



# A dynamic model for valuing flexible mining exploration projects under uncertainty



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## ABSTRACT

Mining ventures are long term irreversible capital investments that operate in a highly uncertain environment and which typically present significant managerial flexibility. It is a well-known fact that due to their option-like characteristics, the value of these managerial flexibilities is not captured by traditional valuation techniques, such as the discounted cash flow method.

In this article we develop a dynamic model for the assessment of the financial viability of flexible mining projects in the exploration stage (junior mines). We assume the firm has the option to defer the initial investment for a period of time, and once invested, has the additional flexibility to expand or even abandon the project. The model simulates the managerial decision making process and determines the value of the flexibility, or real options, associated with the mining project. On the other hand, for the case of firms that are listed in the stock market, the model assesses the likely impact of these options on the firm's market value. We present a case study where we apply this model to a silver junior mining venture in Perú. The results indicate that the combined real options associated with the project may have a significant impact on its value, suggesting that the firm's stock is undervalued by approximately 25%.

## 1. Introduction

The mining industry operates as a segmented business divided into prospectors, junior mining firms and majors. Greenfield exploration is typically conducted by prospectors, who seek to identify areas that have potential for further development. Once such a site is identified, junior mining firms raise capital in the market in order to perform the geological and geophysical surveys, tests, drilling and sampling that are required to assess the value and the full extent of the reserves, so it can be sold to a major who will actually build and explore the mine.

After years of steady growth that began after the turn of the millennium, by the middle of the second decade, the mining industry worldwide began facing a more challenging economic environment due to high volatility and a sharp reduction in metal prices. Many mining projects, especially those in the early exploration stage of Junior mines, found it difficult to fund their capital investment needs as investors became unsure of the value the project would generate. This uncertainty can be observed in the behavior of the stock prices of Junior

mines. Fig. 1 illustrates the evolution of prices from 2011 to 2016 of an Exchange Traded Fund (ETF) that follows a set of junior mining companies worldwide, where the long term negative trend and high price volatility in this period can be observed. This fund was liquidated in 2016 due to the lack of market liquidity for these stocks.

Mining projects are long term irreversible capital investments that operate in a highly uncertain environment and present significant managerial flexibility. It is a well-known fact that managerial flexibility has option like characteristics, and as such, may add value to a project. Given that traditional project valuation techniques such as the Discounted Cash Flow method (DCF) do not capture the value of this flexibility, this class of projects may be undervalued unless option pricing methods, such as the real options approach, are applied. It is worth noting that the ETF index follows closely metal prices, as represented by the metals and mining Index in Fig. 2, which further suggests that valuation reports provided to the market or investors are done using mainly traditional DCF methods.

Mining projects are subject to both private and market risks.

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Fig. 1. Evolution of Junior mine prices.  
 Source: Bloomberg

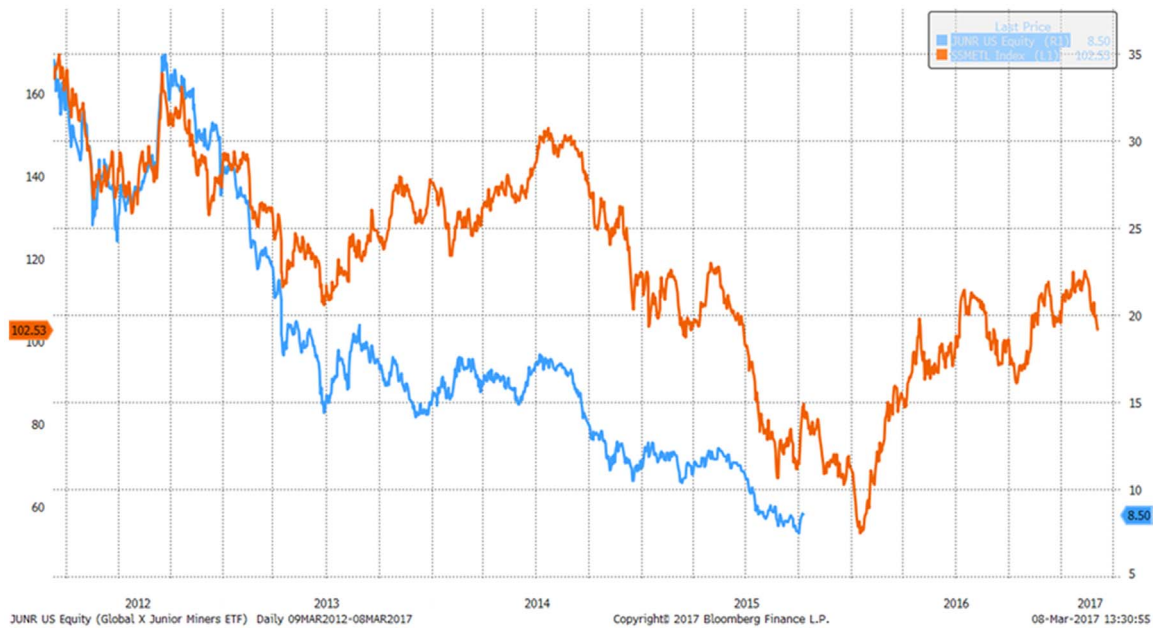


Fig. 2. Junior mine prices vs S & P mining and metal index.  
 Source: Bloomberg

Private risks include the uncertainty over the potential exploration volume of the field, the quality of the ore, socioeconomic and environmental factors that may appear due to the needs and influence of the communities located in the vicinity of the project and others. As these uncertainties are uncorrelated with the market, it is assumed they are fully diversifiable, and thus, command no risk premium to the investor.

On the other hand, the main source of market uncertainty in a mining project is the future evolution of market prices of the metal or commodity being explored.

Typical flexibilities associated with mining projects are the option to defer the investment to a future date, split the investment in different stages, expand the operations if market conditions are

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