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# Decreasing minerals' revenue risk by diversification of mineral production in mineral rich countries

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ABSTRACT

There are numerous countries that have a variety of mineral products and commodities which are the source of government revenue and foreign exchange. Mineral revenues are essential for the development of mineral rich countries. Generally, the minerals market has many risks; therefore the revenue gained from minerals is accompanied with a level of risk. In order to plan for mineral revenue by governments, the risk of mineral revenue should be decreased. In this paper, minerals are considered as risky assets to apply the Modern Portfolio Theory (MPT). This method is able to decrease the risk of minerals' revenue by optimum diversification. As a case study, mineral production of Iran's mining sector is studied. The non-linear model is solved by quadratic programming. To achieve the country's expected revenue the model determines the type and quantity of minerals to be produced. The findings show that the MPT model has an adequate potential to reduce the risk of the government's mineral revenue compared with the current situation.



## Introduction

Some of the world's countries are rich in mineral resources. Mineral and energy commodities play an important role in national economic development (Dorian and Humphreys, 1994). Mineral resources are a gift of nature available to be developed, sold, and used to improve the country's life standard. Mineral production generates income and foreign exchange (if exported), can stimulate local economies through the local purchase of inputs, and can be the basis for downstream processing and manufacturing industries. Mining companies employ workers, who earn income, some of which they spend on domestically produced goods and services. Governments receive tax revenues from mineral production, which are available to fund education, health care, roads, electric-power supplies, and other forms of infrastructure (Eggert, 2001; Power, 2007). Foreign direct investment, balance of payments, human capital development and social investment are other benefits of mineral industry. The mining industry makes a major contribution to the economy of mineral rich countries. It is a very important force in the global economy, occupying a primary position in the supply chain resources. Despite this fact, its role varies and greatly differs at the national level from one economy to another (Dorin et al., 2014).

Minerals are essential in a large number of industries such as constructions, electronics, glasses, and metals. Mining is economically critical for millions of the world's poorest people with some 50 countries being significantly dependent on mining (International Council on Mining and Metals (ICMM) 2014). The contributions of mining to the economy of countries with low or middle national income, where mining brings significant direct economic benefits, are presented in Table 1.

Mineral price has volatility (Brunetti and Gilbert,1995; Eggert, 2001; McMillan and Speight, 2001; Watkins and McAleer, 2004; Dooley and Lenihan, 2005; Panas and Ninni, 2010; Arouri et al., 2012; Cochran et al., 2012; Ma, 2013; Arezki et al., 2014; Gil-Alana and Tripathy, 2014). Common features of commodity-producing countries are the enormous price swings that lead to equally enormous swings in export revenues, leading to boom-and-bust cycles that tend to persist for several years at a time (Mahmud and Basher, 2014). Export earnings from mineral products tend to be volatile, especially in the case of minerals and metals whose prices are determined in the international markets. Such fluctuations have harmful effects on countries whose economies are based on mineral production. The volatility of minerals revenue makes it difficult to plan investment because of the tendency to induce sudden swings in exchange rates and in tax revenues from the mineral sector. In order to ensure mineral revenue in the mineral countries, governments need to reduce the mineral market risk.

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**Table 1**
Contributions of mining to low and middle income economies in resource rich countries (International Council on Mining and Metals (ICMM) (2012)).

| Mining benefits | Share in the countries |
|---|---|
| Foreign direct investment (FDI) | 60–90% of total FDI |
| Government revenue | 30–60% of total exports |
| Government revenue | 3–20% of government revenues |
| National income (GDP[a]) | 3–10% of total national income |
| Employment | 1–2% of total employment |

[a] Gross Domestic Product.

In the stock market, the total risk of any portfolio can be broken down into systematic and unsystematic components (Lee et al., 2010). Factors specific to the asset can generate volatility, for example, a change of management within a company. This type of volatility is unique to the asset, or unsystematic. Of the two components of risk, unsystematic risk specific to particular assets can be eliminated via portfolio diversification (Marty, 2013). The percentage of risk that may be eliminated by holding a widely diversified portfolio, which varies from 56 to 89% depend on the country (Elton et al., 2014). Efficient diversification for constructing a portfolio is carried out by using the modern portfolio theory, which was introduced by Markowitz (1952).

In this paper, the mineral market is considered similar to a stock market. This paper demonstrates how governments can use portfolio-optimization methods to determine a set of mineral productions that provide the minimum risk for a given level of revenue. The aim of this paper is providing a method for achieving sustainable revenue for these mineral countries. The proposed method is based on Markowitz's modern portfolio theory.

## Modern portfolio theory

The mean–variance framework, pioneered by Markowitz (1952), has long been recognized as the cornerstone of Modern Portfolio Theory (MPT) and has been widely adopted and applied in both academia and industry (Yao et al., 2014). In the portfolio selection problem, given a set of available securities or assets, one wants to find out the optimum way of investing a particular amount of money in these assets. Each one of the different ways to diversify this money among several assets is called a portfolio. For solving the portfolio selection problem, Markowitz (1952) presented the mean-variance model, which assumes that the total return of a portfolio can be described using the mean return of the assets and the variance of return (risk) among these assets. The portfolios that offer the minimum risk for a given level of return form what is called the efficient frontier. For every level of desired mean return, this efficient frontier gives us the best way of investing the money (Fernández and Gómez, 2007). MPT is a mathematical problem. According to Markowitz, investors could virtually eliminate their exposure to the risks unique to individual securities by choosing stocks that do not move precisely together. An investor is supposed to be risk-averse, hence he/she wants a small variance of the return (i.e. a small risk) and a high expected return (West, 2006). MPT is typically applied to common stocks. However, it can also be applied to bonds if there are risks with respect to default, exchange rates, inflation, etc. (Muller, 1987).

When assets are combined in a portfolio, the expected return is a weighted average of the individual asset's expected return. The weights are the proportions of these assets held in the portfolio. The portfolio risk is however more complex. The portfolio risk depends not only on the weights and the individual risks but also on the correlation between assets. The correlation coefficient, $\rho$, measures joint movements between two variables. The ρ value may vary from $-1.0$ to $+1.0$ as illustrated in Fig. 1. A compounded portfolio with an overall low correlation is crucial for investors' that aims to diversify in order to eliminate the risk (Sharpe, 2000).

Fig. 2 illustrates four concepts of portfolios. A feasible portfolio is any portfolio whose proportions sum is equal to one. A feasible set is the set of portfolio means and standard deviations generated by the feasible portfolios. This feasible set is the area inside and to the right of the curved line. A feasible portfolio is on the envelope of the feasible set if for a given mean return it has minimum variance. Finally, a portfolio is efficient if it maximizes the return given the portfolio variance (or standard deviation). The set of all efficient portfolios is called the efficient frontier; this frontier is the heavier line in the graph (Benninga, 2008).

### *Standard modern portfolio theory*

The standard Markowitz mean-variance model for the portfolio selection problem is as follows (Markowitz, 1952):

$$minVar(r_p) = min \sum_{i=1}^{N} \sum_{j=1}^{N} x_i \sigma_{ij} x_j \tag{1}$$

Subject to:

$$\sum_{i=1}^{N} \mu_i x_i = R \tag{2}$$

$$\sum_{i=1}^{N} x_i = 1 \tag{3}$$

$$0 \le x_i \le 1, \ i = 1, \ldots, N \tag{4}$$

where $N$ is the number of assets available; $\mu_i$ is the mean return of asset $i$; $\sigma_{ij}$ is the covariance between returns of assets $i$ and $j$; $R$ is expected return of portfolio and $x_i$ is the decision variable that represents the proportion of capital to be invested in asset $i$.

Eq. (1) minimizes the total variance (risk) associated with the portfolio while Eq. (2) ensures that the portfolio has an expected return of $R$. Eq. (3) ensures that the sum of assets' proportions in the portfolio is one. In Eq. (4) the proportion held in each asset is between zero (minimum amount) and one (maximum amount). This formulation (Eqs. (1)–(4)) is a quadratic programming problem and nowadays it can be solved optimally using available software tools. By solving the above optimization problem continuously with a different $R$ each time, a set of efficient points is traced out. This efficient set is called the efficient frontier and is a curve that lies between the global minimum risk portfolio and the maximum return portfolio. In other words, the portfolio selection problem is to find all the efficient portfolios along this frontier (Chang et al., 2009).

### *General modern portfolio theory*

According to Fernández and Gómez (2007), the general mean-variance model for the portfolio selection problem is similar to as the standard model. In this regard, Eqs. (1)–(3) remain in the general model. But some new constraints are added to the model as follows:

$$\sum_{i=1}^{N} z_i = k \tag{5}$$

$$\varepsilon_i z_i \le x_i \le \delta_i z_i, \ (i = 1, \ldots, N) \tag{6}$$

$$z_i \in [0, 1], \ (i = 1, \ldots, N) \tag{7}$$

where $K$ is the desired number of different assets in the portfolio with no null investment; $\varepsilon_i$ and $\delta_i$ are the lower and upper bounds