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Real options in metal mining project valuation: Review of literature

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ABSTRACT

This paper presents a literature review of the academic literature that covers real option analysis in the context of metal mining investments. Real options are of growing importance in metal mining, because of increased uncertainty of markets and complexity of new projects. The central promise of real option valuation methods applied to project analysis is to both hedge and enhance expected economic returns. The reviewed literature is sorted on the basis of the valuation approach used and by the type of real options studied. The distinction between real options "on projects" and "in projects" is made and discussed.

1. Introduction

Mining investments are capital intensive and practically irreversible projects with long, but often limited economic lives. The economic viability of these large investments depends typically on the uncertain development of world market prices of metals and on how project specific risks materialize. Mining investments are very large real investments and their valuation should be conducted by taking into consideration the type of uncertainty that surrounds them and the special circumstances, including real options that may be found connected to these investments (Collan, 2011a).

A real option (RO) is a right, but not an obligation, to undertake business initiatives that are connected to and exist on real assets or within real assets, e.g., see (Amram and Kulatilaka, 1999; Trigeorgis, 1993a). Surveys of Bartrop and White (1995), Bhappu and Guzman (1995), Smith (2002) indicate that methods mainly ignoring the real option nature of projects are still the most commonly used project valuation techniques in the mining industry – namely static discounted cash flow (DCF) methods such as Net Present Value (NPV) and Internal Rate of Return (IRR) as they are in industry also in general (Ryan and Ryan, 2002).

Real options can be used to enhance the return from these assets or to protect the asset returns, when negative events take place. This kind of management flexibility is an important ability in the metal mining industry, where the main value drivers of projects, such as commodities prices and exchange rates may experience high volatility and thus affect investment value, e.g., see Hall and Nicholls (2007).

Crowson (2003) suggests that the decreasing quality of untapped orebodies has already resulted in a technological shift towards hydrometallurgical methods in mining/enrichment technology and increasing size of new mines. Although these large modern, low-cost operating mines may have only little real option value (see, e.g., Slade, 2001), the real options aspects should not be ignored. Coldwell et al. (2003) concludes that the economic significance of real options should be ascertained in a case-analysis of an individual operation.

This paper is a literature review of real option analysis in the context of metal mining investments. The paper continues with a brief introduction to real options. The material of the research is then introduced and limitations discussed. Section two is a brief overview to existing "standard" for metal mining asset valuation. Third section discusses the key uncertainties to be addressed in the analysis of metal mining investments. Section four lists real options identified from the covered literature. Section five discusses the solution methods of real option problems arising from the RO-analysis. Section six compares the treatment of RO-framework in the three most commonly applied income valuation methods, namely DCF, option agreement method and dynamic DCF models. Section seven summarizes the key aspects of covered literature. The paper closes with results and discussion.

1.1. Real options

The term "real options" was coined by a theoretical study of corporate debt policies in Myers (1977). He divided corporate assets into two categories: assets in place and real options (growth opportunities), from which the latter are valuable sources of managerial flexibility stemming from the company's capabilities and core competencies (Allen et al., 2008).

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Real option analysis (ROA), in a broad sense, refers to applying an "option-based view of the world" to capital budgeting. Real option valuation (ROV) refers to the practical implementation of option valuation techniques to real investments. In the academic literature the terminology "ROV" and "ROA" is often used interchangeably. Option valuation was originally developed for the pricing of financial options and the notable models designed for financial option valuation include the well-known Black-Scholes option pricing formula (Black and Scholes, 1973) and the binomial option valuation method (Cox et al., 1979). Simulation was first used by Boyle (1977) for the pricing of options.

The existing RO-literature on mining investments covers a full range of managerial flexibilities from strategic corporate level decision making to mining fleet's transport route optimization studies. For purposes of this review, the real options of mining investments are divided into two categories: real options *"on projects"* and *"in projects"*. Similar framework on the classification of real options has been presented by, e.g. Botín et al. (2012).

The RO classification "on projects" should be understood as a means to exploit the flexibility inherent in sequential investments as proposed in Adner and Levinthal (2004). That is, there are several discrete sequential options before the actual extraction of mineral reserve. Under uncertainty having flexible strategies and ability to delay decisions can add value compared to making all strategic decisions during project planning.

Real options *in projects* refer to the available managerial flexibility from "an industrial engineering/production management perspective" (Bengtsson, 2001). The idea is presented in Fig. 1. According to Groeneveld and Topal (2011) real options "in projects" can be viewed as flexibility of the underlying engineering system to respond to the resolution of uncertainties. For example, some of the initial mining infrastructure can be built large enough to allow rapid expansion of the production in the later stages of the project in a case of favorable metal price development. In a broad sense, de Neufville (2003) includes all flexibility providing elements of an engineering system as real options.

1.2. Material and limitations of the review

The material of this paper consists of 92 academic research papers of mining investment literature of which the majority is published during the last 20 years (1995–2015). The material is supplemented with general real option literature. Following the review guidance of Webster and Watson (2002), the metal mining investment analysis can be identified as a "mature" topic with a wealth of accumulated knowledge. Therefore, rather than contributing on new theoretical foundations, this paper concentrates on synthesizing the existing literature.

Some earlier review works include a widely cited review of Davis (1996) on the real option values of mineral properties. Discussion on the general microeconomic features of mining investments is presented by Cairns (1998). Eves (2013) provides a review of on the valuation methodology of mining assets. A short review of ROV studies regarding natural resource industries (including oil) is presented by Shafiee et al. (2009).

The detailed accounting aspects of mining dealt with in, e.g. Mohebbi et al. (2007) and Smith (2002) are beyond the scope of this paper, such as capitalization of development expenditures and the reporting smooth yearly cash flows. Technically oriented optimization studies of mining operations are also left out as they do not consider the value of optimization from the overall economical point of view.

The valuation of metal mining projects is traditionally done as stand-alone ventures and more rarely multiple projects are considered as a real asset portfolio. Bowen (1984) writes that essentially, one may have to choose whether to use a single project framework or a portfolio approach in the analysis. In this paper the main focus is on the valuation of single projects. For selecting and valuing real option portfolios one should refer to e.g., (Archer and Ghasemzadeh, 1999; Carazo et al., 2010; Childs et al., 1998; Dias, 2006; Ross, 2004).

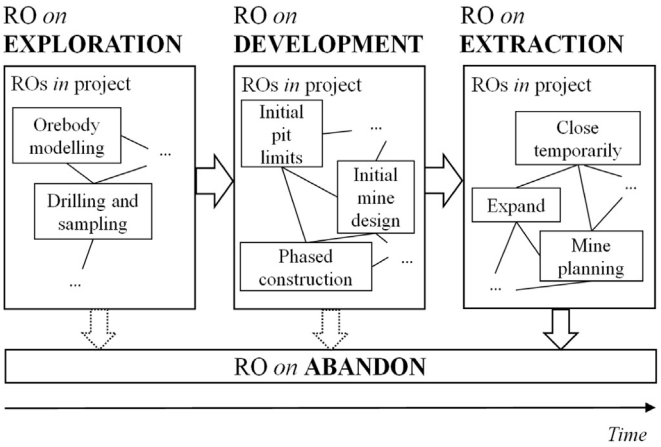

Fig. 1. Illustration of the applied real options classification for metal mining projects.

2. Valuation framework

2.1. Standards of valuation

The valuation of assets, according to Bartrop and White (1995), CIMVAL (2003), is done as an operating concern to arrive at value or worth. Laughton (2007) points out two main purposes for valuation: firstly for trading of assets in the markets and secondly for decision making purposes. Several professional codes have been developed to standardize the field of mining asset valuation such as:

- *Standards and Guidelines for Valuation of Mineral Properties* CIMVAL (2003) by Canadian Institute of Mining, Metallurgy and Petroleum;
- *Australasian Code for Public Reporting of Technical Assessments and Valuations of Mineral Assets (The VALMIN Code)* by The VALMIN Committee (2015, 2005).
- *The South African Code for the Reporting of Mineral Asset Valuation (The SAMVAL Code)* by the South African Mineral Asset Valuation (SAMVAL) Working Group (2009) and
- *International Minerals Property Valuation Standards Template (Includes Petroleum* by International Valuation Committee IMVAL (2015).

The codes classify the valuation approaches as income, market or cost based. The classification of CIMVAL (2003) is illustrated in Fig. 2.

Collan and Kyläheiko (2013) note that the usability of valuation approach is critically dependent on the type of prevailing uncertainty: the discounted cash flow method (income approach) is only applicable when valuing assets whose cash flows can be evaluated relatively accurately. They suggest that the market approach, which is based on transactional data of similar type of assets and the analysis of market conditions at the time of transaction, is most suitable for short run decision making under parametric uncertainty. According to Collan and Heikkilä (2011)