reaches the threshold π^*, they should invest the capital I in CSR. At this time, the enterprise value is $V_1(\pi_{t^*}^*)$ and the expected value function is as follows:

$$E[dV_1(\pi_{t^*}^*)] = E\left[\int_{t^*}^{\infty} e^{-r_1(t-t^*)}\pi dt\right] + U(E[\pi_{t^*}^*]) \tag{5}$$

Where $E\left[\int_{t^*}^{\infty} e^{-r_1(t-t^*)}\pi dt\right]$ means the operating cash flows after investing in CSR and the risk coefficient (discounted rate) is r_1.

This paper uses the utility function *U(I)* as follows :

$$U(E[\pi^*]) = a(E[\pi^*]-I)^2 + b(E[\pi^*]-I)+c \tag{6}$$

where a 、 b 、 c are known coefficients. This paper assumes that the utility function is related with the expected profit and investment money. Here we only choose the increasing part of the parabola to comply with the general utility preference.

This model describes the changes of operating revenues when investing in CSR. Firms may decrease their operating revenues because of extra investment in CSR, but this can be offset by earning intangible value like raising public image, improving public relationship, and reducing the environment pollution. Managers can use this model to find out the balance between revenues and the overall environment.

III. DECISION THRESHOLD

Based on the value-matching condition and smooth-pasting condition introduced by [12], the threshold $\pi^*(t^*)$ at each stage can be counted in order to find the maximum enterprise profit $E[\pi_t^*]$ and the coefficient of the potential entering loss *A*.

1. The value-matching condition for the waiting and entering stages

$$\begin{aligned} &E\left[\int_0^{t^*} e^{r_0(t^*-t)}\pi_t dt \mid \pi_0 = \pi\right] - E\left[A\left[\pi_{t^*}^*\right]^{\beta}\right] - I \\ &= E\left[\int_{t^*}^{\infty} e^{-r_1(t-t^*)}\pi_t dt\right] + U(E[\pi^*]) \end{aligned} \tag{7}$$

Eqn. (7) can be simplified as follows:

$$\begin{aligned} &e^{r_0 t^*}\pi\frac{1-e^{-(r_0-\alpha)t^*}}{(r_0-\alpha)} - AE[(\pi_{t^*}^*)^{\beta}] - I \\ &= e^{r_1 t^*}\pi\frac{e^{-(r_1-\alpha)t^*}}{(r_1-\alpha)} + U(E[\pi^*]) \end{aligned} \tag{8}$$

By incorporating $E[(\pi_{t^*}^*)^{\beta}] = \pi^{\beta(\alpha-\frac{1}{2}\sigma^2+\frac{1}{2}\beta\sigma^2)t^*}$ (MPG) and $t^* = \frac{1}{\alpha}\ln(\frac{E[\pi_{t^*}^*]}{\pi})$ (the geometric Brownian motion expectation formula) into Eqn. (8), the simplified result can be obtained as follows:

$$\begin{aligned} &\pi_0\cdot\tilde{\pi}^{r_0}(r_0-\alpha)^{-1}[1-\tilde{\pi}^{-(r_0-\alpha)}] \\ &-\pi_0\cdot \mathrm{A}\cdot\tilde{\pi}^{S} - I = \pi_0\cdot\tilde{\pi}^{r_1}(r_1-\alpha)^{-1} \\ &\cdot\tilde{\pi}^{-(r_1-\alpha)} + (a(E[\pi^*]-I)^2 + b(E[\pi^*]-I)+c = 0 \end{aligned} \tag{9}$$

Where $S \equiv \beta(\alpha-\frac{1}{2}\sigma^2+\frac{1}{2}\beta\sigma^2)$, $\tilde{\pi}=(\frac{E[\pi^*]}{\pi_0})^{\frac{1}{\alpha}}$.

2. The smooth-pasting condition for the waiting and entering stages

By using the smooth- pasting condition introduced by [12], i.e. the first-order differential on $E[\pi_{t^*}^*]$ of Eqn. (9), the following result can be derived:

$$\begin{aligned} &\frac{r_0}{\alpha}\tilde{\pi}^{r_0-1}\cdot\pi_0\cdot\frac{1}{r_0-\alpha}[1-\tilde{\pi}^{-(r_0-\alpha)}]+\tilde{\pi}^{r_0}\cdot\pi_0\frac{1}{r_0-\alpha}\cdot\frac{(r_0-\alpha)}{\alpha}\cdot\pi_0^{\frac{r_0-\alpha}{\alpha}} \\ &E[\pi^*]^{\frac{-r_0}{\alpha}} - \frac{S}{\alpha}\mathrm{A}\cdot\pi_0\cdot\tilde{\pi}^{S-\alpha} = \frac{r_1}{\alpha}\tilde{\pi}^{r_1-\alpha}\cdot\pi_0\cdot\frac{1}{r_1-\alpha}\tilde{\pi}^{-(r_1-\alpha)} + \\ &\tilde{\pi}^{r_1}\pi_0\cdot\frac{1}{r_1-\alpha}\frac{-(r_1-\alpha)}{\alpha}\pi_0^{\frac{r_1-\alpha}{\alpha}}E[\pi^*]^{\frac{-r_1}{\alpha}} + 2a(E[\pi^*]-I)+b \end{aligned} \tag{10}$$

$E[\pi_{t^*}^*]$ and the parameter *A* can be obtained by the Simultaneous non-linear equations of Eqn. (9) and (10). It is assumed that $C_1 \equiv \frac{\pi^{1-\frac{r_0}{\alpha}}}{r_0-\alpha}$; $C_2 \equiv \pi^{1-\frac{s}{\alpha}}$; $C_3 \equiv \frac{r_1-r_0-2\alpha}{(r_0-\alpha)(r_1-\alpha)}$, so the coefficient of the potential entering loss A can be derived as follows:

$$A = \frac{U(I)-(I+K)-\left(1-\frac{r_0}{\alpha}\right)C_1 E[\pi_{t^*}^*]^{\frac{r_0}{\alpha}}}{(1-\frac{s}{\alpha})C_2 E[\pi_{t^*}^*]^{\frac{s}{\alpha}}} \tag{11}$$

By incorporating Eqn. (11) into Eqn. (10), we can find $E[\pi_{t^*}^*]$ follows the non-linear equation below:

$$\left[\frac{r_0}{\alpha}+\frac{s}{\alpha}\left(\frac{r_0-\alpha}{\alpha-s}\right)\right]C_1\left[E[\pi_{t^*}^*]\right]^{\frac{r_0}{\alpha}}-C_3E[\pi_{t^*}^*] + \left(\frac{s}{\alpha-s}\right)\left[U(E[\pi^*])+I\right]=0 \quad (12)$$

In Eqn. (12), we can find the best expected profit $E[\pi_{t^*}^*]$ and use $t^* = \frac{1}{\alpha}\ln(\frac{E[\pi_{t^*}^*]}{\pi})$ to find the optimal time point t^* for investing in CSR.

IV. NUMERICAL EXAMPLE ANALYSIS

According to practical experience, Eqn. (9) and (10) provide the reference of the relationship between waiting stage and entering stage to substitute the mathematical model for the practical illustration. The study uses the MATLAB software to solve the numeric of the parameters.

We assume that the firm's growth rate α =0.1 per month and the volatility of the firm growth rate σ =0.17 per month. The market risk premium of the waiting stage and entering stage (r_0 , r_1) are 0.02 and 0.03 per month respectively. The fixed cost of investing in CSR is 10 million per month. The coefficients of the utility function are -0.1, 80 and 100 respectively.

TABLE I
NOTATION AND PARAMETER VALUES

Variable	Notation	Parameter value
Average growth rate of operating revenues	α	0.1
Volatility growth rate of operating revenues	σ	0.17
Risk premium on waiting stage	r_0	0.2
Risk premium on entering stage	r_1	0.3
Fixed cost of investing in CSR	I	1,000,000
Initial operating revenues	π_0	500,000
Coefficient of utility function	a	-0.1
Coefficient of utility function	b	80
Coefficient of utility function	c	100

We use the above numerical example, value-matching condition and smooth- pasting condition to calculate firm's threshold. The threshold $E[\pi_{t^*}^*]$=6129300 and the potential entering loss A= 6.7906. The optimal time point for investing in CSR t^* =25.06.

The threshold $E[\pi_{t^*}^*]$=6,129,300 means when we consider investing in CSR for 10 million dollors, the expected profit should be over 6,129,300 and then we will decide to invest in CSR. As long as we know the $E[\pi_{t^*}^*]$in this model, we can find out the optimal time point for investing in CSR. In this case, we take one month for a time period, which means operating after 25 months is the best time point for a firm to invest in CSR. As we all know, the utility function is decided by a decision maker's subjective thinking, so the coefficient in this utility function varies from people to people and industry to industry. To find out the unique utility function for each firm/industry may be further researched.

V. CONCLUSION

In consideration of the development of the technology industry and the issue of global warming caused by the environmental pollution and deterioration, "Corporate Social Responsibility (CSR)" has become the subject of attention. That is, the management should consider not only corporate financial performance but also the problem of the environmental economics caused by the environmental pollution. This paper explores how enterprises evaluate the relationship between the additional cost for protecting the environment and the intangible firm value generated from investing in CSR in order to obtain the maximum firm value under the consideration of environmental economics. This paper introduces the real options model to find the optimal time point for investing in CSR.

This paper assumes that corporate operating revenues follow geometric Brownian motion and introduces utility functions to describe the intangible benefits generated from investing in CSR. This paper uses the real options approach to construct a mathematical model to find out the optimal time point t^* for investing in CSR under the assumption that the potential exiting value does not exist.

One of the features in this model is the concept of potential loss. In most of the previous studies, we decide to invest in something because it may increase the expected operating revenues. But investing in CSR is most likely to decrease operating revenues. Firms invest in CSR because of the intangible profit. We use the potential entering loss to take the decreasing revenue into account. The other feature is the utility function. It's hard to illustrate the benefit generated from investing in CSR; here we introduce the utility function to describe it. By adjusting the coefficient in the utility function, the result can be applied to different firms. The result can provide a feasible evaluation criterion for enterprises to invest in CSR in the future.

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Using Real Options to Evaluate the Reasonable Renminbi Exchange Rate Interval

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Abstract - **Under the circumstances whether the Renminbi (RMB) exchange rate should be appreciated or depreciated to reach the reasonable level, the current RMB exchange rate seems to be improperly valued. This paper uses the Pearson correlation analysis and regression analysis to select six macroeconomic indicators and then uses the positive and negative relative weight to do the empirical analysis to find out the reasonable RMB exchange rate ranges. Furthermore, this paper will introduce the real options approach to get the appropriate RMB exchange rate interval in consideration of the influences of the potential value of appreciation or depreciation and other unexpected events on the exchange rate. The results will provide another measure or thinking of evaluating the reasonable RMB exchange rate interval.**

Keywords - **Renminbi, exchange rate interval, real options**

I. INTRODUCTION

Since Chinese government made economic reform in 1979, the continuing economic growth and large amounts of imports and exports have caught the public attention. Based on the regional analysis of the annual Economic Report released by the United Nations in January 16, 2009 in Beijing, China will be still the driving force of the economic growth in the world in 2009. Therefore, any change in China's economy will affect the world's economy; the RMB exchange rate which has the biggest impact on the foreign trade has also become the major issue of debate.

In the recent years, the RMB exchange rate faced the pressure of appreciation owning to the high economic growth, continuing foreign trade surplus, increase of foreign direct investment, accumulated foreign exchange reserves, high domestic savings, and people's optimistic expectations in China. Reference [1] pointed out the RMB should be appreciated because of the macroeconomic and money supply penalty cost. Reference [2] considered the real RMB had been persistently undervalued at an average rate of 10% for 2003 to 2005. In addition, [3] showed the RMB would be appreciated gradually in the long term in the future based on the historical exchange rate, volume of exports, trade surplus, and foreign exchange reserves from July 2005 to 2007.

However, some scholars thought there was no need to adjust the RMB. Shah-Sheng Do and Reference [4] used the single-equation model to show that the RMB was close to equilibrium since 1994, while [5] used the pooled OLS based on the PPP theory to estimate that the RMB seemed to be undervalued. But [5] pointed out that there was no evidence to show that the RMB was improperly valued if they added sampling uncertainty and serial correlation to the exchange rate.

There were some arguments that the RMB should be depreciated recently. The reasons may be the subprime mortgage crisis in Europe and the United States in 2008, global economic recession, Big Mac index, and China's exchange rate policy. Reference [6] used the single-equation regression approach to explain the RMB was overvalued since 1995 based on the government expenditure, domestic banks' credit volume, terms of trade, net exports, and spread between the domestic and foreign interest rates. Furthermore, [7] explored that the reason for the depreciation of the RMB was the problem of unemployment. After the financial tsunami, many workers in China faced the problem of unemployment, so China has already faced an internal economic crisis and will employ the policy of depreciating the RMB to solve this problem.

Based on the above, the RMB seems to be improperly valued.

There are no definite conclusions in the factors affecting the exchange rate, but the only thing we can make sure is that there is not only one factor affecting the exchange rate.

According to the international finance theory, the balance of international payments, inflation, interest rate differences, fiscal deficits, economic growth rate, policy intervention, expectation, money supply, tariffs, import quotas, preference of domestic and foreign products, and productivity level will affect the exchange rate. Reference [8] established the equilibrium exchange rate equation where labor productivity, money supply, and the terms of trade were the factors affecting the RMB exchange rate. Reference [9] used the OLS method to estimate the equilibrium exchange rate of the RMB, and confirmed that the rate of inflation, growth rate of GDP, foreign exchange reserves, monetary policy, fiscal policy, and Asian financial crisis significantly affected the RMB exchange rate by the regression gradual selection method. Moreover, [10] and [11] considered the factors probably affecting the RMB exchange rate were economic growth, China's macro-control policy, the growth of GDP, flows of trade and foreign investment, prosperity of the financial industry, rapid flow of capital, international environment and relationship.

To sum up, this paper will establish a regression model based on the above-mentioned macroeconomic factors affecting the exchange rate in order to understand how the RMB exchange rate is affected by different economic conditions. In addition, the non-recurrent events will considerably impact the exchange rate and may lead to the jumping change of the exchange rate. Therefore, this paper will add the influences of sudden events on the exchange rate to the case study and use the real options to set up a mathematical model in order to explore the reasonable RMB exchange rate interval.

II. THE MODEL

The data of this paper come from the Annual Report published by the Chinese National Statistical Bureau from 1995 to 2006. Under the normal international trade, the macroeconomic indicators significantly impact the exchange rate. This paper will take the macroeconomic indicators from the relevant literature as the independent variables in the regression model. At the same time, this paper introduces the concept of relative weighting to measure the impacts of macroeconomic variables on the exchange rate and establish the regression model.

However, the non-recurrent events like China's policies, the global economic situation, and the Olympic Games may lead to the jumping change of the exchange rate and the intangible value derived from the potential pressure of appreciation and depreciation. This paper will add the data of non-recurrent events in the recent years and introduce the real options to derive the reasonable RMB exchange rate interval, which can be the direction of the following development model.

According to the international finance theory and literatures, this paper selects some macroeconomic variables which may affect the exchange rate: the growth rate of foreign direct investment, growth rate of trade surplus, growth rate of foreign exchange reserves, growth rate of unemployment rate, growth rate of price, growth rate of the Shanghai Composite Stock Price Index, growth rate of savings rate, growth rate of money supply, growth rate of domestic industrial output, growth rate of the ratio of industry output to gross domestic output, growth rate of national finance, growth rate of the retail volume of social consumption goods, growth rate of total national income, growth rate of GDP, growth rate of interest rate, economic growth rate, growth rate of the degree of dependence on foreign trade, and growth rate of the degree of dependence on exports.

The correlation among these variables was excluded by the Pearson correlation analysis. The analysis used the SPSS14.0 statistical software package. Then, this paper takes the growth rate of exchange rate as the dependent variable and the macroeconomic variables as the independent variables for the regression analysis. The growth rate of trade surplus (TSV), growth rate of the Shanghai Composite Stock Price Index (SPV), growth rate of savings rate (SRV), growth rate of unemployment rate (URV), growth rate of money supply (MSV), and growth rate of the degree of dependence on exports (DEV) are the variables with the most explanatory power for the regression model of the growth rate of exchange rate. The regression test results are presented in Table I.

TABLE I
The regression test results of six macroeconomic variables

R	Adjusted R-squared	F-test	Significance
0.986	0.929	22.87	0.005

The maximums, minimums, and weighted sums of the above-mentioned six macroeconomic variables from 1995 to 2006 are listed in Table II and III, from which we can see:

The standardized β value of each variable divided by the sum of standardized β values is the relative weight of each macroeconomic variable, so we can know the magnitude and direction of the influence of each macroeconomic variable on the growth rate of exchange rate. For example, the growth rate of the degree of dependence on exports, growth rate of money supply, and growth rate of unemployment rate have positive effects on the growth rate of exchange rate, while the growth rate of savings rate, growth rate of the Shanghai Composite Stock Price Index, and growth rate of trade surplus have negative effects on the growth rate of exchange rate.

The weighted sum of the minimums of the variables which have positive effects on the growth rate of exchange rate is -0.0353, meaning when these three variables increase by one unit, the RMB should be appreciated by 3.53% at most. The weighted sum of the averages is 0.1044; meaning when these three variables increase by one unit, the RMB should be depreciated by 10.44% on average. The weighted sum of the maximums is 0.2243; meaning when these three variables increase by one unit, the RMB should be depreciated by 22.43% at most.

The weighted sum of the minimums of the variables which have negative effects on the growth rate of exchange rate is 0.1652; meaning when these three variables increase by one unit, the RMB should be depreciated by 16.52% at most. The weighted sum of the averages is -0.1855, meaning the RMB should be appreciated by 18.55% on average. The weighted sum of the maximums is -1.0339, meaning the RMB should be appreciated by 103.39% at most.

When calculating the magnitude of the influences of these six variables on the growth rate of exchange rate, the weighted sum of the averages of the variables which have positive effects on the growth rate of exchange rate plus the weighted sum of the averages of the variables which have negative effects on the growth rate of exchange rate should be zero because the total magnitude of appreciation of the RMB should equal that of depreciation of the RMB. From Table II and III, it is clear that the magnitude of depreciation of the RMB is smaller than that of appreciation of the RMB, so we give a multiplier to adjust the magnitude of depreciation in order to match with the magnitude of appreciation. In addition, we can calculate how much the RMB should be depreciated in total by adding the adjusted weighted sum of the maximums of the variables which have positive effects on the growth rate of exchange rate to the adjusted weighted sum of the minimums of the variables which have negative effects on the growth rate of exchange rate. We can calculate how much the RMB should be appreciated in total by adding the adjusted weighted sum of the minimums of the variables which have positive effects on the growth rate of exchange rate to the adjusted weighted sum of the maximums of the variables which have negative effects on the growth rate of exchange rate.

TABLE II

The maximums, minimums, and weighted sums of the macroeconomic variables which have positive effects on the growth rate of exchange rate

The variables with positive effects	Standardized β value	Relative weight	Minimum (appreciation)	Average	Maximum (depreciation)
DEV	0.6556	0.5849	-0.1373	0.0595	0.1930
MSV	0.4353	0.3884	0.1227	0.1717	0.2526
URV	0.0299	0.0267	-0.1000	0.1091	0.5000
Weighted sum			-0.0353	0.1044	0.2243
Adjusted multiplier				1.777	
Adjusted weighted sum			-0.0628	0.1855	0.3987

TABLE III

The maximums, minimums, and weighted sums of the macroeconomic variables which have negative effects on the growth rate of exchange rate

The variables with negative effects	Standardized β value	Relative weight	Minimum (depreciation)	Average	Maximum (appreciation)
SRV	-0.7744	-0.3698	-0.0343	0.0172	0.0719
SPV	-0.9267	-0.4425	-0.2062	0.2192	1.3043
TSV	-0.3930	-0.1877	-0.3264	0.4377	2.2917
Weighted sum			0.1652	-0.1855	-1.0339
Adjusted multiplier				1	
Adjusted weighted sum			0.1652	-0.1855	-1.0339

The total magnitude by which the RMB should be appreciated and the total magnitude by which the RMB should be depreciated under the influences of macroeconomic variables are listed in Table IV. To avoid the problem of different measurement standards, this paper standardizes the total magnitude of appreciation and depreciation. The standardized values are 0.6678 and -1.2988 respectively. It means that the distance from the magnitude by which the RMB should be depreciated to the growth rate of the average RMB exchange rate is 0.6678 standard deviations at most, while the distance from the magnitude by which the RMB should be appreciated to the growth rate of the average RMB exchange rate is 1.2988 standard deviations at most.

TABLE IV

The standardized values for the total magnitude of appreciation and depreciation

	Depreciation	Average	Appreciation
Adjusted weighted sum for the variables with positive effects	0.3987	0.1855	-0.0628
Adjusted weighted sum for the variables with negative effects	0.1652	-0.1855	-1.0339
Total magnitude of appreciation or depreciation	0.5639	0.0000	-1.0967
Standardized value	0.6678		-1.2988

The average of the growth rate of the RMB exchange rate is -0.0042 and the standard deviation of the growth rate of exchange rate is 0.0081 from 1995 to 2006. From the above model, we can know that the distance from the magnitude by which the RMB should be depreciated to the growth rate of the average RMB exchange rate is

0.6678 standard deviations at most, while the distance from the magnitude by which the RMB should be appreciated to the growth rate of the average RMB exchange rate is 1.2988 standard deviations at most. Therefore, the reasonable predicted interval of the growth rate of the RMB exchange rate is from -0.0148 to 0.0013. Then, this paper does the empirical analysis for the above-mentioned estimated results: the average of the RMB exchange rate of 8.2552 from 1995 to 2006 plus the predicted growth rate can derive the reasonable RMB exchange rate interval of 8.1333 to 8.2655. However, the real RMB exchange rate interval was from 7.9718 to 8.3510 from 1995 to 2006. The reason is because this paper has not added the influences of the sudden events like policies on the RMB exchange rate yet. For instance, China changed its exchange rate system from pegged to the USD to a basket of currencies in 2005, leading to the jumping fluctuation of the RMB exchange rate. Therefore, this paper establishes the intangible value function and introduces the real options in order to derive the optimal RMB exchange rate interval in next section.

The non-recurrent events which are evaluated by the real options with the jumping fluctuation in this paper can be divided into two parts. One is the real government intervention, which means the government adjusts foreign exchange reserves to intervene in the exchange rate. The other is the potential government intervention, which means the potential value of the exchange rate intervention that the government is waiting for.

The major variable of this real options model is foreign exchange reserves (F_t). Suppose F_t follows arithmetic Brownian motion (ABM) with drift α and volatility σ. When a non-recurrent event q occurs, F_t jumps by an amount ξ. The process F_t that contains both continuous and discontinuous changes is as follows:

$$dF_t = \alpha \cdot dt + \sigma \cdot dw_t + \xi \cdot dq \text{ ; } dw_t \sim N(0, dt),$$

$$dq = \begin{cases} 1 \text{ with probability } \lambda \text{dt} \\ 0 \text{ with probability } 1\text{-}\lambda \text{dt} \end{cases}$$

According to Ito's Lemma [12], the growth rate of exchange rate should be:

$$R = R(F_t, q)$$

$$E[dR(F_t,q)] = E[R_{F_t} \cdot dF_t + 1/2 \cdot R_{F_tF_t} \cdot (dF_t)^2 + (R(F_t(1+\xi)) - R(F_t))dq]$$

$$= \alpha k \cdot R(F_t) + 1/2 \cdot \sigma^2 k^2 \cdot R(F_t) + \lambda \cdot R(F_t) \cdot (e^{\xi k \cdot (\alpha - \frac{1}{2}\sigma^2)t + (\xi k)^2 + \frac{1}{2}\sigma^2 t} - 1)$$

From the risk-neutral condition:

$$k = \frac{(-\alpha) \pm \sqrt{\alpha^2 + 2\sigma^2 \cdot [\lambda \cdot e^{\xi k \cdot (\alpha - \frac{1}{2}\sigma^2)t + (\xi k)^2 + \frac{1}{2}\sigma^2 t} - r]}}{\sigma^2}$$

Suppose how much the government intervenes in the exchange rate depends on the macroeconomic conditions and potential value of government intervention. Based on the value-matching condition and smooth- pasting condition advocated by the Reference [13], we can calculate the optimal F_t as follows:

(1) The value-matching condition and smooth- pasting condition of depreciation:

$$a_1 F_{t1} + b_1 = R_H^0 + A_1 e^{k_1 F_{t1}} \quad a_1 = A_1 k_1 e^{k_1 F_{t1}}$$

(2) The value-matching condition and smooth- pasting condition of appreciation:

$$a_2 F_{t2} + b_2 = R_L^0 + A_2 e^{k_2 F_{t2}} \quad a_2 = A_2 k_2 e^{k_2 F_{t2}}$$

$a_1 F_{t1} + b_1$, $a_2 F_{t2} + b_2$ are real values of government intervention; R_L^0 , R_H^0 are the influences of macroeconomic variables from regression ; $A_1 e^{k_1 F_{t1}}$, $A_2 e^{k_2 F_{t2}}$ are potential values of government intervention.

Finally, we verify this model through some numbers in Table V. From these numbers, the predicted growth rates of exchange rate are 0.0229 and -0.2125. That is, the optimal RMB exchange rate interval is from 6.501 to 8.4442, so there is no need to adjust the RMB exchange rate from 1995 to 2006.

TABLE V

The Numbers in real options model

Variables	Sources	Value
α	Empiricism	0.2963
σ	Empiricism	0.1569
λ	Empiricism	0.0833
ξ	Assumption	0.1, -0.1
R_H^0	Regression	0.0013
R_L^0	Regression	-0.0148
a_1	Regression and Assumption	0.0066
a_2	Regression and Assumption	-0.0538
b_1	Regression and Assumption	0.007
b_2	Regression and Assumption	-0.028

III. CONCLUSION

Nowadays, any change in China's economy will affect the change of the global economy. Therefore, whether the RMB exchange rate which has the biggest impact on foreign trade is reasonable or not has become the subject of debate.

At the beginning, this paper uses the Pearson correlation analysis to exclude the correlation among variables and then does the regression test analysis. We find that the growth rate of trade surplus, growth rate of the Shanghai Composite Stock Price Index, growth rate of savings rate, growth rate of unemployment rate, growth rate of money supply, and growth rate of the degree of dependence on exports are the most explanatory power for the regression model of the growth rate of exchange rate. Then, the relative weights of these six variables are calculated in order to understand the magnitude and direction of the influence of each macroeconomic variable on the growth rate of exchange rate. The weighted sums of these six variables are the magnitudes which the RMB should be appreciated or depreciated from 1995 to 2006.

To avoid the problem of different measurement standards, this paper standardizes the estimated magnitude of appreciation and depreciation.

However, the non-recurrent events may change the exchange rate a lot. This paper evaluates them by the real options with the jumping fluctuation.

Finally, with the empirical analysis and some assumptive parameters, the optimal RMB exchange rate interval is from 6.501 to 8.4442. That is, there is no need to adjust the RMB exchange rate from 1995 to 2006.

The results can provide another measure or thinking of evaluating the reasonable RMB exchange rate interval, and provide a reference of the optimal timing for China to implement the economic policies in the future.

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