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The Economic Feasibility Study on Development of Coal Mine Using Real Options

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Abstract **-** This study re-evaluate a Korean bituminous coal mining project in Real Option Method(ROM) and compare ROM with Discounted Cash Flow Method(DCFM) to present that ROM has advantage over the application of a DCFM under uncertainty of business environment. This study concludes that the value of ROM is higher than the value of DCFM as much as the value of option to expand because ROM gives better information to determine when the investor has the option to expand the investment

Keywords**:** Real option, Feasibility Study, Mining, Coal

1. Introduction

Although South Korean companies may have financial supports from their government, many of them are reluctant to engage in mining projects because of uncertainty of business environment, such as commodity price volatility. In spite of the volatility, they still use traditional Discounted Cash Flow Method (DCFM) to value mining projects in foreign countries, so that they cannot have flexibility to make a decision to expand or postpone under uncertainty. On the contrary to DCF, Real Option Method (ROM) gives flexibility using options. So, the main objective of this study is to apply ROM to a case-study, a Korean bituminous coal mining project through the use of the binomial tree and a expand option and shows usefulness and necessity of ROM. The paper proceeds as follow: Section 2 presents shortcoming of DCFM as a traditional evaluation methods, and analyse ROM to propose an alternative; Section 3 re-evaluates an investment of a bituminous coal project applied DCFM in ROM and compare ROM to DCFM; Section 4 provides the necessity of ROM to evaluate oversea mining projects based on the result of ROM evaluation and conclusion.

2. Discounted Cash Flow Methods and Real Option Method

2.1. Discounted Cash Flow Method – Static NPV

DCFM is commonly used to evaluate domestic and oversea South Korean mining project. The technique of DCFM estimate the future new cash flows generated over the entire project life cycle using annual single-point forecasts of production and economic variables, such as future mineral commodity prices, production amounts, grades, recoveries, consumable amount and prices, labour. These forecasts are used to construct an annual expected project new cash flow equal to revenue less capital and operating costs, government and third royalties, corporate income taxed, transport costs, insurance, and other deduction. Then this expected net cash flow is used to calculate a project Static Net Present Value (“NPV”) as an indication of project viability. The calculation of a Static NPV requires estimating net annual cash flows and then discounting each annual cash flow for the value effects of uncertainty and time to determine a cash flow present value. NPV is the sum of these present values.

$$\text{NPV} = \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t} - I_0 \qquad (1)$$

CFt : Net Cash Flow during the period t

r : Discount Rate
I0 : Total initial investment costs
t : number of time periods`

The value effect of uncertainty and time is recognized by summarizing their impact into a single constant risk-adjusted rate that is used in the discounting process. This discount rate is likely used for a broad class of investment projects regardless of the actual uncertainty characteristics of the particular project.

Although NPV has been used widely in mining projects, it has shortcomings in its calculation process.

First, the use of a single discount rate implies that project cash flow uncertainty increases through time in a regular manner. However, most mine valuation professionals would agree that the cash flow uncertainty changes in a dynamic and erratic manner due to changes in mineral grades and prices, operating costs, mining method, exhaustion of tax shields, and tax and royalty rates among other things.

Second, NPV ignore the effects of contingent cash flows and flexibility. In the life of projects, volatility of mineral commodity prices may lead change of production policy, sliding scale royalty rates, and eventually change of cash flow structure. So, a risk adjustment method that responds to changes in cash flow uncertainty would be preferred.

2.2. Evaluation of investment in Real option methods

The ROM approach considers multiple decision pathway as a consequence of high uncertainty coupled with flexibility in choosing optimal strategies or options along the way when new information becomes available. That is management has the flexibility to make midcourse strategy correction when there is uncertainty involved in the future. As information becomes available and uncertainty becomes resolved, management can choose the best strategies to implement. DCFM, static NPV, assumes a single static decision, while ROM assumes multidimensional dynamic decisions, where management has the flexibility to adapt given a change in the business environment. That is, ROM provides additional insights beyond DCFM. So, using ROM approach, an expanded net present value (NPV) can be calculated that includes static NPV determined from a conventional DCFM analysis plus an option premium that reflects the value of strategic options (Samis, M. et al. 2006).

Expanded NPV = Static NPV + Option premium

- Expanded NPV : Value of investment using ROM
- Static NPV : Value of conventional DCFM
- Option Premium : Value of strategic options(management flexibility) in uncertainty

2.3. Black-Scholes model and Binomial tree as a framework of ROM

- Black-Scholes model

Black and Scholes (1973) developed the first mathematical model of pricing European Call options by the following equation.

$$C = SN(d_1) - Xe^{-r(T-t)}N(d_2)$$
$$P = Xe^{-r(T-t)}N(-d_2) - SN(-d_1)$$
$$d_1 = \frac{\ln\left(\frac{S}{X}\right) + (r + \frac{\sigma^2}{2})(T-t)}{\sigma\sqrt{T-t}} \quad (2)$$
$$d_2 = \frac{\ln\left(\frac{S}{X}\right) + (r - \frac{\sigma^2}{2})(T-t)}{\sigma\sqrt{T-t}}$$

Where,

C: call option value, P: put option value
S: underlying asset price, X: exercise price
r: risk free rate, σ : volatility of underlying asset
T: time to expiration, t: time t
N(d): normal cumulative distribution function

Above Black-Scholes model is comprised a risk-free portfolio where returns can be represented by the risk-free rate. One crucial hypothesis of the model is the possibility to replicate the option with the underlying and a bond. This means that the holder of the option holds at the same time a portfolio that is designed to eliminate the risk stemming from the option. And the model assumes following:

1. The risk-free rate is known and constant over time;
2. The asset pays no dividends;
3. The option can only be exercised at the maturity date;
4. There are no transaction costs when buying or selling an asset or derivate;
5. It is possible to invest any fraction of assets or derivate to the risk-free interest rate;
6. There are no penalties when short-selling is made;
7. The model is developed from the concept that the option asset price has a continuous stochastic behavior, defined by the Geometric Brownian Motion (GBM)

- Binomial tree model

Compare with Black-Scholes model, the binomial tree model by Cox, Ross, and Rubinstein(1979) is simple and efficient method allows the holder of an option to decide whether it is most beneficial to exercise the option or to wait until its maturity date, at every time instant. So, the model can calculate not only European options but American options (Trigeorgis 1997).

And this model assumes that the maturity date of an option can be divided in discrete periods whose dimension will be represented by δt. Additionally, the price of the underlying asset is subject to a given behavior, and it will be multiplied by a random coefficient m or d, at each period (δt). It should be noted that random coefficients are defined as the price variation rate of the underlying asset. Since this rate can be ascending (u) or descending (d), reflecting the favorable or unfavorable market conditions, these multiplicative factors are dependent on volatility (σ) and length of the periods (δt). Fig.1. presents a binomial tree for the underlying asset, illustrating its price evolution. The nodes at the right represent the distribution of possible future values for the underlying asset.

The multiplicative factors, (u), probability of price increase and (d), probability of price decrease, are given by:

$$\mathrm{u} = e^{(\sigma \cdot \sqrt{\delta t})} \tag{3}$$

$$\mathrm{d} = e^{(-\sigma \cdot \sqrt{\delta t})} \tag{4}$$

The probability of the stock price to increase or to decrease is given by a risk-neutral measure. Therefore, the stock price increases with a probability equal to:

$$\mathrm{p} = (\mathrm{e}^{(r^f \cdot \delta^t)} - d)/(u - d) \tag{5}$$

and decreases with a probability given by:

$$\mathrm{q} = 1 - \mathrm{p} \tag{6}$$

After determining those parameters, the option value can be obtained through a binominal tree. In this tree each gain obtained for the underlying asset price is represented. For the case of a call option, this value is given by the maximum difference between the value of the underlying asset and its exercise price, and zero, i.e. max(S-K, 0). For the case of a put option, the value corresponds to the maximum difference between the exercise price and its stock price, and zero, i.e. max(K-S, 0). From the option value given by the nodes at the right of the tree, it is possible to calculate the other values applying the neutral probability on each pair of vertically adjacent values. They are mathematically represented by the following equation:

$$\mathrm{Cn} = (\mathrm{p} \cdot SU^{n} + (1 - p) \cdot e^{-r^{f} \cdot \delta^{f}} \quad (7)$$

Where,
Cn: the option value at node n
p: risk neutral probability
SUn: the asset value at node by probability of price increase
SDn: the asset value at node by probability of price decrease
rf: risk free rate

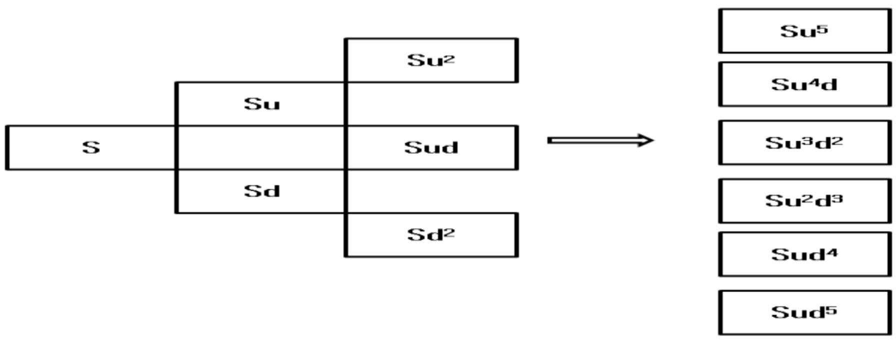

Fig. 1: The binomial tree for the evolution price of the underlying asset.

3. A case study of Korean bituminous coal mining project

3.1. Summary of the bituminous coal project

A consortium by Korean companies acquired shares of the project in A country to take 3million tons of annual total bituminous coal production. There are 4 open pit mines and 7 underground mines in the project site. The periods of development and production are 3 years and 20 years each. One of open pit mines will state to operate at the first year of production, and then other open pit mines will be phased in over period of production. The start of production in underground mines is depended on business environment because of low grade and high cost compare with open pit mines in the project. The value of the project by NPV is $ 1,317,665 (Table 1 and Table 2).

Table 1: Reserve of open pit mines and underground mins.

	Reserve		Resources	Planned life of production
	Proved	Probable		
Open pit	40 mil ton	237 mil ton	407 mil ton	20year
Underground	44 mil ton	35 mil ton	300 mil ton	-
Total	84 mil ton	272 mil ton	706 mil ton	20year

Table 2: The cash flow of the project.

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total Sales Revenue		0	0	318,162	761,441	699,172	740,128	779,187	770,878	639,724	635,780
Total Capital	18,000	390,000	1,000	1,000	18,000	13,000	48,000	26,000	4,000	48,000	4,000
Net Mine Operating Costs		0	16,740	159,468	274,476	265,092	309,820	311,601	284,086	280,951	307,954
Tax			-10,737	42,238	115,107	92,620	92,714	37,204	-15,207	-17,340	-25,661
Working Capital		0	2,064	-8,554	-15,283	5,668	-16,154	26,889	23,042	61	3,460
Net After Tax Cash Flows	-18,000	-390,000	-9,067	124,010	344,939	286,549	270,543	284,226	300,240	166,152	198,930
	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Total Sales Revenue	653,255	653,255	643,806	613,559	613,559	613,559	613,559	613,559	613,559	613,559	613,559
Total Capital	48,000	18,000	4,000	48,000	5,000	48,000	18,000	5,000	5,000	5,000	-58,000
Net Mine Operating Costs	299,625	298,359	275,860	268,564	290,444	311,607	325,995	327,687	320,071	320,071	320,071
Tax	-22,119	-22,279	-17,135	-19,871	-26,195	-32,544	-36,620	-37,158	-33,583	-33,988	-47,983
Working Capital	-1,182	-196	-1,304	101	2,697	2,609	1,774	209	-939	0	0
Net After Tax Cash Flows	179,369	207,087	234,850	173,564	199,714	141,989	162,512	175,922	181,112	180,578	257,573

* Discount rate : 9%, Tax : 30%

3.2. Valuation of the Project ROM

The valuation of the project by NPV assumed only development and production of open pit mines at the first stage and did not include any cost and revenue of underground mines which is to decide to start operation in accordance with changes of market environment. Thus, this study assumes that underground mines would be developed and operated allowing for the market environment to value the project using option to expand, one of real options.

3.2.1. Estimation of Parameters for ROM

- Estimation of volatility of bituminous coal price

Estimation of volatility in real option valuation techniques is calculated based on past movement of stock price or revenues, otherwise it is estimated by simulating the future predicted revenue. But, this study choose monthly Australian coal prices(New castle FOB) from Jan. 2002 to Nov. 2010 by applying the first difference of log and estimates the monthly standard deviation. The estimated monthly standard deviation is multiplied by. From the estimation of coal price volatility, the annual standard deviation 29.91% is obtained. (Table 3)

Table 3: The volatility of the bituminous coal price.

Monthly average	1.26%
Monthly standard deviation	8.64%
Annual average	15.17%
Annual standard deviation	**29.91%**

- Underlying asset value (S)

The value of NPV which is already calculated as cash flow analysis of the project plus the amount of investment is the underlying asset value of the project (Table 4).

Table 4: Underlying asset value.

Unit: thou $

Investment (A)	NPV(B)	Underlying asset value S = A + B
409,000	1,317,665	1,726,665

- Maturity(T) and Exercise price(X)

The expiration of the expansion option is assumed in fifth year where production from underground mines is stated. And the exercise price of the option is $263,387, investment to develop underground mines.

- Expansion Factors (Ef)

If open pit mines and underground mines are operated together, total amount of production in the project is increased by 1.36 times compare with the production from open pit mines only (Table 5).

Table 5: The total amount of production in the project.

	Open pit mines only	Expansion (Open pit mines+ Underground mines)	The rate of increase in production amounts
Total amount of production	162,479	220,661	1.358091

- Probabilities of ascending coal price and descending coal price (u & d)

Probabilities of ascending coal price $u = e^{(\sigma\cdot\sqrt{\delta t})}$, and descending coal price $d = e^{(-\sigma\cdot\sqrt{\delta t})} = 1/u$. Using two equations, the probability of ascending coal price $u = e^{(0.2991\cdot\sqrt{1})} = 1.349$, the probability of descending coal price d= 1/1.349= 0.741.

- Risk-free rate (r^f)

It is 2.66%, which is the return rate of US Treasury bonds with a maturity of 10 years at 1, Nov, 2010.

- Risk neutral probability (p)

The risk neutral probability is 0.470 result in substituting the values of probabilities of ascending coal price and descending coal price into the equation of risk-neutral probability, $p = (e^{(r^f\cdot\delta^t)} - d)/(u - d)$.

3.2.2. Valuation by the expand option

Table 6 shows the possible evolution of the underlying asset price(s) from the left to the right using probabilities of ascending coal price and descending coal price. And it is necessary to calculate using recursive backward iteration to estimate the option value on the basis of the value of underlying asset.

The calculation of the investment value at the maturity date is to select the greater value between the exercise value and the maintain value. For example, the investment value, including the expand option, at the maturity date, Su5, is as follows.

$$V(Su5) = Max[Su5, Su5 \times Ef - X] = Max[7{,}705, 7{,}705 \times 1.36 - 264] = 10{,}201$$
$$V(Sd5) = Max[Sd5, Sd5 \times Ef - X] = Max[387, 387 \times 1.36 - 264] = 387$$

Since the value of expand investment, $10,201 million, is greater than the value of underlying asset, $ 7,705 million at Su5 node, the expand option has to be exercised to invest for expanding. But the expand option cannot be exercised at SD5 node because the value of expand investment is lower than the value of underlying asset at SD5 node.

The value from Su4 points, using the risk-neutral probability, is inversely calculated from the maturity time of expansion options as follows

$$Su4, Max\ [Su5 \times Ef - X,\ p \times Su5 + (1 - p)\times Su4D\ /\ /\ e^{Rf*\Delta t}\ ]$$

$$= [10,201 \times 0.0266 - 264,\ 0.470 \times 10,201 + (1-0.470) \times 5,489/ \ / \ e^{0.0266 \times 1} = 7,502$$

The value of the expand option is larger than the value of the underlying asset at Su4 node, so the optimal decision is to expand the project. The optimal decision and the option value at each node are showed in Table 7 through the calculation as described above and the value of the project by expand option is provided in Table 8.

Table 6: Evolution of the underlying asset of the project using the binomial distribution model.

unit: mil $

															SU20	684,780
													SU19	507,731		
															SU19D	376,458
													SU18D	279,125		
															SU18D2	206,958
													SU17D2	153,449		
															SU17D3	113,775
													SU16D3	84,359		
															SU16D4	62,548
													SU15D4	46,376		
															SU15D5	34,386
													SU14D5	25,495		
															SU14D6	18,904
												---->	SU13D6	14,016		
												---->			SU13D7	10,392
										SU5	7,705	---->	SU12D7	7,705		
								SU4	5,713			---->			SU12D8	5,713
						SU3	4,236			SU4D	4,236	---->	SU11D8	4,236		
				SU2	3,141			SU3D	3,141			---->			SU11D9	3,141
		SU	2,329			SU2D	2,329			SU3D2	2,329	---->	SU10D9	2,329		
S	1,727			SUD	1,727			SU2D3	1,727			---->			SU10D10	1,727
		SD	1,280			SUD2	1,280			SU2D4	1,280	---->	SU9D10	1,280		
				SD2	949			SUD3	949			---->			SU9D11	949
						SD3	704			SUD4	704	---->	SU8D11	704		
								SD4	522			---->			SU8D12	522
										SD5	387	---->	SU7D12	387		
												---->			SU7D13	287
												---->	SU6D13	213		
															SU6D14	158
													SU5D14	117		
															SU5D15	87
													SU4D15	64		
															SU4D16	48
													SU3D16	35		
															SU2D17	26
													SU2D17	19		
															SU2D18	14
													SUD18	11		
															SUD19	8
													SD19	6		
															SD20	4

Table 7: Evolution of the value of the project by a expand option and the decision tree.

Unit: mil $

										SU5	10,201
								SU4	7,502		Expand
						SU3	5,503		Expand	SU4D	5,489
				SU2	4,022		Expand	SU3D	4,009		Expand
		SU	2,926		Expand	SU2D	2,913		Expand	SU3D2	2,899
S	2,120		Expand	SUD	2,103		Expand	SU2D3	2,088		Expand
	Expand	SD	1,513		Expand	SUD2	1,492		Expand	SU2D4	1,475
			Expand	SD2	1,067		Expand	SUD3	1,038		Expand
					Expand	SD3	745		Expand	SUD4	704
							Expand	SD4	522		Do not invest
									Do not invest	SD5	387
											Do not invest

Table 8: The value of the project by a expand option.

	Value(mil $)	Refer
A_ underlying asset value	1,727	Underlying asset S
B_ Option value of underlying asset	2,175	Option value of underlying asset S
C_ the value of option	449	B - A
D_ NPV	1,318	Value of the project using NPV
Expanded value of the project	1,766	C + D

4. Conclusion

Traditional methods such as NPV, IRR do not provide the optimal time to invest and the true value of project in uncertainty. However, ROM is a methodology used to evaluate real assets that considers management flexibility over the project's lifetime. As new information is considered and uncertainties are revealed, an investor can estimate the final project value using ROM. Thus, this study re-estimated a Korean bituminous coal mining project using ROM) and compare ROM with Discounted Cash Flow Method(DCFM) to present that ROM has advantage over the application of a DCFM under uncertainty of business environment. Unlike NPV, which neglect uncertainty over coal prices, ROM considers these uncertainties. So this study concluded that the value of ROM is higher than the value of DCFM as much as the value of option to expand because ROM gives better information to determine when the investor has the option to expand the investment.

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