Real options in mine project budgeting – Polish mining industry example

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Abstract

Traditional methods of capital budgeting often fail to assign the proper value or timing to management decisions. The theory of option pricing can produce a valuation that resolves these issues. This paper compares the results of two capital budgeting approaches on the example of Polish zinc-and-lead mining. Option pricing approach is used to value the project and find the best operating strategy. The sensitivity analysis due to volatility of zinc prices and defer mine opening time is considered.

1 Introduction

Most investment decisions share three important characteristics in varying degrees. First, the investment is partially or completely irreversible. In other words, the initial cost of investment is at least partially sunk — you cannot recover it. Second, there is uncertainty over the future rewards from the investment. The best you can do is to assess the probabilities of the alternative outcomes that can mean greater or smaller profit (or loss) for your venture. Third, you have some leeway about the timing of your investment. You can postpone action to get more information (but never, of course, complete certainty) about the future. These three characteristics interact to determine the optimal decisions of investments.

The basic inadequacy of the net present value (NPV) approach and other discounted cash flow (DCF) approaches to capital budgeting is that they ignore, or
cannot properly capture, management's flexibility to adapt and revise later decisions. The traditional NPV approach, in particular, makes implicit assumptions concerning an 'expected scenario' of cash flows and presumes management’s commitment to a certain 'operating strategy'. Typically, an expected pattern of cash flows over a specified project life is discounted at a risk-adjusted rate (derived from the prices of a twin traded financial security, usually employing the Capital Asset Pricing Model (CAPM)) to arrive at the project’s NPV.

In the real world of uncertainty and competitive interactions, however, the realization of the cash flows will probably differ from what management originally expected. As new information arrives and uncertainty about future cash flows is gradually resolved, management may find that various projects allow it varying degrees of flexibility to depart from and revise the operating strategy it originally anticipated. For example, management may be able to defer, expand, contract, abandon, or in various other ways alter a project at various stages during its useful life.

Conventional methods are limited in providing appropriate tools to manage risk and uncertainty and strategic mine investment projects. Advances in modern finance theory have provided solutions to these limitations. This has led to significant effects on financial markets, such as options, futures, swaps and other exotic derivatives. These instruments have been extended to evaluate physical assets, such as opportunities to explore, develop, produce and sell mineral resources.

The primary objective of this paper is to extend the mineral resource model to develop the derivative mine valuation method based on the arbitrage pricing theory. The derivative mine valuation is examined and compared with results from DCF methods. The calculations are made on the example of Polish zinc-and-lead ores mining. The presented example shows the method of undeveloped reserves pricing which has – using standard DCF calculation – negative NPV value.

2 Valuation methods based on discounted cash flow

The main idea behind the discounted cash flow analysis is that time is valuable. Suppose that $CF_t$ is the expected cash flow associated with the project in year $t$. The net present value of this project is given in discrete capitalization model

$$NPV = \sum_{t=0}^{T} \frac{CF_t}{(1+r)^t}$$

where $T$ is the planning horizon of the investment and $r$ is the risk-adjusted discount rate. If we assume that investment $I$, takes place in the initial period, then a project should be adopted if its net present value exceeds its investment cost, i.e., $NPV > I$.

The popularity of DCF approach derives from its sound theoretical foundations. If the set of discounted cash flows is correctly determined, then the sum of these flows yields the market value addition to the firm acquiring the mining. Performing
these calculations correctly, however, is very difficult, and the DCF approach as
applied has few major weaknesses that inhibit correct mining project valuation.

Although the idea of NPV is rather simple, however it contains many draw-
backs. The most important is that cash flows must be forecast over the expected
lifetime of the investment project. This means that one has to obtain estimates of
future commodity prices, exchange rates, mining and processing costs, taxation
policy, macroeconomic cycles, and political stability. Detailed feasibility studies
are used to forecast costs. However, different companies, as well as the govern-
ment, may have different assessments of future statistical distributions, and thus
expected path, of mining process, none of which need conform to the aggregate
expectations held by capital markets. This also leads to divergent valuations.

The second drawback is that an appropriate risk-adjusted discount factor must
be obtained. In theory this is accomplished through the application of an equilib-
rrium model such as the CAPM model. The model states that, under certain assump-
tions, the appropriate rate of return of any risky asset can be obtained as a function
of the riskless rate of return \( r_f \) and the rate of return of the market portfolio \( r_m \).
Thus, the expected rate of return of the risky asset \( r_j \) is given as follows

\[
  r_j = r_f + \beta_j (r_m - r_f)
\]

where 'beta' coefficient \( \beta_j = \sigma_{jm}/\sigma_m^2 \) expresses the price sensibility of \( j \)-th asset
to market price sensibility.

An important insight that emerges from the CAPM model is that only system-
atic or undiversifiable risk needs to be priced. This insight is particularly important
for mining projects. Indeed, most geologic and metallurgical uncertainty is project
specific. Moreover, commodity price and exchange rate risk can be hedged. Fur-
thermore, even not hedged, price uncertainty is not strongly correlated with returns
on the market portfolio. Together, these factors imply that, in spite of being highly
risky, mining projects should not command large risk premia.

The process of choosing the correct set of risk-adjusted discount rates in the
presence of the complex statistical structure of the cash flows is difficult task,
which is also a subject to a great deal of subjectivity and error. For example, the
investment-timing rules used by the firm will affect the risk of the cash flows in
complicated ways. Thus, the optimal-timing rule will need to take account of this
relationship. Companies, as well as the government, often resort to simple rules
of thumb such as "use 20 percent for the exploration phase and 10 percent there-
after". The choice of discount rates is crucial, however the DCF valuations are very
sensitive to the rates chosen [10].

The next drawback is that the proper timing of exploration and development is
not transparent. The choice of timing for the DCF calculations is therefore arbitrary
and subject to error. This problem leads to valuations that are divergent between
companies, the government, and the capital markets. Moreover, the DCF calcula-
tions, particularly Monte Carlo applications, are very complex and costly.

A final drawback with DCF analysis is concerned with managers passivity. It
is assumed that a project will be undertaken today and will continue to produce
until reserves are exhausted. Real world managers, in contrast, have considerable
30  Risk Analysis III

flexibility in choosing the timing of projects. In addition, once a mine is operational, managers have discretion concerning extraction rates, cut-off grades, capacity expansions, temporary closings, reopenings, and eventual abandonment. It is the value of this flexibility that distinguishes appraisals based in option pricing theory form DCF calculations.

3 Valuation methods based on option pricing theory

The NPV rule, however, is based on some implicit assumptions that are often overlooked. Most important, it assumes that either the investment is reversible, that is, it can somehow be undone and the expenditures recovered should market conditions turn out to be worse than anticipated, or, if the investment is irreversible, it is a now or never proposition, that is, if the firm does not undertake the investment now, it will not be able to in the future.

Although some investments meet these conditions most do not. Irreversibility and the possibility of delay are very important characteristics of most investment in reality.

The basic inadequacy of the NPV approach and other DCF approaches to capital budgeting is that they ignore, or cannot properly capture, management’s flexibility to adapt and revise later decisions (i.e., review its implicit operating strategy). The traditional NPV approach, in particular, makes implicit assumptions concerning an ‘expected scenario’ of cash flows and presumes management’s commitment to certain operating strategy.

A financial option gives the owner the right, without an associated symmetric obligation, to buy (a call option) or to sell (a put option) a specified quantity of the financial asset (the underlying security or claim upon which the option is contingent) for a specified price (the exercise or strike price) on or before a specified date (the expiration or maturity date). If the option can be exercised before maturity, it is called an American option; if only at the maturity, an European option.

Investing in a mining project has much in common with exercising a financial option. First, both are at least partially irreversible. Once an option has been exercised it is dead, and once project development has begun, sunk costs cannot be recouped. Second, it is rarely optimal to exercise an American call option as soon as it is in the money, since share prices can rise still farther. In a parallel fashion, the simple NPV rule, invest if \( NPV \geq I \), is rarely optimal, since delaying can yield valuable information about prices and costs. In each case, taking an irreversible action means forfeiting the option to wait for new information concerning market conditions. When this information is valuable, the lost option value must be added to the direct cost of investing. Therefore, Option Pricing Theory (OPT) assigns at least as high a value to a potential investment project as the value that is obtained using DCF techniques. In other words, flexibility cannot have a negative price.

To stress the analogy with options on financial assets, the opportunities to acquire real assets are sometimes called real options.

The OPT is based on the dynamic arbitrage models of derivative securities by Black, Scholes [2] and Merton [8] and the mineral resource model by Brennan and
Schwartz [4]. These models help to evaluate complex assets and provide methods for designing hedging positions for firms to maximize trading portfolio values in competitive markets. The dynamic arbitrage theory is based on a small set of propositions about the structure of financial markets and the information content of prices in these markets. The key proposition is that evaluation in competitive markets can be made, to a good approximation, as if these markets were efficient and free of transaction barriers. In efficient financial markets without barriers, different assets with the same cash flows have the same price. Moreover, in such markets, it is possible to replicate the cash flows from a complex asset, such as a mineral venture, by trading in portfolio of more basic and simpler assets such as futures contracts on appropriate commodities. Finally, all asset prices are determined by the overall risk performances of investors. Therefore, the basic assets that provide the information about risk discounting are those directly associated with the key future macroeconomic variables such as the future commodity contracts which are related to the corresponding future prices of commodity.

The value of the European call option can be calculated from the formula

\[ C(t) = S(t) N(d_1) - X e^{-r(T-t)} N(d_2) \] (3)

where \( X \) is the strike price of the option, \( r \) risk free interest rate (for the maturity \( T \)), \( S(t) \) the price of the underlying asset at time \( t \), \( \sigma \) volatility of the stock prices, \( N(\cdot) \) is the cumulative standard normal distribution function, and

\[
d_1 = \frac{\ln S(t)/X + (r + \frac{1}{2} \sigma^2)(T - t)}{\sigma \sqrt{T-t}}
\]

\[
d_2 = d_1 - \sigma \sqrt{T-t}.
\] (5)

4 Polish zinc-and-lead mine as an example

The zinc-and-lead Olkusz-Pomorzany mine is at the final stage of its life. At present the mine operates on deposit of Pomorzany, which will be depleted within 8-10 years. The chance to extend mine’s lifetime is to develop and mine the deposit of Klucze, which is localized north of Pomorzany deposit.

Klucze deposit was discovered in 1956 during appraisal of the Pomorzany deposit. The first diamond drillings started with 35 boreholes. The results were very promising – 7.2 millions tonnes of ore were identified in 1964. Until late 1990s there have been bored further test wells (370 at present) which help to learn about deposit much more – the workable reserves have been then estimated at 5.7 millions tonnes of ore with Zn and Pb grades of 4.8% and 2.2% respectively.

The idea of developing and mining the Klucze deposit has been always put off mainly because of occurring better ore bodies to mine. Nowadays, in prospect of soon depletion of Pomorzany resources, it is often taken into consideration to open Klucze deposit. But the mine opening makes sense only when the Pomorzany mine still operates. This means, considering depletion time of deposit Pomorzany, that deposit Klucze must, if even, be developed within next 8-10 years.
The development and mining plan of Klucze deposit assumes then driving development drifts from the excavations of the Olkus-Pomorzany mine. After development, assessed at 2 years (drifts driven from three points of the mine with monthly progress of 150 meters), the deposit will be mining (room and pillar method) with the yearly output rate of 33,000 tonnes as long as reserves in Olkus-Pomorzany will have been depleted. The summary of capital investments has been valued at about 22 millions of US dollars.

The problem of investment risk on Klucze deposit has been estimated as extremely high-risk venture. Many factors were involved here – first of all, irregular and uncertain character of the deposit, second, location of a part of deposit within the borders of preserved areas, third, lower prices on metal markets. The last evaluation of Klucze deposit was made in 2000. The evaluation was conducted with the DCF analysis. Because of the risk involved, the 20% risk-adjusted discount rate was assumed. The evaluation showed that investment is unreal and uneconomic. If the NPV of expected cash flows from Klucze deposit is less than zero the natural idea is to use OPT to evaluate the deposit. Investing in a project like Klucze can be viewed as a financial option. The investors have the right to incur investment expenses and receive, in effect, the developed ore body. This flexibility, which can be priced using OPT, is a source of additional value on real assets. This surveillance has fundamental importance for mining project valuators.

As mentioned above, investing in mineral project has much in common with financial option. But each mining project is not, in fact, simple option problem – in mostly cases we deal with compound option. Possessing a mining property gives us the right to explore (option to explore); exercising the option to explore – paying exploration cost (diamond wells or exploratory drifts) the owner receives appraised ore body. Having an identified deposit the investor has an option to develop – that means pay development cost and receive a developed deposit in result. Now, having a developed deposit, the investor has an option to start production (paying start-up costs), then options to expand, temporary close or abandon the mining venture.

The Klucze deposit is at stage before development. The managers of Olkus-Pomorzany mine have the option to develop – pay development cost in excess 22 millions of dollars and receive the developed ore body or abandon this venture. Because of project-specific restrictions we assume that once developed the deposit is mined at a known rate (and grades) and cost until reserves are depleted. These assumptions map perfectly compound option problem into single-option one.

Under these assumptions the stock price in Black-Scholes formula responds undeveloped deposit, current stock price – present value of developed reserves, exercise price – development cost.

For the simplicity of analysis, we assumed that 1 tonne of zinc is equal to 2 tonnes of lead, so all the calculations will be made on zinc deposit.

First of all we use a DCF model to determine the net present value of mine. We allowed zinc prices to be uncertain and we assumed the deterministic working costs. We assumed the risk-adjusted discounted rate as 20%. The NPV of project mining was negative. The results are given in table 1.
Table 1: Zinc spot prices and value of NPV project.

<table>
<thead>
<tr>
<th>Spot price of Zn [US$]</th>
<th>NPV of the mine opening [mln US$]</th>
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<tbody>
<tr>
<td>700</td>
<td>-57.130</td>
</tr>
<tr>
<td>800</td>
<td>-47.946</td>
</tr>
<tr>
<td>900</td>
<td>-38.762</td>
</tr>
<tr>
<td>1000</td>
<td>-32.102</td>
</tr>
<tr>
<td>1100</td>
<td>-25.758</td>
</tr>
<tr>
<td>1200</td>
<td>-19.441</td>
</tr>
<tr>
<td>1300</td>
<td>-13.196</td>
</tr>
</tbody>
</table>

Second, we applied OPT to evaluate Klucze deposit ore. The zinc price has been changing dramatically during the last decade. Only in the last 2 years, the spot price at the London Metal Exchange (LME) was changing from 1243 US$/tonne (September 2000) to 732 US$/tonne (December 2001). We calculated the standard deviation and drift in monthly percent changes of zinc spot prices at the LME for the 1989-2001 period. The calculation was done for the mine opening postponed until 5 years. We assumed the risk-free rate as 5%. The zinc spot price was recalculated to the present value of the developed mine project with risk-adjusted discounted rate of 10%. The results of such investment project are given in Table 2.

Table 2: Zinc spot prices, present value of developed reserves (PVDR), NPV value, option’s value and the whole project’s value.

<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>900</td>
<td>3.354</td>
<td>-31.246</td>
<td>0.098</td>
<td>-31.148</td>
</tr>
<tr>
<td>950</td>
<td>7.581</td>
<td>-26.231</td>
<td>1.041</td>
<td>-25.190</td>
</tr>
<tr>
<td>1000</td>
<td>11.808</td>
<td>-21.502</td>
<td>2.943</td>
<td>-18.559</td>
</tr>
<tr>
<td>1050</td>
<td>16.035</td>
<td>-16.812</td>
<td>5.523</td>
<td>-11.290</td>
</tr>
<tr>
<td>1100</td>
<td>20.262</td>
<td>-12.136</td>
<td>8.561</td>
<td>-3.576</td>
</tr>
<tr>
<td>1150</td>
<td>24.489</td>
<td>-7.460</td>
<td>11.909</td>
<td>4.449</td>
</tr>
<tr>
<td>1200</td>
<td>28.716</td>
<td>-2.800</td>
<td>15.473</td>
<td>12.673</td>
</tr>
</tbody>
</table>

The value of call option to postpone mine opening is given on figure 1. The simulation was done using Matlab Financial Toolbox. Up to now we have implic-
Present value of developed reserws [mln US$]

Figure 1: Value of call option to postpone mine opening.

ity assumed that the volatility of the zinc price (in our calculations 40%), time to maturity of the option (5 years), development cost (19.383 mln US$) and convenience yield (0%) are constant. In practice, all these parameters change over time. This means that the value of the option is sensitive due to above mentioned parameters. Next, the sensitivity analysis using Greek parameters was considered. We calculated sensitivity measures:

- **vega** – the change of present value of developed reserves relative to the volatility of the zinc price
- **theta** – the change of present value of developed reserves relative to time.

The results are shown on fig. 2 and fig. 3 respectively.

If vega is high in absolute terms, the project value is very sensitive to small changes in volatility of zinc price. If vega is low in absolute terms, volatility changes have relatively little impact on the value of the project.

**Theta** is not the same type of hedge parameter as vega or delta. This is because there are some uncertainty about the future of zinc price volatility or zinc price, but there is no uncertainty about passage of time.

5 Conclusions

The two methods of capital budgeting – discounted cash flow and option pricing approach – were compared in this paper. Considerations have been taken into
account on the example of Polish zinc-and-lead mining. In this case it was shown that traditional approach undervalues mineral resources whereas option pricing approach gives the positive value of managerial flexibility. Moreover, sensitivity analysis based on Greek parameters was done. Simulation results were presented using Matlab Financial Toolbox.

References

Figure 3: Sensitivity of call option to time to maturity.


