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Valuation of a hypothetical mining project under commodity price and exchange rate uncertainties by using numerical methods

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ABSTRACT

One of the goals presented here is the use of a radial basis function (RBF) method to approximate the numerical values of a gold mining project. RBFs have many attractive features compared to implicit finite differences method (FDM) and explicit FDM. They are mesh-free, computationally more efficient in high dimensions, and very accurate. In other words, the model is more comprehensive, and results are more accurate compared to the previous works. This paper compares accuracy of the RBF method with that of the implicit method (FDM) in this case study. The results indicate that convergence order of the RBF is higher than that of the implicit method. Also, this paper compares the results of the RBF method with those of implicit method for various scenarios.

The most important goal presented here is combining exchange rate uncertainty together with commodity price (spot price) uncertainty. In fact, this paper tries to address this question: how can we model the exchange rate volatility and the correlation coefficient between returns of commodity price and exchange rate in assessing a gold mining project. Considering the disadvantages of the Discounted Cash Flow (DCF) method which does not use uncertainties, the approach presented here makes use of real options valuation for a gold mine project valuation. This paper uses an explicit method (FDM) for these calculations. The results indicate increasing volatilities for either or both commodity price or exchange rate results in decreasing the maximum project value. Also, the correlation coefficients between returns of commodity price and exchange rate in different years are negative and statistically significant. The final result indicates that with an increase in the correlation coefficient, the volatility of gold price in terms of Canadian dollar decreases and therefore the maximum project value increases too. In summary, the exchange rate volatility and the correlation coefficient between returns of commodity price and exchange rate have a significant impact on mining project values.

1. Introduction

A widely accepted method of mining project valuation is DCF; however, it has some disadvantages. One of the most important disadvantages is that it cannot model uncertainty in the commodity price and uncertainty in the exchange rate. This has led to several studies that use the Real Options Valuation (ROV) method as a technique to value natural resource investments under conditions of uncertainties. Myers (1977) studied "real options", where corporate investment opportunities are considered as call options on real assets. This takes advantage of the Black-Scholes-Merton option valuation framework introduced in 1973 (Black and Scholes, 1973; Merton, 1987). Another disadvantage has been revealed by many studies that show managers do not necessarily consider the forecasts of a DCF method (Colwell et al., 2003; Hayes and Garvin, 1982; Hayes and Abernathy, 1980) because it fails to take into account managerial flexibilities and financial options and uncertainties. First, this paper compares the results of the RBF method with those of the implicit method for a gold mining project including commodity price volatility without exchange rate volatility. The RBF method is more comprehensive and realistic. This method is more accurate compared to previous works. Increased accuracy is obtained using the computationally efficient mesh-free RBF methods. Finally, this paper uses explicit method to approximate the numerical values of a gold mining project including exchange rate volatility together with commodity price volatility.

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Nowadays, investors' decisions about financial markets and financial derivatives consider market conditions. For example, Brennan and Schwartz (1985) obtained the value and optimal production policy of a natural resource investment, considering the price of a commodity with a recognizable future market. They indicate that managers can use financial derivatives in order to hedge against uncertainties. In fact, these derivatives help managers to be flexible against risks. Therefore, they can reach a better value for a project.

Brennan and Schwartz (1985) made use of real options frameworks in the mining industry. They considered a stochastic model for natural resource investments. Since then, Brennan and Trigeorgis (2000), Copeland and Antikarov (2001), Dixit and Pindyck (1994), Trigeorgis (2000, 1996, 1993), Topal (2008) used real options theory for investments decision making. So far, most studies focused on theory (Brennan and Schwartz, 1985; Cortazar and Casassus, 1998; Colwell et al., 2003; Cortazar et al., 2001). More recently, Haque et al. (2014) further developed a theoretical method and enhanced an approach to approximate solutions to modeling equations using an explicit numerical approach.

Commodity price (spot price) and exchange rate are stochastic, so Geometric Brownian Motion (GBM) is used to model them. First, this paper uses a model that includes commodity prices together with financial market tools such as options, hedging and futures market contracts. A PDE is derived from the GBM, and then can be solved numerically through FDM (implicit and explicit methods) and the Radial Basis Function (RBF) method. Second, another PDE will be constructed by adding exchange rate movement. This PDE is also solved numerically.

RBFs methods have many attractive features. The first of these features is that they are high dimensional splines, making them efficient for any number of dimensions. The second feature is that they are very accurate. For sufficiently smooth functions, the multiquadratic (MQ) RBF method is exponentially or spectrally accurate (Scott et al., 2009). Finally, the third feature is that they are mesh-free. This means that RBF require a smaller number of nodes compared to methods that use a full mesh like FDMs (Peña, 2003).

One of the goals of this paper is the use of the RBF method to approximate the value of a gold mining project because this method is more accurate than other numerical method. This paper shows the results of the RBF method and implicit method for a gold mining project including only commodity price volatility.

The main goal of this paper is to model exchange rate uncertainty in assessing a gold mining project. In fact, this paper will try to address a hypothesis. This hypothesis is "the volatility of exchange rate and correlation coefficient between returns of commodity price and exchange rate will influence valuing of a gold mining project". Commodity, country, and total reserve selection is arbitrary. Here is the explanation of our choices. The gold is selected because it is an important commodity in the global economy. Our work can apply to other commodities such as oil, copper, etc. Canada is selected because it has traditionally been a world leader in the mining industry. Iran (the country of 4 authors) was considered; however, there is insufficient data from Iran for our investigation. A small-sized hypothetical mine is selected for several reasons. Using a small size allows a comparison with Haque's work (2014). Generally, when spot gold price decreases significantly, the smaller and nimbler mines have been the winner in Canada, because they focus on good mining practices and minimizing dilution (business.financialpost.com). Additionally, there are many small mines in Iran. This approach could be extended to large mines as well.

The rest of this paper is organized as follows:

- Theory and calculation section: Models for commodity price movements and exchange rate movements are described first, followed by a PDE to value the real option. Volatilities for the commodity price and the exchange rate are discussed in a historical context. The real options scenarios for mining projects are considered. Finally, implicit, explicit, and radial basis function methods are explained.
- Results and discussion section: The first calculation implements only commodity price uncertainty by using a RBF method and a FDM. Accuracy of the RBF method and implicit method is compared in this section. Also numerical results for the value of a gold mine project together with sensitivity analysis are presented. Next, exchange rate uncertainty is incorporated, and the results are approximated by an explicit method.
- Conclusion section: Summaries of results and discussions are presented in this section.
- Details of the RBF method are discussed in the Appendix A.

2. Theory and calculations

2.1. Real options for the gold mining project

Considering uncertainties, a manager can make use of different options during the life of a mine under different scenarios. Real options here include the delay and abandon option, the temporary closure option, and the accelerate/decelerate options and expansion options for mine operation. These options are explained here, and will be explained in the results section.

Delay and abandon option: considering commodity price depreciation, a manager can postpone to begin the gold mine operation. A manager can delay the project if the maximum project value is $0, i.e. total cash flows of the project will be negative. If the total cash flow is negative for a longer duration, a manager can use the abandon option.

Temporary closure option: if the commodity price declines noticeably, then a manager can make use of the option to close it temporarily. When the commodity price increases, a manager can make decision to reopen the mine.

Accelerate/decelerate options and expansion options: for example, if the commodity price increases significantly, a manager can accelerate the production rate. This increases the value of the project and may improve the return on investment.

2.2. Determination of historical volatility of the commodity price (spot gold price), exchange rate (USD to CAD), and reverse Canadian-Dollar Effective Exchange Rate Index; and correlation coefficient between returns of the commodity price and exchange rate (reverse CERI)

Volatilities for the commodity price and exchange rate (the standard deviation of the log returns) are input parameters for this model. Estimation of historical volatility is based on the calculation of the standard deviation of daily returns. For example, the steps for gold price volatility are as following:

1-Calculate the log returns of gold prices, relating today's gold price to yesterday's gold price. This is $r_t = \ln(P_t/P_{t-1})$ 2-Claculating the variance of the log returns based on the formula $\sigma^2=(1/n\text{-}1)\sum_{t=1}^{n}(r_t\text{-}\bar{r})^2$ where $\bar{r}=(1/n)\sum_{i=1}^{n} r_i$ 3-Taking the square root of the variance to get the standard deviation, and converting it to an annualized volatility. The daily historical volatility is given by $\sigma=\sqrt{(1/n\text{-}1)\sum_{t=1}^{n}(r_t\text{-}\bar{r})^2}$. Annualized volatility is calculated by $\sigma_{an}=\sigma\times\sqrt{T}$, where T is the number of intervals per annum.

We obtain the volatility for each year. Then, we consider largest (smallest) volatility from 1998 to 2015 as the maximum (minimum) volatility.

The average volatility of gold price, σ_P, from January 02, 1998 to December 31, 2015 is 17.6%. Over the same period, the minimum gold price volatility is 12.72% and the maximum gold price volatility is 34.32%. Resource data are from www.quandl.com.

The average volatility of exchange rate,σ_E, from January 02, 1998 to December 31, 2015 is 9.55%. Over the same period, the minimum