

Validating the Technology Valuation with Monte Carlo Simulation

DEOKKYO OH (Corresponding Author), Young-Hee Cho

*Korea Corporate Governance Service/ Research fellow

76 Youinaru-ro, Yeongdeungpo-gu, Seoul 150-977, Korea.

**Korea Institute for the Advancement of Technology / senior manager

305 Teheran-ro, Kangnam-gu, Seoul 135-780, Korea

1. INTRODUCTION

Technology valuation is performed when a company needs a decision making on project financing, especially Research and Development (R&D) project financing but some people wonder whether or not it reflects the reality due to the subjectivity in the valuation process. It is the very lethal problem especially in the third-party valuation as the fairness is basically required (Hwang 2000, p.7). To reduce or eliminate the subjectivity during valuation, the Monte Carlo simulation is often introduced as one of effective methods (Razgaitis 2003, p.64).

Decision problems usually involve random variables and risk and although expected value and decision analysis techniques can be useful approaches for dealing with analytical models, it is difficult to apply or present a complete picture of risk (Camm and Evans 1999, p. 286). Furthermore, some problems are difficult to solve analytically because they consist of random variables represented by probability distributions (Russell and Taylor 2004, p. 564). To reduce this uncertainty, Monte Carlo (MC) simulation is often utilized.

This research shall focus on performing the MC simulation in the technology valuation to embody the validity and reduce the subjectivity in the valuation. Specifically, the MC simulation shall be performed for the technology valuation for a small and medium enterprise extracting distributions from the external data source to add the validity onto the technology valuation result.

2. TECHNOLOGY VALUATION

Technology assessment is categorized into technology evaluation and valuation. Evaluation means the rating or ranking assessment system that the output is ranking or score. Most evaluation models are developed based on the linear regression equations. Regression analysis is frequently exploited to develop the evaluation model. Technology valuation represents the financial valuation of technologies that the output is the monetary value. That is to say, technology valuation is to find the economic or monetary value of technology at the microeconomic or firm level (Baek, Hong and Kim 2007).

There are largely three valuation approaches: income, cost, market approach (Mard 2000; Pavri 1999; Park and Park 2004). The market approach estimates the market price of a similar technology that has already been traded on the market and applies it to their assessment (Reilly and Schweih 1998; Baek *et al.* 2007). This approach is rather simple and direct method and the prerequisite is the existence of active public market and transaction data of comparable properties (Park and Park 2004). In this approach, determining the similarity level is the most important parameter affecting the value of technology. However, if the market is not well activated, this approach is not effective at all.

Cost approach is to calculate the value based on the cost expensed in developing the technology and the depreciation factor is applied to depreciate the cost annually. This approach necessitates accurate cost data and depreciation but in reality it is difficult to obtain cost data and to estimate depreciation factor (Park and Park 2004). Cost approach is the easiest way to value the technology only if there is enough information on cost, but shows some flaws such that the technology value is lowered as it is estimated by historical total cost. This means technology values cannot be beyond the total costs. This approach is utilized most in the accounting and taxation fields because it is manifest to understand and the depreciation years are already legitimately fixed by types of products.

As cost approach is based on the economic principle of substitution that postulates that a prudent buyer would pay no more and a willing seller could command no more for a technology than the cost to create an intellectual asset of equal desirability and utility, there are two fundamental types of cost quantified, reproduction cost and replacement cost: reproduction cost contemplates the construction of an exact replica of the subject intellectual property, while replacement cost contemplates the cost to recreate the functionality or utility of the subject technology (Park and Park 2004; Cha 2009).

Income approach is to value a technology by the expected future earnings of the technology. In detail, this approach considers the sum of the

present values of future cash flows of the technology as the value of the technology (Baek *et al.* 2007). The income approach is considered to be best suited for the valuation of intellectual property such as patents, trademarks and copyrights (Park and Park 2004). Among three approaches, the most popular method is income approach because it has the strong theoretical background in the academia and it is easy to calculate the technology value (Faulkner 1996; Kelly 2007).

Table 1 below epitomizes and compares three valuation approaches.

Table 1 Comparison of three basic approaches (Park and Park 2004)

Approach	Cost	Market	Income
Definition	Valuing based on cost required to reproduce or replace subject	Valuing based on the price of comparable subjects in market	Valuing based on the present worth of future income flow
Merits	Easy to calculate if cost data is available	Possible to calculate the most rational value if market data is available	Possible to capture present worth based on profit-generating capability
Demerits	Ignorance of future potential of subject	Lack of market data on comparable assets	Chance of error due to subjective estimation

The most popular income approach is Net Present Value (NPV) – Discounted Cash Flow (DCF) analysis. NPV is

$$NPV = PVNCF - NINV = \sum_{t=1}^n \frac{NCF_t}{(1+k)^t} - NINV = \sum_{t=1}^n (NCF_t \cdot PVIF_{t,k}) - NINV$$

where PVNCF is the present value of net cash flows, NINV the net investment, k the cost of capital, NCF the net cash flow, and PVIF the present value interest factor (Moyer, Mcguigan and

Kretlow 2006, pp. 334-335).

Though it has the strong theoretical background, it has the several flaws to overcome: DCF assumes that the same discount rate will be used over the entire time span of the analysis (Faulkner 1996); the standard DCF models ignore the value of management's ability to make downstream decisions (Kensinger 1987); and managers have the flexibility to change course when conditions change and show DCF can give a

significantly incorrect answer when these options to change course are present (Trigeoris and Mason 1987; re-quoted by Faulkner 1996). There are so much research to overcome flaws of NPV-DCF method in the DCF domain: Stewart *et al.* (2001) proposed the Risk-adjusted NPV (rNPV), using the Acmed's rNPV that is the NPV of the risk-adjusted payoff minus the sum of the NPV of the risk-adjusted costs and argued that by rNPV approach, biotechnology companies may be able to seek debt financing even at early R&D stages; Herbohn and Harrison (2005) suggest that three performance criteria, NPV, Profitability Index (PI) and Internal Rate of Return (IRR), should be used together in assessing projects; and Shrieves and Wachowicz (2001) show that the discounting of appropriately defined cash flows under the Free Cash Flow (FCF) valuation approach is mathematically equivalent to the discounting of appropriately defined economic profits under the Economic Value Added (EVA) approach, positing that FCF approach focuses on the periodic total cash, whereas EVA approach requires defining the periodic total investment in the firm and FCF and EVA are conceptually equivalent to NPV.

As well as the DCF domain efforts to overcome the flaws of DCF, Real Option Valuation (ROV) is regarded as an alternative approach method. Triest and Vis (2007) argue that the DCF method can be extended using the so-called real options approach to valuation as the real options approach allows for flexibility in pursuing or abandoning lines of research and in the actual application of technology, since this will generally require irreversible investments. Real options represent the application of options methodology to business situations (Boer 2000) and differ from financial ones in several important respects: they cannot be valued the same way, they are typically less liquid, and the real value of an investment to one firm may differ a lot from its value to another firm (McGrath and MacMillan 2000). The ROV approach is to project valuation seeks to correct the deficiencies of traditional methods of valuation, NPV and DCF through the recognition that active management and managerial flexibility can bring significant value to a project (Jacob and Kwak 2003). It incorporates the financial concepts of options in technology valuation and as options are not considered as an obligation but a right, the investors have the opportunity to correct their decision according to future environment (Copeland and Antikarov 2001; Baek *et al.* 2007). ROV is truly an extension to DCF analysis in that it requires more information, not different information: next to expected cash flows, the essential ingredient is the standard deviation of these expected cash flows (Triest and Vis 2007), however real option models are superior to simple NPV valuation models in that they recognize the

importance of managerial flexibility (Jacob and Kwak 2003; Boer 2000; Razgaitis 2003, p. 68). ROV is generally preferable to DCF for high risk investments (Sharp 1991; re-quoted by Faulkner 1996), especially suitable for young patents where there is much uncertainty about the effectiveness and the rewards of the technology (Triest and Vis 2007). If the technology is already developed and commercialized, DCF analysis is preferable to ROV (Triest and Vis 2007). Eichner, Gemünden and Kautzsch (2007) performed the binomial real option valuation obtaining three critical factors that are the most sensitive factors to the value of the company, present value, volatility, and investment expenditure and argued that the real option valuation can create value beyond the value of expected cash flow presented by DCF analysis by managerial flexibility and volatility.

However, ROV is not always utilized. For ROV, managers should understand their options. Good managers have always understood their options under changing circumstances and arguably a good portion of their tactical skill was to recognize and evaluate the available options and neglecting the options approach was one of the traps, pitfalls and snares in the valuation of technology (Boer 2000). For managers' better understanding their options, real option reasoning is highly recommended, which is a logic for funding projects that maximizes learning and access to upside opportunities while containing costs and downside risk (McGrath and MacMillan 2000).

3. MONTE CARLO SIMULATION

MC simulation is more narrowly defined as a technique for selecting numbers randomly from a probability distribution for use in a simulation (Russell and Taylor 2004, p. 564) as is based on repeated sampling from the probability distributions of model inputs to characterize the distributions of model outputs and we may construct a distribution of potential outcomes of key model variables along with their likelihood of occurrence by randomly selecting model inputs and evaluating the outcomes (Camm and Evans 1999, p. 286) so the purpose of MC process is said to generate the random variable by sampling from the probability distribution (Russell and Taylor 2004, p. 564; Chib and Greenberg 1996). Technically, the MC simulation as a variance-reducing techniques because as a simulation progresses the variance of the mean decreases (Hillier and Lieberman 2001, p.1126). This provides an assessment of the risk associated with a set of decisions that analytical methods generally cannot capture and managers can use a simulation model to help identify good decisions (Camm and Evans 1999, p. 286). The conventional analysis with the MC simulation is

best/ worst case analysis and what-if analysis (Ragsdale 2008, pp.561-562).

Many modern complex stochastic systems can be modeled as discrete event systems, for example, communication networks, computer systems, production lines, flexible manufacturing systems, traffic systems, reliability systems, project networks, and flow networks, which systems are driven by the occurrence of discrete events over time, studying their performance and optimization of their parameters are important tasks and the conventional approach for analyzing such complex system is a simulation, which means the standard computer-based discrete event simulation which involves writing a computer program to mimic the system and then performing a MC simulation (Rubinstein 1989).

Specifically, the MC simulation is applied for design and operation of queuing systems, managing inventory systems, estimating the probability of completing a project by the deadline, design and operations of manufacturing and distribution systems, financial risk analysis, health care applications such as resource allocation, expenditure under insurance plans, timing and location of ambulance services, operation of emergency room (Hillier and Lieberman 2001, pp. 1097-1126), and estimation of willingness-to-pay (Kanninen and Kristrom 1993).

One of the most sophisticated MC simulation approaches is Markov Chain Monte Carlo (MCMC) approach that is mostly utilized in the Stochastic Volatility (SV) model (Poon 2005, p. 59). MCMC is a general method for the simulation of stochastic processes having probability densities known up to a constant proportionality and can be used to simulate a wide variety of random variables and stochastic processes and is useful in Bayesian, likelihood and frequentist statistical inference (Geyer 1992). Chib and Greenberg (1996) also introduced and explained some algorithms regarding MC simulation: Metropolis-Hastings (MH) algorithm proposed by Metropolis, Rosenbluth, Teller and Teller (1953) and Hastings (1970), Gibbs sampling algorithm introduced by Geman and Geman (1984) and extended by Tanner and Wong (1987) and Gelfand and Smith (1990), hybrid MH and rejection sampling (Tierney 1994), and stochastic EM algorithm (Celeux and Diebolt 1985).

The most advantageous thing of MC simulation is that this simulation tool can provide the distribution of forecasting variable, not single-valued answer (Razgaitis 2003, p. 70). Managers can make decisions only about whether to accept if single-valued answer is provided to them. If the distribution of forecasting variable is offered to managers, they can more easily make decisions about whether to accept and propose alternatives by comparing the likelihood of forecasting variable.

That is, managers can estimate feasible answers by investigating the distribution of value of technology. If the valuation result has not a high probability to be higher than the result, the alternative technology value can be suggested by calculating the probability to be higher statistically significantly or to the level that they can consider it. Thus, MC simulation can offer managers more reasonable decision making and make decision making process simpler by suggesting and comparing the probability from the distribution of value of technology, i.e., the simulation result (Sung 2004).

MC simulation is one of the most powerful valuation tools and is very useful to eliminate the uncertainty in valuation (Razgaitis 2003, p. 64). Razgaitis (2003) explains some distributions for cost structure in the MC simulation such as uniform distribution, triangular distribution, and normal distribution: the uniform distribution that can be applied in case of high uncertainty, the normal distribution that is the most frequently used, and some special distributions such as double crown distribution to be combined with the scenario analysis (pp. 91-93, 97-100, 115-120).

Furthermore, Sung (2004) explains the pros and cons of MC Simulation: for Pros: 1) it is possible to make decisions efficiently via this simulation, 2) easy to understand the result; for Cons: 1) it needs the suitable computer software for the purpose, 2) sometimes it is lacked in the confidence on the simulation result, and he

mentions that the confidence problem can be solved by utilizing the valid market information and minimizing the probability of generating the outliers in setting the distributions of variables.

4. ANALYSIS

4.1. Technology valuation

Two kinds of data shall be used in this analysis. The first data set is a firm's valuation result which is a basis of simulation and the second data set is input variables' distributions for simulation. The first data of a valuation result shall be explained in this section.

Table 2 below shows the valuation result that will be adapted to this simulation¹. This firm is a small and medium enterprise (SME) that manufactures several types of portable media players in Korea and was established five years before at the time of valuation. Manufacturers of portable media player come under the industry of electronic components, radio, television and communication equipment and apparatuses (C26)² according to the Korean standard industry categorization. In Table 2, the discount rate is 22.78% which is calculated by adding size and technology risk premiums to Weighted Average Cost of Capital (WACC) as it is conventional to calculate and add two types of risk premiums in the valuation for small and medium enterprises because small and middle sized firms are riskier than large sized companies (Korea Technology Transfer Center (KTTC) 2003, p. 89).

Table 2 Valuation result

Contents (Million Korean won)	T+1	T+2	T+3	T+4	T+5
Revenue (R)	5,406	7,028	8,855	10,449	11,912
Cost of sales (O)	4,757	6,974	9,423	11,636	13,879
Operating expenses (E)	867	1,107	1,333	1,580	1,732
Depreciation (D)	211	337	416	512	619
EBIT(A=R-O-E-D)	-239	-10	544	905	1,330
Income tax (B)	0	0	0	0	266
Depreciation (D)	21	39	53	70	89
Operating Cash Flow (C=A-B+D)	-218	29	597	974	1,153
Increment of working capital (G)	-50	138	127	85	22
Investment for assets (H)	100	129	170	280	400
Total investment (I=G+H)	50	267	297	365	422
FCF (F=C-I)	-268	-238	300	609	731
Discount rate	22.78%				
PV of FCF	-219	-158	162	268	262
Sum of PV(FCF) (J)	316				
Terminal Value (K)	1,674				
NPV (M=J+K)	1,990				
Technology contribution coefficient (N=L*M)	66.77%				
Industry Factor (L)	97.47%				
Individual technology strength (M)	68.50%				
Value of technology (V=M*N)	1,328				

This research is based on FCF analysis which is the most frequently used in valuation. Criteria commonly applied in the capital budgeting decision model as well as the financial valuation are NPV, PI, IRR, and Payback Period (PB) and the primary decision making rule used is NPV that is

$$NPV = PVFCF + TV = \sum_{t=1}^n \frac{FCF_t}{(1+k)^t} + TV = \sum_{t=1}^n \frac{(CF_t - \Delta IC_t - DEP_t)}{(1+k)^t} + TV$$

where PVFCF is the present value of free cash flows, TV terminal value, CF the cash flow, ΔIC the increment of working capital, DEP depreciation, and k the discount rate (Kang, Lee, and Cho 1997, p.139).

The valuation result, value of technology is 1,328 million won while NPV is 1,990 million won. The terminal value is remarkably shown much greater than the sum of present value of FCF as it is assumed to sustain its business of (T+5) year infinitely and continuously. To calculate the value of technology, technology contribution coefficient which consists of industry factor and individual technology strength should be multiplied with NPV. The industry factor of corresponding industry category was calculated as 97.465% on average (KTTC 2006, p. 105) and individual technology strength was calculated to be 68.5%.

4.2. Simulation data

The data of the Bank of Korea are utilized to obtain some variables' distributions because it is difficult to obtain due to the short

history of this firm. As proxies, we chose input variables available in Financial Statement Analysis

(FSA) report of the Bank of Korea (BOK): growth rate of revenue, cost of sales, operating expenses, depreciation cost, and increment of working capital. Extracted data are the average values of the industry category (C26) in Korea. Specifically, these data are obtained from FSA reports for small and middle sized firms, as the FSA report analyzes financial statements of an industry categorizing firms into large and small-and-middle sized firms. The increment of working capital is calculated with the formula of

$$IC_t = \Delta WC_t = WC_t - WC_{t-1} = (R_t + IN_t - P_t) - (R_{t-1} + IN_{t-1} - P_{t-1})$$

where IC represents the increment of working capital, WC working capital, R receivables, IN inventories, and P payables. Thus, distributions of five variables for ten years, 2000 to 2009, are obtained from FSA reports. The extracted data are shown in Table 3 below. Data for three variables show that rates have not a significant trend of increase or decrease but the oscillatory trend over years. Trends of variables are easily understood by seeing charts shown in Figures 1 through 5. This oscillation adds the validity to this MC simulation as shows variables are not dependent on time but seem to be stochastic.

Table 3 Descriptive statistics of Extracted input data

Year	Growth rate of revenue	Cost of sales	Operating expense	Depreciation	Increment of working capital
2000	0.2546	0.8458	0.0972	0.0053	0.0450
2001	-0.028	0.8665	0.1283	0.0053	0.0156
2002	0.1764	0.8457	0.1155	0.0049	0.0465
2003	0.1567	0.8135	0.1308	0.0054	0.0440
2004	0.1980	0.8391	0.131	0.0049	0.0118
2005	0.0297	0.85	0.1094	0.0046	-0.0011
2006	0.0616	0.843	0.1192	0.0039	-0.0003
2007	0.0016	0.8135	0.1423	0.0059	0.0238
2008	0.0661	0.8212	0.1453	0.0057	0.0602
2009	0.1717	0.8111	0.1283	0.0046	0.0201
Max	0.2546	0.867	0.145	0.006	0.060
Min	-0.028	0.811	0.097	0.004	-0.001
Mean	0.109	0.835	0.125	0.005	0.027
SD	0.095	0.019	0.015	0.001	0.021

In Table 3 above, the values of variables are calculated based on revenue, that is to say, the ratios to the revenue. For example, the mean of cost of sales, 83.5% represents the cost of sales takes

83.5% portions of revenue. Coefficient of Variation (CV) expressed by dividing the standard deviation by the mean shall be calculated for four variables to understand the dispersion of each variable. Cost of sales has coefficient of variation of 0.023,

operating expenses 0.118, depreciation 0.117, the increment of working capital 0.8, and growth rate of revenue 0.87. The calculation of CV implies that growth rate of revenue is most widely dispersed related with the mean value, the second most widely dispersed variable is the increment of working capital, and cost of sales is the least widely dispersed among five variables.

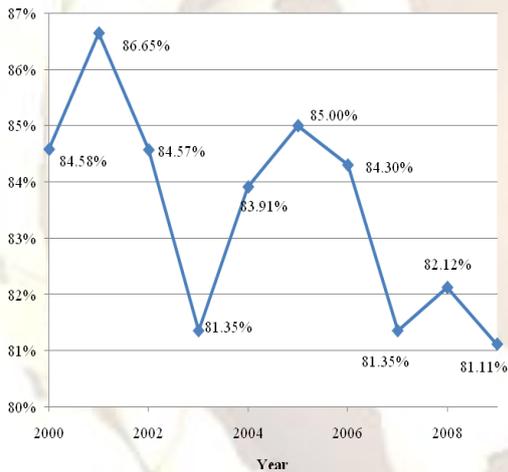
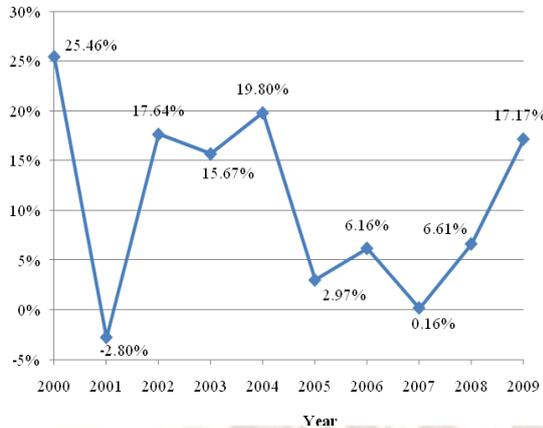


Figure 1 Growth rate of revenue
Figure 2 Cost of sales (rate to the revenue)

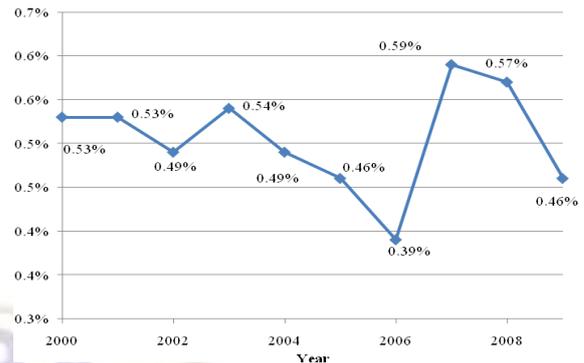
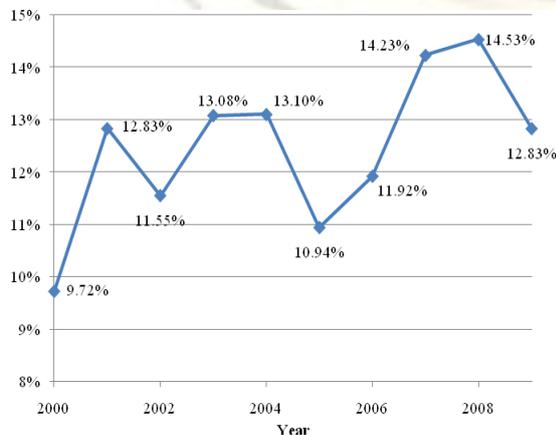


Figure 3 Operating expenses
Figure 4 Depreciation

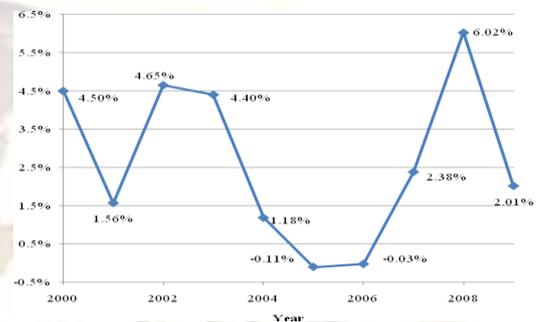


Figure 5 Increment of working capital

4.3. Rules for selecting distributions and making decisions

If a valuation parameter value deviates from the distribution range, the uniform distribution ranged from the value of valuation parameter to the minimum value of distribution or from the maximum value of distribution to the value of valuation parameter will be applied. Otherwise, the normal distribution with the mean and standard deviation illustrated in Table 4 will be applied. This policy is expressed as:

- i) $V \sim N(\mu_F, \sigma_F)$, if $V \in [F_{\min}, F_{\max}]$,
- ii) $V \sim U(V_t, F_{\min})$, if $V \notin [F_{\min}, F_{\max}]$ and $V < F_{\min}$, and
- iii) $V \sim U(F_{\max}, V_t)$, if $V \notin [F_{\min}, F_{\max}]$ and $V > F_{\max}$

where V represents one of five variables above, F_{\min} the minimum value, F_{\max} the maximum, μ_F the mean and σ_F the standard deviation of corresponding external data to a variable, V.

The simulation result is compared with the valuation result and whether it is properly, over or under-estimated shall be determined as follows:

- i) Proper estimation, if $TV \in [TV_{s.\min}, TV_{s.\max}]$,
- ii) Over-estimation, if $TV > TV_{s.\max}$, and

iii) Under-estimation, if $TV < TV_{s.min}$
 where TV represents the technology valuation result (original value of technology), and $TV_{s.min}$ and $TV_{s.max}$ the minimum and maximum values of technology simulated within the properly acceptable range, respectively. To examine the overestimation and find the proper range of value of technology, 20th percentile rule is applied which represents 20 to 30th percentile in the distribution of value of technology is the proper range for the reasonable negotiation (Razgaitis 2003, p. 110). That is to say, this rule permits the 20~30% subjectivity based on the mean value of simulation result as a proper and essential subjectivity. If the technology value exists over this properly accepted range, it can be regarded as an excessively subjective technology valuation result.

Finally, the value of technology is set as the forecasting variable in MC Simulation. Crystal Ball program shall be utilized to perform the MC simulation in this research.

4.4. Simulation Result

Under given assumptions, we obtained the result of simulation after 10,000 trials. The

Table 4 Summary of simulation result

Statistic	Forecast values
Trials	10,000
Mean	357 Million won
Median	328 Million won
Mode	-
Standard Deviation	498
Variance	248,314
Skewness	0.3959
Kurtosis	3.54
Coeff. of Variability	1.39
Minimum	-1,334 Million won
Maximum	2,931 Million won
Mean Std. Error	5

statistics of simulation result is illustrated in Table 4 below. The mean of NPV simulated is 357 million won and the median is 328 million won. As its standard deviation is 498 million won and is a little bit high so the value of technology is recognized to be widely dispersed. Maximum value of technology value is 2,931 million won and the minimum value is -1,334 million won.

Statistics of goodness of fit explain which distribution is fit to the simulation result in Crystal Ball by A-D (Anderson-Darling), χ^2 , K-S (Kolmogorov-Smirnov) test results (see Table 5). The distribution of NPV is best fit to the Gamma distribution with the location of -2,067, the scale of 103 and the shape of 23.46, whose probability density function is mathematically defined

$$f((x - L); k, \theta) = (x - L)^{k-1} \frac{e^{-(x-L)/\theta}}{\theta^k \Gamma(k)}$$

where L represents the location, k is the shape parameter and θ is the scale parameter (Crystal Ball User's Guide 2009, pp.240-242; Coit and Jin 1999).

Table 5 Statistics of goodness of fit

Distribution	A-D	Chi-Square	K-S	Parameters
Gamma	2.5394	78.2376	0.0124	Location= (2,067), Scale=103, Shape=23.46
Logistic	11.1597	230.1892	0.0175	Mean=341, Scale=281
Student's t	15.8957	218.5712	0.0271	Midpoint=357, Scale=483, d.f.=17.0
Normal	16.2357	219.2224	0.0283	Mean=357, Std. Dev.=498
Beta	16.6401	229.5232	0.0286	Min= (6,707), Max=7,422, Alpha=100, Beta=100
Max Extreme	58.5755	588.6304	0.0461	Likeliest=116, Scale=462
Min Extreme	266.5455	2,177.78	0.1018	Likeliest=614, Scale=563
BetaPERT	614.4368	3,911.75	0.1496	Min= (1,357), Likeliest=149, Max=2,962
Triangular	891.1076	4,657.30	0.218	Min= (1,357), Likeliest=149, Max=2,962
Uniform	2,097.17	14,967.27	0.3547	Min= (1,335), Max=2,931
Weibull	5,626.38	15,355.67	0.4378	Location= (1,334), Scale=1,275, Shape=2.41865

- It is ranked by Anderson-Darling test results.

As an analysis result, we obtained the chart of distribution of NPV, forecasting variable in this simulation, under the given assumptions and Figure 6 below depicts the distribution of value of technology which is best fit to the gamma distribution graphically. The probability of lower technology value than the valuation result can be shown by moving the arrows located in the bottom

of the picture. Figure 7 shows the probability to have the lower value of technology than the valuation result, 96.52%. This means the probability of higher value of technology than 1,328 million won is just 3.48%. It shows that the valuation was performed optimistically and overestimated.

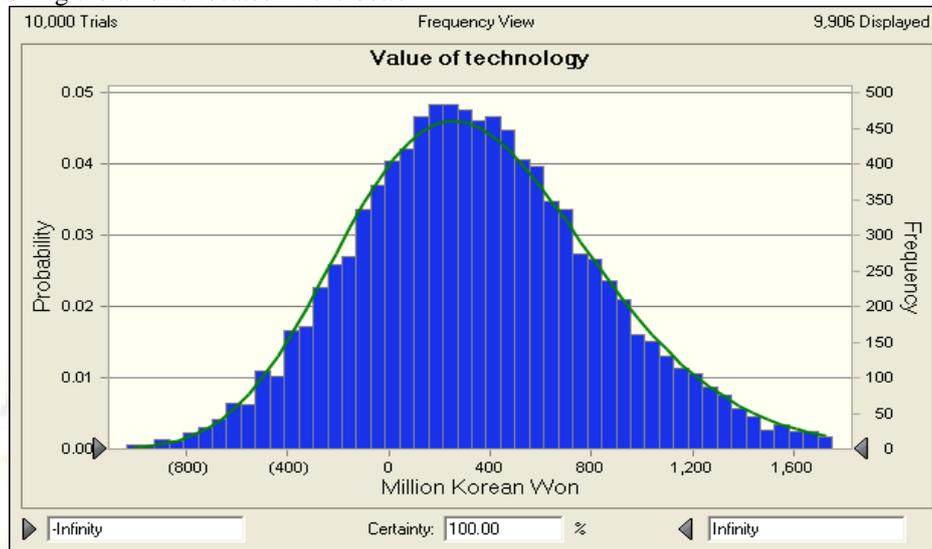


Figure 6 Distribution of value of technology

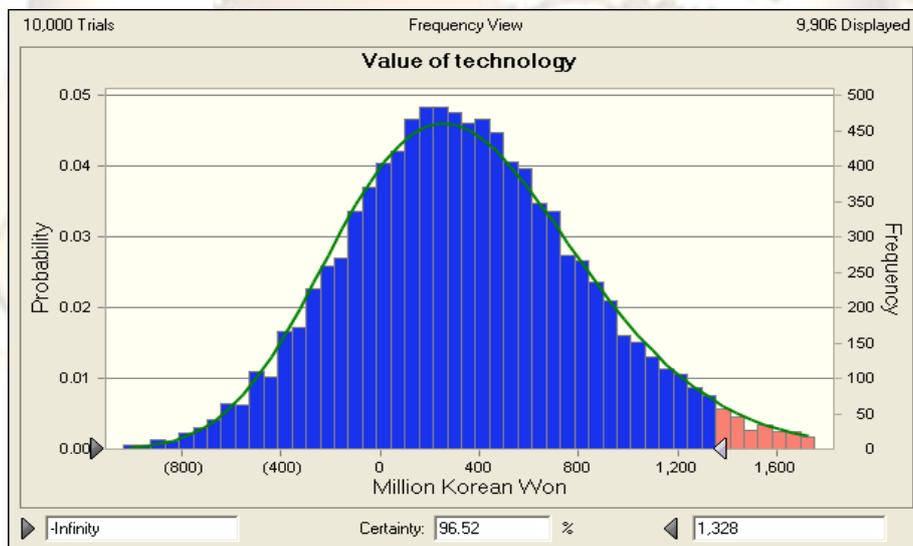


Figure 7 Probability to have the lower technology value than the valuation result

Table 6 depicts the percentile of forecasting variable, the value of technology. Under Razgaitis' suggestion, the proper range of value of technology, 20 to 30th percentile, is 583~755 million won for this technology. Figure 8 depicts the location of this feasible range of value of technology. It is located in near the mean value because the mean has the highest probability and as the value goes far from the mean the probability is lowered

exponentially. As the technology value is about 1.3 billion won, beyond the upper limit of proper range, 755 million won, we can say that the technology valuation is over estimated.

Table 6 Percentile of value of technology

Percentile	Forecast values (Unit: million won)
100%	-1,334
90%	-252
80%	-54
70%	88
60%	208
50%	328
40%	449
30%	583
20%	755
10%	1,002
0%	2,931

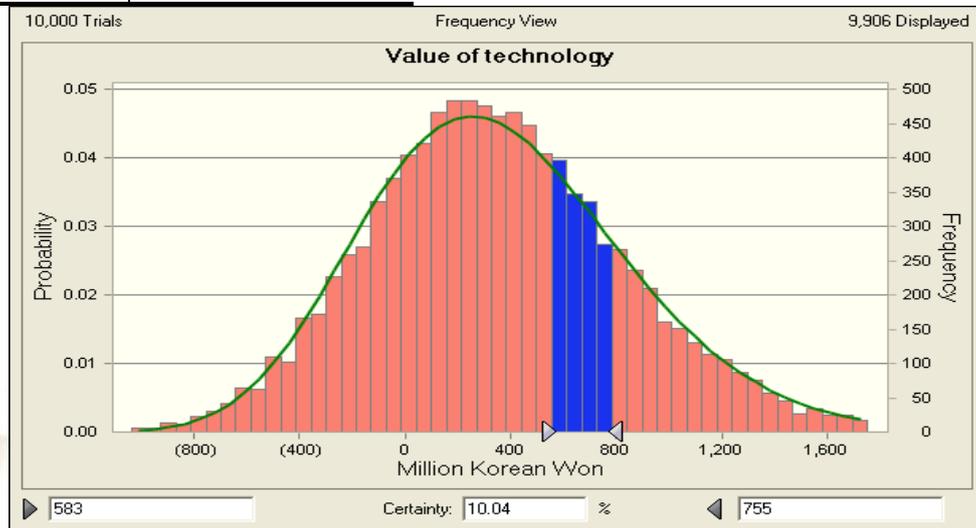
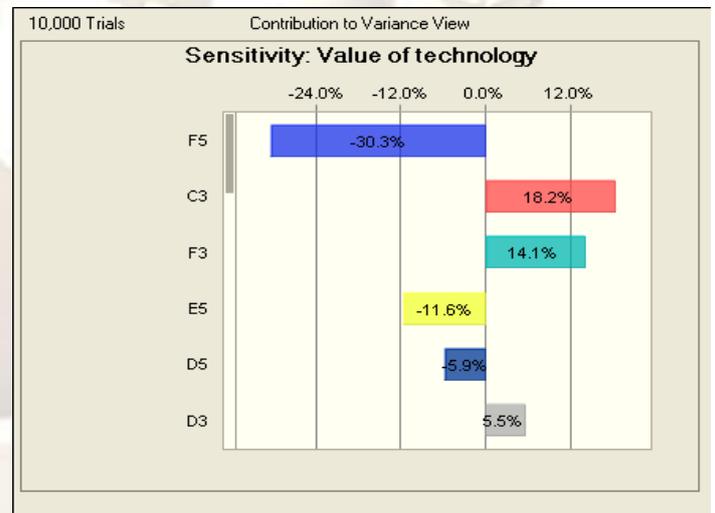


Figure 8 20~30 % range of value of technology

Finally, the sensitivity analysis is performed for this simulation. We shall choose the contribution to variance view which illustrates the effects of all assumptive distributions on the value of technology are ranked from the largest contribution to technology value uncertainty (variance) to the least and the five percentage rule shall be applied in determining the contribution of variables on forecasting variable that all assumptions that contribute less than five percentage of the uncertainty can be ignored (Razgaitis 2003, pp. 120-121). As shown in Figure 9, all variables exhibited have the contribution of over 5% of the variance to the value of technology. Growth rate of revenue has the positive effect on the value of technology, while cost of sales has the negative effect (refer to Figure 9). The cost of sales in (T+5) year is significantly the most important factor, which shows that the horizon value is much greater than the sum of present values, and the growth rate of revenue in (T+2) year is the second most important factor. The third most important factor is the growth rate of revenue in (T+5) year.



Label	Content
C3	Growth rate of revenue in (t+2) year
D3	Growth rate of revenue in (t+3) year
D5	Cost of sales in (t+3) year
E5	Cost of sales in (t+4) year
F3	Growth rate of revenue in (t+2) year
F5	Cost of sales in (t+5) year

Figure 9 Sensitivity analysis result

5. CONCLUSIONS

We performed the MC simulation for the valuation for a specific small-sized firm. Throughout the simulation, we could find out the likelihood of value of technology under given distributions (assumptions), estimate the proper range of value of technology with the 20th percentile rule of Razgaitis (2003, p.110), and decide if the valuation result is properly estimated or not.

MC simulation can effectively reduce the subjectivity in the technology valuation by utilizing the fair data such as the FSA data from the BOK. Modelers should be aware of the importance of fair data. Fair data can validate the valuation data reducing the subjectivity. As the third-party technology valuation is required the fairness enough to be perceived commonly in the society, especially in Korea (Hwang 2000, p. 7), to be sure, the MC simulation with the fair data can satisfy this requirement.

As MC simulation can help valuation more persuasive thus, it is thought to be applied to other valuation approaches: cost and market approaches. For the market approach, it can be utilized in estimating the similarity based on the probability. The representative similar technology or company is chosen to compare, then how much a technology is similar with the representative should be estimated expressed as a probability. Finally, the value of technology is calculated by multiplying the market value and the similarity level. For the cost approach, it can be applied in estimating the depreciation factor, replacement cost, and reproduction cost. Replacement and reproduction cost may vary with the manufacturers so there must exist deviations. With the shapes of deviations, we can implement the MC simulation to obtain the distribution of outputs.

For further research, it still needs the reconsideration of 20th percentile rule. This rule can be different by regions as people, society and its atmosphere, and environment which affect the technology value are different. In addition, reflection of economic trend can be considered as it is not considered as a parameter in this research. Calculating and estimating the neutral growth rate of revenue in the MC simulation by subtracting the growth rate of revenue from that of gross

domestic product and can make valuation more feasible.

REFERENCES

1. Baek, D., Sul, W., Hong, K. and Kim, H. (2007). A technology valuation model to support technology transfer negotiations. *R&D Management*, 37(2), 123-138.
2. Boer, F. Peter (1999). *The valuation of technology: Business and financial issues in R&D*. NJ: John Wiley&Sons.
3. _____ (2000). Valuation of technology using real options. *Research Technology Management*, 43(4), 26-30.
4. Bowman, E. H. & Hurry, D. (1993). Strategy through the option lens: an integrated view of resource investments and the incremental-choice process. *Academy of Management Review*, 18(4), 760~782.
5. Bullard, C. W. and Sebald, A. V. (1988). Monte Carlo analysis of input-output models. *The review of Economics and Statistics*, 70(4), 708-712.
6. Camm, J. D., and Evans, J. R. (1999). *Management science & decision technology*. OH: South western college publishing.
7. Cha, S. (2009). Technology Valuation. *News & Information for chemical engineers*, 27(4), 459-461.
8. Chib, S. and Greenberg, E. (1996). Markov Chain Monte Carlo Simulation Methods in Econometrics. *Econometric Theory*, 12(3), 409-431.
9. Coit, D. W. and Jin, T. (2000). Gamma distribution parameter estimation for field reliability data with missing failure times. *IIE Transactions*, 32, 1161-1166.
10. Copeland, T., Koller, T and Murrin, J. (2002). *Corporate valuation*. 2nd edition, NJ: John Wiley&Sons.
11. Eichner, T., Gemünden, H. G., and Kautzsch, T. (2007). What is technology worth? A real options case study on technology carve-out venture valuation. *Journal of investing (Fall)*, 96-103.
12. Faulkner, T. W. (1996). Applying 'Option Thinking' to R&D valuation. *Research Technology Management*, 39(3), 50-56.
13. Geyer C. J. (1992). Practical Markov Monte Carlo. *Statistical Science*, 7(4), 473-483.
14. Hanke, J. E., and Wichern, Dean W. (2003). *Business forecasting*. 8th edition, NJ: Prentice Hall.
15. Herbohn, J. and Harrison, S. (2005). Introduction to discount cash flow analysis and financial functions in Excel.

- Socio-economic research methods in forestry*, 109~118.
16. Hillier, F. S. and Lieberman, G. J. (2001). *Introduction to Operations Research*. 7th Ed., NJ: McGraw-Hill.
 17. Hwang, K. (2000). *Towards a science of technology valuation*. Presentation material.
 18. Jacob, W. F. and Kwak, YH. (2003). In search of innovative techniques to evaluate pharmaceutical R&D projects. *Technovation*, 23, 291-296.
 19. Kang, H., Lee, W., and Cho, J. (1997). *Corporate valuation theory: EVA and value creation management*. Seoul: Hongmunsa.
 20. Kanninen, B. J. and Kristrom, B. (1993). Sensitivity of willingness-to-pay estimates to bid design in dichotomous choice valuation. *Land Economics*, 69(2), 199-202.
 21. Kelley, Jim (2007). Financial planning: Valuation strategies require a specific toolkit. *Accounting Today*, January, 16-17.
 22. Korea Technology Transfer Center (2003). *Technology Valuation Manual based on Income Approach (IT)*.
 23. Korea Technology Transfer Center (2006). *Technology Valuation Manual*. 2nd Ed.
 24. Kress, G. J. and Snyder, J. (1994) *Forecasting and market analysis techniques: a practical approach*. CT: Quorum books.
 25. Lee, Y. and Han, K. (2005). A study on technology contribution coefficient calculation in technology valuation. *Proceedings of Korea Industry Management System Journal*, 206-213.
 26. McGrath, Rita G. and MacMillan, Ian C. (2000) Assessing technology projects using real options reasoning. *Research Technology Management*, 43(4), 35-49.
 27. Moyer, R. C., Mcguigan, J. R. and Kretlow, William J. (2006). *Contemporary financial management*. 10th edition, OH: South-Western Thomson Learning.
 28. Oracle (2009). *Crystal Ball User's Guide*. Release 11.1.1.3.00.
 29. Park, Y. and Park, G. (2004). A new method for technology valuation in monetary value: procedure and application. *Technovation*, 24, 387-394.
 30. Poon, S-H. (2005). *A practical guide to forecasting financial market volatility*. NJ: John Wiley & Sons.
 31. Ragsdale, Cliff T. (2008). *Managerial Decision Modeling*. OH: Tompson South-western, 2008.
 32. Razgaitis, R. (2003). *Deal making using real options and Monte Carlo analysis*. NJ: John Wiley&Sons, 64-124.
 33. Rossky, P. J., Doll, J. D., and Friedman, H. L. (1978). Brownian dynamics as smart Monte Carlo simulation. *Journal of Chemical Physics*, 69(10), 4628-4633.
 34. Rubinstein, R. Y. (1989). Sensitivity analysis and performance extrapolation for computer simulation models, *Operations Research*, 37(1), 72-81.
 35. Russell, R. S. and Taylor, B. W. III (2004). *Operations management: Quality and competitiveness in a global environment*. 5th edition, NJ: John Wiley & Sons.
 36. Shrieves R. E. and Wachwicz, J.M. (2001). Free cash flow, economic value-added, and net present value: a reconciliation of variation of discount-cash-flow valuation. *Engineering Economist*, 46(1), 33-52.
 37. Stewart, J. J., Allison, P. N., and Johnson, R. S. (2001). Putting a price on biotechnology. *Nature biotechnology*, 19, 5-9.
 38. Sung, O. (2004). A study on real option valuation for technology investment using the Monte Carlo Simulation. *Journal of Korea technology innovation*, 7(3), 533-554.
 39. The Bank of Korea (1999-2009). *Financial Statement Analysis*.
 40. Triest, S. van and Vis, W. (2007). Valuing patents on cost-reducing technology: A case study. *International Journal of Production Economics*, 105, 282-292.
 41. Wright, J. F. (2002). *Monte Carlo analysis and due diligence of new business ventures*. NY: Amacom.