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Discussions on the Determinants of R&D Value Based upon Real Options

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Abstract— Referring to the characteristic of to invest now in order to obtain future success that an R&D project owns, the application of real option model (ROM) has become more important since it can deal with the situation of investment under uncertainty. A previous study had identified a determinant of information cost will influence the real R&D option value. We infer that the determinants called exponential decay and Poisson event will influence the R&D option value with even larger magnitude than the information cost, either numerical simulation or statistical evidence sustain such an inference. Not commonly seen in ROM literatures, a series of empirical tests were exploited to prove the practicability of our models. The results showed that the R&D value derived by our models can explain either common or idiosyncratic risk level of firms. We also suggested a framework of how to estimate the information cost; the estimated information cost base on real data can heave the explanation power of our models.
Keywords— R&D, real options, information cost, exponential decay, poisson event

1. INTRODUCTION

In the age of knowledge economy, the importance of R&D outweighs than ever since it brings up the prospect of firm's future success. An emerging view deemed R&D an option whereas we hold it for acquiring future opportunities (Perlitz et al. 1999). Literatures dispersed in finance and accounting have uniformly exhibited that R&D investment is positively correlated with subsequent advantages in earnings, growth, productivity and stock returns. These facts inspired more industries to invest R&D in order to lever their future gain.

Due to the 'option like' property of R&D, a theory of 'real R&D option' burgeoned; economists exploit ideas of it and build real option models (ROM) to explore the value as well as to price R&D. ROM diverges from conventional approaches like 'Discounted Cash Flow' (DCF) in valuing an investment. It is able to excavate the hidden value of R&D including options as to wait, to extend, to downsize or to abandon. It is also able to depict the rules of an investment under uncertainty. The merits above are helpful to solve an existing poser: why an investment is launched with negative 'Net Present Value' (NPV) as observed from many real cases (Dixit and Pindyck, 1994). This poser is beyond traditional understanding but ROM can provide explanation to it based on optional viewpoint.

R&D is an activity full with miscellaneous information. To disregard the influence of information in pricing R&D could be risky since, firms learn and are benefited from other firms' knowledge especial in a same industry (Lev and Sougiannis, 1996); firms maintain a certain R&D capacity for the 'follow up' purpose in order to exploit external knowledge (Mowery, 1983). These literatures have elucidated an information spillover effect thus it should be considered in a pricing model. Bellalah (1999, 2003) followed Merton's (1987) investor recognition hypothesis and firstly incorporated the information cost into ROMs. According to Bellalah, information cost will lower the R&D's market value but has no affection on its payoff. However, we reserve query especial to the second assumption and will try to extend Bellalah's model to see how the R&D's payoff could be affected.

Graham and Harvey (2001) investigated then found only 27% of managers in U.S. really use ROM for application on decision making and perplexities solving. Copeland et al. (2005) commented the lack of evidence in proving ROM's correctness impedes the application of it. For better convincingness, to have the new developed ROM

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underwent more discreet tests can be a useful way. Based on the same reason, we shall let the models developed in this study went through dual examination including numerical and statistical analysis based upon real data.

To sum up, in this paper we will identify important factors which influence the R&D value other than the already known one. The influence magnitude of new identified factors will be measured and compared with the known factor also. Moreover, the managerial implication of these new identified factors will be excavated and discussed.

2. LITERATURE BACKGROUNDS

The knowledge economy prelude an age stressing the functions of producing, distribution and utilization of knowledge to support the growth. R&D plays a key role in this mission since it enable firms to exploit deposit of knowledge, skill, experience and other in intangible manifestation to eventually promote sales, services and profit. Cohen and Levine (1989) commented that the R&D research keeps growing which corresponds to the economic and social welfare demand. For the business' point of view, literatures have shown that R&D deeply involves with corporation running for example: Hirschey and Weygandt (1985) proved that the Tobin's Q (the ratio of market value to replacement cost of assets) is cross-sectional correlated with R&D intensity with lag effect of five years; Smith and Watts (1992) documented that the R&D investment influences to corporate leverage policy; Titman and Wessels (1988) discussed the relationship between R&D activities and corporate capital structure; Sougiannis (1994) proved that the R&D investment is positively correlated with profitability and stock return; Chambers et al. (2002) asserted that a higher excess return of R&D-intensive firms is mainly attributable to mispricing problem because investors are unable to see through earnings distortion caused by conservative accounting ways in pricing R&D.

According to the theory of 'Capital Asset Pricing Model' (CAPM), an investor shall be more prudent in returns if he fully knows the risk level of invested portfolio. Following this context, some literatures discussed the relationship between investment's intensity and risk level. Black and Scholes (1973) expounds that a firm's risk will be increased by R&D expenditure. Chan et al. (2001) found that the market do not effectively value the stock of firms with R&D and attribute it to mis-report of intangible-asset like R&D; whereas it leads also the consequence of mis-state the level of corporate systematic risk. Ho et al. (2004) exploited ways including portfolio analysis and simulations to test the relationship between R&D and Beta (β), a coefficient that represents systematic risk, a positive correlation was obtained. Ho et al. noticed the optional intrinsic of R&D but its derived value was not eventually estimated. This paper will explore the option value of R&D and use this derived value to inspect the relationship between R&D and Beta again.

As commented by Mowery (1983), the firm who invests more in their R&D is more able to exploit external information than firms with lower R&D expenditure; Lev and Sougiannis (1996) pointed that firm hires scientist not just for producing indigenous knowledge but also for following others. Merton (1987) noticed the importance of information and developed a modified CAPM incorporating with information cost (CAPMi) model. He defined the information cost a sunk cost for pursuing better control on first and second movement of an object's innovation; the sales price, revenue or stock price can be the objects. Bellalah (1999, 2003) followed the same idea but distinguished the information cost a more meticulous classification. However, to merely count information cost in pricing R&D is insufficient because any single technology developed by R&D could deteriorate while time elapse; the value of developed technology could also vanish over night due to either evolution or the expiration caused by new specification. These events make R&D an exposure to intimidation of depreciation and sudden death within lifetime. We shall use terms of Poisson event discussed by McDonald and Siegel (1984) and exponential decay to express the situations above. Be noticed the terms including exponential decay, Poisson event and information cost are not mutually exclusive; they can thus be discussed once in pricing models.

There are dichotomous assertions in viewing the R&D investment. The 'General Accepted Accounting Principles' (GAAP) mandates the R&D investment to be expensed. The absence of a relation between R&D expenditures and subsequent benefits is the major concern of this mandate formed in 1974 (see also 'Statement of Financial Accounting Standards' (SFAS) No. 2). Meanwhile, there is an opposing postulation as to let R&D be capitalized. Baber et al. (1991) asserted that a manger may entrench himself from 'real earnings management' as to cut R&D expenditures in order to surpass the earning threshold; Bushee (1998) observed the phenomenon of 'myopic R&D investment' and concluded that full expensing R&D may result a more costly earnings management than capitalization; Lev and Sougiannis (1996) developed a framework to estimate R&D capital; Chan et al. (2001) argued that the capital cost, equity value or stock price could be biased if the R&D capital is not figured as intangible assets; Beaver and Ryan (2000) pointed out two problems of either persistent bias or transitory lag may distort the financial information; the first one relates with accounting rule as to expensing R&D, the second one relates with the deferred effectiveness of R&D. Albeit there are some provisions to conditionally recognize R&D capitalization, the reliability, objectivity, and value-relevance of R&D capitalization are under critiques therefore the 1974 mandate is still valid. 1 Due to the same reason, we adopt the GAAP's 'expensed' view in valuing R&D rather than the 'capitalized' view.

3. METHODOLOGY

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Information cost can be seen as sunk cost that a firm will expense it for having a clearer vision of future investment. Roberts and Weitzman (1981) stressed the importance of information in strategy forming. However, as the stochastic process was not exploited by them, the yields implicitly tell that whenever information gathering, rather than waiting, immediately yields information. Their results more or less deviate from reality since to spend information cost can though reduce the uncertainty, but can not eliminate it at once. It is more plausible that a firm shall keep issuing cost before the arrival of new information. Different than a deterministic setting, Bellalah (1999) firstly built ROMs incorporating with information costs including λ_M (market), λ_F (option) and λ_P (price) based upon contingent claim analysis. According to Bellalah, information cost lowers the investment's market value but have no influence on its payoff. We reserve queries on it by two reasons: first, the technology advancement and competition which were categorized as exogenous factors (Martzoukos and Trigeorgis, 2002) shall affect the investment's payoff. These kinds of events will shorten the lifetime of an existing investment and lower the sum of payoff. Second, like many assets showed, the distribution of return is often skewed and fat tailed which can be attributed to occurrence of rare event. The catastrophe happens on an investment is analogous to this issue. To sum above, Bellalah's model can be seen as a polar case and we will try to add exogenous factors including depreciation accelerator θ and probability of rare event ξ into models.

Like the definition in Lin and Wu (2004) as well as Dixit and Pyndick (1994), the value of a R&D project can be seen as a combination of: V (expanded project value)=I (NPV of investment)+F (the value of affiliated options). F can be seen as a function of price of R&D yield which means F=F(P). For analytical convenience, we set a state variable x to represent the output of R&D with price P, P moves as $dP=\alpha Pdt+\sigma Pdz$ (a setting called geometric-Brownian process, which is suitable for consumer products; if the product what we are discussing is crude oil, copper or coal, a mean-reverting process could be adequate since its price is expected to revert to a normal level, see the discussion in Dixit and Pindyck (1994). Investment I requires a payoff $\mu=\alpha+\delta$; μ represents the required rate of return and is the sum of expected capital gain (α) and dividend (δ) in the portfolio holding period. Be notice that $\mu=\alpha+\delta$ can be synonymous to $\mu_x=r+\phi\rho_{Mx}\sigma_x$ if a CAPM manner is possessed; or $\mu_x=r+\phi\rho_{Mx}\sigma_x(1-\phi^{-1}\sigma_M^{-1}\lambda_M)-\lambda_x$ if a CAPMi manner is possessed (r is risk free rate, $\phi=(r_M-r)/\sigma_M$ represents the market price of risk, $\rho_{Mx}=COV(M,x)/\sigma_M\sigma_x$ means as its expression, λ_M is the weighted average information cost of market, λ_x is the aggregate information cost of asset x).

The R&D investment I is expected to bring up a revenue stream $E(P_t)$. This stream is expected to be proliferated with pace of $Pe^{\alpha t}$; therefore the value of an infinite project can be $V(P)=\int_0^\infty Pe^{\alpha t}e^{-\mu t}dt=P/(\mu-\alpha)=P/\delta$. While the R&D is depreciated with an exponential decay process, the present value of revenue stream over an R&D's lifetime is $E(\int_0^T e^{-\mu t}P_t dt)=\int_0^T Pe^{\alpha t}e^{-\mu t}dt=P\left[1-e^{-\delta T}\right]/\delta$; thus an infinite project can be expressed as $V(P)=\int_0^\infty \theta e^{-\theta T}P\cdot(1-e^{-\delta T}/\delta)dT=P/(\delta+\theta)$, be noticed that the p.d.f. of exponential distribution is additionally applied. The form of $P/(\delta+\theta)$ tells that an exponential decay can be taken as an additional depreciation factor showing up at denominator; we shall see a similar treatment while the Poisson event is considered. According to McDonald and Siegel (1984), the Poisson event can be deemed a jump which alters the price process as $dP=\alpha Pdt+\sigma Pdz-Pdq$, where

$$dq=\begin{cases}0, & \textit{with probability } 1-\xi dt\\ \phi, & \textit{with probability } \xi dt\end{cases} \tag{1}$$

ϕ means the jump scale. Be noticed that the relationship between ξ and projet's lifetime can be expressed as $E[T]=\int_0^\infty \xi Te^{-\xi T}dT=1/\xi$. For example, supposing a single project is expected to survive 5 years under the threat of sudden death, its annual probability of sudden death should be 20%. In accordance with this, The expected present value of profit flow is:

$E\left[\int_0^T e^{-\mu t}P_t dt\right]=\int_0^T Pe^{(\alpha-\xi\phi)t}e^{-\mu t}dt=P(1-e^{-(\delta+\xi\phi)T})/(\delta+\xi\phi)$, while the exponential decay and Poisson event are jointly considered, the project value becomes:

$$V(P)=\int_0^\infty \theta e^{-\theta T}P(1-e^{-(\delta+\xi\phi)T})/(\delta+\xi\phi)dT=\theta P/(\delta+\xi\phi)\left[\int_0^\infty e^{-\theta T}dT-\int_0^\infty e^{-(\delta+\theta+\xi\phi)T}dT\right]=P/(\delta+\theta+\xi\phi).$$

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Again, the impact of sudden death can be smoothened as an additional discount factor in the denominator. These techniques shall enable us to mathematically handle the spiky events. Notably, the modeling work here follows with the fashion of stochastic dynamic programming used by Lin and Wu (2004). However, Lin and Wu focused on the choice of location site problem, we focused on, as Bellalah (1999) did, how the exogenous factors influence to R&D value; the case of compound options thus were considered rather than the Lin and Wu's discussion.

The target variable what we are trying to solve is the option value F(P). After knowing F, we can have the investment project value V subsequently. Under this purpose we build a portfolio $\Phi = F(P) - nP$ as to long one unit of option and to short n units output with price P. The portfolio's payoff within a short interval can be expressed as:

$$r\left[F - nP\right]dt = dF - ndP - n\delta Pdt \quad (2)$$

The right side of equal sign shows the portfolio holder has to refund dividend $n\delta P$ accrued in dt to the long position holder, otherwise no rational investor will accept this trade. The left side means the portfolio holder will be rewarded on a risk neutral and arbitrage free rate r. Let $n = F^{'}(P) = F_P$, $dF = F_p dP + \frac{1}{2}F_{PP}(dP)^2$, and $(dP)^2 = \sigma^2 P^2 dt$, equation (2) can be expanded by Itô's lemma to have a Bellman equation like:

$$(1/2)\sigma^2 P^2 F_{PP} + (r - \delta)PF_P - rF = 0 \quad (3)$$

In derivation stage, we shall let $n = F^{'}(P)$ to eliminate the disturbance term dz. (3) is a Partial Differential Equation (PDE) and we can solve F from it as to impose conditions of 'absorption' ($F(0) = 0$),'value matching' ($F(P^*) = V(P^*) - I$) and 'smooth pasting' ($F^{'}(P^*) = V^{'}(P^*)$) to keep the F value in a feasible region. However, there seems a theoretic discrepancy if we contemplate (2): the left side belongs to risk neutral but the right side is risk averse since investors ask premium δ to avoid the risk of stock on hold. Why does this discrepancy occur? Referring to Cox and Ross (1976), any price deviation to an asset's fair market price will soon to be explored by arbitragers. If the prevailing price is too low, an arbitrager will buy, refurbish and resell it to earn the spread, vice versa. Such an opportunity will soon to be exhausted thus only a risk free rate will be gained in long run equilibrium. So the right side represents the investors' request but the left side exhibits the long-lasting fact. If a CAPMi manner is possessed, (2) and its corresponding Bellman equation (3) will be changed as:

$$\left[(r + \lambda_F)F - (r + \lambda_P)nP\right]dt = dF - ndP - \delta nPdt \quad (4)$$

$$(1/2)F_{PP}\sigma^2 P^2 + (r - \delta + \lambda_P)F_P P - (r + \lambda_F)F = 0 \quad (5)$$

Herewith we tabulate all the important variables used in our R&D valuation model in Table 1 for reader's easier indexing.

To diverge from the Bellalah (1999, 2003), we shall add exogenous factors including exponential decay θ and Poisson event ξ into models. Only the mathematical progress belonging to the last two models will be performed in Appendix since any simpler one can be a degenerate form of them by letting part of the conditions θ, ξ, λ_M, λ_F and λ_P be zero. Table 2 shows the description along with important dimensions of our models.

Table 1 The list of important symbols and its definition

Symbol	Definition
F	The value of real R&D option. F is a function of product price (P).
P	The price of the product empowered by a R&D project
σ	Volatility of product price
r	Risk free rate
δ	Dividend rate
λ_P	Information cost of product price
λ_F	Information cost of the corporation value in a derivative market
ξ	Probability of Poisson event
ϕ	Jump scale. It can be seen as the damage scale while a Poisson event happened.
A_1	Constant in the solution form of F. A_1 has to be determined.
β_1	Positive root of the quadratic equation
β_2	Negative root of the quadratic equation
θ	Exponential decay. It is tantamount to the rate of depreciation.
I	Net present value of R&D investment

The sequence of symbols follows their appearing sequence in the modeling stage

Table 2 The important dimensions of F1, F2, F3, F4, Fi1, Fi2, Fi3, and Fi4

	description	condition parameters	option type		description	condition parameters	option type
F1	option allowing for exponential decay	θ	simple	Fi1	option with information cost allowing for exponential decay	θ, λ_M, λ_P, λ_F	simple
F2	option with future replacement options allowing for exponential decay	θ	compound	Fi2	option with information cost and future replacement options allowing for exponential decay	θ, λ_M, λ_P, λ_F	compound
F3	option allowing for exponential decay and Poisson event	θ, ξ	simple	Fi3	option with information cost allowing for exponential decay and Poisson event	θ, ξ, λ_M, λ_P, λ_F	simple
F4	option with future replacement options allowing for exponential decay and Poisson event	θ, ξ	compound	Fi4	option with information cost and future replacement options allowing for exponential decay and Poisson event	θ, ξ, λ_M, λ_P, λ_J	compound

While the influence of exogenous factors are considered, it is risky if let the government intervention be absent from the array of our settings. For the R&D activities, there are plenty ways of government intervention, mostly incentive, to be applied with statute base. The incentive here in Taiwan includes dollar patronage, investment tax credit and tax holidays for yield of new investment; the last two are mostly applied. Jou and Lee (2001) focused on R&D and taxation problems following the context of optimal incentive literatures. They asserted that an even rate of investment tax credit should be given across industries and the same rate of punitive tax should be imposed on disinvestment. They also questioned to the present situation of that government is lenient to the R&D seller as to keep them 'exempted' but no mercy to the R&D buyer. Their discussion stands analogously to a regulator or social planner's viewpoint, instead of a firm level concern. However, the influence of incentive in our case should be low if we look to sample companies' income statements- the ratio of sum of tax credit and exemption to sales reached highest 3.3% only by the company of Ambit in 2001 and lowest zero by the company Accton from 1999 to 2002; the average is 0.96%. Since it is minor, we decided not to load additional parameter into models but let its potential influence, if any, be emerged in later statistical analysis.

4. NUMERICAL AND STATISTICAL ANALYSES

Table 2 has shown total eight models with different combination of exogenous factors. We are going to justify either the plausibility or correctness of these models via means of simulation and statistical tests.

The 'LAN' industry in Taiwan was selected as the empirical base to examine our models. LAN is the abbreviation of 'Local Area Network' which means a group of computers or associated devices that share a common communications line or wireless link under a framework of a single processor or server within a geographic area. The LAN industry in Taiwan is eye-catching referring to its annual global share 76.5%, 53%, 90.9% and 84% on NIC (network interface card), Hub / Switch, SOHO router and WLAN (wireless LAN). The high visibility and high R&D orientation of this industry tells it should be an ideal base to verify our models. We focused on the listed LAN companies in Taiwan; D-link, Accton and Ambit meet with the requirement and are selected. Including the assets, equity, net sales, degree of leverages and other relevant features were collected from data bank of Taiwan Economic Journal (TEJ). Stock information was collected from both TEJ and the website of Taiwan Stock Exchange Corporation (TSEC). It should be noted that Ambit was acquired by Honghai on April 1st, 2004. Even though, we still remain Ambit in analyses to alienate the survivorship bias. Observation period was set from January 1st, 1999 to March 31st, 2006 using a weekly base. The rolling regression developed by Fama and French (1993) was used to estimate either the CAPM or CAPMi's moving β belonging to each company, 861 time series samples were collected.

4.1 NUMERICAL ANALYSIS

To start the simulation, we firstly use the LAN's 2005 industrial quarter level of investment NT$235,708,000 and its threshold price NT$34,130,000 (which can be acquired by $P^* = (I\beta_1'(\theta+\delta+\xi\phi))/(\beta_1'-1)$, see Appendix) as the base.2 For simplification, we shall let P^* be NT$34,000,000 and expand it from the pivot 34,000 (NT$000) with 2,000 per tick. Table 3 exhibits the change of Fi3 and Fi4 influenced by θ (exponential decay), ξ (Poisson event), and λ_F (information cost of R&D option). The column of '(base)' denotes the fundamental situation with the bottomed line settings of table.[3] Table 3 confirmed a negative correlation between information cost and R&D option value which is in line with Bellalah (1999). Bellalah explained such a negative correlation is because that an investor shall ask higher return once he had paid additional expense like information cost. Be noticed that the degree of negative relation is different among parameters. Poisson event gives a most significant impact; then is the depreciation; information cost is the minimum one. The fact elucidates that our incorporation of exogenous factors including exponential decay and Poisson event is meaningful. Since Poisson event is most powerful, it navigates the major move of option value. The F4(P) in row of $\theta = 0.07$, $\xi = 0.03$, $\lambda_F = 0.02$ showed: even though the θ and λ_F are higher than (base)'s setting, the option value is still higher than (base) because of ξ's reduction.

A graphical image is also illustrated. Figure 1 and Figure 2 demonstrate the Fi3 and Fi4 value plane under influence of λ_F and ξ. Figure 3 and Figure 4 demonstrate an additional influence caused by λ_P. In Figure 1, the back (right) plane exhibits Fi3 which moves with information cost λ_F while keeping ξ fixed; the front (left) plane exhibits Fi3 which moves with information cost λ_F and Poisson event ξ simultaneously. As it shows, the plane will mainly incline toward the ξ axis if the move of ξ is considered. This expounds that ξ is a more influential factor on the option value than information cost. The identical arrangement and outcome can be seen also in Figure 2, Figure 3 and Figure 4. In Figure 3 and Figure 4 we let λ_P join to the analyses and innovate with λ_F. The major difference than in Figure 1 and Figure 2 is that the plane toward the information cost axis becomes a positive slope. This implies that the appreciation of λ_P will raise the option value and partly cancel the influence of λ_F. The option value's depreciation caused by ξ can somehow be alleviated by the raise of λ_P but not much; ξ is still the major strength to domain the option value plane. Bellalah (2003) did not individually isolate the influence of information cost λ_M, λ_F and λ_P but a lump sum effect was surveyed. We firstly noticed that the λ_P moves conversely to λ_F. This result implies that though λ_P shows up as a cost now, it brings up a better stochastic control on price therefore it benefits the R&D option value in future.

Table 3 The change of option value

P	Fi3(P)			Fi4(P)		
(NT$000)	(base)a	$\theta = 0.03$	$\theta = 0.07$	(base)b	$\theta = 0.03$	$\theta = 0.07$
30,130	40,173	46,354	35,447	18,599	31,883	8,099
32,130	42,840	49,431	37,800	19,833	34,000	8,636
34,130	45,507	52,508	40,153	21,068	36,116	9,174
36,130	48,173	55,585	42,506	22,302	38,233	9,711
38,130	50,840	58,662	44,859	23,537	40,349	10,249
		$\xi = 0.03$	$\xi = 0.07$		$\xi = 0.03$	$\xi = 0.07$
30,130		51,150	32,674		44,751	4,117
32,130		54,546	34,842		47,721	4,390
34,130		57,941	37,011		50,692	4,663
36,130		61,336	39,180		53,662	4,936
38,130		64,732	41,349		56,633	5,210
			$\lambda_F = 0.02$			$\lambda_F = 0.02$
30,130			37,030			13,885
32,130			39,488			14,806
34,130			41,946			15,728
36,130			44,404			16,650
38,130			46,862			17,571
			$\theta = 0.07,\ \xi = 0.03,\ \lambda_J = 0.02$			$\theta = 0.07,\ \xi = 0.03,\ \lambda_F = 0.02$
30,130			40,173			28,707
32,130			42,840			30,613
34,130			45,507			32,518
36,130			48,173			34,424
38,130			50,840			36,329

a, b The 'base' uses $\sigma = 10\%$, $r = 5\%$, $\delta = 5\%$, $\theta = 5\%$, $\xi = 5\%$, $\lambda_p = 0$ and $\lambda_F = 0$.

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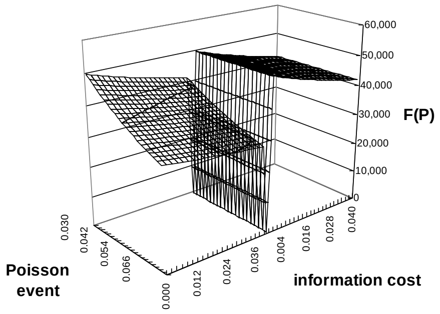

Figure 1 Value plane of Fi3

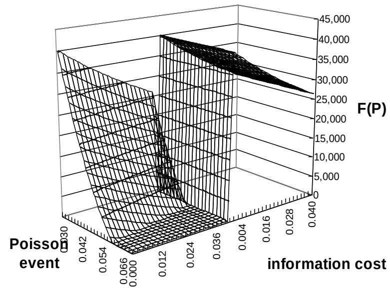

Figure 2 Value plane of Fi4

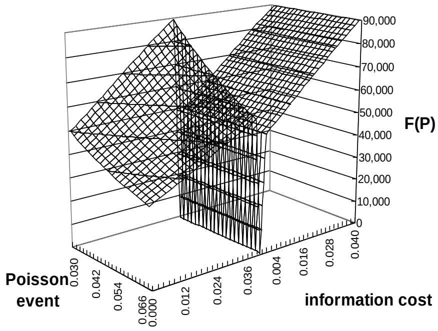

Figure 3 Value plane of Fi3
(λ_P moves from 0 to 4%)

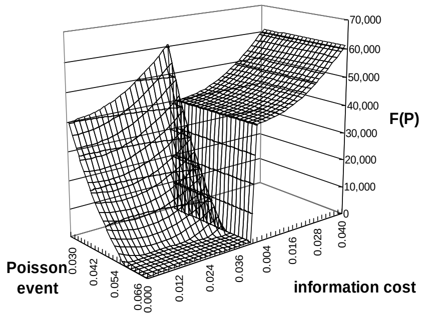

Figure 4 Value plane of Fi4
(λ_P moves from 0 to 4%)

4.2 STATISTICAL ANALYSIS

Statistical tests shall help us a clarification to the issue of ROM's correctness concerned by Copeland et al. (2005). Since the eight option models were conducted based upon either CAPM or CAPMi, the systematic risk coefficient (β_i, its estimator is expressed as b_i) belonging to CAPM (expressed as $R_{it} - R_{ft} = a_i + b_i(R_{mt} - R_{ft}) + u_{it}$) and CAPMi (expressed as $R_{it} - (R_{ft} + \lambda_V) = a_i + b_i(R_{mt} - R_{ft} - \lambda_m) + u_{it}$)4 will be an ideal 'triangulation' point for justifying correctness. More than this, we can test again the hypothesis by Black and Scholes (1973) and Ho et al. (2004) who asserted a positive relation between R&D investment and a firm's risk.

An OLS model regressing CAPM's β on both R&D expenditure (I) and R&D project value ($V = F + I$) was firstly applied. Result of significant and positive coefficient on either I or V is in line with findings of Black and Scholes (1973) as well as Ho et al. (2004). However, the extremely low DW value (from 0.02 to 0.03) raised our awareness. Generally, low DW can be attributed to an autoregression problem thus an autoregressive (AR) model can be applied. But, as forewarned by Henry and Mizon (1978), low DW can also be the symptom of a 'mis-specified' dynamic problem. To solve it the intertemporal variables y_{t-1} and x_{t-1} must be considered in regressions. For cautiousness, we shall exploit both SHM and AR model in our discussion.[5]

Table 4 A comparison on explanatory power of different R&D value approaches

(Dependent var.:CAPM's β_t)					
X_t (Independent var.):	I	V1	V2	V3	V4
Panel A-1 SHM model					
C	-0.006	-0.013	-0.014	-0.009	-0.007
	(-0.303)	(-0.687)	(-0.845)	(-0.487)	(-0.380)
β_{t-1}	0.986	0.983	0.982	0.984	0.983
	(160.086)***	(151.466)***	(147.526)***	(154.834)***	(152.976)***
$\ln X_t$	0.464	0.382	0.324	0.426	0.429
	(21.252)***	(22.103)***	(22.650)***	(21.282)***	(19.857)***
$\ln X_{t-1}$	-0.462	-0.379	-0.320	-0.423	-0.426
	(-21.061)***	(-21.785)***	(-22.237)***	(-21.042)***	(-19.652)***
Adj R^2	0.973	0.974	0.974	0.973	0.972
F	(10308.60)***	(10612.77)***	(10814.56)***	(10321.35)***	(9845.64)***
DW	1.897	1.923	1.941	1.908	1.902

N	861				
Panel A-2 Coefficient test					
$H_{a0}: \alpha_1\alpha_2 + \alpha_3 = 0$	(2.235)	(1.788)	(1.272)	(2.220)	(2.528)
$H_{b0}: \alpha_1 = 0$	(25627.38)***	(22941.92)***	(21763.78)***	(23973.66)***	(23401.77)***
$H_{c0}: \alpha_1 = 1$	(5.452)**	(6.702)***	(7.257)***	(6.301)**	(6.617)***
Panel B AR(1) model					
C	-3.091	-2.484	-1.991	-2.855	-2.859
	(-10.383)***	(-11.194)***	(-10.754)***	(-10.979)***	(-10.489)***
$\ln X_t$	0.464	0.382	0.324	0.426	0.429
	(21.257)***	(22.076)***	(22.625)***	(21.261)***	(19.821)***

p <0.1*, p <0.05**, p <0.01***

Table 4: Panel A-1 demonstrates the SHM result. The coefficient of I, V1, V2, V3 and V4 are all significant and positive (refer to the contemporaneous $\ln X_t$). Be noticed that V1 and V2 owns either higher t value or Adj R^2 proves the correctness and superiority. The joint coefficient tests H_{a0} and H_{b0} of Panel A-2 demonstrates that AR(1) setting is adequate therefore we create it in Panel B. The hypothesis H_{c0} justifies whether if β can be explained by itself one period ahead. If H_{c0} is not rejected, it means the move of β a Markov(1) process thus no need for any independent variable while explaining β. The test results belonging to V1, V2, V3 and V4 all surpassed I tell that the importance of V1, V2, V3 and V4 overweighs I. Panel B reports identical DW and Adj R^2 as in panel A-1 therefore we report them only once. The DW value is closing to 2 in Panel B which implies autoregression has been nicely eliminated.

Some literatures decomposed the move of β into accounting and financial factors likewise: financial and operating leverage (Mandelker and Rhee, 1984), business cyclicality (Rose et al., 2002), assets size, liquidity, profitability (ROE is the proxy) and debt-equity ratio (Mear and Firth, 1988). We shall follow this context and take those factors as control variables in discussing the explanatory power of V on β. A stepwise regression was firstly conducted as to remain the important variables. After filtration, the financial leverage (Finan), debt-equity ratio (DE), liquidity (LQ) and profitability (ROE) are remained as following:

$$\beta_{it} = \alpha_0 + \alpha_1 Finan_{it} + \alpha_2 DE_{it} + \alpha_3 LQ_{it} + \alpha_4 ROE_{it} + \sum_{k=1} \alpha_{5k} (I/S)_{i,t-k} + u_{it},\ \ i = 1,2,3 \tag{6}$$

$$\beta_{it} = \alpha_0 + \alpha_1 Finan_{it} + \alpha_2 DE_{it} + \alpha_3 LQ_{it} + \alpha_4 ROE_{it} + \sum_{k=1} \alpha_{5k} (V_j/S)_{i,t-k} + u_{it},\ \ j = 1,2,3,4 \tag{7}$$

The suffix 'i' identifies company and 'j' identifies the category of V. (6) and (7) postulate that β can be viewed as a function of the past R&D investment (I) or the R&D project value (V). To eliminate the scale effect, we let I and V be divided by amount of sales. However, multicolinearity could still be a problem on terms of $\sum_{k=1} \alpha_{5k}(I)_{i,t-k}$ since the benchmark of I_t could correlates with I_{t-1} or even earlier ones (so do the V_t) thus, a polynomial distributed lags (PDL) technique is exploited.[6] We set the lags k being truncated at 52 (52 weeks equal a year) to see the annual effect.

Table 5 The explanatory power of different R&D value approaches

(Dependent var.:CAPM's β_t)					
X_t (Independent var.):	I/S	V1/S	V2/S	V3/S	V4/S
C	-1.573	-1.259	-1.372	-1.317	-0.123
	(-15.297)***	(-12.475)***	(-14.292)***	(-12.340)***	(-10.196)***
Finan	2.147	1.854	1.950	1.941	1.962
	(25.165)***	(21.262)***	(22.863)***	(21.332)***	(19.368)***
DE	-0.385	-0.308	-0.312	-0.356	-0.438
	(-9.705)***	(-7.931)***	(-8.207)***	(-8.890)***	(-10.504)***
LQ	0.001	0.001	0.001	0.000	0.000
	(4.180)***	(4.861)***	(10.256)***	(2.620)***	(2.038)***
ROE	1.393	0.886	0.131	1.323	1.277
	(5.057)***	(3.326)***	(0.495)	(4.772)***	(4.329)***
I/S or Vj/S ($\sum_{k=1}^{52} \alpha_{5k}$)	(12.488)***	(15.789)***	(16.913)***	(13.179)***	(9.253)***
Adj R^2	0.618	0.641	0.645	0.612	0.551
F	(164.73)***	(181.27)***	(184.81)***	(160.54)***	(124.83)***

p<0.1*, p<0.05**, p<0.01***

In Table 5 the R&D value expressed in either expenditure (I) or project value (V) have both positive aggregate coefficient. V1 and V2 have either higher coefficient or Adj R^2 than I. The minor deficiency of V3 and V4 did not devastate the correctness since it has the right sign of coefficient and comparable Adj. R^2 with I. Results of Table 5 expounds that the derived R&D value V is explanatory to firm's risk level.

An alternative way to eliminate scale effect as well as to count the idiosyncrasy between firms can be referred to Sundaram et al. (1996). According to Sundaram et al., the change of R&D investment can be compound with other variable's change for example the sales. To eliminate such a compound influence, which can also be called 'contaminating effect', we may conduct two stage regressions as to extract pure I as well as V then see their explanatory power on β. Table 6 showed, after filtering the contaminating effect, the change of R&D project value ΔV still has a better explanatory power on β referring to higher coefficient and Adj R^2.

So far we have let β of CAPM be regressed on I or V and other firm characteristics. However, since the residual's variance / standard error of CAPM may reflect a firm's idiosyncratic risk, it will be an interesting exploration if let the residual's variance / standard error of CAPM be regressed on the nominated factors again. We used the residual's standard error of CAPM (denoted as CAPMRESIDLSE) as the dependent variable for this test. Table 7 showed that either I or V is a powerful explanatory variable to the idiosyncratic risk. The Adj R^2 of regression with V4 exceeded 24% more than the Adj R^2 of regression with I. It is noticeable that the explanatory power of V1, V2, V3 and V4 seems 'dual', which means a poorer explanatory variable in Table 5 can be a better one in Table 7. This fact implies a researcher can have different choice of ROM by different viewpoint while explaining a firm's risk.

Table 6 Regression analysis for the contaminating effect elimination

Panel A (Dependent var.: ΔI or ΔVj)	ΔI	ΔV1	ΔV2	ΔV3	ΔV4
C	-0.001 (0.230)	-0.000 (0.641)	-0.000 (0.933)	-0.001 (0.149)	-0.002 (0.019)**
Δsales	0.894 (0.000)***	0.765 (0.000)***	0.711 (0.000)***	0.860 (0.000)***	0.901 (0.000)***
Adj R^2	0.054	0.038	0.032	0.049	0.052
F	(49.042)***	(33.972)***	(28.270)***	(44.311)***	(47.071)***
Panel B (Dependent var.: CAPM's Δ β_i)					
C	1.122 (0.000)***	1.122 (0.000)***	1.122 (0.000)***	1.122 (0.000)***	1.122 (0.000)***
Δsales	6.716 (0.000)***	6.716 (0.000)***	6.716 (0.000)***	6.716 (0.000)***	6.716 (0.000)***
ΔIresidl or ΔVresidl	0.447 (0.367)	0.818 (0.089)*	0.865 (0.067)*	0.724 (0.139)	0.802 (0.096)*
Adj R^2	0.016	0.019	0.019	0.018	0.018
F	(7.001)***	(8.058)***	(8.295)***	(7.703)***	(8.001)***

1. ΔIresidl and ΔVresidl are the residuals which can not be explained by the Δsales in 'Panel A' regression.
2. p<0.1*, p<0.05**, p<0.01***

Table 7 The explanatory power of different R&D value approaches to firm's idiosyncrasy

(Dependent var.:CAPMRESIDLSE) X_t (Independent var.):	I/S	V1/S	V2/S	V3/S	V4/S
C	-1.241 (-1.921)*	-0.659 (-0.960)	-3.205 (-4.575)***	0.982 (1.527)	3.580 (5.636)***
Finan	4.098 (7.646)***	3.560 (5.998)***	6.166 (10.342)***	2.177 (3.973)***	0.614 (1.149)
DE	1.267 (5.080)***	0.981 (3.713)***	0.175 (0.631)	1.402 (5.807)***	1.197 (5.434)***
LQ	-0.006 (-5.243)***	-0.000 (-0.414)	0.005 (5.891)***	-0.007 (-6.641)***	-0.012 (-10.766)***
ROE	21.106 (12.198)***	19.009 (10.491)***	12.577 (6.509)***	22.050 (13.205)***	19.598 (12.588)***
I/S or Vj/S ($\sum_{k=1}^{52} \alpha_{5k}$)	(16.480)***	(13.083)***	(7.420)***	(18.036)***	(20.394)***

Adj R^2	0.411	0.357	0.270	0.456	0.511
F	(71.73)***	(55.48)***	(36.98)**	(83.937)***	(106.66)***

p <0.1*, p <0.05**, p <0.01***

In the following we will use CAPMi's β to be regressed on firm's characteristics as well as V incorporating with information costs λ_M (market), λ_F (option) and λ_P (price). Be noticed that in Table 8 the level of information cost is artificial instead of a real one. Bellalah (2003) reminded that the information cost is subjective to managers and usually hard to be observed; who made an alternative as to set it 'virtually' in analyses. We follow Bellalah's method and set the costs a similar level. Table 8 shows that both accumulated t and Adj R^2 of V is changed comparing with Table 5 after the joint of information cost. The influence direction onto Adj R^2 caused by the joint of λ_F is inconsistent among ROMs and so is λ_P. It is noticeable that the influence direction between λ_F and λ_P is contrary. Once λ_F joined the statistic analysis, it will deteriorate / ameliorate the statistical power; the entrance of λ_P will ameliorate / deteriorate the result by an opposite way. This is similar to what we saw in numerical analysis.

Table 8 The change of explanatory power influenced by information cost

λ_M = 5%, λ_F =		3%		5%		7%	
	Vi1/S	(14.824)***a	0.630b	(14.393)***	0.626	(14.064)***	0.621
	Vi2/S	(16.882)***	0.646	(16.865)***	0.647	(16.850)***	0.647
	Vi3/S	(13.052)***	0.611	(12.983)***	0.610	(12.923)***	0.610
	Vi4/S	(9.377)***	0.553	(9.454)***	0.555	(9.528)***	0.556
λ_M = 5%, $\lambda_F = \lambda_P$ =		3%		5%		7%	
	Vi1/S	(16.269)***	0.646	(16.436)***	0.647	(16.534)***	0.647
	Vi2/S	(16.916)***	0.645	(16.911)***	0.644	(16.905)***	0.644
	Vi3/S	(13.402)***	0.616	(13.547)***	0.618	(13.682)***	0.620
	Vi4/S	(8.976)**	0.547	(8.782)**	0.545	(8.581)**	0.542

1. a, b represent the t value of $\sum_{k=1}^{52}\alpha_{5k}$ and Adj R^2 .

2. p <0.1*, p <0.05**, p <0.01***

4.3 MORE EMPIRICAL EXPLORATION

The inference what Bellalah (1999, 2003) have made was based upon hypothetical information cost instead of the real one obtained from markets. The concept of information cost was originated from Merton's (1987) investor recognition hypothesis. According to Merton, the information cost can be priced and determined by equilibrium of financial markets. However, there are scarce open markets to trade R&D thus it makes hardness for both information gathering and cost estimation. More than this, R&D trade usually went under-the-table due to commercial confidence (Lev and Sougiannis, 1996) which also makes the information sparse and vague. Bellalah (2003) made a suggestion as to exploit proxies collected from futures, spot and option markets to infer the information cost, though this idea was not eventually carried out by Bellalah but only simulations instead. We shall try to accomplish this part herewith.

There are three kinds of information cost, λ_M (market), λ_F (option) and λ_P (price), to be incorporated into our models. We shall try to find out the information cost implicitly contained by Taiwan weighted stock index (TAIEX) (the proxy of λ_M), stock options (the proxy of λ_F) and common stocks (the proxy of λ_P). Be noticed that, first, there is no real TAIEX trade therefore we shall utilize the data of Taiwan stock index options (TXO) to assimilate the whole market; second, there is no individual stock option offered by D-link, Accton and Ambit, therefore we shall utilize the data of Taiwan electronics options (TEO) instead since TEO focused on a specific sector of industries and the sample companies are constituents of this sector. Before the tasks being launched, there will be two main issues ahead: What is an adequate proxy of information cost? How can the information cost be evaluated adequately? For the first question, we refer to Amihud and Mendelson (1989) who asserted the bid-ask spread a good proxy of information cost. For the second question, we follow the principles adopted by Chicago Board Options Exchange (CBOE) which demands only the contract series of 'near-the-money', 'nearby' and 'second-nearby' being applied for volatility index (VIX) estimation,7 see the interpretation in Whaley (2000) also. The major concern of above principles is to avoid low liquidity and low efficiency of remote contracts distorting the estimates. The estimation of information cost has similar apprehension therefore the same rules are applied.

TEO was offered on March 28th, 2005. Ambit was acquired by Honghai on April 1st, 2004 therefore Ambit shall be excluded from analysis. We collect the data of TXO, TEO and individual stock form TEJ's respective module since April 1st, 2005 to March 31st, 2006. It showed the averaged information cost implied by TXO, TEO and stocks are

2.14%, 23.24% and 0.23% (D-link: 0.15% and Accton: 0.31%) which remarkably deviate from the λ_M , λ_F and λ_P 's traditional level set by Bellalah (1999, 2003). Table 9 tells, first, either R&D investment I or the R&D project value V derived by our models are explanatory to the risk level β , this corresponds to our previous inference. Second, the Adj R^2 of Table 9 advances 39.69% than of Table 8 (refer to column $\lambda_M = 5\%$, $\lambda_F = \lambda_P = 7\%$) which expounds the essentiality of using 'real' (or quasi-real) cost in analyses. Table 9 also sustains the value of our exploration and the estimation on real information cost. However, a caveat stands because V does not significantly surpass I. This problem could be caused by too short sample period and immaturity of TEO.

Table 9 The explanatory power of different R&D value approaches based on real data

(Dependent var.: CAPMi's β_t) X_t (Independent var.):	I/S	V1/S	V2/S	V3/S	V4/S
C	3.589 (4.330)***	3.842 (4.616)***	-1.297 (-0.867)	3.794 (4.594)***	3.541 (4.263)***
Finan	2.766 (3.349)***	2.980 (3.603)***	2.737 (1.883)*	2.942 (3.584)***	2.727 (3.290)***
DE	-0.666 (-2.840)***	-0.665 (-2.829)***	-0.487 (-1.902)*	-0.664 (-2.833)***	-0.666 (-2.840)***
LQ	0.002 (1.331)	0.002 (1.521)	0.005 (3.449)***	0.002 (1.470)	0.002 (1.309)
ROE	6.525 (5.232)***	6.561 (5.211)***	9.756 (7.274)***	6.506 (5.176)***	6.584 (5.259)***
I/S or Vj/S ($\sum_{k=1}^{13} \alpha_{5k}$)	(7.651)***	(7.768)***	(1.984)**	(7.798)***	(7.571)***
Adj R^2	0.859	0.858	0.836	0.859	0.859
F	(79.23)***	(78.78)***	(66.48)***	(79.08)***	(79.13)***

$p<0.1$*, $p<0.05$**, $p<0.01$***

5. CONCLUSIONS

Bellalah (2003) followed the context of Merton's (1987) investor recognition hypothesis and firstly incorporated the information cost into ROMs for R&D value exploration. According to Bellalah, information cost is a kind of exogenous factor which influences R&D's market value but will not affect R&D's payoff. We are not satisfied with this setting since R&D's payoff shall be affected by some external situations like technology innovation or fading away. We therefore extend Bellalah's model as to incorporate exponential decay and Poisson event, which allows the changing to R&D's payoff, as the mean to access reality more.

As presumed, the factors of exponential decay and Poisson event have much stronger effect than the information cost to R&D value. In other words, the Bellalah's (2003) model could be biased since these two 'demerit' items were not included; this lead to a managerial implication- technological innovation and revolution are common in modern industries thus it will be risky for a manager if he does not figure them while valuing an R&D project. The results affiliated with information cost are mostly congruent with past finding- the information cost will heave the required rate of return (Merton, 1987) and lower the option value (Bellalah, 2003). However, the information cost regarding price move contrary. The concept of information cost regarding price was firstly identified by Bellalah but who did not analyze it individually; we made a first surveillance herewith. The information cost regarding price represent the cost for tracing the movement of product price; the higher the cost, the better the price control, and so forth it should benefit to the option value. A story of 3rd generation (3G)8 cell phone may give us an illustration: the forerunner like Nokia had suffered for huge loose because of inadequate price policy, nevertheless its technology achievement was remarkable. It tells the price failure may offset the R&D value, and vice versa. Notably, the aggregation effect of information cost will be overwhelmed if exponential decay and Poisson event is considered. Again, exponential decay and Poisson event are the most crucial ones as demonstrated. In our simulation, the sensitivity of information cost onto R&D value is roughly half to the exponential decay and one third to the Poisson event.

Since R&D relates to firm-level decision, to use crude numbers for analysis without adjustment by firm's scale could generate us spurious result. To solve this problem, we applied several ways including the procedure of scale elimination, multiple stages regression and to use the residual's standardized error as the regressand. All these efforts aimed to diminish the idiosyncrasy between firms (Dai et al., 2008). By doing so, the conclusion what we acquire will be a general conclusion and less related to the scale of observed company. According to the analysis result, information cost is a weaker explanatory variable to firm's Beta. This can be blamed by either ways; firstly, the information cost is not a strong factor to explain the R&D value; second, the level of information cost set by Bellalah (2003) could be problematic. To the first query, indeed the information cost is not a strong factor; the numerical evidence showed that a sudden event will devastate the R&D value far beyond the information cost; again, Bellalah's model is too unilateral. To the second query, we think to use the real data to estimate the information cost could improve it. The statistical outcome sustains our presumption- its explanatory power appreciated about 40% if real data was applied. Lastly, we have created a process of how to estimate the information cost based upon Amihud and Mendelson's (1989) definition about information cost; Bellalah did not really estimate the information cost.

So far only few managers really use ROM for eventual business running since its correctness is queried (Graham and Harvey, 2001; Copeland et al., 2005). Moreover, its complexity could impede the willing of application. We are less concern to the second issue because a computerized module can overcome it. Correctness seems a more critical issue substantially because manner of either too optimistic or too pessimistic could lead to a false decision. In our discussion, the Bellalah's (2003) model is apparently too optimistic. We have found two factors which are commonly seen in daily life that will devastate the R&D project value remarkably. We also look closer to the elements of information cost then see how the individual element influences to the R&D project value. Numerical and statistical means were used to sustain our viewpoint.

Leaving the too detailed discussions, one may be interested to know how to exploit the techniques as well as findings from this study. For technique wise, as stressed, all the computation can be easily handled by computers; moreover, problems with analytical solutions can be easily solved by spreadsheet software like EXCEL® For the application of findings, there are two orientations to dwell- firms can utilize the methods we developed to know the value of owned investment project. On the other hand, since new investment will inevitably raise a firm's risk, an astute investor can set a threshold on low-enough-price then buy the stock; by doing this, he may compensate the increased risk and earn abnormal return as well.

A limitation of this study is that the research outcome is applicable to scenario based upon infinite option settings only. The background behind the infinite settings is that we assume the opportunity of R&D investment always exists. In fact, according to Perlitz et al. (1999), a productive asset may expire due to its exhaustion, for example a mine or an oil field, thereof an R&D opportunity affiliated with it may end up also. To deal with this situation, a finite option model in Black-Scholes (1973) style incorporating with important exogenous factors could be a potential subject to drill with

6. NOTES

(1). For example, FASB made an exception in 1985 (SFAS No. 86) to conditionally recognize the capitalization of software development cost instead of full expensing; UK's SSAP 13 conditionally admits the development expenditures may be deferred to future periods.

(2). In 2005, the annual R&D expenditure of D-link is NT$95,974,000 and Accton is NT$1,003,743,000; the industrial R&D intensity defined by Sundaram et al. (1996) of D-link is 0.153 and Accton is 2.128. We calculated the annual weighted investment first then divided it by four to transform it into the quarter base.

(3). The spirit of the parameters setting is same with the threshold price P^* as we collected measurements from real case to keep our analyses virtual. For example, the real σ level in 2005 is 10.4% thus we let it be 10% for easier recognition without too much deviation from reality.

(4). $R_{it} - R_{ft} = a_i + b_i(R_{mt} - R_{ft}) + u_{it}$ is the ex post form CAPM comparing with $\mu_x = r + \phi\rho_{Mx}\sigma_x$. The situation is same with CAPMi.

(5). The AR(1) model $y_t = \alpha x_t + u_t,\ u_t = \rho u_{t-1} + e_t,\ |\rho| < 1$ can be rewritten as $y_t = \rho y_{t-1} + \alpha x_t - \alpha\rho x_t + e_t$ which corresponds to $y_t = \alpha_1 y_{t-1} + \alpha_2 x_t + \alpha_3 x_{t-1} + e_t,\ |\alpha_1| < 1$ also. α_1 is identical to ρ, α_2 is identical to α, and α_3 is identical to $-\alpha\rho$. To justify the appropriateness of AR(1), Sargon (1964) as well as Henry and Mizon (1978) suggested a series of tests including H_{0a}, H_{0b} and H_{0c} as listed in Table 4: Panel A-2.

(6). The PDL is also called the Almon lag procedure (Almon, 1965). We hereby set $\alpha_{5,k} = h_0 + h_1 k + h_2 k^2 + h_3 k^3$, so $\sum_{k=0}\alpha_{5,k}(I)_{i,t-k} = \sum_{k=0}\left(h_0 + h_1 k + h_2 k^2 + h_3 k^3\right)\cdot(I)_{i,t-k} = h_0 W_{0t} + h_1 W_{1t} + h_2 W_{2t} + h_3 W_{3t}$, where $W_{0t} = \sum_{k=0}(I)_{i,t-k}$, $W_{1t} = \sum_{k=0}k(I)_{i,t-k}$, $W_{2t} = \sum_{k=0}k^2(I)_{i,t-k}$, and $W_{3t} = \sum_{k=0}k^3(I)_{i,t-k}$. We set the degree being three since the significance level of h in equation (6) remarkably descends since the degree of four.

(7). CBOE also demands the contract series of second-nearby and third-nearby being applied if the date to option's expiration is less than six. This is due to the possible fluctuation on option price while approaching to expiration; which could distort the volatility index estimation. We fulfilled this rule in our information cost estimation also.

(8). The high price and high rate obstruct consumers to buy or to subscribe 3G since part of its functions and services is available on the 2G, 2.5G cell pones or the WiMax communication system available for laptop.

7. APPENDIX

The Bellman equation belonging to the 'option with information cost allowing for exponential decay and Poisson event' (Fi3) can be expressed as:

$$(1/2)F_{PP}\sigma^2P^2+(r-\delta+\lambda_P)F_PP-(r+\xi+\lambda_F)F+\xi F((1-\phi)P)=0 \quad \text{(A1)}$$

Since (A1) is a homogeneous linear equation with second order, its solution can be a linear combination of two linearly independent terms like $F=F(P)=A_1P^{\beta_1}+A_2P^{\beta_2}$, where $\beta_1>1$ and $\beta_2<0$ as an ordinarily setting of fundamental quadratic equation. We have to solve four parameters before getting F therefore the boundary conditions can be exploited here. The option value F should be close to zero when P is close to zero therefore A2 must be zero. Since $V=P/(\delta+\theta+\xi\phi)=I+F$ and $F=A_1P^{\beta_1}$, makes $A_1P^{\beta_1}=P/(\delta+\theta+\xi\phi)-I$. The conditions of 'value matching' and 'smooth pasting' shall demand that:

$$\beta_1A_1P^{\beta_1}=P/(\delta+\theta+\xi\phi)=\beta_1(P/(\delta+\theta+\xi\phi)-I) \quad \text{(A2)}$$

β_1* can be solved through the quadratic equation. A1* is the function of β_1* , δ , θ , ξ , ϕ and I. $P*=(I\beta_1'(\delta+\theta+\xi\phi))/(\beta_1'-1)$, which is the threshold price what we exploited in numerical analysis.

The form of Bellman equation belonging to the 'option with information cost and future replacement options allowing for exponential decay and Poisson event' (Fi4) is more complicated because a compound situation should be considered. When $P<P*$, the value of the compound option over next interval is:

$$F=Pdt+(1-\theta dt)e^{-(r+\lambda_F)dt}E\left[F(P+dP)\right]+\theta dte^{-(r+\lambda_{F'})dt}E\left[F'(P+dP)\right] \quad \text{(A3)}$$

This means an installed investment could either survive with probability $(1-\theta dt)$ or die with probability θdt ; once previous investment dies, the firm will utilize a simple option $F'(P)$ in hand to launch the next investment. Through Itô's lemma F can be expanded as

$$F=Pdt+(1-\theta dt)(1-(r+\lambda_F)dt)\left[F+F_P(\alpha+\lambda_P)Pdt+(1/2)F_{PP}\sigma^2P^2dt-\xi Fdt+\xi F((1-\phi)P)dt\right]$$
$$+\theta dt(1-(r+\lambda_{F'})dt)\left[F'+F'_P(\alpha+\lambda_P)dt+(1/2)F'_{PP}\sigma^2P^2dt--\xi F'dt+\xi F'((1-\phi)P)dt\right]$$

when $P>P*$, F can be expanded as:

$$F=Pdt+(1-\theta dt)e^{-(r+\lambda_F)dt}E\left[F(P+dP)\right]+\theta dte^{-(r+\lambda_F)dt}E\left[F(P+dP)-I\right]=$$
$$=Pdt+(1-\theta dt)(1-(r+\lambda_F)dt)\left[F+F_P(\alpha+\lambda_P)Pdt+(1/2)F_{PP}\sigma^2P^2dt-\xi Fdt+\xi F((1-\phi)P)dt\right]+$$
$$\theta dt(1-(r+\lambda_F)dt)\left[F+F_P(\alpha+\lambda_P)dt+(1/2)F_{PP}\sigma^2P^2dt-\xi Fdt+\xi F((1-\phi)P)dt-I\right]$$

The respective Bellman equation becomes:

$$(1/2)F_{PP}\sigma^2P^2+(r-\delta+\lambda_P)F_PP-(\theta+r+\lambda_F+\xi)F+\theta F'+P=0 \quad \text{(A4)}$$

$$(1/2)F_{PP}\sigma^2P^2+(r-\delta+\lambda_P)F_PP-(r+\lambda_F+\xi)F-\theta I+P=0 \quad \text{(A5)}$$

Be noticed that (A3) and (A4) will meet tangentially on P*. This can be carried as a new boundary condition for solving F.

REFERENCES

1. Almon, A. (1965). The Distributed Lag Between Capital Appropriations and Expenditures. *Econometrica*, 33, 178-196.
2. Amihud, Y. and Mendelson, H. (1989). The Effects of Beta, Bid-Ask Spread, Residual Risk, and Size on Stock Returns. *Journal of Finance*, 44, 478-486.
3. Beaver, W.H. and Ryan, S. (2000). Biases and Lags in Book Value and Their Effects on the Ability of the Book-to-Market Ratio to Predicted Book Return on Equity. *Journal of Accounting Research*, 38, 127-148.
4. Bellalah, M. (1999). Valuation of Futures and Commodity Options with Information Costs. *Journal of Futures and Markets*, 19, 645-664.

5. Bellalah, M. (2003). On Irreversibility, Sunk Costs and Investment under Incomplete Information in Paxson D. A. (ed.), Real R&D Options, 1st edn. (Butterworth Heinemann, Burlington, MA).
6. Black, F. and Scholes, M. (1973). The Pricing of Options and Corporate Liabilities. *Journal of Political Econometrics*, 81, 637-654.
7. Bushee, B.J. (1998). The Influence on Institutional Investors on Myopic R&D Investment Behavior. *Accounting Review*, 73, 305-333.
8. Chambers, D., Jennings, R.R.B. and Thompson, I.I. (2002). Excess Return to R&D-Intensive Firms. *Review of Accounting Studies*, 17, 133-158.
9. Chan, L. K. C., Lankonishok, J. and Sougiannis, T. (2001). The Stock Market Valuation of Research and Development Expenditures. *Journal of Finance*, 66, 2431-2457.
10. Cohen, W. and Levine, R. (1989). Empirical Studies of Innovation and Market Structure in Schmalensee, R. and Willig, R. (eds.), Handbook of industrial organization (Elsevier, North Holland).
11. Copeland, T.E., Wetson, J.F. and Shastri, K. (2005). Financial Theory and Corporation Policy, 4th edn. (Pearson Addison Wesley, Boston, MA).
12. Cox, J.C. and Ross, S. A. (1976). A Survey of Some New Results in Financial Option Pricing Theory. *Journal of Finance*, 31, 383-402.
13. Dai, J., Huang, X. and Ma, L. (2008). Analysis of Bank's Behavior on Capital Adequacy Supervision and Capital Idiosyncracy. *Canadian Social Science*, 4, 9-15.
14. Dixit, A.K. and Pindyck, R.S. (1994). Investment Under Uncertainty, 1st edn. (Princeton University Press, Princeton, NJ).
15. Fama, E.F. and French, K.R. (1993). Common Risk Factors in The Returns on Stocks and Bonds. *Journal of Financial Economics*, 33, 3-55.
16. Graham, J. and Harvey, C. (2001). The Theory and Practice of Corporate Finance: Evidence from the Field. *Journal of Financial Economics*, 60, 187-243.
17. Henry, D.F. and Mizon, G.E. (1978). Serial Correlation as a Convenient Simplification, Not a Nuisance: a Comment on a Study of The Demand for Money by the Bank of England. *Economic Journal*, 88, 549-563.
18. Hirschey, M. and Weygandt, J. (1985). Amortization Policy for Advertising and Research and Development Expenditures. *Journal of Accounting Research*, 23, 326-335.
19. Ho, Y.K., Xu, Z.Y. and Yap, C.M. (2004). 'R&D Investment and Systematic Risk. *Accounting and Finance*, 44, 393-418.
20. Jou, J.B. and Lee, T. (2001). R&D Investment Decision and Optimal Subsidy. *R&D Management*, 31, 137-148.
21. Lev, B. and Sougiannis, T. (1996). The Capitalization, Amortization, and Value Relevance of R&D. *Journal of Accounting*, 21, 107-138.
22. Lin, C.T. and Wu, C.R. (2004). Strategic Timing Decision for Entering Foreign Market: A Real Options Approach. *International Journal of Operations Research*, 1, 23-28.
23. Mandelker, G.N. and Rhee, S.G. (1984). The Impact of Degrees of Operating and Financial Leverage on Systematic Risk of Common Stock. *Journal of Financial and Quantitative Analysis*, 45-58.
24. Martzoukos, S.H. and Trigeorgis, L. (2002). 'Real (Investment) Options with Multiple Sources of Rare Events. *European Journal of Operational Research*, 136, 696-706.
25. McDonald, R. and Siegel, D. (1984). The Value of Waiting to Invest. *Quarterly Journal of Economics*, 99, 707-727.
26. Mear, R. and Firth, M. (1988). 'Risk Perceptions of Financial Analysis and The Use of Market and Accounting Data. *Accounting and Business Research*, 18, 335-340.
27. Merton, R. C. (1987). A Simple Model of Capital Market Equilibrium with Incomplete Information. *Journal of Finance*, 42, 483-510.
28. Mowery, D. (1983). The Relationship Between Intrafirm and Contractual Form of Industrial Research in American Manufacturing, 1900-1940. *Explorations in Economic History*, 20, 351-374.
29. Perlitz, M., Peske, T. and Schrank, R. (1999). 'Real Options Valuation: The New Frontier in R&D Project Evaluation. *R&D management*, 29, 255-269.
30. Roberts, K and Weitzman, M.L. (1981). Funding Criteria for Research, Development and Exploration Projects. *Econometrica*, 49, 1261-1288.
31. Smith, C.W. and Watts, R.L. (1992). The Investment Opportunity Set and Corporate Financing, Dividend and Compensation Policies. *Journal of Financial Economics*, 32, 263-292.
32. Sougiannis, T. (1994). The Accounting Based Valuation of Corporate R&D. *Accounting Review*, 69, 44-68.
33. Sundaram, A.K., John, T.A. and John, K. (1996). An Empirical Analysis of Strategic Competition and Firm Values, the Case of R&D Competition. *Journal of Financial Economics*, 40, 459-486.
34. Titman, S. and Wessels, R. (1988). The Determinant of Capital Structure Choice. *Journal of Finance*, 43, 1-19.
35. Whaley, R.E. (2000). The Investor Fear Gauge. *Journal of Portfolio Management*, 26, 12-17.