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Pricing High-Tech Company by Real Options Approach – A Case Study of HTC

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Abstract

Traditionally, Discounting Cash Flows (DCF) approaches are used to project valuation and then extend to company valuation. With the uprising development of options theory and computational techniques, an alternative valuation approach –real options approach is proposed to emphasize what traditional valuation approaches neglect. Since high-tech companies have option-like characteristics and asymmetric payoffs, this paper attempts to apply real options pricing model developed by Schwartz and Moon (2000, 2001) to price high-tech companies and look for the key value drivers. The paper adopts case study methodology, focusing on a leading company --High Tech Computer (HTC), which is develops and produces Smart phones and Pocket PCs. After simulations, it seems this model can produce a reasonable result for valuation purpose.

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Chapter 1 Introduction

1.1 General Background Information

Valuation of common equity is probably one of the most researched topics in the finance literature. Traditionally, Discounting Cash Flows (DCF) approaches are used to value a company. There are many pioneer and classic studies of equity valuation models: Williams (1938), Durand (1957), Miller-Modigliani (1961), Gordon (1962), Malkiel (1963), and Mao (1966), which facilitate the development of techniques of valuing common equities. However, a series of works by Hayes and Garwin (1982), Myers (1984), Trieorgis and Manson (1987) and Dixit and Pindyck (1995) have pointed out the inappropriateness of traditional valuation models. Critics of the DCF criterion argue that all of these models begin with a positive stream of dividends, earnings, or cash flows and do not consider companies' flexibility and strategic considerations. It is suggested that DCF approaches are useful in company valuations when companies' cash flows are stable. While they may be problematic when valuing the company with great potential growth opportunities, especially those with great research and development (R&D) capabilities (Myers and Majluf 1984). Thus, several high technology industries characterized by a preponderance of companies with negative earnings and R&D projects, have presented a serious challenge to our traditional valuation methodology. Moreover, our current business environment is being shaped by large-scale and long-term trends, such as deregulation and increased global competition. The convergence of these factors has sparked a search for strategic frameworks and capital budgeting tools that can help managers evaluate and manage uncertain opportunities.

Following by the uprising development of the concept of options, an alternative valuation approach –real options approaches are proposed to emphasize what traditional valuation approaches neglect. Real option approaches are more focused on describing uncertainty and in particular the managerial flexibility inherited in many investments. As Amram and Kulatilaka (1999) suggested, options approaches are especially appropriate to adopt when the uncertainty of the environment is high or when the projects are involved with sequential or phased investment decisions because the flexibility of multistage decision-making should be explicitly taken into account. Clearly for some industries flexibility might be of minor interest while to high technology industries, it is of great value. For high technology industries, companies' revenues are much related to the uncertainty coming from the capability of R&D and competitors' threat thus companies have to keep high flexibility to react. Therefore, innovative capability and technology skills are regarded as the most valuable assets that should be take into account to reflect company's potential profitability. As Kester (1984) states that R&D is just like the growth of options; future uncertainty, the time of delay investment and interest all affect its potential value. Thus we can infer that high technology companies with high-level R&D projects have option-like characteristics and asymmetric payoffs, so the real options approaches may be more suitable than traditional valuation models in valuing those companies. Moreover, as Lander and Pinches (1998) point out, options' value is so much related with following three factors: uncertainty, new information and managerial flexibility, which just present the characteristics of high technology industries. It seems real options models form a consistent theory to answer some crucial questions of corporate finance. They provide the solution to include flexibility in the value, and explain risk can be valuable for companies.

Though a number of excellent performers do instinctively or intuitively view real options valuation can compensate DCF methods at a certain degree, and also there is growing support to options valuation theory in academia, but it seems practitioners have not recognized or applied the power of real options. The reason for this is there are still some restrictions and difficulties when applying real options model in real assets valuation, such as the problem of risk-neutral valuation. But these restrictions can be fixed. For example, several studies proposed solutions for pricing contingent claims on an asset by replacing its expected cash flow or actual growth rate (α) with a certainty equivalent growth rate and then behaving as if the world were risk-neutral (Constantinides 1978, Cox, Ingersoll, and Ross 1985, and Hull and White 1988). The main reason of unpopular might be that options theory is notoriously arcane. Many discussions in the literature are presented in the mathematics of Black-Scholes valuation when they go beyond the conceptual level. Another reason for apparent neglect may be the complexity in describing uncertainty makes executives regularly fail to account for the hidden options in projects (Copeland, Koller, and Murrin 2000). Thus, managers are claimed to be unfamiliar with the use of real options.

1.2 Motivation of Research

A fairly large body of literature has conceptually supported real options approaches in the application of valuing uncertainties of investment projects and highlights their advantages of considering managerial flexibility. However, within that literature, there have been relatively few attempts when it comes to develop a real options model to company valuation, though we know real options approaches may be the better approach in some cases, such us company's early stage of full uncertainties. The earlier study of Schwartz and Moon (2000, 2001) attempts to value Internet companies and fills the valuation gap by taking the special characteristics of high-growth companies into account. Because high-tech companies also share the similar characteristics with Internet companies, we would like to follow this model to value high-tech companies to see if real options approach can provide an alternative thinking for the high-tech companies' relatively higher stock price. Moreover, the real options models are seemed to be not so practical and popular in use, we hope this study can enhance its practicability more or less.

1.3 Research Objectives and Methodology

The aim of this dissertation is to develop a real options valuation model that is capable of pricing a company. We emphasize on the high-tech companies which characterized with high potential growth but full of uncertainty, attempting to follow real options pricing model developed by Schwartz and Moon (2000, 2001) to get the rational price of high-tech company and look for the key value drivers of it.

This dissertation adopts a case study methodology and demonstrates how real options analysis is used to investigate the value of a high technology company—High Tech Computer (HTC). HTC is a listed company in Taiwan which develops and produces Smart phones and Pocket PCs. Business Week's 2006 "InfoTech 100" ranked HTC as the fastest growing companies with 102% sales growth in 2005 and overall ranked 3rd place among all world's information technology companies. We hope to provide an alternative framework, which is more appropriate to capture the features of high technology and high-growth companies and then infer the reasonable price of them.

1.4 Structure Overview

The remainder of this dissertation is organised as follows. Section 2 reviews the theory of real options in earlier literature. Section 3 introduces our valuation model and also the parameters for implementing simulations. Section 4 presents the analysis results of valuation and sensitive analysis to find out key drivers of the company. Section 5 sums up and concludes.

Chapter II Literature Review

2.1 Definitions and Concept of Real Options

Various definitions of real options have been proposed over the course of decades of research. Amram and Kulatilaka (1999) define real options as, "In a narrow sense, the real options approach is the extension of financial option theory to options on non-financial assets."And the term is defined by Dixit and Pindyck (1995) as "Opportunities are options – right but not obligation to take some action in the future." Trigeorgis (1996) also proposed similar view with Dixit and Pindyck (1995) stating"Similar to options on financial securities, real options involve discretionary decisions or rights, with no obligations, to acquire or exchange an asset for a specified alternative price." Copeland and Antikarov (2001) present a more clear definition to real option :"A real option is the right, but not the obligation, to take an action (e.g. deferring, expanding, contracting, or abandoning) at a predetermined cost called the exercise price, for a predetermined period of time – the life of the option."Above definitions agree that options are rights not obligations. The key difference of the definitions lies in the scope of real options, from assets in a narrow sense to actions in a broad sense.

Generally, the option thinking is initially drawn from the early literature of environmental economics such as Weisbrod (1964), and Arrow and Fisher (1974), which basically focus on analyzing the governmental investment decisions given the irreversible and unrecoverable environments. Later, the idea of growth opportunities as options is proposed in economic literature of capital budgeting by Myers (1977), who suggested using techniques like those used to value put and call options on stocks to value real investments where management can exercise options to adapt strategies during the course of the project. As he points out, many corporate assets, particularly growth opportunities, are analogous to call options on the future growth and the value of such real options depends on discretionary future investment by the company.

Based on Myers's (1977) idea, Kester (1984) then conceptually proposes a similar point of view that discretionary investment opportunities are analogous to ordinary call options on securities, thus termed options on real assets. Trieorgis and Manson (1987) further points out the current project also can create the future and follow-up investment opportunities as long as there exists managerial flexibility that means flexibility can improve a project's upside potential while limiting downside losses and hence the distribution of a project's value is skewed. As such, an option premium should be paid for the options created by the management flexibility and the project's expected value is thus increased. Based on this logic, even a project with a negative NPV can still be valuable as long as managers have flexibility to postpone the investments waiting for favorable future conditions.

Dixit and Pindyck (1995) then applied options theory to company's capital investments. He suggests an investment opportunity is like a financial call option and the greater the future uncertainty over the potential profitability of the investment exists, the greater the incentive to wait and to keep the opportunity alive rather than exercise it by investing at once. Because most investment projects are irreversible and are capable of being delayed, companies can wait for more information to make decisions, and this flexibility is like a call option. When a company decides to carry out investment projects, it gives up the option to wait and hence, lose of option value is an opportunity cost that must be taken into account. Therefore, when investment decisions are made, the present value of cash generated must exceed the cost of the project by an amount equal to the value of keeping the investment option alive.

These studies have suggested that growth opportunities possessed by a company can be regarded as real options and applied contingent-claims analysis to evaluate them in conjunction with the company's operating environment. Therefore, the options perspective can help companies integrate capital budgeting with long- term strategic planning and capture the flexibility of management to address uncertainties as they are revealed. The flexibility that management has may include defer, abandon, expand, contract and switch use but traditional NPV capital budgeting approach fails to account for this flexibility and to integrate the flexibility with strategic planning. Thus, in following section we present comparison of traditional NPV approach and real options approach.

2.2 Traditional DCF approaches vs. Real Options approach

The purpose of this section is not to argue for one method or another, but to connect the appropriate choice of approach, and the reasons that drive the choice, to insights about investment decisions, valuation, and strategy.

2.2.1 Criticism of traditional DCF approaches

Traditional DCF approaches have been frequently adopted for making investment decision or company valuation. Theses method explicitly assume the project will meet the expected cash flow with no intervention by management in the process. All the uncertainty is handled in the risk-adjusted discount rate, which is based on the capital asset pricing model (CAPM). This whole process is static. At most, the expected value of the cash flow is incorporated into the analysis. However, over the past decade, as real option theory has been the subject of a growing body of literature and has gathered support, it is now widely acknowledged that the DCF approaches fail to capturing complex uncertainties, managerial flexibility, and strategic importance of investments. Here, we present some studies as follows criticizing the flaws of traditional capital budgeting approach.

As Myers (1977) states, the traditional DCF analysis implicitly makes the underlying assumptions regarding the static scenario of expected cash flows, meaning management can only passively response to uncertain situations. Hayes and Garwin (1982) also criticize DCF approaches in two aspects: First, the implicit assumptions of DCF approaches rest upon, including the cash generating rate, the growth rate and the hurdle rate, are not clear and often been misestimated, which can lead to misperceptions of uncertainties and the myopia of investment decision making. Second, the assumption that investment processes are reversible, leading to systematic bias against investment in new capital stock. The reversibility of investment may be problematic when considering the process incurs no any additional cost. The similar point of view is proposed by Dixit and Pindyck (1995), stating the assumptions that investment projects are reversible and undeferrable are not appropriated. Because the initial investment cost of most investment projects are sunk cost which cannot be retrieved and the most important is, investors have rights to choose the timing of investments. Thus they insist that the traditional DCF approach is not sufficient for managers to make investment choices, they need to consider the value of keeping their options open.

Moreover, Myers (1984) points out that some investments are prerequisites in a chain of interrelated projects, and hence the value of these investments derives not only from their expected directly cash flows but rather from the fact that they unlock future growth opportunities. As such, DCF methods ignore the interaction between each project and cannot capture the project value properly. Trieorgis and Manson (1987) extend Myers' (1984) idea and explain that DCF approaches often lead to under investment and myopic investment decisions because they fail to capture management flexibility. They suggest two extra values embedded in an investment project: operating flexibility and strategic option. Managers can adapt and revise their later decisions as the market condition changes, such as to defer the investment or to expand the operating scale.

To sum up, we can infer Dixit and Pindyck (1994) studies which collect previous studies and summarize main flaws of traditional DCF approach in three aspects: First, traditional DCF approach usually assumes decisions are made in one time, but in fact, due to the insufficient information and full of uncertain factors, only few managers can make proper decision in first stage of investment. Therefore, it is important that investors have rights to choose the timing of investments. Second, traditional DCF approach usually makes too many assumptions of static scenario of expected cash flows, such as cost, revenues, interest rates and time horizon. Thus there may be a difference between the theoretical results and real situation. Third, the estimation of discount rate is calculated by CAPM. Though it is simple and understood by corporate practitioners, to summarize the risk profile of capital investments may be problematic due to failing capturing complex uncertainty and also cash flows are very sensitive to discount rate, thus inaccuracy estimation of discount rate will result in the valuation useless.

2.2.2 Real options approach

To a certain degree the real options approach is able to overcome the deficiencies of the traditional present value technique through an understanding of the interactions, interdependencies, and competitive interactions among projects. Real option approach seems more appropriate to value R&D projects and provide the reasons for our study in this paper by applying real options in high technology companies with high level of R&D. The reasons are:

Firstly, real option approach confers certain reactive flexibilities on its holder that is the option to invest, wait, or divest in response to new information. The characteristics of R&D projects, they are contingent decisions that depend on the sequential steps in the future. Investing in the next R&D milestone can be regarded as investing in a call option on the forthcoming milestone. The real options thinking are very important for management in evaluating investment opportunities with respect to projects‘ valuable contingent claims, and also help management in evaluating growth opportunities that are relevant to the research stage of R&D projects.

Secondly, strategic considerations are magnified or made explicit by the analysis, thus it skews the results of the traditional NPV analysis which allows for gains on the upside, and minimizes the downside potential, thus increasing the valuation. As Smit and Trigeorgis (2004) mentions, real options approach to asset valuation is regarded as strategic NPV, which is equal to traditional NPV plus strategic value. In the case of R&D projects, the real options approach to appraisal can be used for managing financial impact in a way that unfavourable outcomes is minimized, while opportunities to create value are exploited. Also, real options evaluation capture the upside potential risk more properly, rather than reward higher risk at a higher discount rate for cash flow. Its sensitivity to the value of these possibilities is what makes a real option a better valuation tool than NPV.

Here we summarize some advantages of real options, which refer to McKINSEY quarterly journal (1997) highlighting the importance of it. They are: emphasizing opportunities, enhancing leverage, maximizing rights, and minimizing obligations. First, a real-option strategy emphasizes the logic of strategic opportunism. It forces managers to compare every incremental opportunity arising from existing investments with the full range of opportunities open to them. Second, real-option strategies promote strategic leverage, encouraging managers to exploit situations where incremental investment can keep their company in the game. This is different from simultaneous investment in multiple opportunities, however, which reduces the upside as well as the downside. Thus, leverage distinguishes real option strategies from traditional diversification strategies that reduce risk. Third, the right empowers managers to defer the proprietary investment opportunity without increasing the exercise price. Fourth, financial options impose no obligation to invest; therefore investors are protected if the stock price falls below the exercise price. Real-option strategies strive to incorporate this feature into real-market investments, minimizing managers' obligations in situations characterized by uncertainty and irreversibility.

Although real options approach seems to excel DCF approaches in many aspects, it still has its difficulties in application. The challenge in applying real options is that the growth options are not terribly visible to outsiders and prior experience in other industries may not prove a useful guide. From an external vantage point, the framing of a company with high level of R&D-- growth options--has a larger component of judgment than in established industries. In contrast to growth options in real options, financial options have terms that are well-specified and transparent. Financial option pricing models can be quickly and readily tested against market movements, and the feedback from such tests can be used to reduce model error. For real options in established industries, where the underlying economics, opportunities, and constraints are well understood, errors in the real options model can be also be bounded to some degree, although market imperfections and differences among real assets increase the role for judgments and the size of the model error. For real options present in Internet companies, there is potential for even larger model error since the options are opaque and the markets are new.

2.2.3 Combination of traditional DCF approaches and real options approach

Although traditional investment analysis has inappropriateness (e.g.the inappropriate assumptions and lack of management flexibility), this does not mean that traditional NPV calculations should be rejected, but rather they need to be augmented by option aspects in an expanded NPV framework. Some researchers (McDonald and Siegel 1985, Trigeorgis and Manson 1987) proposed modified approaches: the traditional static NPV of directly measurable cash flows and an option premium capturing the value of strategic and operating options under active management. The motivation for using such an options-based approach to capital budgeting arises from its potential to conceptualize and quantify the flexible and sequential component of value. As Trigeorgis (1996) states that an expanded-NPV analysis bypasses the problem of discount rate by relying on the notion of a comparable security to properly price risk while still being able to capture the dynamic interdependencies between cash flows and future optional decisions.

McDonald and Siegel's (1985) modified NPV rule is presented as:

NPV=PV(P)+PV(C)+RO

PV(P) = the present value of expected revenue

PV(C) = the present value of cost of investment

RO = the value of option

In addition, Trigeorgis and Manson (1987) also propose similar concept to modify traditional NPV model:

Expanded NPV=Static NPV+ Option Value

In the studies discussed above, traditional NPV is an exception of real option method. When an investment project is revaluated in real option method, we can obtain the expanded NPV. If the option value is trivial, the valuation between real option method and traditional NPV method has no much difference. There are several reasons for this situation. When option is exercised, the value of option is disappear due to the value of time vanishing, thus the options approaching maturity and out-of- price have less value. Another saying is the value of waiting is offset by the cost of waiting. All of these result in the value of option trivial. In this way, when considering the effectiveness and accuracy, traditional NPV method may be better than real option method. Therefore, different investment projects should be evaluated by different method under its nature and situation.

2.3 Solving Real Options—Option Pricing Models

There are no specific option pricing theories devoted to real options. Since real options are similar to financial options, they can be valued by pricing models. This section examines the applicability of the three most important options valuation techniques to real options: the partial differential equation (PDE) approach, the simulation approach, and the dynamic programming approach.

2.3.1 The PDE approach

The PDE approach equates the change in option value with the change in the value of the tracking portfolio. The option value is established in one equation as a direct function of the inputs. If available, closed-form analytical solution for partial differential equation is the best way to get the value of an option. But analytical solution proposed for pricing only European contingent claims and for perpetual American put and call options on normally or lognormally distributed underlying assets. This approach does not allow analysis of early exercise and multi-dimensional real option problems. Therefore, most real options do not fit these categories perfectly, but they are useful limiting cases and valuation bounds for some real options that do occur naturally. However, when readily available solutions exist, they may be useful. This is especially true at initial, rough option valuations.

The most typical analytical solution to solve a European call option is the Black-Scholes Equation proposed by Black, Scholes and Merton (1973). The Black - Scholes model is a continuous-time model, which assumes that the value of the underlying asset follows a lognormal distribution and the expected rate of return and volatility of the asset remain constant. Also, this equation must be satisfied by the price of any derivative dependent on a non-dividend-paying stock. The full expression of Black-Scholes Formula can be written as:

$$C = S_o N(d_1) - Ke^{-rt} N(d_2)$$

$$P = Ke^{-rt} N(-d_2) - S_0 N(d_1)$$

$$d_1 = \frac{Ln(S_0/k) + (r + \sigma^2/2) T}{\sigma \sqrt{T}}$$

$$d_2 = \frac{Ln(S_0/k) + (r - \sigma^2/2) T}{\sigma \sqrt{T}}$$

Where C= European call

P= European put

S_0 = Stock price at time 0

K= Strike price

r = Continuously compounded risk-free rate

σ = Stock return volatility

T= Time to maturity

The formula is the result of solving a PDE, seemingly opaque and incomprehensible to those not familiar with financial mathematics or physics. Thus applying this formula to real options, to understand the underlying assumptions of it is important, otherwise it is very easy to apply the formula blindly and obtain a useless and misleadingly precise value of real options. For example, the price assumption for Black-Scholes approach is not discussed in finance literature, since prices are intrinsic to financial markets, stocks, and derivatives. But for real options, it is sometimes not the case that the analyst has a market price for the subject studied. In addition, the no arbitrage condition is often hard to satisfy for real options. The payoff of a stock option can be perfectly matched by a portfolio of stocks and loan, but a real option is hard to match. Moreover, Black-Scholes' Geometric Brownian motion assumption has the property that the price grows forever. For some underlying assets, for example the stock price because of continuous inflation and investment, this is an acceptable assumption. For other underlying assets, however, the Geometric Brownian motion is not a best assumption.

2.3.2 Simulation

Simulation models roll out hundreds of possible ways of evolution of the underlying asset from the present to the final decision date in the option. The optimal investment strategy at the end of each way is determined and the payoff calculated. The current value of the option is found by averaging the payoffs and then discounting the average back to the present. Monte Carlo simulations are by far the most used one. Simulation models have been used for many years to analyze European options, but it was generally felt that they would not be useful in analyzing American options. This is because simulation is a forward approach, with the underlying asset starting at a fixed price and undergoing random increments going forward. Simulation needs an analytic form of exercise condition for the options. If there are no closed-form analytical exercise conditions, for example American options, the simulation technique may not work without special treatment.

While Monte Carlo simulation does not have as many assumptions as the Black-Scholes formula. Its strengths are in implementing different decision rules and relationships, and in adding new sources of uncertainty that means it can tackle problems with complex and non-standard payoffs. Simulation is computationally less burdensome in handling multiple risk drivers, which is a distinct advantage over the numerical methods. If it is possible to specify the stochastic processes for the underlying uncertainties, and to describe the function between the input uncertain variables and the output payoff, computers can do the complicated computation work.

On the other hand, there are still some limitations for using Monte Carlo simulation. First, the sound stochastic models for the underlying uncertain variables, especially the parameters in the stochastic models are necessary. If we use the wrong model or wrong parameters, the results may be both useless and misleading. Second, the computational cost could be expensive for simulation methods. To get the required accuracy, the convergence could be slow and time consuming. Third, it is a computation problem that the number of samples per variable increase exponentially with the number of variables to maintain a given level of accuracy. If there are multiple sources of uncertainty, then it could be computationally prohibitive to calculate the value at required accuracy.

2.3.3 Dynamic programming --Binomial Trees Model

Dynamic programming solves the problem of how to make optimal decisions when the current decision influences in future payoffs. This method rolls out possible values of the underlying asset during the life of the options in a discrete tree structure and then folds back the values of the optimal decisions in the future and calculate the final option value. Dynamic programming can manage complex decision structures, multiple relationships between the value of the option and the value of the underlying asset, and complicated forms of leakage, such as those that vary with time and the value of the underlying asset.

Cox, Ross and Rubinstein (1979) proposed Binomial options pricing model could be viewed as the representative of this method. The binomial option valuation approach values options in discrete-time and is based on a simple representation of the value evolution of the underlying asset. The option's life is divided into n intervals and we can improve the precision of binomial tree method to a very high level by dividing the life span of an option into more stages. In each time period the underlying asset can take only one or two possible values. One advantage of Binomial trees is it works with both risk-neutral valuation and actual valuation. Risk neutral valuation uses risk-neutral probabilities and discounts at risk-free interest rate; actual valuation uses actual probabilities and discounts at risk-adjusted rates. In practice it is not easy to obtain the appropriate risk-adjusted discount rate (Hull, 2006). In addition, the approach is not necessary binomial; it could be trinomial or more. The essence of different multinomial is the same: the approach allows the recombination of states to decrease the computational burden.

The advantage of the binomial model is that they are quite easy to grasp and cover a wide spectrum of option types and decision structures (Mun, 2002). Also it can deal with American-style options. Compared with Black-Scholes model, it can deal with more than Black-Scholes model because it simplifies some strict assumptions of Black-Scholes model which is more practical in real world. For example, we can establish different tree for different stochastic processes. The recombination structure of the binomial tree implies path independence. If the new process has path-dependent features, we can break the recombination structure of the tree. However, the limitations arise when we have multiple stochastic variables. The number of nodes required will grow exponentially with the number of factors. Thus, the solution to these models is generally too messy to implement in a spreadsheet. Under this circumstance, it will become computationally time-consuming to derive the option value.

2.3.4 Summary

Depending on the circumstances, some techniques may be more effective or accurate than others. To summarize, Black-Scholes approach should be used with great care when applied to real options, we have to justify its assumptions, but when readily available solutions exist, they may be useful, especially true at initial, rough option valuations. Simulation is very useful but we need to understand its limitations and apply variance reduction techniques. Binomial tree is versatile and powerful, and relatively straightforward, easy to understand and calculate, thus it is extensively used by practitioners. But if path dependency exists, we have to break the recombination structure of the tree and limit the number of periods considered.

2.3.5 Using Option Pricing Models on Real Options

When valuing more complicated real option, analytical models usually will simplify assumptions, such as growth rate, cost of capital and volatility. However, in real projects, projects usually are more complex and involve multiple interacting real options. For a high-growth technology company, the above parameters may not just constants due to quick change of market condition and decision-making may also change correspondingly. Under this circumstance, closed form analytical solutions may not exist and it may not be always possible to write down the set of partial differential equations which describe the stochastic process of asset behaviour (Trigeorigs, 1993). Although analytical solutions can obtain company's valuation quickly and exactly, many assumptions have to be loosened to fit in Black and Scholes' model when applying to real projects. For example, it is reasonable to assume risk-free rate is a constant, because the period of financial derivatives usually are not too long. However, the period of real options can last several ten years, thus to assume discount rate as a constant risk-free rate may not be reasonable. Moreover, the movement of company's value may be follow stochastic process; drift and volatility may not be constants. The assumption of no arbitrage condition of Black-Scholes which uses similar assets to create risk-free portfolio is not always for sure in real options.

Therefore, it is suggested that numerical methods may be more appropriate to value such complex options. In other words, Monte Carlo simulation, binomial trees models that can approximate the underlying stochastic process directly. In this paper, we apply Monte Carlo simulation approach to value a high growth company.

2.4 Adapting Options Theory to Real Options Valuation

Increasingly, real options theory has been proposed as a major means of managing investment uncertainty; however, there are still some concerns when applying financial options theory to real options valuation. As Bowman and Moskowitz (2001) states, there are two main problems with implementing real options approaches. First is how analogous is the assumptions of the option pricing model to the real option of interest; second is how correct are the input parameters. In the section, we will discuss the pitfalls of the real options analysis and how to avoid them.

2.4.1 Critiques on Real Options

One of the important assumptions of Black-Scholes is the tradability of the underlying assets. This is to construct a hedged riskless portfolio with a long position in the asset and a short in the option. On the basis of no-arbitrage equilibrium, the risk-neutral valuation is utilized to derive the value of the option. While practical problems with risk-neutral pricing arise when inferred option pricing parameters do not apply to the real world. In practice, most of underlying assets of real options are not traded; for example, it is hard to replicate portfolio for pioneering R&D projects to validate the no-arbitrage analysis. Since the real assets do not quite fit with the original assumptions, it causes major critiques on the real options theory. As Sick (1995) states, if we simply plug the data of real projects into financial option formula, it will incur the problem of applicability.

Another difficulty associated with the underlying asset is the assumption of the geometric Brownian motion, which allows the variance of the underlying asset increasing over time. However, the geometric Brownian motion may be realistic for describing the movement of assets like stocks but not for all of the asset prices. In some situations, the mean-reverting process may be more appropriate. For example, according to Dixit and Pindyck (1994), oil price tends to fluctuate up and down in the short run but in the long run it draws back to a certain level. Thus it is important to apply the proper stochastic process in the real options valuation. In this paper, we also assume it is more reasonable that company's sales will converge to a stable level.

Moreover, the measurement of the underlying volatility is also a difficult issue. Since the option value is highly sensitive to the volatility of the underlying asset, misestimated volatility can lead to significant error in option valuation. Perlitz, Peske and Schrank (1999) suggest five different kinds of volatility: the future, the implicit, the seasonal, the forecast, and the historical volatility. To illustrate, the future volatility is unknown, but we can use the other four types as an estimate. And the historical volatility is derived from the historical data; the forecast volatility can be acquired from specialized institutions; the implicit volatility can be calculated by option market prices and certain option pricing models; the seasonal volatility can be obtained when underlying asset has seasonal movements.

Another problem is even when we use risk neutral valuation, the higher moments (e.g., skewness and kurtosis) are neglected in options valuation. If higher moments play a part in the asset pricing model, then practical problems arise because the variance and higher moments can differ between the real and risk-neutral worlds. However, according to Hull and White (1987), Scott (1987, 1997), and Bares (1996) point out, higher moments have been considered in the data generating process in continuous-time models, described by the stochastic volatility or they can also be captured by adding jump model. On the other hand, discrete-time model has its limitation in dealing with this issue, thus, due to many sources of uncertainty to affect the value of the company in high technology industry, in this paper we will adapt continuous-time model.

2.4.2 The Problem of Risk-Neutral Valuation

Valuing options involves substituting the real growth rate of the underlying asset with the risk-neutral growth rate. But we can find that the expected growth rate changes, consequently the discount rate changes to reflect the increase in risk. These two events happen to offset each other exactly. Suggesting that the derivative will be valued equivalently in the risk-averse and the risk-neutral world. Being independent of risk attitudes and of considerations of capital market equilibrium, such risk-neutral valuation enables present value discounting at the risk-free interest rate.

The advantage of the risk-neutral framework lies in the avoidance of appraising a risk-adjusted discount rate. However, risk-neutral valuation is only appropriate for traded assets. For the assets non-traded, expected growth rate of underlying assets (α) and risk attitudes as well have to put into considerations in options valuation. In many cases, real options approach is hard to avoid the problem of deciding risk adjusted discount rate and decision maker's subjective valuation of risk. This implies that real options analysis cannot obtain an objective valuation based on market observable prices, and people can maneuver the real options analysis. Everybody can reach a different result from his or her own real options analysis and there is no possibility to prove who is correct and who is wrong, because the subjective valuation of risk enters the analysis.

Financial options theory can still be applied to real options with a few adjustments. Constantinides (1978), Cox, Ingersoll, and Ross (1985), and Hull and White (1988), have suggested that any contingent claim on an asset, traded or not, can be priced in a world with systematic risk by replacing its expected cash flow or actual growth rate (α) with a certainty equivalent growth rate ($\alpha^* = \alpha - \lambda\sigma$ by subtracting a risk premium appropriate in market equilibrium) and then behaving as if the world were risk-neutral. This is analogous to discounting certainty-equivalent cash flows at the risk-free rate, rather than expected cash flows at the risk adjusted rate. This market price of risk λ is defined as $(\mu - r) / \sigma$, (μ=total return , r=risk free rate, σ=deviation of risk or return) that is the extra return acquired per unit of risk. With the market price of risk, we can link the risk-free rate and risk-adjusted discount rate and helps us move from a world with risk preference to a risk neutral world. The valuation obtained from the risk neutral world is valid in the worlds with risk preference. With the validity of risk neutral valuation, we can obtain an objective value of options independent of individual risk preference. Thus, for real options with non-traded assets, affecting the pay off structure of the option, we need to observe the variables real growth rate and the market price of risk. Subsequently, the process can be adjusted to facilitate risk-free discounting.

2.5 Attempts on Company Valuation with Real Options

Real options approaches have widely applied in a variety of aspects with different types of options, such as in natural resource investments, land development leasing, flexible manufacturing or R&D and company valuation. As concerning for applying real options approaches in company valuation, the challenge is the growth options are not so visible to outsiders. In contrast to high technology companies' growth options, financial options have terms that are well-specified and transparent. Thus, financial option pricing models can be quickly and readily tested against market movements, and the feedback from such tests can be used to reduce model error. However, for real options presented in high technology industry, where the underlying economics, opportunities, and constraints are not so clear, errors in the real options model may become larger, since the options are opaque and the markets may be new. Moreover, market imperfections and differences among real assets increase the role for judgment and the size of the model error.

There are some frameworks proposed for applying real options to the valuation of companies. Berk, Green, and Naik (1999) develop a dynamic model of a multistage investment project that captures many features of R&D ventures and start-up companies which values a company's cash flows based on a stochastic investment process. A company's value is as a collection of existing projects and growth options. One distinguish feature of their model is that it explicitly incorporates the changes in the company's systematic risk over time which means it captures different sources of risk and allows us to study their interaction in determining the value and risk premium of the venture. They use a simulation methodology and calibrate their model using macroeconomic data. While their model appears to address several important market anomalies, it is not readily applicable to the valuation of individual companies.

The other framework is proposed by Schwartz and Moon (2000,2001) applying real-option theory and capital budgeting techniques to value Internet stocks. In their framework, instead of detailing the real options themselves, they specify the stochastic forms of revenues and revenue growth that reflect the exercise of real options. For example, revenue may spurt up in the short run but is expected to revert back to a lower and stable long-run growth level which is consistent with a burst of growth immediately after the exercise of an expansion option. This strategy implicitly summarizes both investment behavior and market conditions. Using Monte Carlo simulations, they derive the value of an Internet company based on companies specific and industry specific parameters. Their model is essentially a stochastic continuous time version of the multistage valuation models used in the earlier literature.

Chapter III Methodology

3.1 Model Conception

The value of company is composed by the present value of cash flows and the present value of real options. Traditional NPV valuation is only an exception of real options valuation, that is when the uncertainty disappeared, the results obtained from above two methods are indifferent. However, companies are operating with a great deal of uncertainties, thus in each different point of time, the present value of companies' future cash flows will change as well. We assume, in the stage before the company going mature, if company's cash flows of running are less than the cash flows of stop running, the company is flexible to close down the business. Thus, in different point of time, the valuation of the company is fluctuated according to the changes of cash flows resulted from various decisions and events.

In the traditional industry lifecycle hypothesis, sales and earnings are typically the variables that mature over time. This hypothesis posits that an industry goes through a number of stages: Introduction, Growth, Maturity, and Decline phases as in Porter (1998). Inflection points in the rate of growth of sales usually define these stages. Though not every company will go through every stage stated above, in this model the company is assumed to go through a normal life cycle. In the period before the company moves forward to the stage of mature, company's profits are mainly influenced by the uncertainties of revenues, the growth rate of revenues and operating costs. Then, to capture this source of uncertainty, we can assume these three main uncertainties following stochastic processes and we also assume there are several state variables affecting company's future cash flows in current point of time, and the company has abandon options to exit market when going bankrupt. Thus, we can infer the company's cash flows in this period. In addition, the model has to calculate an appropriate discount rate to infer company's present value. In order to avoid to value in risky environment, we follow Cox, Ingersoll and Ross's (1985) study to do risk adjustments by replacing assets' expected cash flows or actual growth rate with a certainty equivalent growth rate when pricing contingent claims on an asset. In this way, we can have a risk neutral valuation to discount cash flows by risk free rate.

Based on above idea, we follow Schwartz and Moon's (2000, 2001) model to formulate the model in continuous time, form a discrete time approximation, and its implementation is done by simulations. Schwartz and Moon's model is originally set to measure Internet companies' rational price. The main premise of the model is that the present value of companies must take into account the extreme uncertainty surrounding all variables that determine future cash flows. Moreover, the growth rates and the volatility of those variables, although currently very high, will decrease with time until they reach levels comparable to those of mature companies. This model fills the valuation gap by taking the special characteristics of high growth companies into account. High growth companies usually have significant R&D and marketing expenditures leading to negative initial cash flows that eventually will become positive at an uncertain point in the future. Furthermore, revenues, rates of growth in revenues and costs are most of the time highly volatile resulting in a high-risk profile in financial, market and technological aspects. However, while the downside risk, i.e. the risk of bankruptcy, is limited to the invested amount of cash, the potential upside is not. That makes the payoff profile of an investment in high growth stocks look rather option-like. In this way, we follow Schwartz and Moon's work to use a real option framework to value high technology growth companies.

3.2 Model Assumptions

In this model, when simulating the revenue process, we have to make some crucial assumptions as following:

(1) Revenues, growth in revenues and variable costs follow a random process through time.

(2) Revenues, growth in revenues and variable costs are suffered from many unanticipated market factors, thus revenue growth rates and costs are assumed to start at high and decline over time to industry average

(3) There are three sources of uncertainty: the changes in revenues, the expected rate of growth in revenues and the variable costs. We assume only the changes in revenues has a risk premium associated with it.

(4) The unanticipated changes in revenues and variable costs are assumed to converge to a more normal level whereas the unanticipated changes in the expected growth rate are assumed to converge to zero.

(5) We assume the bankruptcy condition of the company as: the company runs out of cash.

(6) If the company survives, at the end of the time horizon, it is worth the discounted value of its cash balance plus M times EBITDA.

(7) To avoid having to define a dividend policy in the model, we assume that the cash flow generated by the company's operations remains in the company and earns the risk free rate of interest.

3.3 Continuous-Time Model

We assume that there are three basic sources of uncertainty in the valuation of company. First, revenues are uncertain. Second, the growth of revenues is uncertain. Third, variable costs are uncertain. In the following sections, we specify how those three variables evolve over time.

(A) Revenues

First we assume company's sales are followed by stochastic process and consider R_t as the instantaneous rate of sales or revenues at time t. The dynamics of these revenues are given by the stochastic differential equation:

$$\frac{dR_t}{R_t} = \mu_t dt + \sigma_t dz_1 \qquad (1)$$

Where μ_t (the drift) is the expected rate of growth in revenues and is assumed to follow a mean-reverting process with a long-term average drift $\bar{\mu}$. σ is volatility in the rate of revenue growth and term z_1 has a standard normal distribution (N(0,1)) and is independent over time. In addition, in order to conform to the high uncertainty of high technology industry and consider the threat of other competitors, it is safe to say that the growth of these companies, although uncertain, will decrease in volatility over time, as will the revenues themselves. In this way, we assume μ will converge stochastically to a sustainable rate of growth for the industry, thus μ_t follows as:

$$d\mu_t = \kappa(\bar{\mu} - \mu_t)\, dt + \eta_t dz_2 \qquad (2)$$

where η_0 is the initial volatility of expected rates of growth in revenues. The mean-reversion coefficient (κ) describes the rate at which the growth is expected to converge to its long-term average. And we define $\ln(2)/\kappa$ as the "half-life" of the expected rate that converges to the long-term rate; any deviation μ is expected to be halved in this time period. Term z_2 follows a Winner process and draws from a normal distribution.

Moreover, we also assume the unanticipated changes in revenues (σ_t)converge to a more normal level and the unanticipated changes in the drift (η_t)converge to zero:

$$d\sigma_t = \kappa_1 (\overline{\sigma} - \sigma_t)\, dt \qquad (3)$$

$$d\eta_t = \kappa_2 (0 - \eta_t)\, dt = -\kappa_2 \eta_t\, dt \qquad (4)$$

where κ_1 is the rate that σ_t converge to $\overline{\sigma}$, κ_2 is the rate that η_t converge to zero.

The unanticipated changes in the growth rate of revenues and the unanticipated changes in its drift may be correlated:

$$dz_1 dz_2 = \rho_{12}\, dt \qquad (5)$$

where z_2 is a random variable that reflects the draw from a normal distribution.

(B) Cost

We assume that the company's cost changes over time. In general, production cost can be decomposed into variable cost and fixed cost. Variable cost is usually a fraction of revenues. Therefore, an equation for cost can be written as:

$$\text{Cost}_t = \alpha_t R_t + F \tag{6}$$

where α is a fraction between 0 and 1 and F represent all fixed cost. The variable costs parameter α_t in the cost function is assumed to be stochastic reflecting the uncertainty about future potential market changes and technological developments. It follows the stochastic differential equation:

$$d\alpha_t = \kappa_3 (\bar{\alpha} - \alpha_t)\, dt + \varphi_t\, dz_3 \tag{7}$$

Where dz_3 has a standard normal distribution (N(0,1)) and is independent over time. The process α_t has the same mode as the growth rate of revenues, μ_t described above. That means the mean-reversion coefficient (κ_3) describes the rate at which the variable costs are expected to converge to its long-term average, and ln(2) κ_3 is the half-life of the deviaitons. The unanticipated changes in variable costs are also assumed to converge to a more normal level:

$$d\varphi_t = \kappa_4 (\bar{\varphi} - \varphi_t)\, dt \tag{8}$$

Also, unanticipated changes in variable costs, and both revenues and growth rates in revenues may also correlated. Therefore,

$$dz_1\, dz_3 = \rho_{13}\, dt \tag{9}$$

$$dz_2\, dz_3 = \rho_{23}\, dt \tag{10}$$

Where z_3 is a random variable that reflects the draw from a normal distribution.

(C) Net after-tax rate of net income

Assume that the corporate tax rate is τ_c and tax will be levied only when there is no loss-carry-forward i.e. there are no losses in previous periods that offset current gains. Also, the company's investment (hardware, software, building, etc.) depreciates at rate Dep. The net after-tax rate of net income (Y_t) to the company is:

$$Y_t = (R_t - Cost_t - Dep_t) (1- \tau_c) \quad (11)$$

Loss-carry-forward (L_t) can be presented as follows:

$$dL_t = - Y_t \, dt \qquad \text{if } L_t > 0 \quad \text{or} \quad (12)$$

$$dL_t = \max(-Y_t \, dt, 0) \qquad \text{if } L_t = 0 \quad (13)$$

(D) Depreciation, Capital expenditures and Property, Plant and Equipment

We assume capital expenditures, $Capx_t$, to be a fraction (CR) of sales, and depreciation is assumed to be a fraction (DR) of the accumulated Property, Plant and Equipment. So they can be presented as follows:

$$Capx_t = CR * R_t \quad (14)$$

$$Dep_t = DR * P_t \quad (15)$$

The accumulated Property, Plant and Equipment at time t, P_t, depends on the rate of capital expenditures for the period, $Capx_t$, and the corresponding rate of depreciation, Dep_t. We can get the increment of Property, Plant and Equipment at time t from capital expenditures at that period deducting depreciation, thus the accumulated Property, Plant and Equipment at time t is the increment at time t plus the accumulated Property, Plant and Equipment of previous period.

$$dP_t = (Capx_t - Dep_t)\, dt \qquad (16)$$

(E) Cash available (X_t)

According to all above, the amount of cash available (X_t) to the company can be presented as:

$$dX_t = (rX_t + Y_t + Dep_t - Capx_t)\, dt \qquad (17)$$

Therefore, the increment of free cash flow at time t is the increment of interests and cash plus the after- tax revenue of this period plus the non-cash part, such as the difference between the depreciation and capital expenditures.

Here, we simplify the model by assuming once the amount of company's available cash reaches zero, it goes bankrupt. In addition, we assume that the cash flow generated by the company's operations remains in the company, earns the risk-free rate of interest, and will be available for distribution to the shareholders at an arbitrary long-term horizon, T, by which time the company will have reverted to a normal company i.e. grows steadily.

(F) The value of the company at time t

After determining all models variables, the objective of the model is to find the value of the company at the current time (V_0). At time T, the value of company includes two components. One is cash available and the other is terminal value for the company (M). Schwartz and Moon (2000, 2001) set the terminal value at the horizon to be a multiple, (e.g., 10 times) of earnings before interest, taxes, depreciation, and amortization (EBITDA), which would make the value less sensitive to the horizon chosen. The payoff from the company from today to T periods ahead in the future, under the risk-neutral valuation, is X_T + M (R_T-$Cost_T$). Kaplan and Ruback (1995) provable empirical evidence that shows that discounted cash flows provide a reliable estimate of the market value. Therefore, the value of the company today until horizon T is:

$$V_0 = E_Q \{[X_T + M (R_T - Cost_T)] e^{-rT}\} \quad (18)$$

Where Term E_Q is the expected value under the risk-neutral measure at a risk-adjusted interest rate, e^{-rt} is the continuously compounded discount factor.

(G) Risk-adjusted stochastic process

The model has three sources of uncertainty. The first is about the changes in revenues and the second is about the expected rate of growth in revenues. Third, there is uncertainty about the variable costs. We assume only the first uncertainty has risk premium associated with it. Under Brennan and Schwartz (1982) there are some simplifying assumptions-- the risk-adjusted processes for the state variables can be obtained from the true processes, and the risk-adjusted process for revenues can be obtained as follow:

$$\frac{dR_t}{R_t} = (\mu_t - \lambda_t \sigma_t)\, dt + \sigma_t dz^*_1 \qquad (19)$$

where the market prices of factor risks, λ is constant and the asterisk indicates that the process is risk adjusted.

(H) Determining stock price

Most analyst and investors more concerned about stock price than whole value of the company. In this way, in order to determine the price of a share of the company, we need to know the capital structure of the company in detail, i.e. how many shares are outstanding, how many shares are likely to be issued to stock option holders, and convertible bondholders. We also need to know how much of the cash flows will be available to the shareholders after coupon (interest) and principal payment to the bondholders. To simplify, we assume company do not pay dividends and stock options and convertibles will be exercised at their maturities. In this way, the cash flows available to shareholders is obtained by subtracting the principal and after-tax coupon payments on the debt and add the payments by option holders at the exercise of the options.

After writing a few more formulas, we can finally express the stock price of the company, S, as a function of the initial variables: revenues, expected growth in revenues, variable costs, loss-carry-forward, cash balances and accumulated Property, Plant and Equipment and time. The value of the stock can be expressed as:

$$S = \text{Function}(R; \mu; \alpha; L; X; P; t) \qquad (20)$$

Applying It^o's Lemma to (20) yields an expression for the company value dynamics:

$$dS = S_R dR + S_\mu d\mu + S_\alpha d\alpha + S_L dL + S_X dX + S_P dP + S_t dt + \frac{1}{2} S_{RR} dR^2 + \frac{1}{2} S_{\mu\mu} d\mu^2 + \frac{1}{2} S_{\alpha\alpha} d\alpha^2 + S_{R\mu} dR\, d\mu + S_{R\alpha} dR\, d\alpha + S_{\mu\alpha} d\mu\, d\alpha \qquad (21)$$

This company value dynamics or we can say the corresponding stock price dynamics is the analog to the geometric Brownian motion in the Black and Scholes model. However, this stochastic differential equation cannot be evaluated straightforward, since the various partial derivatives cannot be obtained analytically. The above problem is too complicated to be solvable by hand. We use simulations in order to find a solution of the entire value of the company and its price per share.

3.4 Discrete version of the model—Modeling paths of stochastic processes

The model developed in the previous section is path-dependent. The cash available at any time, which determines when bankruptcy is triggered, depends on the whole history of past cash flows. Similarly, the loss-carry-forward and the depreciation tax shields, which determine when and how much the company has to pay corporate taxes, are also path-dependent. Due to the path dependency of the model, this differential equation cannot be solved analytically. Solving for the values of the company can be taken into account by using Monte Carlo simulation. In order to realize the simulation, we have to discretize the differential equations of the state variables to transform the path-dependent model into the discrete version.

To implement the simulation, we use the discrete version of the risk-adjusted process to generate paths for the revenues, growth rate of revenues, and variable costs. The paths are as follows:

$$R_{t+\triangle t} = R_t\, e^{\{[\mu_t - \lambda_1 \sigma_t - (\sigma_t^2/2)]\triangle t + \sigma_t \sqrt{\triangle t}\, \varepsilon_1\}} \tag{21}$$

$$\mu_{t+\triangle t} = e^{-k_\triangle t}\ \mu_t + (1- e^{-k_\triangle t}) - \overline{\mu} + \sqrt{\frac{1- e^{-2k_\triangle t}}{2k}}\ \eta_t\ \varepsilon_2 \tag{22}$$

$$\alpha_{t+\triangle t} = e^{-k_\triangle t}\ \alpha_t + (1- e^{-k_\triangle t}) - \overline{\alpha} + \sqrt{\frac{1- e^{-2k_\triangle t}}{2k}}\ \varphi_t\ \varepsilon_3 \tag{23}$$

where

$$\sigma_t = \sigma_0\, e^{-kt} + \overline{\sigma}\,(1- e^{-kt}) \tag{24}$$

$$\eta_t = \eta_0\, e^{-kt} \tag{25}$$

$$\varphi_t = \varphi_0\, e^{-kt} + \overline{\varphi}\,(1- e^{-kt}) \tag{26}$$

Here, equations (24) to (26) are applied to calculate the volatility of revenue, the volatility of the rate of growth rate and the volatility of the variable costs, which are obtained by integrating (3), (4) and (8), with initial values σ_0 η_0 and φ_0. These are exact solutions, not approximations. ε_1 ε_2 ε_3 are standard correlated normal variates.

After obtaining the paths of these stochastic processes, we use a Monte Carlo simulation to calculate the company value which follow the measure of Schwartz and Moon (2000,2001). Simulating many revenue paths over time and calculate and discount the operating cash flows along each path. We also simulate the cash available at any time. We then say that the company goes bankrupt when the cash available touches zero. After proceeding in the same manner n times and averaging all discounting cash flows in horizon allows the determination the value of the company.

3.5 Simplify Parameters

When we write a model, there is always a trade-off between confusing the main points by adding too many details and oversimplifying the equations and rendering the model useless for practical applications. In this model, we need about 20 parameters for implementing, some can observed from financial reports and others can be estimated from data available. For tractability purposes, we thus make a few simplifying assumptions enabling us to reduce the number of parameters.

Here, we have to simplify some parameters as follows:

(1) We assume all mean-reversion coefficients $\kappa_1, \kappa_2, \kappa_3, \kappa_4$ equal κ that means all the mean reversion processes in the model have the same speed of adjustment coefficient.

(2) In order to simplify the model, we assume the unanticipated changes in the growth rate of revenues and the unanticipated changes in its drift are not correlated, i.e. z_1 and z_2 are independent (ρ_{12}=0) and the correlation coefficients between unanticipated changes in variable costs, and both revenues and growth rates in revenues are zero (ρ_{23}=0, ρ_{13}=0). According to the sensitive analysis of Schwartz and Moon (2001), this parameter seems

not so critical to the valuation.

(3) We assume the risk premium in this model is constant.

3.6 Case summary

In order to examine the model described in the previous section, we implement the procedure by valuing a sample company. In view of high-tech company's potential growth opportunity and the value of growth options is an important part in high -tech company's valuation, we chose High Tech Computer (HTC)-- a listed company in Taiwan Stock Exchange—to price it in real options model. HTC engages in the design and manufacture of mobile computing and communication solutions for original equipment manufacturer and original design manufacturer customers worldwide. The company's products include smart phone, personal digital assistant phone, personal digital assistant compact, and smart music phone. Since March 2002 going to public, HTC is continuing experiencing a high growth rate in revenues. Figure 3.1 presents some basic financial data of HTC for the latest 5 years. Business Week's 2006 "InfoTech 100" ranked HTC as the fastest growing companies with 102% sales growth in 2005 and overall ranked 3rd place among all world's information technology companies. HTC seems enjoying Google-like growth. Sales in 2005 had doubled to $2.2 billion, with profits tripling, to $356 million. In 2006 it still has 45% growth in sales with doubled profits. Figure 3.2 shows HTC revenues annually and Figure 3.3 presents the sales growth rate for latest 5 years. We can see sales grew dramatically at beginning and then began to slow and the growth rate of sales starts out very high and then declined which is consistent to our model assumptions. Moreover, just like other high-tech companies, HTC now boasts a 950-person research and development team; the company is all about R&D and innovation.

Reflecting on stock price, HTC is also presenting a quite high stock price compared with other listed companies in Taiwan Stock Exchange. HTC has been listed for only about 5 years, with the rocketed revenues and distinguished R&D ability; its stock price is usually the highest one in Taiwan Stock Exchange. Therefore, we chose HTC as a sample case, trying to apply real options model to rationalize its high stock price.

Table 1. Revenues and costs of HTC (Unit: NTD thousands)

Year	Revenues	COGS	Gross profit	Other expanses	EBITDA
2002	20,644,316	17,041,738	3,602,578	1,484,059	2,118,519
2003	21,821,605	17,938,644	3,882,961	2,063,501	1,819,460
2004	36,397,166	28,493,144	7,904,022	3,593,602	4,310,420
2005	72,768,522	54,758,040	18,010,482	5,170,003	12,840,479
2006	104,816,548	70,779,066	34,037,482	7,485,516	26,551,966

Figure 1. HTC Annually Sales from 2002 to 2006 (Unit: NTD thousands)

Figure 2. HTC annually sales growth rate from 2002 to 2006

3.7 Data and Software

Some of these parameters are easily observed from HTC's annual financial reports; others can be estimated from data available for financial institutions. However, some parameters, requiring the use of judgment, can be determined by management's forecasted estimates or analysts' investigation. Finally, these parameters, which are difficult to observe or estimate, are consulted directly from any previous reference. The data of our study is obtained as follows:

- HTC's past annual financial reports are obtained from Taiwan Securities and Futures Information Center.
- HTC's historical stock prices are acquired from Taiwan Stock Exchange Corp.
- Company's future projections are obtained from the research department of Yuanta Core Pacific Securities- the biggest securities firm in Taiwan.

As previously mentioned, Monte Carlo Simulation will be performed in this model. There is a great deal of software that can perform Monte Carlo Simulation, such as Excel VBA or Matlab. In this dissertation, Matlab's Monte Carlo Simulation is used.

3.8 Estimation of the Parameters

The model described in the previous section requires many parameters for implementing the calculation of company value. In our study we estimate parameters from HTC's historical financial reports of 2002 to 2006 and set 2006 as the basic year.

(1) Revenue dynamics

(A) Initial Revenue R_0

As the starting value for the revenue simulation we take the actual revenues for 2006 of NTD104,816,548,000.

(B) Initial volatility of revenues σ_0

The initial volatility of revenues is the standard deviations of past changes in revenues which is obtained from annually date from 2002 to 2006, to give 39.6%.

(C) Initial expected rate of growth in revenues μ_0

We took the average growth rate in revenues over the past available income statement (2002 to 2006), the initial expected growth rates in revenues is taken to be 54.12%.

Table 2. The mean and deviation of growth rate in revenues of HTC from 2002 to 2006 (unit: NTD)

Year	Revenues	Growth Rate
2002	20,644,316,000	
2003	21,821,605,000	0.057027
2004	36,397,166,000	0.667942
2005	72,768,522,000	0.999291
2006	104,816,548,000	0.440411
Mean		0.541168
Stdev.		0.396019

(D) Initial volatility of expected rates of growth in revenues η_0

To obtain this unobservable and critical parameter, Schwartz and Moon (2001) imply it from the volatility of the stock. Thus, we infer the initial volatility of the expected rate of growth in revenues from the observed stock price volatility of HTC. Figure 3.2 depicts the daily stock price of HTC during 1 April 2002 to 30 June 2007. The annual implied volatility of the stock during this period is 60.46%.

Figure 3. Daily stock price of HTC during 1 April 2002 to 30 June 2007

(E) Long-term rate of growth in revenues $\overline{\mu}$

We can estimate the long-term rate of growth in revenues from other stable companies in this industry. Here we infer from Nokia and Motorola's rate of growth in revenues; Nokia is 5.6%, Motorola is 6.5% annually. [1]Therefore, we take 6% per year as long-term rate of growth in revenues.

(F) Long-term volatility of the rate of growth in revenues $\overline{\sigma}$

Similarly, we picked the above companies' standard deviations of past changes in revenues for the estimation of the long-term volatility of revenues. The standard deviations of past changes in revenues of Nokia is 10.60%, Motorola is 20.06% annually. Therefore, we estimate long-term volatility of the rate of growth in revenues is 15% per year.

[1] The annual financial reports of Nokia and Motorola are acquired from their official website.
http://www.nokia.com/A4399348
http://phx.corporate-ir.net/phoenix.zhtml?c=90829&p=irol-annualreports

Table 3. The mean and deviation of growth rate in revenues of Nokia and Motorola (Unit: Dollars in millions)

Nokia			Motorola		
Year	Revenues	Growth rate	Year	Revenues	Growth rate
2000	30376		2000	32107	
2001	31191	0.02683	2001	26468	-0.17563
2002	30016	-0.03767	2002	23422	-0.11508
2003	28455	-0.05201	2003	23155	-0.01140
2004	29267	0.028536	2004	31323	0.352753
2005	34191	0.168244	2005	36843	0.176228
2006	41121	0.202685	2006	42879	0.163830
Mean		0.056103	Mean		0.065116
Stdev.		0.105981	Stdev.		0.200555

(G) Speed of adjustment for the rate of growth process κ

The mean reversion parameter that determines how fast the initial growth rate of revenues reverts to its long-term rate. It is estimated from assumptions about the half-life of the process to long-term rate of growth in revenues. According to the analysis report by professional financial institution,[2] HTC's strategy is different from other competitors; they focus on innovation and have their own brand. While others are mainly doing ODM which focus on costs down. Recently HTC have launched several new types of smart phone (HTC touch) and as reports predict, in the short run, other competitors will still focus on ODM and these newly-released cell phones with innovative technology will make HTC predominate other competitors for at least 2.5 years. Thus here we assume that

[2] The prediction of HTC is according to the analysis report by Yuanta Research Center, which is the biggest security firm in Taiwan.

the half-life of the deviations of HTC was approximately 2.5 years, and we can get κ is 0.2773. (ln(2)/2.5)

(H) Speed of adjustment for the volatility of revenue process κ_1

To simplify, the speed of adjustment for the volatility of revenue process κ_1 is assumed to be the same with speed of adjustment for the rate of growth process.

(I) Speed of adjustment for the volatility of the rate of growth process κ_2

To simplify, we use κ to replace κ_2.

(J) Market price of risk for the revenue factor λ_1

λ is a unobservable parameter. We assume $\rho_{Rm}/\sigma_m(\mu_m\text{-}r)$ as the market prices of risk for revenue factor.[3] The ρ_{Rm} is the correlation between percentage changes in revenues and the return on the Taiwan Stock Index per quarter (second quarter of 2002 to second quarter of 2007) calculated as –0.2868. The average and standard deviation for the return on the Taiwan Stock Index is 2.23% and 8.25%. And the risk-free interest rate, R, is set as 2.515% according to one-year time deposit rate of Bank of Taiwan. [4]Therefore, λ_1 is 0.01 per quarter, 0.04 annually.

(K) Market price of risk for the expected rate of growth in revenues factor λ_2

Similarly, the market price of risk for the expected rate of growth in the revenues factor can also obtained as above method. But to put it simply, we assume

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[3] We infer from Hull (2006) who mentioned how to calculate the market price of risk. According to CAPM, $\mu_r - R = \beta(\mu_m\text{-}R)$ and $\beta = \rho_{Rm}\ \sigma_R/\sigma_m$. Also we know $\lambda = (\mu_R\text{-}R)/\ \sigma_R$, Therefore we can get $\lambda = \rho_{Rm}(\mu_m\text{-}R)/\ \sigma_m$, where ρ_{Rm} is the correlation between percentage changes in revenues and the return of the market, μ_m and σ_m are the average and standard deviation for the return on the market, R is risk free rate.

[4] Sources: https://ebank.bot.com.tw/default.asp?FrnName=BRate

changes in growth rates to be uncorrelated with the return on the Taiwan Stock Index (ρ =0). Therefore λ_2=0.

(2) Costs

(A) Variable costs α_t

Using HTC's financial data from 2002 to 2006, we regress the total costs on total revenues and find out the relationship between costs and revenues is 0.717, so we define 0.717 as the initial variable cost as a fraction of revenues. The regression shows fairly significant with sig. is 0.00015 and R square is 0.99488. Figure 3.4 presents the results of the regression.

(B) Fixed costs F

We define the operating expense, which includes selling, general, administrative (SG&A), and other expenses; for example, R&D expenses, training expense, and rental expense as fixed costs. From the regression result of total costs and revenues, we assume the constant as the fixed cost and get NTD 4,973,705,340.

Table 4. HTC Costs-Revenues Regression summary

	Coefficients	Standard Error	t –Stat	P-value	Lower 95%	Upper 95%
Intercept	4,973,705,340	1,806,778,913	2.752802	0.070576	-776,276,929	10,723,687,609
X variable 1	0.717255	0.029696	24.153157	0.000156	0.622749	0.811762

Figure 4 Costs V.S. Revenues

(C) Long-term variable costs $\bar{\alpha}$

Here we assume the long-term variable costs will remain at 0.717.

(D) Initial volatility of variable costs φ

Using HTC's financial data from 2002 to 2006, we regress the total costs on total revenues and obtain the standard deviation of 0.03.

(E) Long-term volatility of variable costs $\bar{\varphi}$

We assume in the long run, HTC's volatility of variable costs will decrease to 0.015, the half of the initial volatility of variable costs.

(F) Speed of adjustment for the variable costs process κ_3

To simplify, we use κ to replace κ_3.

(G) Speed of adjustment for the volatility of variable costs process κ_4

To simplify, we use κ to replace κ_4.

(3) Net after-tax rate of net income

(A) Tax rate τ_c

We set tax rate as 25% according to Taiwan's corporate tax code.

(B) Depreciation DR

We found the relationship between the depreciation and the accumulated property, plant and equipment from past 5 years financial data of HTC and get the annual depreciation allowance is about 13% of the accumulated property, plant and equipment of the previous year. Therefore, we can obtain the amount of depreciation at each time by multiply the fraction, 13% to the accumulated property, plant and equipment.

(4) Cash available

(A) Initial cash balance available X_0

We observe the initial cash balance available from HTC's balance sheet at the end of the year 2006, which was NTD34,397,388,000

(B) Initial loss carry-forward L_0

The initial loss carry-forward is also obtained from HTC's balance sheet at the end of the year 2006, which was NTD428,077,000.

(C) Capital expenditures CR

Capital expenditures are assumed to be a fraction of revenues. Observing from HTC's past financial data, we found the fraction is about 1.5%. Therefore, we can obtain the current capital expenditures by multiply 0.015 to current revenues. Also, the initial capital expenditure is unobservable; we adopt analysts' reports of Yuanta research center, which indicate the capital expenditure of HTC in 2007 is NTD 845 millions.

(D) The initial property, Plant and Equipment P_0

The initial property, Plant and Equipment is observed from financial date of the end of the year 2006, which was NTD 2,909,624,000.

(5) The value of company

(A) Time increment for the discrete version of the model Δt

Seasonal effects are obvious in HTC; usually the sales in quarter 4 are much higher than other seasons. To smooth of seasonal effects and to consist with typical annual longer-term analyst projections, we chose time increment for the discrete version to be 1 year.

(B) Horizon for the estimation T

According to Wu (2000), the period that the company can make abnormal earnings is usually 10 years, thus we use this for estimation. We estimate HTC will have 10 years high growth since it was listed. It was listed in 2002, so we infer it still can have abnormal returns in following 5 years.

(C) Risk-free interest rate r

We set risk-free interest rate as 2.515% according to one-year time deposit rate of Bank of Taiwan.

(6) Stock price

(A) Total debt

Observing from HTC's balance sheet at the end of year 2006, the total debt is NTD23,421,959,000. And as balance sheet shows, HTC did not issue convertible bonds and employee stock options.

(B) Preferred stocks

Observing from HTC's balance sheet at the end of year 2006, HTC did not issue preferred stocks.

(C) The number of shares outstanding

Observing from HTC's balance sheet at the end of year 2006, the number of shares outstanding in 2006 was 4,364,192,000 shares.

Finally, we summarize the parameters used in this model as follows:

Table 5. Parameters Used in the Valuation of HTC (unit: NTD thousands)

Parameter	Formula Notation	Program Notation	Description
Revenues			
Initial Revenue	R0	r0	104,816,548
Initial volatility of revenues	$\sigma 0$	sigma0	0.396
Initial expected rate of growth in revenues	$\mu 0$	mu0	0.5412
Initial volatility of expected rates of growth in revenues	$\eta 0$	eta0	0.6046
Long-term rate of growth in revenues	$\bar{\mu}$	muba	0.06
Long-term volatility of the rate of growth in	$\bar{\sigma}$	sigmaba	0.15

revenues			
Speed of adjustment for the rate of growth process	κ	k	0.2773
Market price of risk for the revenue factor	λ_1	Lambda1	0.04
Market price of risk for the expected rate of growth in revenues factor	λ_2	Lambda2	0
Costs			
Variable costs	α_t	Alpha0	0.717
Fixed costs	F	F	4,973,705
Long-term variable costs	$\bar{\alpha}$	alphaba	0.717
Initial volatility of variable costs	φ_0	Phi0	0.03
Long-term volatility of variable costs	$\bar{\varphi}$	phiba	0.015
Net after-tax rate of net income			
Tax rate	τc	tax	0.25
Depreciation	DR	DR	0.13
Cash available			
Initial cash balance available	X_0	X_0	34,397,388
Initial loss carry-forward	L_0	L_0	428,077
Initial Capital expenditure	capt	CR_0	845,000
Capital expenditure	CR	CR	0.015
Accumulated Property, Plant and Equipment	P_0	P_0	2,909,624
The value of company			
Risk-free interest rate	r	r	0.02515
Horizon for the estimation	T	T	5
Time increment for the discrete version of the model	Δt	deltat	1
multiplier	M	M	10
Stock price			
The number of shares outstanding	4,364,192		
Total debt	23,421,319		

Chapter IV Analysis Results

In this chapter, first section we will analyze our simulation results and compare the model price with market price to rationalize our model. Second section will be presented with sensitive analysis, which considers the effect of the level of change of parameters in our model results.

4.1 Results

Using the parameters stated as above, we applied Matlab program to do 10000 times simulations with steps of one year and up to a horizon of 5 years to obtain the value of HTC's. After deducting total debt, the market price is obtained by dividing total outstanding shares. We get different results at different round. The 115 different kinds of simulation results as follows:

Table 6. Simulation Results of HTC

n: Simulation Times

bpp: bankruptcy probability

V0:Value of company

stdV0: Standard errors

Vstock: Simulation stock price

Simulation Round	deltat	T	n	bpp	V0	stdV0	Vstock
1	1	5	10000	0	2.58853E+12	352.63359	593.1281779

2	1	5	10000	0	2.95566E+12	407.0218242	677.2533334
3	1	5	10000	0	1.93884E+12	260.5550062	444.2603389
4	1	5	10000	0	1.89209E+12	248.0553246	433.5495083
5	1	5	10000	0	2.79741E+12	379.7319786	640.9903687
6	1	5	10000	0	2.41191E+12	334.380787	552.6598403
7	1	5	10000	0	2.61441E+12	354.9647596	599.0590331
8	1	5	10000	0	2.54256E+12	355.3577401	582.5968335
9	1	5	10000	0	2.0214E+12	276.5872713	463.1786228
10	1	5	10000	0	2.7963E+12	394.3436777	640.7378824
11	1	5	10000	0	2.64822E+12	360.2166862	606.8055189
12	1	5	10000	0	2.72823E+12	365.1840151	625.139497
13	1	5	10000	0	2.45662E+12	339.0225041	562.9044471
14	1	5	10000	0	1.90057E+12	258.7157363	435.4908213
15	1	5	10000	0	1.93147E+12	265.2652383	442.5728103
16	1	5	10000	0	2.39684E+12	322.9182316	549.206954
17	1	5	10000	0	2.09523E+12	290.5526579	480.0954397
18	1	5	10000	0	2.68231E+12	368.1168861	614.6178322
19	1	5	10000	0	2.707E+12	369.1813562	620.2747331
20	1	5	10000	0	2.75218E+12	387.8712541	630.6271383
21	1	5	10000	0	2.87585E+12	389.2526248	658.9660092
22	1	5	10000	0	2.10338E+12	284.5961264	481.9620766
23	1	5	10000	0	2.48194E+12	346.2201864	568.7048882
24	1	5	10000	0	2.51885E+12	339.6222934	577.1621759
25	1	5	10000	0	2.8649E+12	394.9630447	656.4560714
26	1	5	10000	0	2.83E+12	382.819369	648.4588295
27	1	5	10000	0	1.90992E+12	258.6245754	437.6332725
28	1	5	10000	0	2.27968E+12	313.1006031	522.3601863
29	1	5	10000	0	2.39219E+12	329.3187431	548.1405278
30	1	5	10000	0	2.66322E+12	369.6740636	610.244128
31	1	5	10000	0	2.50636E+12	343.6111211	574.3008534
32	1	5	10000	0	2.90484E+12	397.0826374	665.6067531
33	1	5	10000	0	2.46839E+12	349.3605455	565.6003624
34	1	5	10000	0	2.08607E+12	282.6771724	477.9957661
35	1	5	10000	0	1.98494E+12	266.289472	454.8232069
36	1	5	10000	0	2.47479E+12	338.7790651	567.0671336
37	1	5	10000	0	2.05792E+12	284.6741881	471.5469192

38	1	5	10000	0	2.84746E+12	390.2437673	652.4587019
39	1	5	10000	0	2.6679E+12	370.3100101	611.3158263
40	1	5	10000	0	2.11986E+12	283.6446199	485.7384257
41	1	5	10000	0	2.38885E+12	335.072461	547.374484
42	1	5	10000	0	1.92776E+12	261.1588365	441.7210181
43	1	5	10000	0	2.00483E+12	277.4172292	459.3826402
44	1	5	10000	0	1.8969E+12	262.5493337	434.6508524
45	1	5	10000	0	2.96217E+12	413.6536671	678.7438571
46	1	5	10000	0	1.98952E+12	267.5343992	455.8743699
47	1	5	10000	0	2.03143E+12	273.3381761	465.4776386
48	1	5	10000	0	1.93707E+12	265.5558381	443.8560503
49	1	5	10000	0	1.98288E+12	265.3111487	454.352704
50	1	5	10000	0	1.89631E+12	258.6621538	434.5159072
51	1	5	10000	0	2.661E+12	365.1054109	609.7337805
52	1	5	10000	0	1.9033E+12	266.1689787	436.1177777
53	1	5	10000	0	1.95542E+12	260.1991591	448.0595503
54	1	5	10000	0	2.86497E+12	396.545819	656.471776
55	1	5	10000	0	2.25793E+12	307.3311373	517.3768097
56	1	5	10000	0	2.59897E+12	359.5906531	595.5218192
57	1	5	10000	0	1.89227E+12	254.5256292	433.5893662
58	1	5	10000	0	2.94769E+12	404.3530215	675.4269674
59	1	5	10000	0	2.11176E+12	282.6031353	483.8826221
60	1	5	10000	0	2.08545E+12	287.3927442	477.8542774
61	1	5	10000	0	2.27879E+12	312.7838502	522.1551577
62	1	5	10000	0	2.71195E+12	372.2913425	621.4088958
63	1	5	10000	0	2.6688E+12	367.918684	611.5228583
64	1	5	10000	0	2.49017E+12	337.5972894	570.591555
65	1	5	10000	0	2.57001E+12	345.3859784	588.8859723
66	1	5	10000	0	2.43965E+12	338.4210163	559.0152675
67	1	5	10000	0	1.89343E+12	253.0211649	433.8566928
68	1	5	10000	0	2.88037E+12	395.4232155	660.0008035
69	1	5	10000	0	2.63758E+12	363.4157989	604.3683856
70	1	5	10000	0	2.6787E+12	371.9899292	613.7907901
71	1	5	10000	0	2.36752E+12	326.6078594	542.4886489
72	1	5	10000	0	2.87388E+12	401.9602744	658.5129322
73	1	5	10000	0	2.12824E+12	290.364259	487.6593545

74	1	5	10000	0	2.11932E+12	284.1490364	485.6157943
75	1	5	10000	0	2.89305E+12	404.3785353	662.9072435
76	1	5	10000	0	2.6602E+12	360.5014176	609.5511926
77	1	5	10000	0	2.45272E+12	342.9590962	562.0110534
78	1	5	10000	0	2.40343E+12	325.1407426	550.7148476
79	1	5	10000	0	2.56211E+12	355.8873164	587.0750175
80	1	5	10000	0	2.06288E+12	282.7176823	472.6839068
81	1	5	10000	0	2.2057E+12	298.7109262	505.409194
82	1	5	10000	0	1.95146E+12	264.2939678	447.1531773
83	1	5	10000	0	2.16895E+12	295.5763549	496.9880118
84	1	5	10000	0	2.04684E+12	279.5741739	469.0073417
85	1	5	10000	0	2.07337E+12	280.1452589	475.086136
86	1	5	10000	0	2.51627E+12	341.7746608	576.5714538
87	1	5	10000	0	2.64822E+12	362.4628216	606.8064782
88	1	5	10000	0	2.94443E+12	401.507593	674.6795642
89	1	5	10000	0	2.04576E+12	273.8162063	468.7600387
90	1	5	10000	0	2.86787E+12	387.3393186	657.1369132
91	1	5	10000	0	1.96218E+12	263.3180649	449.6088826
92	1	5	10000	0	2.28085E+12	309.4930177	522.628471
93	1	5	10000	0	1.90519E+12	260.8713737	436.5511034
94	1	5	10000	0	2.77E+12	383.1440869	634.7098198
95	1	5	10000	0	1.96762E+12	264.5799467	450.8548905
96	1	5	10000	0	2.2032E+12	294.4009149	504.8353055
97	1	5	10000	0	2.73253E+12	384.3316086	626.1255879
98	1	5	10000	0	2.13296E+12	296.6392025	488.7404638
99	1	5	10000	0	2.26357E+12	310.4407395	518.6687192
100	1	5	10000	0	2.69327E+12	369.5792962	617.129458
101	1	5	10000	0	2.51648E+12	331.0141752	576.6196909
102	1	5	10000	0	2.53545E+12	352.8226917	580.9660185
103	1	5	10000	0	2.15634E+12	309.2433838	494.097546
104	1	5	10000	0	2.58805E+12	357.496179	593.0186715
105	1	5	10000	0	1.88102E+12	255.3554319	431.0121028
106	1	5	10000	0	2.6259E+12	357.7194705	601.6925218
107	1	5	10000	0	2.68148E+12	376.9759351	614.4285279
108	1	5	10000	0	2.02436E+12	275.6997874	463.855805
109	1	5	10000	0	2.1768E+12	282.9642107	498.7854745

110	1	5	10000	0	2.42762E+12	338.7765057	556.2591837
111	1	5	10000	0	2.06919E+12	282.2572414	474.1289538
112	1	5	10000	0	2.56513E+12	350.6855673	587.7668642
113	1	5	10000	0	2.87891E+12	403.7613279	659.66668
114	1	5	10000	0	2.18638E+12	300.9957764	500.9817989
115	1	5	10000	0	2.72018E+12	366.8469513	623.2962465

As we can see from above table, there are no bankruptcies at each round, namely, the bankruptcy probability equals to zero. That is to say, according to the condition we set, it seems HTC does not have the bankrupt crisis. This also provides us an alternative method to value the credit of company.

Although the bankruptcy probability at each round presents consistent result, the company's value has a little difference at each round; however it seems the difference is in an acceptable range. The simulation results show the average value of HTC is NTD 2,385,904 millions, and the stock price of HTC is 546.70. Since the data we collected for parameters estimation up to the end of year 2006, this model price should reflect the available information until year 2006. In order to realize the rationality of the simulation results, we show the distribution of simulation stock price and HTC's market price in first quarter of 2007 in Figure 5. And in Figure 6, we compare the average of simulation price and HTC's the market price in first quarter of 2007.

Figure 5. The Simulation Price and the Market Price of HTC

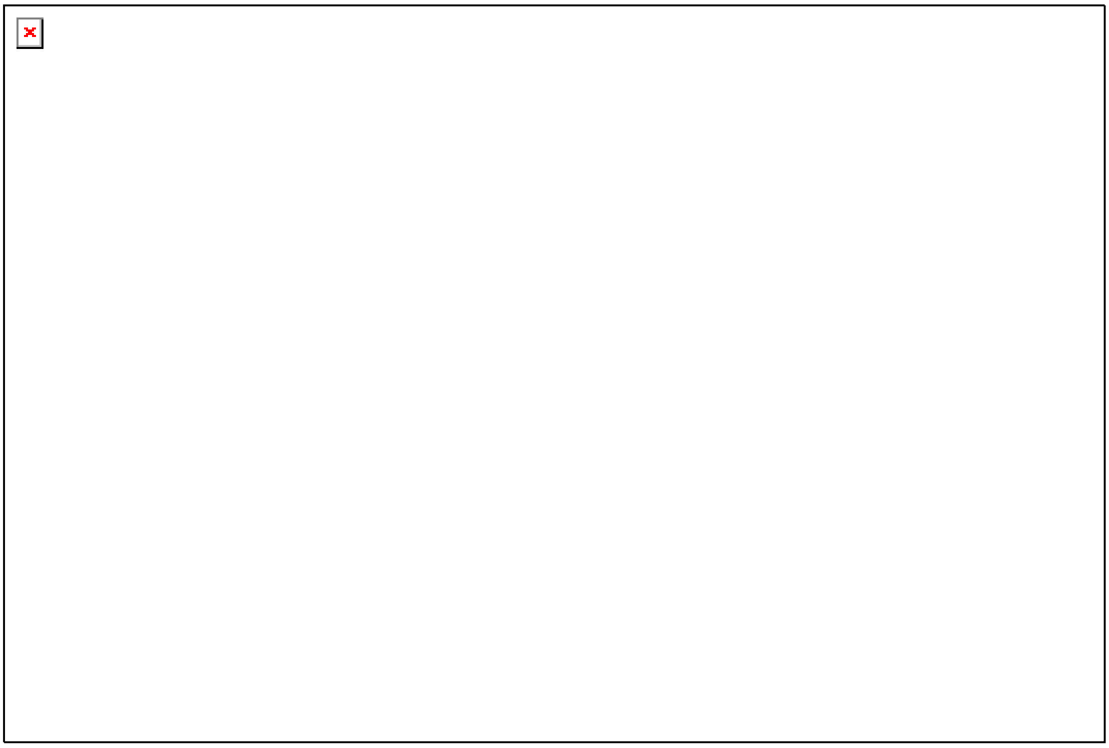
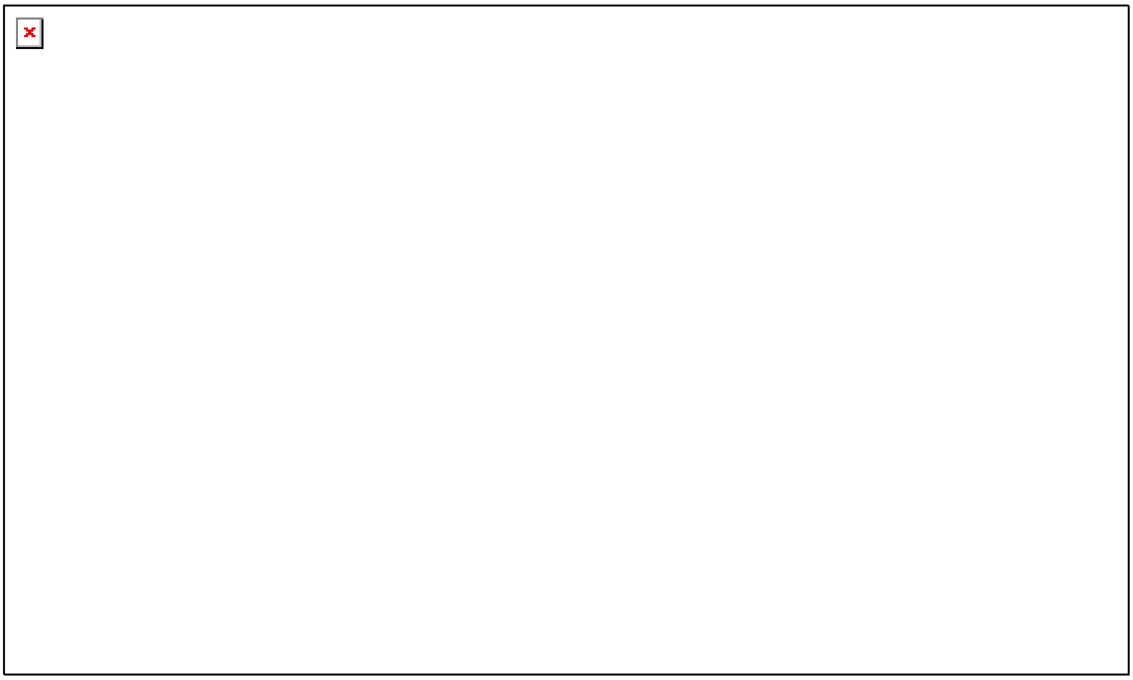


Figure 6. The Average of Simulation Price and the Market Price of HTC



Comparing with the market price, we can see the simulation price is higher than market price. The actual stock price of HTC in the end of Jan. 2007 is 487.5, 484.5 in the end of Feb. and 510 in the end of Mar., and we can find that the market value decline in the beginning and then break through the model average price 546.70, finally it tends to go up to the model price. It seems our model with real options method can be applied to value HTC's stock price and to be an alternative method in valuation of high-tech companies.

The difference between traditional valuation method and real options method is the latter method considers the value of options which is neglected by traditional method. Thus we can also obtain the Net Present Value of the cash flows using exactly the same data as in the previous analysis by setting all the volatilities in the model to zero (The program codes is shown in Appendix 2). The result shows the company's stock price is 479.5815 and this price is less than the real option methods' value by 67.1187 (See the figure 5 and 6). Therefore, we may interpret this difference of 67.1187 is the amount that investors are willing to pay for HTC's future potential growth.

4.2 Sensitivity analysis

In this section we perform some sensitivity analysis on the more controversial parameters of the model to find out the most critical parameters. We obtain the HTC values by changing 10%, 20%, 30%, 40%, and 50% for the indicated parameter while leaving all the other parameters the same as the base valuation. It is used to test the influence of the key parameters in the model. Thus, we get the results as shown in the table 7.

Table 7. Sensitivity Analysis

R_0	Model Price	Volatile Rate	σ_0	Model Price	Volatile Rate
52408274000	543.9491231	-0.50321	0.198	546.293523	-0.074387517
62889928800	540.3260226	-1.16594	0.2376	539.653958	-1.28886759
73371583600	534.2493238	-2.27746	0.2772	540.432128	-1.146528275
83853238400	538.5844077	-1.48451	0.3168	544.566466	-0.390293314
94334893200	545.1435895	-0.28473	0.3564	537.361391	-1.708214026
1.04817E+11	**546.7002**	**0**	**0.396**	**546.7002**	**0**
1.15298E+11	535.2770025	-2.08948	0.4356	546.634766	-0.01196896
1.2578E+11	535.0862425	-2.12437	0.4752	548.459547	0.321811938
1.36262E+11	549.4355308	0.500335	0.5148	538.509817	-1.49814885
1.46743E+11	542.5463001	-0.75981	0.5544	543.978389	-0.497861642
1.57225E+11	543.2541868	-0.63033	0.594	531.566502	-2.768189622
μ_0	Model Price	Volatile Rate	η_0	Model Price	Volatile Rate
0.2706	529.2202335	-3.19736	0.3023	541.266	-0.99399
0.32472	544.9665956	-0.3171	0.36276	547.5997	0.164534
0.37884	535.3698222	-2.0725	0.42322	545.6629	-0.18973
0.43296	535.0567507	-2.12977	0.48368	536.0423	-1.9495
0.48708	556.2850453	1.753218	0.54414	549.7953	0.566134
0.5412	**546.7002**	**0**	**0.6046**	**546.7002**	**0**
0.59532	537.5926439	-1.66591	0.66506	538.5444	-1.49182
0.64944	536.9872038	-1.77666	0.72552	540.5193	-1.13058
0.70356	548.7924254	0.382701	0.78598	533.2953	-2.45197
0.75768	541.1396392	-1.01711	0.84644	541.099	-1.02455
0.8118	543.8820961	-0.51548	0.9069	560.0243	2.437189
k	Model Value	Volatile Rate	a_0	Model Value	Volatile Rate
0.13865	558.1873	2.101166	0.3585	547.5323	0.1522
0.16638	549.4097	0.495617	0.4302	550.6889	0.729596
0.19411	533.4026	-2.43234	0.5019	541.1051	-1.02343
0.22184	537.2619	-1.72641	0.5736	547.7557	0.193062
0.24957	556.3743	1.769548	0.6453	540.0828	-1.21043
0.2773	**546.7002**	**0**	**0.717**	**546.7002**	**0**
0.30503	546.873	0.031609	0.7887	534.3754	-2.2544

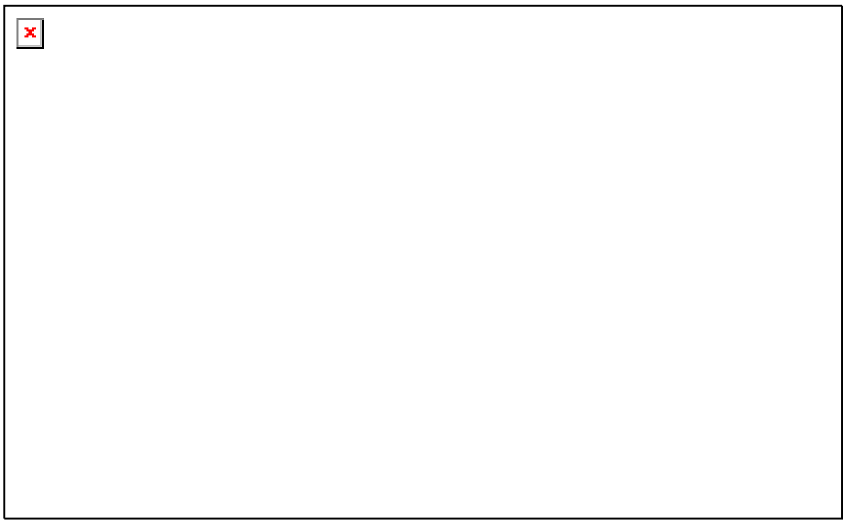
0.33276	536.9919	-1.77579	0.8604	544.476	-0.40683
0.36049	544.5354	-0.39598	0.9321	544.384	-0.42367
0.38822	544.3848	-0.42353	1.0038	533.4873	-2.41684
0.41595	544.6899	-0.36771	1.0755	554.1649	1.365404
φ_0	Model Value	Volatile Rate	*DR*	Model Value	Volatile Rate
0.015	546.3511	-0.06385	0.065	545.3837	-0.24082
0.018	539.2095	-1.37016	0.078	546.0752	-0.11431
0.021	541.6048	-0.93203	0.091	554.0739	1.348762
0.024	546.016	-0.12516	0.104	547.2125	0.09371
0.027	534.1751	-2.29103	0.117	557.011	1.886014
0.03	**546.7002**	**0**	**0.13**	**546.7002**	**0**
0.033	541.467	-0.95724	0.143	558.0435	2.074862
0.036	548.7806	0.380538	0.156	535.6122	-2.02816
0.039	535.4554	-2.05685	0.169	556.2916	1.754409
0.042	542.3427	-0.79706	0.182	537.6167	-1.66152
0.045	543.2425	-0.63247	0.195	531.0667	-2.85961
X_0	Model Value	Volatile Rate	*CR*	Model Value	Volatile Rate
1.72E+10	538.3397	-1.52926	0.0075	548.5915	0.345951
2.06E+10	547.471	0.140987	0.009	543.7931	-0.53175
2.41E+10	550.1166	0.624906	0.0105	534.1782	-2.29047
2.75E+10	542.9589	-0.68435	0.012	547.0452	0.063113
3.1E+10	547.4126	0.130314	0.0135	549.3671	0.487811
3.44E+10	**546.7002**	**0**	**0.015**	**546.7002**	**0**
3.78E+10	546.6368	-0.01161	0.0165	538.4306	-1.51263
4.13E+10	550.806	0.751008	0.018	557.8648	2.042177
4.47E+10	545.0083	-0.30948	0.0195	544.9996	-0.31106
4.82E+10	550.6779	0.727582	0.021	529.1547	-3.20935
5.16E+10	540.1367	-1.20056	0.0225	543.0266	-0.67197
P_0	Model Value	Volatile Rate	*T*	Model Value	Volatile Rate
1.45E+09	554.1948	1.370877	2.5	510.0667	-6.70084
1.75E+09	545.6708	-0.1883	3	537.992	-1.59286
2.04E+09	550.5663	0.707172	3.5	540.4979	-1.13451
2.33E+09	549.7042	0.54948	4	546.7883	0.01611
2.62E+09	546.9265	0.041398	4.5	554.5119	1.428874

2.91E+09	**546.7002**	**0**	**5**	**546.7002**	**0**
3.2E+09	539.5918	-1.30023	5.5	530.0534	-3.04497
3.49E+09	544.4748	-0.40707	6	542.6954	-0.73255
3.78E+09	535.4574	-2.05648	6.5	543.2945	-0.62296
4.07E+09	547.4661	0.140088	7	528.8193	-3.2707
4.36E+09	535.6036	-2.02974	7.5	539.7912	-1.26377

From Table 7, we can find five parameters that have a significant effect on the value of the stock. They are initial expected rate of growth in revenues (μ_0), the speed of adjustment for the rate of growth process (k), variable costs (a_0),the horizon for the estimation (T) and The property, plant and equipment (P_0) (Figure7-11), but the others does not have significant effect (Figure.12-15). We present the detail analysis as follows.

(1) The initial expected rate of growth in revenues μ_0

The initial expected rate of growth in revenues μ_0 will influence the company's value via revenues R_t. From figure 7, we can see that the total trend is upward, it means that along with the increase of the μ_0, the model value of the stock become higher and higher.



(2) The speed of adjustment for the rate of growth process k

The speed of adjustment for the rate of growth process k, from figure 8, we can see that the total trend is downward, it means that along with the increase of the k, and the model value of the stock become lower and lower. This result is reasonable. When the speed of adjustment for the rate of growth process k is getting slow, it means the length of time that the company ahead of other companies becomes longer, and thus has positive contribution to the value of company. For example, when k decreases from 0.2773 to 0.24957, the company's price goes up from 546.70 to 556.37. Therefore, k is a critical parameter to the value of company. We can say to have a higher stock value, companies have to keep and enhance their competitive advantages, such us critical technology.

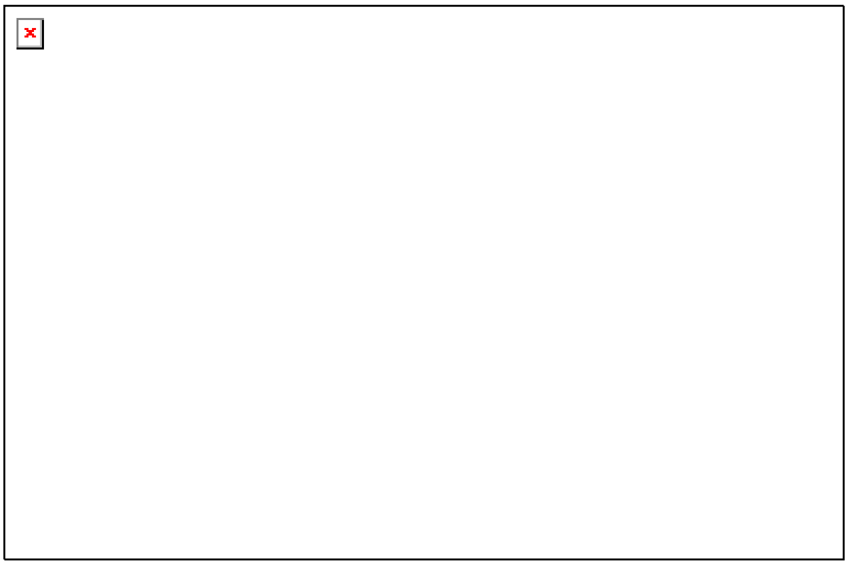
(3) The variable costs a_0

The variable costs also present with the same trend as previous parameter (See the Figure 9). The correlation between variable costs and the value of company is negative. This result is not surprising, because costs have direct effect on the margin and thus influence the value of company. For example, when a_0 goes up from 0.717 to

0.7887, the stock price goes down from 546.7 to 534.37.

(4) The horizon for the estimation T

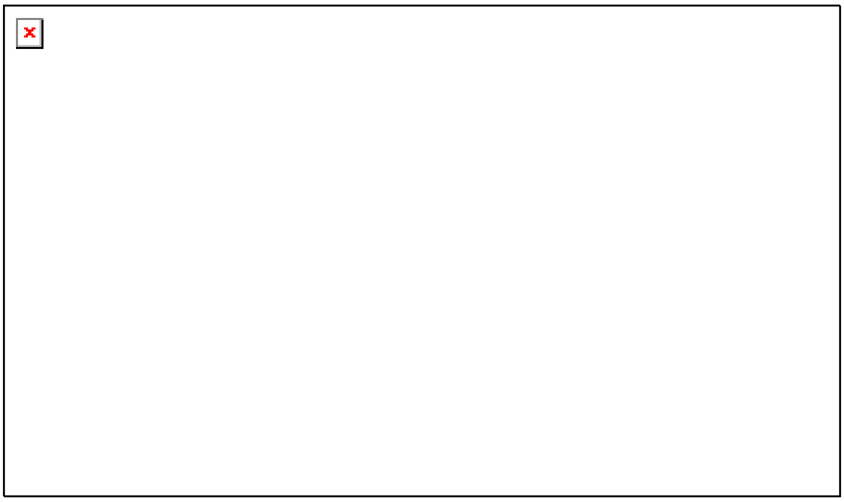
The horizon for the estimation T is also an important parameter. From figure 10, we can see that the total trend is upward, it means that along with the increase of the T, and the model value of the stock become higher and higher. If the T is higher, it means the time that company earns abnormal profits is longer. So, the value of the company will grow, and the price of the stock is also become higher.

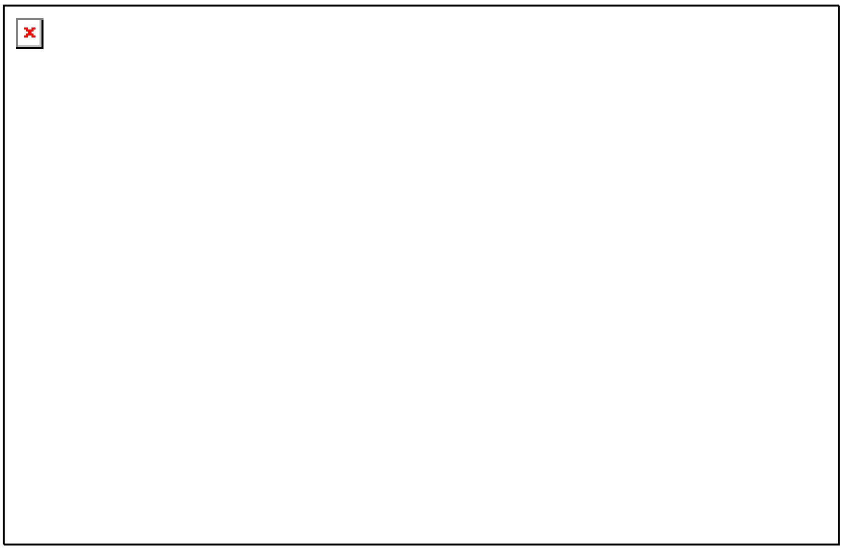


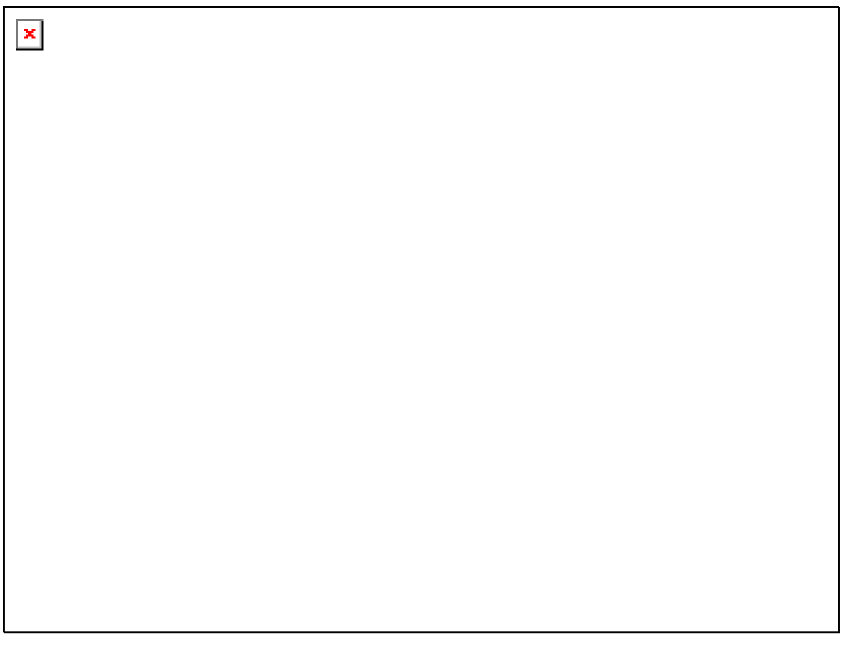
(5) The property, plant and equipment P_0

From figure 7, we can see that along with the increase of the P_0, the simulation value of the stock become smaller and smaller. Because if the Property, Plant and Equipment of the company is larger, and the depreciation will become higher. So, the value of the company will depreciate, the stock value will become lower.

The effects of other parameters are not obvious, namely which are not important for this model. In order to show this result, we also plot some figures of these parameters' situation (Figure 12-15).







In a word, from the sensitivity of these parameters, we get five key factors. Although the results are affected by simulation, we get different model values at different simulation times. This causes directly the trend of these five factors is not consistent, but we can also find the general trend as mentioned above.

Chapter V Conclusion

This chapter aims at summarizing the findings and drawing a conclusion of this research. First, we summarize the findings and then the advantage and limitations of this research will be addressed. Second, recommendation toward future studies will be presented.

5.1 Summary of the Study

Since high-tech industries are characterized with highly uncertainty and have potential growth due to their capabilities of R&D, the valuation of high-tech companies has never been an easy thing. In this paper, we apply a simple model with real options concept to value a high-tech company-HTC and price its stock price that is based fundamentally on assumptions about the expected growth rate of revenues and on expectations about the cost structure of the company. We use the company's financial data until the end of 2006 to estimate parameters and adopt Monte Carlo simulations to obtain the reasonable stock price; the average stock price is 546.70. Verifying with HTC's stock price of first quarter of 2007, the model stock price tend to go up and close to the market price at the end of first quarter. Thus, it seems this model can produce a reasonable result for valuation purpose.

In addition, by the means of sensitive analysis, we can see there are five parameters which are critical to drive HTC's valuation. They are: initial expected rate of growth in revenues (μ_0), the speed of adjustment for the rate of growth process (k), variable costs (a_0),the horizon for the estimation (T) and The property, plant and equipment

(P_0). Also, we can infer some important findings as follows:

1. The initial expected rate of growth in revenues

   The uncertainty of the expected revenue growth rate is usually interpreted as a chance, not as risk. For relatively mature companies, value decreases with volatility, which is consistent with traditional DCF methods. However, for high-tech companies with high-growth and future perspectives but full of uncertainties, value increases with higher volatility of revenues; this is due to the fact that increasing volatility is interpreted as a chance. Thus the expected rate of growth in revenues can have a great deal of influence on high-tech companies' value which presents a positive relationship with companies' value.

2. The speed of adjustment for the rate of growth process

   For high-tech companies, the core competency is the capability of R&D. Because the high-tech industry's environment is changing fast, other competitors may develop new technology and bypass the original advantageous company in a short time. In this way, in order to strengthen companies' advantage, companies have to slow the speed of adjustment for the rate of growth process by holding critical technology or improving management skills and then the period that they ahead of other competitors can get longer. When the speed of adjustment for the rate of growth process becomes slow, the value of company becomes higher.

3. Variable costs

   Because the costs have direct influence on the margin and thus affect the value of companies, it is suggested that high-tech companies should keep watch for the expenses of R&D.

4. The horizon for the estimation

   This horizon means the period of time that high-growth companies earn abnormal return. Thus it is obvious that the longer of this period, the higher of the value of company.

5.2 The Usefulness of the Model

The study is seen to provide a systematic way of thinking about the value drivers of a high-tech company and directs attention to the parameters that are most important in the valuation. Those parameters' expectation are likely to change when different economic environments, potential improvements, and so forth. Also, the model deals explicitly with asymmetric payoffs of high-tech companies in early stage, the large uncertainty in sales and sales growth and cost uncertainty, which seems to be a more appropriate approach for describing the features of high-tech companies. Finally, the model yields several observable outputs: price and volatility that can be taken as a reference for market participants when investing.

Another advantage of this model is it combines the traditional DCF techniques and also considers the real options approach under uncertainty which is flexible to apply to the valuation of company at the mature stage. After removing the volatilities in the model, company's valuation can be obtained by discounting cash flows with the risk-adjusted discount rate. In addition, we can determine the bankrupt conditions to speculate this company's probability of bankrupt to have some understanding of company's credit.

Finally, because Monte Carlo simulation can deal with more complicated model with path-dependent variables, we can incorporate more various stochastic variables into model and making the results more realistic. The advantage of simulation method helps us expand the model and make it more applicable when executing.

5.3 Limitations of the Study

One drawback of the methodology, however, is the large number of parameters that must be estimated prior to the implementation of the Monte Carlo simulation, which highlight a tradeoff present in valuation models, precision and insight gained from detail versus additional model error. The usefulness of option pricing models relies greatly on the correctness of the models' inputs. However, it is difficult to determine these inputs to the evaluation model. Also, we assume normal distributions of the stochastic variables without testing the statistical hypothesis. It could also make an influence to the model to yield an appropriate value.

Another limitation is, although this model provides an alternative method to assess the value of company, in the real world, the valuation of a high-tech company needs more discussion on the external environment such us the interaction of competitors; some are difficult to quantify in a model design. Therefore, any model is just an attempt to simplify reality, which is always a great deal more complex, random, and unpredictable elements could affect the stock price. A model maybe can be constructed to explain nearly 100 percent of what happened in the past. However, the future is always unpredictable that create outliers, it is hardly to model all of the variables into models.

5.4 Further Research

Here we suggest several aspects for further research:

1. In this paper, we only focus on one company of high technology industry with high-level R&D. The further research can acquire more companies in different industry with same features to test the appropriateness of the model. Further, to find out and compare the critical parameters that affect the value of stocks in different industries.

2. The real options model used in this paper can be expanded in further research. For example, introducing more stochastic variables into our model, such us the interest rate. Also, we can consider the company's dividend policy and relax the bankrupt condition to allow the probability of future financing.

3. The value of parameters can have huge impact on the results, thus parameters estimation can be treated as the very important part of the research. Because we choose those parameters based on historical financial reports, they may not display the future condition. To elevate the accuracy of estimation, a more thorough analysis could use cross sectional data from a larger sample of companies to estimate the parameters.

4. Company's value and stock price may be affected by many other factors, which this model did not consider. It is suggested that future study can extend to incorporate more external factors such us the competitors' reactions and threat of potential competitors.

Reference

[1] Amram, M., and Kulatilaka, N., (1999), *Real Options - Managing Strategic Investment in an Uncertain World,* Harvard Business School Press, Boston, MA.

[2] Arrow K.J., and Fisher A. C., (1974) "Environmental Preservation, Uncertainty, and Irreversibility," *Quarterly Journal of Economics*, 88, 312-319

[3] Bares, D. S., (1996) "Jumps and stochastic volatility: exchange rate process implicit in Deutsche mark options," *Review of Financial Studies*, 9, 69-107.

[4] Berk, J.B., Green, R.C., and Naik V., (1999) "Optimal investment, growth options, and security returns," *Journal of Finance*, *54* (5), 1553-1608.

[5] Black, F., and Scholes, M., (1973) "The Pricing of Options and Corporate Liabilities" *Journal of Political Economics,* 81, 637-659.

[6] Bowman, E.H., and Moskowitz, G.T., (2001) "Real Options Analysis and Strategic Decision Making," *Organization Science*, 12 (6), 772-777

[7] Brennan M., and Schwartz E., (1982) "An equilibrium model of bond pricing and a test of market efficiency." *Journal of Financial and Quantitative Analysis*, 17,301-329.

[8] Copeland, T., Koller T., Murrin J., (2000), *Valuation, Measuring and Managing the Value of Companies, 3rd edition*. McKinsey & Company, Inc.

[9] Copeland, T., and Antikarov, V., (2001), *Real Options: A Practitioner's Guide,* Texere, New York.

[10] Constantinides, G., (1978) "Market risk adjustment in project valuation," *Journal of Finance*, 33, (2) 603-616.

[11] Cox, J.C., Ross, R.A. and Rubinstein, M., (1979) "Option Pricing: A Simplified Approach," *Journal of Financial Economics*, 7, 229-263

[12] Cox, C., Ingersoll, J. E., and Ross S. A., (1985) "An intertemporal general equilibrium model of asset prices," *Econometrica*, 53, 363-384.

[13] Dixit, A.K. and Pindyck, R.S., (1994), *Investment under Uncertainty*, Princeton University Press, US.

[14] Dixit, A.K. and Pindyck, R.S., (1995) “The options approach to capital Investments,” *Harvard Business Review*, 73, 105-115.

[15] Durand, D. (1957) “Growth stocks and the St. Petersburg paradox,” *Journal of Finance*, 12, 348-363.

[16] Gordon, M. (1962), *The Investment, Financing, and Valuation of the Corporation*, Irwin, Homewood Ill.

[17] Hayes, R. and Garvin D., (1982) “Managing as if Tomorrow Mattered,” *Harvard Business Review,* 60, 71-79.

[18] Hull, J. C., and White A., (1987) “The pricing of options on assets with stochastic volatilities,” *Journal of Finance*, 42, 281-300.

[19] Hull, J. C., and White A., (1988) “An overview of contingent claims pricing,” *Canadian Journal of Administrative Sciences*, 55-61.

[20] Hull, J.C., (2006), *Options, Futures and Other Derivatives*, *6th ed*. Prentice-Hall, Upper Saddle River, NJ.

[21] Kaplan, S. N. and Ruback, R. S., (1995) “The valuation of cash flow forecasts: an empirical analysis,” *The Journal of Finance*, 4, 1059-1093.

[22] Keith J. Leslie and Max P. Michaels (1997) “The real power of real options” *The McKINSEY Quarterly*, 1, 4-22.

[23] Kester, C., (1984) “Today’s Option for Tomorrow’s Growth.” *Harvard Business Review*, 62 (March/April), 153-160.

[24] Lander, M., and Pinches , E., (1998) “Challenges to the Practical Implementation of Modeling and Valuing Real Options, ”*The Quarterly review of Economics and Finance* 38 (special Issue), 537-567.

[25] Malkiel, B.G., (1963) "Equity yields, growth, and the structure of share prices," *American Economic Review*, 53 (5), 1004- 1031.

[26] Mao, J.C., (1966) "The valuation of growth stocks: the investment opportunity approach," *Journal of Finance*, 21 (1), 95-102.

[27] McDonald, R., and Siegel, D., (1985) "Investment and the valuation of firms when there is an option to shut down," *International Economic Review*, 26 (2), 331-349.

[28] Miller, M. and Modigliani, F., (1961) "Dividend policy, growth, and the valuation of shares, "*Journal of Business*, 34 (4), 441- 433.

[29] Mun, J. (2002), *Real Option Analysis: Tools and Techniques for Valuing Strategic Investments and Decisions,* John Wiley & Sons, U.S.A.

[30] Myers, S. C., (1977) "Determinants of corporate borrowing," *Journal of Financial Economics*, 5 (2), 147-176.

[31] Myers S.C., (1984)"The capital structure puzzle," *Journal of Finance* ,39**,** 575-592.

[32] Myers, C., Majluf, S., (1984) "Corporate Financing and Investment Decisions When Firms Have Information That Investors Do Not Have," *Journal of Financial Economics*, 187-221.

[33] 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

[34] Porter, M. E., (1998) *The Competitive Advantage of Nations*, The Free Press, New York.

[35] Schwartz, E. S., and Moon, M., (2000) "Rational pricing of Internet companies," *Financial Analyst Journal*, 56 (3), 62- 75.

[36] Schwartz, E. S., and Moon, M., (2001) "Rational pricing of Internet companies revisited," *The Financial Review*, 36, 7-26

[37] Scott, L. O., (1987) “Option pricing when the variance changes randomly: theory, estimation, and an application,” *Journal of Financial and Quantitative Analysis*, 22, 419-438.

[38] Scott, L. O., (1997) “Pricing stock options in a jump -diffusion model with stochastic volatility and interest rates: application of Fourier inversion method,” *Mathematical Finance*, 7, 413-426.

[39] Sick,G., (1995) “Real Options.” *Handbooks in Operations Research and Management Science-Finance 9*, Ch.21, North-Holland

[40] Smit, Han T. J., and Trigeorgis, L., (2004), *Strategic Investment：Real Options and Games,* Princeton University Press, Princeton, N.J.

[41] Trigeorgis, L., (1993) “Real Option and Interactions with Financial Flexibility,” *Financial Management*, 22 (3), 65-77.

[42] Trigeorgis, L., (1996), *Real Options-Managerial Flexibility and Strategy in Resource Allocation*, Massachusetts Institute of Technology Press, U.S.

[43] Trigeorgis, L., and Mason, S. P., (1987) “Valuing managerial flexibility,” *Midland Corporate Finance Journal*, 14-21.

[44] Weisbrad, B. A., (1964) “Collective-Consumption Services of Individual-Consumption Goods.” *Quarterly Journal of Economics*, 78, 471-477

[45] Williams, J.B. (1938), *The Theory of Investment Value*, Cambridge, MA: Harvard.

[46] Wu,C.M., (2001), *Business Valuation: Cases Studies Analysis*, Zhi-Sheng Press, Taiwan,

Websites:

Business Week
http://www.businessweek.com/it100/2006/index.html

Taiwan Securities and Futures Information Center
http://www.sfi.org.tw/english/

Taiwan Stock Exchange Corp.
http://www.tse.com.tw/en/

Appendix 1 Matlab Programming Codes for HTC Value

function result0=montecarlo1(n)
Instruction
This program use Monte Carlo methods to calculate the company value V0
n: Simulation times

1.Parameters

1.1 Revenues

```
R0=104816548000; % Initial Revenue
sigma0=0.396; % Initial volatility of revenues
mu0=0.5412; % Initial expected rate of growth in revenues
eta0=0.6046; % Initial volatility of expected rates of growth in revenues
muba=0.06; % Long-term rate of growth in revenues
sigmaba=0.15; % Long-term volatility of the rate of growth in revenues
k=0.2773; % Speed of adjustment for the rate of growth process
lambda1=0.04; % Market price of risk for the revenue factor
lambda2=0; % Market price of risk for the expected rate of growth in revenues
              factor
```

1.2 Costs

```
alpha0=0.717; % Variable costs
F=4973705340; % Fixed costs
alphaba=0.717; % Long-term variable costs
phi0=0.03; % Initial volatility of variable costs
phiba=0.015; % Long-term volatility of variable costs
```

1.3 Net after-tax rate of net income

```
tauc=0.25; % Tax rate
DR=0.13; % Depreciation
```

1.4 Cash available

```
X0=34397388000; % Initial cash balance available
L0=428077000; % Initial loss carry-forward
CR0=845000000; % Initial Capital expenditure
CR=0.015; % Capital expenditure
P0=2909624000; % Accumulated Property, Plant and Equipment
```

1.5 The value of company

```
r=0.02515; % Risk-free interest rate
T=5; % Horizon for the estimation
deltat=1; % Time increment for the discrete version of the model
M=10; % multiplier
```

1.6 Stock price

```
debt=23421959000;% Total debt
stocknumcb=0; % stock numbers converted by convertible bonds;
stocknumout=4364192000; % The number of shares outstanding
newstocknum=stocknumcb+stocknumout;% the total stock numbers
```

2.Calculation

2.1 initial data

```
t=[0:deltat:T];
lt=length(t);
etat=eta0;
sigmat=sigma0;
mut=mu0.*ones(1,n);
Rt=R0.*ones(1,n);
phit=phi0;
alphat=alpha0.*ones(1,n);
costt=zeros(1,n);
Pt=P0.*ones(1,n);
Capxt=CR.*Rt;
Dept=DR.*Pt;
Yt=(Rt-costt-Dept).*(1-tauc);
Xt=X0.*ones(1,n);
bp(1,:)=zeros(1,n);%bankruptcy probablity
```

2.2 recurrence

```
for i=2:lt
% Calculate Rt
etat(i)=eta0.*exp(-k.*t(i));
```

```
    sigmat(i)=sigma0.*exp(-k.*t(i))+sigmaba.*(1-exp(-k.*t(i)));
    epsilon2=randn(1,n);
    mut(i,:)=mut(i-1,:).*exp(-k.*deltat)+muba.*(1-exp(-k.*deltat))+…
            etat(i-1).*sqrt((1-exp(-2.*k.*deltat))./(2.*k)).*epsilon2;
    epsilon1=randn(1,n);
    Rt(i,:)=Rt(i-1,:).*exp((mut(i-1)-lambda1.*sigmat(i-1)-0.5.*(sigmat(i-1).^2)).*
          deltat+…sigmat(i-1).*sqrt(deltat).*epsilon1);

% Calculate costt
    phit(i)=phi0.*exp(-k.*t(i))+phiba.*(1-exp(-k.*t(i)));
    epsilon3=randn(1,n);
    alphat(i,:)=alphat(i-1,:).*exp(-k.*deltat)+alphaba.*(1-exp(-k.*deltat))+...
              phit(i-1).*sqrt((1-exp(-2.*k.*deltat))./(2.*k)).*epsilon3;
    costt(i,:)=alphat(i,:).*Rt(i,:)+F;

% Calculate Xt
    Pt(i,:)=CR.*Rt(i-1,:).*deltat+(1-DR).*Pt(i-1,:).*deltat;
    Capxt(i,:)=CR.*Rt(i,:);
    Dept(i,:)=DR.*Pt(i,:);
    Yt(i,:)=(Rt(i,:)-costt(i,:)-Dept(i,:)).*(1-tauc);
    Xt0=Xt(i-1,:).*(1+r).*deltat+(Yt(i-1,:)+(Dept(i-1,:)-Capxt(i-1,:))).*deltat;
    bp(i,:)=Xt0<=0;%record the bankruptcy times
    Xt0(Xt0<=0)=0;
    Xt(i,:)=Xt0;
end
```

3.Calculate the company value V0

```
V0T=Xt(lt,:)+M.*(Rt(lt,:)-costt(lt,:)).*exp(-r.*T);
V0Tnew=V0T(:,all(bp<=0));%the have not bankruptcy of company value of
simulation
bpp=sum(~all(bp<=0)).*100./n;%bankruptcy probability
V0=mean(V0Tnew);%Company value
stdV0=std(V0Tnew);%standard errors
vstock=(V0-debt)./newstocknum;%stock price
stdvstock=(stdV0-debt)./newstocknum;%standard errors
result0= [deltat,T,n,bpp,V0,stdvstock,vstock]
```

Appendix 2 Matlab Programming Codes for HTC NPV

```
function result0=NPV(rs)
------------------------------------------------------------------------
Instruction
------------------------------------------------------------------------
This program use to calculate   the Net Present Value of the cash flows of
the company value V0
rs: the risk-adjusted discount rate
------------------------------------------------------------------------
1.Parameters
------------------------------------------------------------------------

1.1 Revenues
    R0=104816548000; % Initial Revenue
    mu0=0.5412; % Initial expected rate of growth in revenues
    muba=0.06; % Long-term rate of growth in revenues
    k=0.2773; % Speed of adjustment for the rate of growth process

1.2 Costs
    alpha0=0.717; % Variable costs
    F=4973705340; % Fixed costs
    alphaba=0.717; % Long-term variable costs

1.3 Net after-tax rate of net income
    tauc=0.25; % Tax rate
    DR=0.13; % Depreciation

1.4 Cash available
    X0=34397388000; % Initial cash balance available
    L0=428077000; % Initial loss carry-forward
    CR0=845000000; % Initial Capital expenditure
    CR=0.015; % Capital expenditure
    P0=2909624000; % Property, Plant and Equipment

1.5 The value of company
    r=0.02515; % Risk-free interest rate
    T=5; % Horizon for the estimation
```

```
    deltat=1; % Time increment for the discrete version of the model
    M=10; % multiplier
```

1.6 Stock price

```
    debt=23421959000;% Total debt
    stocknumcb=0; % stock numbers converted by convertible bonds;
    stocknumout=4364192000; % The number of shares outstanding
    newstocknum=stocknumcb+stocknumout;% the total stock numbers
```

2.Calculation

2.1 initial data

```
  t=[0:deltat:T];
  lt=length(t);
  mut=mu0;
  Rt=R0;
  alphat=alpha0;
  costt=0;
  Pt=P0;
  Capxt=CR.*Rt;
  Dept=DR.*Pt;
  Yt=(Rt-costt-Dept).*(1-tauc);
  Xt=X0;
```

2.2 recurrence

```
for i=2:lt
  % Calculate Rt
    mut(i)=mut(i-1).*exp(-k.*deltat)+muba.*(1-exp(-k.*deltat));
    Rt(i)=Rt(i-1).*exp(mut(i-1).*deltat);

  % Calculate costt
    alphat(i)=alphat(i-1).*exp(-k.*deltat)+alphaba.*(1-exp(-k.*deltat));
    costt(i)=alphat(i).*Rt(i)+F;
```

```
  % Calculate Xt
     Pt(i)=CR.*Rt(i-1).*deltat+(1-DR).*Pt(i-1).*deltat;
     Capxt(i)=CR.*Rt(i);
     Dept(i)=DR.*Pt(i);
     Yt(i)=(Rt(i)-costt(i)-Dept(i)).*(1-tauc);
     Xt(i)=Xt(i-1).*(1+r).*deltat+(Yt(i-1)+(Dept(i-1)-Capxt(i-1))).*deltat;
end
```

2.Calculate the company value V0

```
V0=Xt(lt)+M.*(Rt(lt)-costt(lt)).*exp(-rs.*T);%Company value
vstock=(V0-debt)./newstocknum;%stock price
result0=[deltat,T,V0,vstock];
```

Appendix 3 HTC Balanced Sheet 2006

Account	2006Year	
	Amount(NT$1,000)	(%)
Current Assets	61,810,772	93.66
Cash and Cash Equivalents	34,397,388	52.12
Notes Receivable-Net	58,930	0.08
Accounts Receivable-Net	18,317,979	27.75
Net Accounts Receivable-Related Parties	1,311,790	1.98
Other Receivables-Related Parties	431,598	0.65
Inventories	4,983,891	7.55
Other Prepayments	1,881,119	2.85
Other Current Assets	428,077	0.64
Deferred Income Tax Assets	428,077	0.64
(1310)	0	0.00
Funds and Long-Term Investments	824,481	1.24
Long-Term Investments	821,556	1.24
Long-Term Investments in Stocks	559,877	0.84
Prepayments for Long-Term Investments	261,679	0.39
(1450)	1,733	0.00
(1480)	1,192	0.00
Fixed Assets	2,909,624	4.40
Land	610,293	0.92
Buildings and Structures	1,083,065	1.64
Machinery and Equipment	2,913,495	4.41
Molding Equipment	201,247	0.30
Computer and Telecommunication Equipment	180,855	0.27
Transportation Equipment	1,938	0.00
Office Equipment	105,016	0.15
Original Cost of Fixed Assets	5,123,437	7.76
Accumulated Depreciation-Fixed Assets	-2,684,143	-4.06

Leased Assets	4,712	0.00
Leasehold Improvements	22,816	0.03
Unfinished Construction and Prepayments for Business Facilities	470,330	0.71
Other Assets	449,300	0.68
Guarantee Deposits Paid	36,991	0.05
Deferred Charges	119,059	0.18
Other Deferred Charges	119,059	0.18
Deferred Income Tax Assets	219,230	0.33
Other Assets-Other	74,020	0.11
Other Assets-Other	74,020	0.11
Assets	65,994,177	100.00
Current Liabilities	23,421,319	35.48
Accounts Payable	16,847,039	25.52
Income Tax Payable	1,758,717	2.66
Accrued Expenses	2,340,129	3.54
(2180)	76,470	0.11
Other Payables-Related Parties	35,342	0.05
Balance Payable-Machinery and Equipment	35,342	0.05
Other Current Liabilities	2,363,622	3.58
Other Current Liabilities-Other	2,363,622	3.58
Other Liabilities	640	0.00
Guarantee Deposits	640	0.00
Liabilities	23,421,959	35.49
Capital Stock	4,364,192	6.61
Common Stock	4,364,192	6.61
Capital Surplus	4,452,688	6.74
Capital Surplus-Additional Paid-In Capital	4,410,871	6.68
Capital Surplus-Additional Paid-In Capital-Common Stock	4,410,871	6.68
Capital Surplus-Long-Term Equity Investments	15,845	0.02
Capital Surplus-Net Assets from Merger	25,972	0.03

Retained Earnings	33,988,785	51.50
Legal Reserve	1,991,520	3.01
Special Reserve	6,175	0.00
Unappropriated Retained Earnings	31,991,090	48.47
Cumulative Translation Adjustments	10,786	0.01
(3450)	-238	0.00
(34XX)	10,548	0.01
Treasury Stock	-243,995	-0.36
(3999)	374,000	0.56
Stockholder's Equity	42,572,218	64.50

Appendix 3 HTC Income Statement 2002-2006

HTC Income Statement 2006

Account	2006Year	
	Amount(NT$1,000)	(%)
Operating Income	104,816,548	100.00
Net Sales	103,784,137	99.01
Sales	104,172,460	99.38
Sales Returns	388,323	0.37
Sales Discounts and Allowances	0	0.00
Other Operating Income	1,032,411	0.98
Operating Cost	70,779,066	67.52
Gross Income (Loss)from Operations	34,037,482	32.47
Unrealized Gain from Inter-Affiliate Accounts	164,011	0.15
Realized Gain on Inter-Affiliate Accounts	15,077	0.01
Operating Expenses	7,336,582	6.99
General and Administrative Expenses	4,382,155	4.18
Research and Development Expenses	2,954,427	2.81
Net Operating Income (Loss)	26,551,966	25.33
Non-Operating Income	1,234,336	1.17
Interest Income	438,982	0.41
Gains on disposal of Fixed Assets	41,361	0.03
Gains on Physical Inventory	0	0.00
Gains on Foreign Exchange	603,127	0.57
(7310)	0	0.00
Miscellaneous Income	150,866	0.14
Non-Operating expenses	828,424	0.79
Interest Expense	298	0.00
Investment Losses	12,554	0.01
(7521)	12,554	0.01
Losses on Sale of Fixed Assets	3,377	0.00

Losses on Physical Inventory	2,032	0.00
Losses on Foreign Exchange	0	0.00
Losses on Inventory Valuation Loss and Obsolescence	729,310	0.69
(7650)	76,470	0.07
Miscellaneous Disbursements	4,383	0.00
Continuing Operations' Income (Loss) Before Tax	26,957,878	25.71
Income Tax Expense	1,710,551	1.63
Income form Continuing Operation (Net of Tax)	25,247,327	24.08
Net Income (Loss)	25,247,327	24.08
Basic Net Income (Loss) per Share	57.85	0.00
Fully Diluted Net Income (Loss) per Share	56.97	0.00

HTC Income Statement 2005

Account	2005Year	
	Amount(NT$1,000)	(%)
Operating Income	72,768,522	100.00
Net Sales	71,893,845	98.79
Sales	72,121,212	99.11
Sales Returns	160,010	0.21
Sales Discounts and Allowances	67,357	0.09
Other Operating Income	874,677	1.20
Operating Cost	54,758,040	75.24
Gross Income (Loss)from Operations	18,010,482	24.75
Unrealized Gain from Inter-Affiliate Accounts	15,077	0.02
Realized Gain on Inter-Affiliate Accounts	6,289	0.00
Operating Expenses	5,161,215	7.09
General and Administrative Expenses	2,761,900	3.79
Research and Development Expenses	2,399,315	3.29
Net Operating Income (Loss)	12,840,479	17.64
Non-Operating Income	217,975	0.29
Interest Income	145,042	0.19

Gains on disposal of Fixed Assets	5,372	0.00
Gains on Sale of Investments	0	0.00
Gains on Physical Inventory	2,074	0.00
Gains on Foreign Exchange	0	0.00
Miscellaneous Income	65,487	0.08
Non-Operating expenses	902,515	1.24
Interest Expense	19,821	0.02
Investment Losses	35,112	0.04
(7522)	35,112	0.04
Losses on Sale of Fixed Assets	2,521	0.00
Losses on Foreign Exchange	238,920	0.32
Losses on Inventory Valuation Loss and Obsolescence	584,174	0.80
Miscellaneous Disbursements	21,967	0.03
Continuing Operations' Income (Loss) Before Tax	12,155,939	16.70
Income Tax Expense	373,995	0.51
Income form Continuing Operation (Net of Tax)	11,781,944	16.19
Net Income (Loss)	11,781,944	16.19
Basic Net Income (Loss) per Share	33.26	0.00
Fully Diluted Net Income (Loss) per Share	32.81	0.00

HTC Income Statement 2004

Account	2004Year	
	Amount(NT$1,000)	(%)
Operating Income	36,397,166	100.00
Net Sales	35,650,261	97.94
Sales	35,808,714	98.38
Sales Returns	51,117	0.14
Sales Discounts and Allowances	107,336	0.29
Other Operating Income	746,905	2.05
Operating Cost	28,493,144	78.28
Gross Income (Loss)from Operations	7,904,022	21.71

Unrealized Gain from Inter-Affiliate Accounts	6,289	0.01
Realized Gain on Inter-Affiliate Accounts	7,241	0.01
Operating Expenses	3,594,554	9.87
General and Administrative Expenses	1,600,582	4.39
Research and Development Expenses	1,993,972	5.47
Net Operating Income (Loss)	4,310,420	11.84
Non-Operating Income	312,956	0.85
Interest Income	60,643	0.16
Gains on disposal of Fixed Assets	10,950	0.03
Gains on Sale of Investments	13,584	0.03
Gains on Physical Inventory	11,078	0.03
Gains on Foreign Exchange	108,247	0.29
Miscellaneous Income	108,454	0.29
Non-Operating expenses	662,848	1.82
Interest Expense	29,367	0.08
Investment Losses	35,606	0.09
(7522)	35,606	0.09
Losses on Sale of Fixed Assets	12,151	0.03
Losses on Physical Inventory	0	0.00
Losses on Inventory Valuation Loss and Obsolescence	543,516	1.49
Miscellaneous Disbursements	42,208	0.11
Continuing Operations' Income (Loss) Before Tax	3,960,528	10.88
Income Tax Expense	105,182	0.28
Income form Continuing Operation (Net of Tax)	3,855,346	10.59
Net Income (Loss)	3,855,346	10.59
Basic Net Income (Loss) per Share	14.21	0.00
Fully Diluted Net Income (Loss) per Share	13.49	0.00

HTC Income Statement 2003

Account	2003Year	
	Amount(NT$1,000)	(%)

Operating Income	21,821,605	100.00
Net Sales	21,190,877	97.10
Sales	21,432,410	98.21
Sales Returns	178,039	0.81
Sales Discounts and Allowances	63,494	0.29
Other Operating Income	630,728	2.89
Operating Cost	17,938,644	82.20
Gross Income (Loss)from Operations	3,882,961	17.79
Unrealized Gain from Inter-Affiliate Accounts	7,241	0.03
Operating Expenses	2,056,260	9.42
General and Administrative Expenses	1,008,071	4.61
Research and Development Expenses	1,048,189	4.80
Net Operating Income (Loss)	1,819,460	8.33
Non-Operating Income	482,678	2.21
Interest Income	45,473	0.20
Investment Income	0	0.00
Gains on disposal of Fixed Assets	380	0.00
Gains on Sale of Investments	874	0.00
Gains on Physical Inventory	0	0.00
Gains on Foreign Exchange	92,465	0.42
Miscellaneous Income	343,486	1.57
Non-Operating expenses	342,293	1.56
Interest Expense	27,404	0.12
Investment Losses	16,202	0.07
(7522)	16,202	0.07
Losses on Sale of Fixed Assets	0	0.00
Losses on Physical Inventory	13,216	0.06
Losses on Foreign Exchange	0	0.00
Losses on Inventory Valuation Loss and Obsolescence	255,134	1.16
Miscellaneous Disbursements	30,337	0.13

Continuing Operations' Income (Loss) Before Tax	1,959,845	8.98
Income Tax Expense	109,113	0.50
Income form Continuing Operation (Net of Tax)	1,850,732	8.48
Net Income (Loss)	1,850,732	8.48
Basic Net Income (Loss) per Share	9.05	0.00
Fully Diluted Net Income (Loss) per Share	8.52	0.00

HTC Income Statement 2002

Account	2002Year	
	Amount(NT$1,000)	(%)
Operating Income	20,644,316	100.00
Net Sales	19,974,168	96.75
Sales	20,124,468	97.48
Sales Returns	103,801	0.50
Sales Discounts and Allowances	46,499	0.22
Other Operating Income	670,148	3.24
Operating Cost	17,041,738	82.54
Gross Income (Loss)from Operations	3,602,578	17.45
Operating Expenses	1,484,059	7.18
Net Operating Income (Loss)	2,118,519	10.26
Non-Operating Income	421,980	2.04
Interest Income	801	0.00
Investment Income	6,020	0.02
Gains on disposal of Fixed Assets	0	0.00
Gains on Sale of Investments	642	0.00
Gains on Physical Inventory	1,993	0.00
Gains on Foreign Exchange	0	0.00
Miscellaneous Income	412,524	1.99
Non-Operating expenses	1,032,470	5.00
Interest Expense	38,524	0.18
Investment Losses	0	0.00

Losses on Sale of Fixed Assets	8,287	0.04
Losses on Physical Inventory	0	0.00
Losses on Foreign Exchange	314,655	1.52
Losses on Inventory Valuation Loss and Obsolescence	655,724	3.17
Miscellaneous Disbursements	15,280	0.07
Continuing Operations' Income (Loss) Before Tax	1,508,029	7.30
Income Tax Expense	43,575	0.21
Income form Continuing Operation (Net of Tax)	1,464,454	7.09
Net Income (Loss)	1,464,454	7.09
Basic Net Income (Loss) per Share	9	0.00