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Assessing investment strategies in mining projects in the Asia-Pacific region

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Declaration

To the best of my knowledge and belief, except where the reference is indicated in the text, this dissertation contains no other published materials extracted whole or in part from a dissertation presented by me for another degree or diploma. No other person's work is used without acknowledgment in the main text of this dissertation. This thesis has not been submitted for any other degree or diploma purposes in any other tertiary institution in Australia or overseas.

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Date: ____________________

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Nam Y Foo

Abstract

Investment activities involved in large-scale projects usually share three characteristics: investment irreversibility; uncertainty over the entire investment process; and choice of timing. These three selected mining projects investment characteristics interact to determine the best strategy in mining investment decisions. However, the standard theory of investment has not recognised the importance of volatility and uncertainty over the economic environment. Managerial flexibility has become the new paradigm for most mining investors in their investment decision behaviour. The main objective of this thesis is to examine the impact of managerial flexibility on the timing of investment decision of mining projects in the Asia-Pacific countries, namely, Australia, Indonesia, Malaysia, New Zealand and Papua New Guinea. This thesis also identifies policy implications in relation to mining investment.

Empirical analysis of mining project investment in this thesis is conducted using two methodologies - traditional static discounted cash flow (DCF) and real options valuation (ROV) approaches. The former approach is used to analyse the project's net present value (NPV) when uncertainty is not taken into consideration. The latter method is used to analyse the project's value when uncertainty is taken into account. In the ROV approach, the American style call option with binomial decision tree analysis is applied to evaluate the project's value. Data sources for this thesis are annual reports for mining companies. Companies are chosen to identify data for a current mining project in each country listed above. Prior to conducting the valuation analysis, forecasting of mineral prices is one of the crucial steps. Forecasting gold and coal prices based on data available from Index Mundi over 40 year periods on a monthly basis. Risk simulator is used to simulate the future gold and coal prices and dynamic programming language, specifically DPL8 is used to conduct the ROV analysis.

Using the traditional static DCF method, the findings of this thesis reveal that mining investors are only making decisions based on limited information to determine their project's NPV. This simple NPV rule is rigid and fails to take managerial flexibility into consideration. A static DCF model is calculated using the simple spreadsheet form and is quite straight forward. Among the five countries used to evaluate a mining project investment, New Zealand is the only country that achieves a negative NPV. Based on this simple NPV rule, the mining investor can abandon this project without any further questions. However, for the rest of the countries, the mining investor can profitably invest based on the NPV.

When considering uncertainty in the project investment, the findings of this study show a completely different story, which is due to timing having value. Applying the strategy of timing flexibility, mining investors can choose the best timing of their investment in which they believe the maximum return will be generated. Using the options to defer the mining project, the calculations in this thesis show that countries with an abundance of mineral resources, such as Australia, Indonesia, Papua New Guinea and Malaysia, offer lucrative revenue for mining investors who plan to invest in these countries. However, the variability of mineral prices and costs may lead investors to defer investment until well into the future. Furthermore, policy choices, such as tax or royalty rates, can lead investors to change the timing of their investment decision. The influence of such choices on the valuation of the example mining project is used to show how policy can affect viability and timing of investment decisions.

Table of Contents

List of Tables

List of Figures

Page

List of Abbreviations and Acronyms

USD$	United States Dollar
@Risk	@Risk Simulator
AIMM	Australian Institute of Mining and Metallurgy
APEC	Asia-Pacific Economic Cooperation
AUS	Australia
ASEAN	Association of Southeast Asian nations
BMI	Business Monitor International
BMMR	Brownian Motion Mean Reversion
BNM	Bank Negara Malaysia
BOI	Bank of Indonesia
BP	British Petroleum
BPNG	Bank of Papua New Guinea
B-S	Black and Scholes
CBA	Cost Benefit Analysis
CPA	Capital Project Appraisal
CPI	Consumer Price Index
CSP	Corporate Social Responsibility
DCF	Discounted Cash Flow
DPL	Dynamic Programming Language
DPS	Dividend per share
DT	Decision Tree
DTA	Decision Tree Analysis
EITI	Extractive Industries Transparency Initiative
EPS	Earning Per Share
EV/EBITDA	Enterprise Value to Earnings before Interest, Taxes, Depreciation and Amortisation
FDI	Foreign Direct Investment
FV	Future Value
GBM	Geometric Brownian Motion
GDP	Growth Domestic Product
GFC	Global Financial Crisis
GHG	Green House Gas

GST	Goods and Services Tax
HR	Hotelling Rule
HWV	Hull-White/Vasicek
ICA	International Commodity Agreements
ICMM	International Council on Mining and Metals
ICT	Information and Communication Technologies
IEA	International Energy Agency
IMF	International Monetary Fund
INDO	Indonesia
IRR	Internal Rate of Return
ITA	International Tin Agreement
JORC	Joint Ore Reserves Committee
LDN	Least Developed Nations
MCI	Mining Contribution Index
MCS	Monte Carlo Simulation
MIGA	Multilateral Investment Guarantee Agency
MLY	Malaysia
MMSD	Mining Minerals and Sustainable Development
MR	Mean Reversion
NGOs	Non-governmental organisations
NIEs	Newly Industrialised Economies
NPV	Net Present Value
NZ	New Zealand
NZPM	New Zealand Petroleum and Minerals
OCR	Official Cash Rate
OECD	Organisation for Economic Cooperation and Development
OPEC	Organisation of Petroleum Exporting Countries
PE	Price Earnings Ratio
PNG	Papua New Guinea
PV	Present Value
RBA	Reserve Bank of Australia
RBNZ	Reserve Bank of New Zealand
RBS	Royal Bank of Scotland

ROI	Return on Investment
ROV	Real Options Valuation
SDE	Stochastic Differential Equations
SX-EW	Solvent Extraction – electronicwinning
UAE	United Arab of Emirates
UNCTAD	United Nations Conference on Trade and Development
UNEP	United Nations Environment Programme
UK	United Kingdom
USA	United States of America
USGS	U.S. Geological Survey
VC	Venture Capital
WACC	Weighted Average Cost of Capital
WBCSD	World Business Council for Sustainable Development
WSSD	World Summit on Sustainable Development
WTO	World Trade Organisation
WWII	World War II

Chapter One

1 Introduction

1.1 The research setting

The remarkable economic growth in the Asia-Pacific region has continued into the new millennium. Over the last 20 years, the region’s economic growth rates have exceeded those in other regions; the Asia-Pacific region has come to be known as the “growth power engine" of the global economy. Over the coming years, the region is expected to continue to enjoy the highest growth rates in the world.

Much research has been conducted on the dynamic economic growth and development in this region. The empirical investigations and their findings show that region’s economies have sustained rapid rates of economic growth for an extended period, in fact higher growth rates than those achieved by the wealthy industrialised countries of Europe and North America (Fu, *et.al.*, 2002)

Since the 1990s, the majority of the Asia-Pacific region’s developing economies have been characterised by rapid urbanisation, large investment in infrastructure development, and by the emergence of new consumers (Schandl & West, 2010) . The emergence of the Asia-Pacific region as a major player in terms of global resource use has driven up the demand for mineral resources. The strong global demand for mineral resources in the region dramatically increased commodity prices to a record high level, peaking in the mid-2000s. Countries, such as Australia, have experienced a resource boom in the mid-2000s as a result of the surge in commodity prices and resource investments, but the current trend of the commodity market is in a different environment as a result of the slow demand for commodities in China and India.

The relative strength of developing economies in Asia, such as China and India, in recent years has been particularly apparent. This relative strength has increased the growth of mining investment activities in the resource-rich countries since 2010. Other industries related to mining investment projects, such as the pipeline industry have also benefited as a result of the mining boom. The unprecedented mining investment activities in the resource-rich countries have increased the prosperity and living standards of these countries.

Mining investments activities differ from investment activities in other sectors. The investment in the resource industry requires significant capital expenditure and is sensitive to any change in economic conditions that can impact the mining project investment decisions. Therefore, the mining companies are challenged by most of the major economic factors, both endogenous and exogenous when undertaking projects.

Mining project investment decisions are fundamental determinants of the economic growth in many resource-rich Asia-Pacific countries. Factors that significantly impact the mining investment decision include geology, engineering, financing, political risks, fiscal issues and market risks.[1] These factors can affect the revenue and the net present value (NPV) of the entire mining project investment.

Despite the considerable attention given to the Asia-Pacific region in relation to its thriving economic growth, economic research on mining investment in the Asia-Pacific region has been vague and incomplete. This is attributable to two reasons. Firstly, there are limited data measuring resource abundance and secondly, the past resource abundance research doesn’t pay much attention to key determinants of the investment decisions (Bond & Malik, 2009).

Otto (1992) states that the attractiveness of mining investment in the Asia-Pacific region is reliant on the competitiveness of nations compared to other regions with the same geological conditions. As mentioned above, there has been little focus on mining investment in the Asia-Pacific region. This research offers the first hands-on study of the mining investment environment facing the Asia-Pacific countries in the twenty-first century.

The mining industry is unique compared to manufacturing industries. Mining involves high capital intensity, long lead time, high risk, and non-renewable resources (Gentry & O’Neil, 1984). These factors can cause uncertainty during the entire process of the mining investment analysis. Investment in large-scale projects, such as mining projects, can be a sunk cost and irreversible. Managing appropriate timing of investment, therefore, is one of the best strategies used in the mining project investment.

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[1] Political risks involve state sovereignty, ownership and control, environment, community, internal security, consistency and constancy of mineral policies.

Many researchers have found that high-risk investment projects should incorporate management flexibility (McDonald, & Siegel, 1986, Pindyck, 1990, Dixit & Pindyck, 1994, Trigeorgis, 1997, Schwartz & Trigeorigis, 2001) . The strategy of flexibility applied to the large-scale mining project adds value to investment in these projects. By ignoring the flexibility, analysts can grossly undervalue the investment project and miss optimal allocation of resources in the economy.

In traditional mining investment, the static discounted cash flow approach (DCF) is the most favoured method used by mining investors when conducting mining investment projects analysis.

A certainty-equivalent cash flows method, such as the DCF, is well suited to forecast the investment analysis when the economic conditions are stable. Based on this situation, this static traditional capital budgeting method makes an implicit assumption concerning “expected” cash flows and presumes management’s passive commitment to that particular static “operating strategy”. In other words, this approach assumes a mining project is initiated immediately and operated continuously at the base scale until the end of the project life.

However, in an actual investment climate, there are many uncertainties, such as a change in economic conditions, the volatility in commodity prices and the policy uncertainty. Understanding the impact of these features by accessing the most flexible approach can completely change what mining investors expect at the outset.

Mining investors should be aware that all information is useful and indeed can impact their investment outcome. This is because when new information arrives, uncertainty about the market condition in relation to the project investment decision and future cash flows is gradually resolved. Mining companies, therefore, are able to use this valuable flexibility to alter their initial operating strategy in order to capitalise on favourable future investment opportunities. Mining managers can defer, expand, contract, abandon, or otherwise change a project at various stages by applying these flexibilities.

The real options valuation (ROV) is another method that has been brought in to supplement the deficiencies of the DCF approach. The ROV approach is likened to financial options and incorporates managerial operating flexibility. The method applies because it has the potential to conceptualise and quantify the value of options in the mining investment project from active management and strategic interactions.

The optimal investment timing under uncertainty often involves a wait-and-see flexibility. Studies show that wait-and-see flexibility in mining project investment can profoundly affect the decision to invest (Dixit & Pindyck, 1994). The main concept of this thesis is to apply the basic theory of irreversible investment under uncertainty to investment decisions in the Asia-Pacific region. The thesis emphasises how the option-like characteristics of mining investment decisions are impacted by the volatility of commodity prices or change in tax rate.

A particular focus of this thesis is the optimal timing investment decisions by mining companies. Using the ROV method, the thesis discusses why mining investment decisions in practice can be different from the traditional DCF method. The strategy of flexibility enables mining firms to decide the viability of the investment projects when uncertainty occurs in commodity prices or fiscal policy regimes. Mining companies certainly do not invest when the commodity prices are at a record low. The investment cannot resume until commodity prices increase substantially. Irreversible mining investment under uncertainty in such investment conditions can be explained once irreversibility and option value are accounted for.

1.2 Issues and the research questions of this thesis

When investments are irreversible, and the economic environment is volatile, the investment climate is unpredictable and the option value of maintaining flexibility is high. The ability to delay is a powerful component of the strategy of mining investment. Irreversibility of investment creates exposure to losses in the highly volatile commodity market, and also when there is variability in government regulations or institutional arrangements. By using the ability to wait, the researcher uses these variables (fluctuation in commodity prices and the variation of tax rates) to gain an insight into the nature of the investment option. In addition, this study also determines how the value of the option and the decision to invest depends on commodity prices and tax rates.

In general, uncertainty leads to delay in the optimal timing of an irreversible investment activity. The motivation of the thesis is to answer the following research questions by presenting empirical analysis using examples from Asia-Pacific mining projects:

When mining companies make the decision to invest in projects in the region is it beneficial to use the strategy of timing flexibility in conjunction with the real options valuation (ROV) instead of the static net present value (NPV) rule?

How can mining companies use the strategy of deferring when commodity prices are volatile to decide the best timing of their investment?

How do different tax flow rates affect the decisions to invest and when to invest if the optimal timing investment rule is applied?

1.3 Background study of the Asia-Pacific region

Countries in the Asia-Pacific region have grown phenomenally since World War II (WWII) despite the oil price shocks in the 1970s, a sluggish world economy in the early 1980s, a rising protectionism and currency appreciation in the late 1980s, and the Asian financial crisis in 1997.

A remarkably high GDP achievement in the last two decades, has produced positive outcomes in the form of rising per capita incomes and much improved living standards, and thus, the Asia-Pacific region has become one of the most influential geo-economics spaces in the world. The significant high growth achievement has made this region comparable to the other growth drivers of the global economy – North America and the Eurozone.

One of the successes was the transformation of the Japanese economy since post WWII. The successful Japanese economy was then followed by the rapid high growth rate of the newly industrialised economies (NIEs), which achieved an average 8 per cent a year in the last three decades prior to the Asian financial crisis. These NIEs are South Korea, Singapore, Taiwan, and Hong Kong, also called the “Asian tigers”. These NIEs have formed the “East Asian development model”, and belong to the Association of Southeast Asian nations (ASEAN) economies along with China. Inspired by these successful economies in East Asia and the NIEs, Indonesia, Malaysia, Thailand and the Philippines have developed their owned outward-oriented economic policies. The development of this policy is to promote the inflow of foreign capital and encourage exports (Dowling & Valenzuela, 2010). The rapid growth in these Asian economies, in particular China, has now become one of the greatest interests for researchers, leaders in the business community, and public policy makers.

Since WWII the Asia-Pacific economy and development have continued to change and transform. Governments in these countries have made significant economic progress to reduce poverty and economic inequality in this region. This is particularly obvious in the resource-rich countries.

The objective of the researcher in this chapter is to review some literature about the endowment of mineral resources in the region and its economic development. Also, the researcher believes that some explanation of the history of the Asia-Pacific economy is required for the reader to understand the recent economic development in which this thesis is focused.

1.4 The Asian growth miracle and recent developments

The Asia-Pacific region can be defined as the area lying mainly to the west of the International Date Line and bounded in the south by Australia and New Zealand, in the west by the coastal countries of Asia, and in the north by Japan (Gapinski, 1999, p.4).

To define the Asia-Pacific region more specifically, this region encompasses the four East Asian Tigers of Hong Kong, South Korea, Singapore, and Taiwan; the three Southeast Asian Lions of Indonesia, Malaysia and Thailand; and the two South Asian Gaurs of Papua New Guinea and the Philippines. These maturing nine countries are known as the Newly Industrialised economies. Vietnam, which is another Asia-Pacific country not falling into these categories is worth nothing with its remarkable high GDP growth. Vietnam’s communist party has recently made some fundamental changes in the way of policy thinking and awareness of the world situation. Vietnam has now reshaped the country’s external foreign diplomat relations and economic development strategies by focusing on international economic integration (APEC, 2013). The remaining countries in this region are the advanced economy countries that are members of the Organisation for Economic Cooperation and Development (OECD). Notably, they are the OECD elephants, Australia, New Zealand and Japan. Also, included is the United States of America (USA), which lies to the east of the Date Line.

Table 1.1 Economic growth and real GDP of the Asia-Pacific region

	2011	2012	2013	2014	2015
OECD members					
Australia	2.6	3.6	2.4	2.6	2.7
Japan	-0.5	1.4	1.5	1.4	1.0
New Zealand	1.9	2.6	2.4	3.3	3.0
East Asian economies	8.2	6.5	6.7	6.8	6.7
China	9.3	7.7	7.7	7.5	7.3
Hong Kong SAR	4.8	1.5	2.9	3.7	3.8
South Korea	3.7	2.0	2.8	3.7	3.8
Taiwan Province of China	4.2	1.5	2.1	3.1	3.9
South-East Asian economies					
Indonesia	6.5	6.3	5.8	5.4	5.8
Malaysia	5.1	5.6	4.7	5.2	5.0
Philippines	3.6	6.8	7.2	6.5	6.5
Singapore	6.0	1.9	4.1	3.6	3.6
Thailand	0.1	6.5	2.9	2.5	3.8
Pacific Island countries including Papua New Guinea[2]	5.4	3.5	2.6	3.5	4.6
Emerging Asian economies[3]	7.9	6.7	6.5	6.7	6.8
Asia	5.9	5.3	5.2	5.4	5.5
The United States of America (USA)	2.0	2.0	2.0	2.8	3.0

Source: The World Bank Dataset (2015), IMF World Economic and Financial Surveys (2014).

Table 1.1 shows the real GDP of the Asia-Pacific countries. The table shows that the momentum of Asian economies is set to continue. In 2014-2015, economic growth in this region is projected at 5.5 per cent annual growth. Strong growth in recent advanced economies, improvement of job markets, robust credit growth, as well as rising

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[2] According to the United States Asia-Pacific Centre for Security Studies, these Pacific Island countries are included in the Asia-Pacific region. These Pacific Island countries and other small states include Bhutan, Fiji, Kiribati, Maldives, Marshall Islands, Micronesia, Palau, Papua New Guinea, Samoa, Solomon Islands, Timor-Leste, Tonga, Tuvalu, and Vanuatu.

[3] Emerging Asia includes China, India, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam.

consumption in China, are among the factors that have sustained the region's economic growth (IMF, 2014)[4].

The "Asian growth miracle" is one of the most remarkable and outstanding features of world economic history during the last thirty to forty years. These economies have flourished and have been sustained for up to four decades as a result of the pace of economic growth and structural change in this region, particularly the pace of growth in per capita income, which is faster than the rest of the world.

Lee and Hong (2010) state that the remarkable achievement of Asian economies in the 1990s is attributed to its large potential for development in infrastructure due to rapid urbanisation. For instance, the North-South Expressway in Malaysia, proposed by the former Malaysian's Prime Minister Tun Dr. Mahathir Mohamad, is one of the significant achievements for Malaysia's economy in its drive for economic diversification.

Another factor that has been attributed to the significant growth in these Asian economies is the structural change in geographic and demographic characteristics. This change is mainly due to younger generations moving from remote towns to capital cities to seek better opportunities as well as education in order to improve their quality of living standards. As well, economic policies and strategies that have attracted foreign investment in this region have contributed to these Asian economies' growth. Among these policies, Lee and Hong (2010) state that economic policies relating to openness are especially important. Furthermore, industrial policy and market intervention have helped to improve the growth path of the dynamic Asian economies (Das, 2014) .

Das (2014) claims three reasons for dynamic Asian industrial policy. Firstly, Asian governments used this policy to protect domestic companies until they became competitive. For instance, many Asian governments invited foreign investors to set up factories in their country in order to absorb new technology for domestic firms. Secondly, the policy has encouraged skilful foreign direct investment (FDI) to play a significant role in these Asian economies by transforming new and innovative

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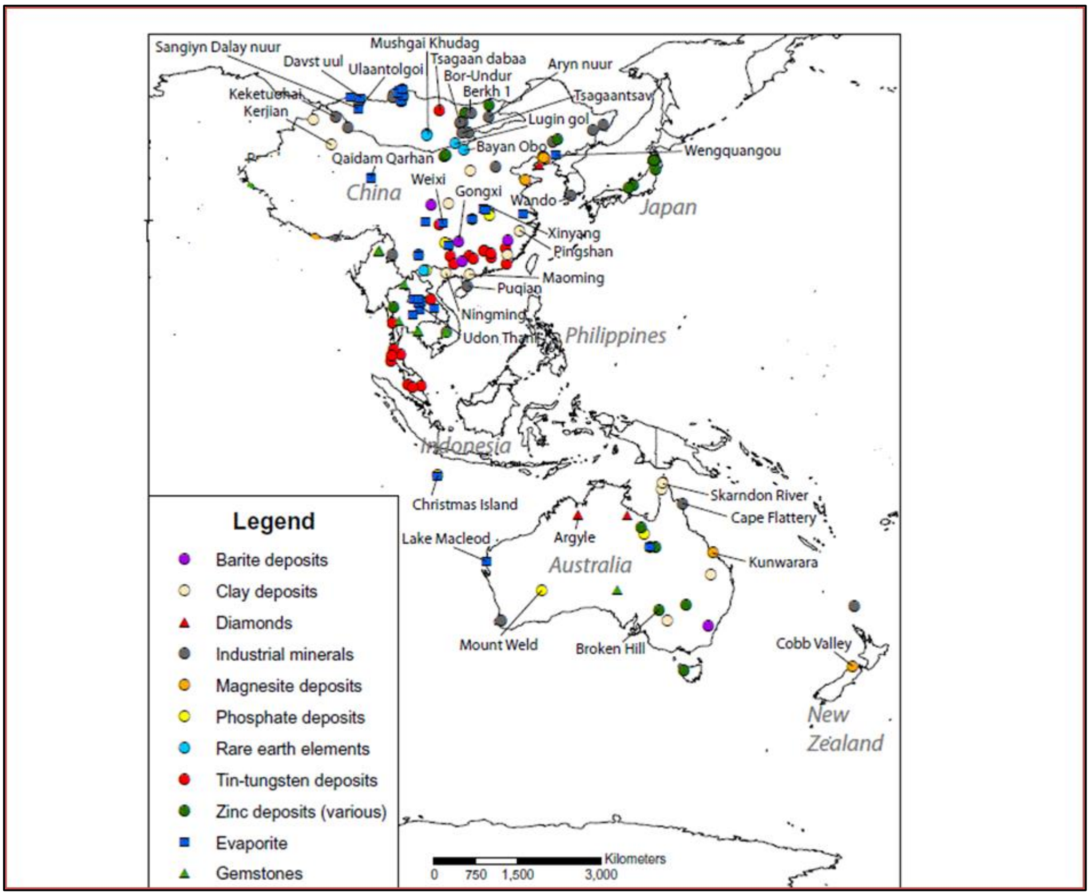
[4] The Asia-Pacific region covers wide range of geographical area including the USA. This study, therefore, is focused on the economic development of the South-East Asian as well as Oceania economies.

technologies to industrial competitiveness. Thirdly, this policy has been used by the Asian governments as an instrument to nurture and strengthen technology-intensive industries. The major contribution of this policy has been to help domestic firms strengthen their technology in a relatively short time so they are ready for export-oriented manufacturing.

1.5 The mining industry and the Asian century

Extractive industries in the Asia-Pacific region are the major contributors to the regional economy. In 2013, approximately of 75 percent of all global mining trade and investment in this region were derived mainly from the resource industry. By such significant of mining investment and trade, the Asia-Pacific has become one of the major mineral producers and consumers in the world (APEC Business Advisory Council, 2014).Figure 1.1 shows the majority of countries lying in this region are endowed with mineral resources, which the extractive industry has played a significant role in this region economic activities.

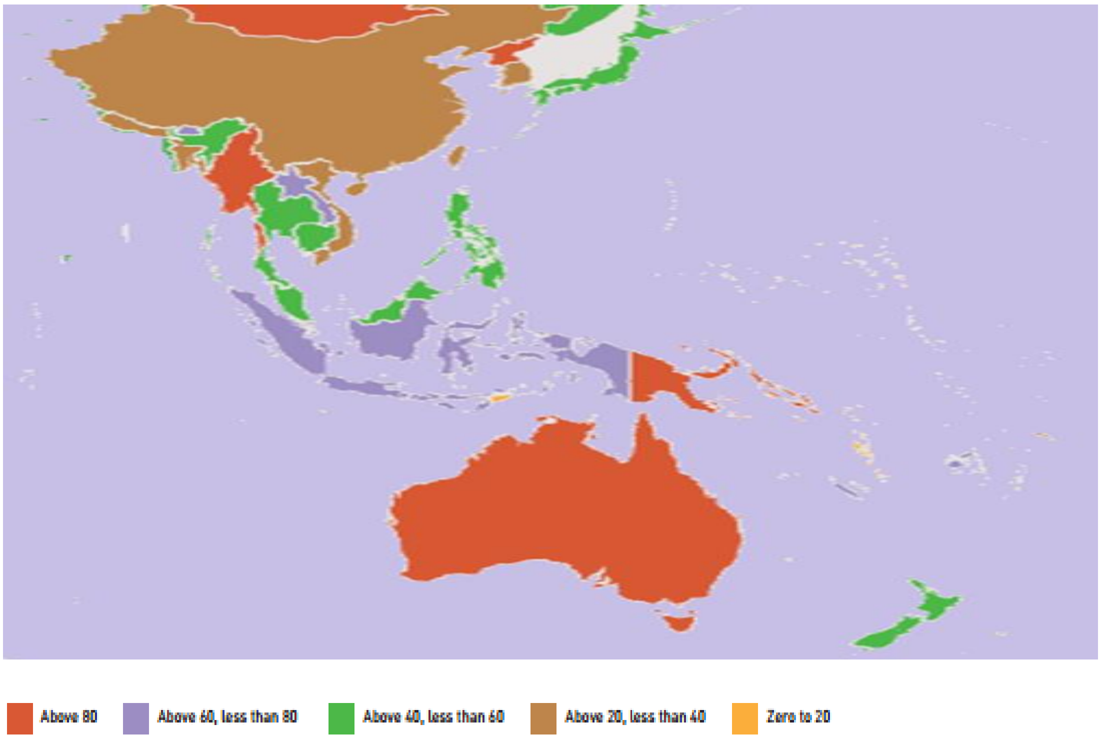
Figure 1.1 Mineral deposits in the Asia-Pacific region



Source: The USGS, 2005

The rapid growth of the economies of the Asia-Pacific countries has dramatically increased the interdependence among these countries in terms of natural resources, finance and trade (Das *et.al.*, 2013) .[5] In world terms, the region contains substantial natural resources, including a wide variety of nonfuel mineral reserves, such as copper, gold, nickel, tin and many more (O'Callaghan & Vivoda, 2010). In 2013 for instance, the Asia Pacific Economic Cooperation (APEC) economies accounted for approximately 76 per cent of world copper reserves; 65 per cent of world zinc reserves; 87 per cent of world lead reserves; and 48 per cent of world nickel reserves (APEC, 2014).[6]

Figure 1.2 Contribution of mining industry to national economies in the Asia-Pacific region



Source: International Council on Mining and Metals,2014; Mineral Council of Australia, 2014

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[5] As a result of interdependence of economies among the countries, organisations, such as the Association of Southeast Asia Nations (ASEAN) and the Asia-Pacific Economic Corporation (APEC) were established in 1967 and 1989 respectively, in order to promote regional economic integration in Asia. ASEAN and APEC have similar goals and objectives on trade and investment liberalisation, facilitation, economic and technical cooperation, food and energy security, natural disaster management and connectivity among the countries in the region (Das, *et.al.*, 2013).

[6] APEC has 21 members which include Australia, Brunei Darussalam, Canada, Chile, People's Republic of China, Hong Kong, China, Indonesia, Japan, Republic of Korea, Malaysia, Mexico, New Zealand, Papua New Guinea, Peru, The Philippines, Russia, Singapore, Chinese Taipei, Thailand, The United States, and Viet Nam. The resource sector is one of the important industries in APEC economies and this region accounts for a substantial share of world mineral resources.

Figure 1.2 shows the contribution of the mining industry to national economies in the Asia-Pacific region using Mining Contribution Index (MCI) based on the 2010 United Nations Conference on Trade and Development (UNCTAD) data. The mining industry ranks highly in its contribution to economies across the Asia-Pacific region. Figure 1.2 indicates that Australia, Indonesia, Malaysia, New Zealand and Papua New Guinea are among the Asia-Pacific countries, which are heavily reliant on the resource sector as one of the major sources of revenue. The resource sector comprises of at least forty per cent and above of most countries' total production and it clearly shows the importance of the mining industry in these countries' national economy.

Compiling the available resources used in the International Council on Mining and Metals (ICMM), Table 1.2 below indicates that the mining industry plays a significant role among the Asia-Pacific countries, particularly countries with an abundance of mineral resources, such as Australia, Papua New Guinea and some Pacific Island countries. According to MCI, over 80 per cent of national economies are dependent on their resource industry as the major export.

The Asia-Pacific region covers a diverse landscape enriched with mineral resources and it is one of the most influential economic zones in the world. Some advanced economies in this region, such as Australia in particular, are significantly affected by the Asian economy as a result of the region's growing demand for commodities. In the global context of mining's contribution, the resource industry can shape national economies. The mining industry can generate 60-90 per cent of the country's foreign direct investment, 30-60 per cent of the total exports, 3-20 per cent of the total government revenues, 3-10 per cent of total national income, and 1-2 per cent of the total employment (ICMM, 2014). In 2014, the MCI index (see Table 1.2 below) shows that a majority of the Asia-Pacific countries are dependent on the mineral resource industry as a major source of revenue to sustain their national economies.

In 2011, the Asia-Pacific region was regarded as being the strongest region in the world in terms of mining industry total project loan financing. For example, in Australia, the total project loan finance figures for 2011 yielded USD23.4 billion, which was the second highest total project loan in the world after India (Austrade, 2012). The increased demand for total project finance loans in the Asia-Pacific region

Table 1.2 Contribution of mining to national economies in the Asia-Pacific region

	2012 Mining export contribution	Total export contribution 2012	2012 production value (% of GDP)	2014 MCI Score
OECD members				
Australia	57.3%	69.0%	10.0%	89.36
Japan	3.7%	5.4%	0.0%	42.09
New Zealand	4.7%	9.5%	0.9%	40.76
East Asian economies				
China[7]	1.5%	2.9%	6.1%	39.54
Hong Kong SAR	14.9%	15.2%	0.0%	53.53
South Korea	2.7%	13.2%	0.1%	35.30
South-East Asian economies				
Indonesia	20.1%	40.7%	6.3%	78.46
Malaysia	2.6%	23.0%	0.6%	45.78
Philippines	6.3%	8.5%	2.5%	57.04
Singapore	1.8%	20.3%	0.0%	16.73
Thailand	5.2%	11.7%	0.7%	55.16
Pacific Island countries[8]				
Fiji	9.3%	34.1%	1.9%	71.94
Papua New Guinea	51.3%	68.5%	26.1%	88.54
Solomon Islands	15.5%	15.6%	10.1%	83.93
Tonga	7.5%	7.5%	0.0%	47.02
The United States of America (USA)	7.7%	15.6%	0.8%	60.88

Source: International Council on Mining and Metals,2014; Mineral Council of Australia, 2014

was attributable to the strong economic development in this region, particularly the strong demand for mineral resources in China and India.

DLA Piper (2012) states that around $8 trillion will be spent on infrastructure projects in Asia over the next decade. The pace of growth of these projects is to remedy the region's historical under-investment and accommodate the explosion in demand. As a result, the opportunities exist for development of the resource sector as a whole

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[7] Taiwan is included in China's MCI.

[8] These four Pacific Island countries are the major exporters of mineral resources. Contribution of mining industry to national economies in other Pacific Island countries such as Marshall Islands, Samoa, Timor-Leste, and Vanuatu are only comprised of zero to 20 percent of their economies. The table, therefore, only shows the countries in which mining industry is their major income that sustain the national economic growth.

including those industries connected to the mining industry, such as infrastructure and pipe line industry are impressive. Among the resource rich countries in the region, Mongolia is regarded as one country that has the potential to become one of the fastest moving markets in the Asia-Pacific region.

As stated above, Asia-Pacific countries are richly endowed with mineral resources and countries with abundant mineral resources should be advantaged as a result of the expanding mineral demand in the region. However, not every country in this region that is endowed with mineral resources is receiving such an advantage. Many countries in the region, such as Malaysia, Philippines, Pacific Island countries and Thailand, with excellent mineral potential have experienced difficulty in attracting mining investors. In 1990s, by contrast, some other countries in this region such as Australia, Indonesia and Papua New Guinea, have experienced significant levels of new investment (Otto & Bakker, 1992).

The resource sector is distinct from the other industries, such as manufacturing and service sectors. It involves high capital intensity, low labour intensity, long lead time, high-risk, non-renewable resource, finite life, volatile markets, many failures and late payback. As a result of these characteristics, the resource sector is substantially different from other industries. Because of uniqueness in this industry, investment criteria need to be assessed carefully when conducting a mining investment analysis.

Mining companies have many countries from which to select. The study by Maponga and Maxwell (2000) find that there are several mining investment criteria that may induce mining investors to favour one country while avoiding another. Some nations are not much favoured by mining investors because they don’t meet the investment criteria used by exploration and mining firms. Investment criteria that could change the mining firm’s behaviour are geological criteria, political criteria, marketing criteria, operation criteria, profit criteria and other criteria.[9] Among these investment criteria, political instability and corruption are the major issues for mining investors to consider if investing in the Asia-Pacific region.

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[9] Other criteria include a mining firm’s experience, specialised company expertise, prior experience of the company employees, and helpfulness of government offices, such as geological survey, department of mines, and ministry for lands.

With respect to geological criteria, mining firms explore to locate minerals and mine to extract minerals. Mining firms assess the investment potential based on the information given by geologists in regard to the likelihood that an area contains an abundance of minerals. Other techniques used by mining firms to assess their geological criteria are information from previous discoveries and past production as an indicator for the future new mining investment. Mining firms also use geo-scientific information, such as topographic maps, geological maps, air photo coverage, airborne geophysics, geochemical data and geological report, for assisting mining company geologists in deciding the next steps of investment (Otto, 1992).

Naito, *et.al.*, (1998) state that mining companies consider regulatory and fiscal systems as on the top list of the investment criteria after geological criteria. Transnational mining companies have been facing substantial challenges as many Asian countries have enacted new mining codes and regulatory systems or revised their mining policies with the intent to encourage mining and exploration activities by both domestic and foreign mining companies.

Vivoda (2010) states that India and China have made changes to their regulatory regimes in order to improve their country's investment climate for foreign mining companies. Both governments have made some amendments for better, more adequate and efficient mining policies in order to attract foreign mining investment.

1.6 Organisation of the remainder of the thesis

Resources scarcity is one of the contemplative issues occurring in today's modern society. Chapter Two presents a literature review in relation to this issue. This chapter highlights issues that require attention for evaluating mineral resources with a focus on studies of resource development in the Asia-Pacific region. The chapter also addresses some contemporary issues in resource scarcity and economic development, such as the recent mining boom.

Chapter Three presents theoretical approaches that are used to evaluate mining projects. The difference between the project and corporate financing is discussed in this chapter. The chapter is, in particular, focused on the project financing of large-scale mining investment projects. In mining project investment, several stages need to be considered prior to investment decisions. Applying the appropriate financial technique is one of the critical points to ensure the return to investment is maximised.

Various methods are discussed in this chapter that can be used to evaluate the mining investment project: the DCF analysis, the payback period, the internal rate of return (IRR), the ROV, the decision tree analysis (DTA), the Monte Carlo simulation (MCS) and the closed-form binomial lattice.

Chapter Four, Part A investigates the research methodology of the mining project investment in the Asia-Pacific region. The chapter discusses two methodologies: the static DCF and the ROV methods. The former considers the static investment analysis without considering investment flexibility. The latter presents the mining investment analysis in which timing flexibility is included. The American-style call option binomial decision tree analysis is used in conjunction with the ROV model.

Chapter Four, Part B examines commodity price uncertainty using the mean reversion (MR) model. Fluctuation of mineral prices in the world commodity market is one of the most significant factors impacting the entire mining investment decision. The chapter examines the forecasting of future mineral prices using the MR based model. Analysis is presented that leads to identifying the critical value of mineral prices for deciding to invest in a project.

Chapter Five presents the empirical evidence using the static DCF model. Five countries in the Asia-Pacific region, namely Australia (AUS), Indonesia (INDO), Malaysia (MLY), New Zealand (NZ) and Papua New Guinea (PNG) are used to investigate the mining investment decision analysis. The chapter examines the net present value (NPV) of a mining project investment without allowing for flexibility in timing of investment. There are two components in this empirical study. First, the DCF method is used to examine the entire mining investment analysis. Second, the DCF method is then applied to examine the effect of variation of tax rates.

Chapter Six investigates the valuation of illustrative mining investment in Asia-Pacific countries using ROV. By allowing mining investors to defer their investment options, flexibility can indeed change the options value significantly. The analysis demonstrates the advantage of using the ROV when uncertainty is present.

Chapter Seven summarises the significant findings and draws conclusions on this study. It discusses policy implications, and suggests future directions for this research. The chapter also addresses some limitations and shortcomings of the study and focuses on issues for future research.

Chapter Two

2 Economic Development in the Mining Industry: A Literature Review

2.1 Introduction

The development of mineral resources became critical at the beginning of the twenty-first century. Globalisation in today's society, particularly in the Asia-Pacific region is highly dependent on minerals and metals economically, socially and culturally (Prior *et.al.*, 2012) . A contemporary research on material flows and resource productivity confirms that the Asia-Pacific region has emerged as one of the biggest resource users over the last two decades (Schandl *et.al.*, 2010).

The relationship of mineral scarcity and economic growth is one of the most debateable issues in the twenty-first century. This issue is more related to exhaustible resources and sustainable development as a result of mining exploitation. Mineral economics and economic growth are linked together. However, investment uncertainties in mineral resources are key factors impacting the economy performance of a nation. This chapter reviews the literature regarding the role of mineral resources in mining investment and economic growth.

The purpose of this chapter is to highlight issues that require attention in the analysis of the impact of increasing resource scarcity. While much of the literature relates to resource scarcity and draws attention to evaluating mineral resources generally, where possible the review covers studies of resource development in the Asia-Pacific region. This literature review provides a sound basis for the analysis of evaluating investment decision making in the region.

The rest of the chapter is organised as follows: Section 2.2 discusses the resources scarcity and economic growth, Section 2.3 discusses some contemporary theories and analysis of the growth model of natural resources, Section 2.4 discusses the empirical result from the recent research in mining investment and Section 2.5 concludes the chapter.

2.2 Scarcity of mineral resources and economic growth

The traditional view is that mineral wealth is one of the most important assets to shape the economic development and growth of nations. Revenue generated from the export of minerals can, to a certain degree, be used to build better infrastructures which benefit communities. Mineral wealth can enhance political stability if issues arising in the exploitation of natural resources such as native land title and environmental concerns are resolved appropriately. Hence economic growth can be bolstered.

The role of mineral resources in economics growth has been a major issue since economic became a profession. The economist, Adam Smith as early as 1776 noted,

> *"Project of mining, instead of replacing the capital employed in them, together with the ordinary profits of stock, commonly absorb both capital and stock. They are the projects, therefore, to which of all others a prudent law giver, who desired to increase the capital of his nations, would least choose to give any extraordinary encouragement ..."* (*Smith, 1776, p. 293)* .

History shows that mineral resources do have an impact in facilitating a nation's economic growth. The industrial revolution began in England, followed by Germany and the United States aided by resource endowments, particularly in coal and other natural resources in these countries. The recent development of the mining industry, such as that in the oil-producing countries in the Middle-east also shows that mineral resources do play a positive role in a nation's development (Tilton, 1992).

The mining industry requires significant amount of natural resource inputs as well as capital, labour force and management inputs (Freebairn & Quiggin, 2010).[10] Mineral exploitation can create more jobs opportunities by encouraging people to participate in apprenticeships. This helps to solve the skills shortages, which are experienced in the industry. The development of the mining industry also helps to create opportunities for other industries, such as housing and construction. The acceleration of the resource industry provides the beneficial economic linkages for the domestic economy.

Resources scarcity is one of the contemplative issues occurring in today's modern society. Balsdon and Deacon (2001) classify the term "exhaustible natural resources

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[10] Unlike other industries, the mining industry is classified as high risk for investment and is characterised by much uncertainty. The primary reason that uncertainty occurs is attributable to the imperfect flow of information between the mining companies and the government. The imperfect knowledge of the mining companies includes lack of knowledge in terms of the quality and quantity of exploitable mineral resources, technology, input costs, and policies such as taxation and environmental policies.

as the natural stocks that are subject to exhaustion as a result of human consumption". Resources not capable of providing continuous flows of consumption are called non-renewable. Natural resources in general are intrinsically linked to environmental economics.

The role of scarcity has dominated economic analysis for nearly two centuries (Dugger & Peach, 2009). The pace of economic growth is driven quickly as a result of high demand for natural resources in a country's economic development. Meadows *et.al.*, (1972, p. 55) in the Club of Rome states: "..... silver, tin, and uranium may be in short supply even at higher prices by turn of the century. By the year 2050, several more minerals may be exhausted if the current rate of consumption continues".

There are three important criteria that indicate that mineral resources are one of the key factors to bolster or cause decline in a country's economic growth (Tilton, 1992). Firstly, mineral deposits in the ground are dormant assets. The ore reserves in the ground do not generate cash flows until the mineral resources are discovered and exploited. Once the exploitation begins, the processing of mineral deposits can contribute to economic growth.

Secondly, the exploitation of mineral deposits in a particular country can generate revenues as the government charges the mining industry taxes. Tax levies in the mining industry are basically similar to other forms of taxes such as personal income tax, the Goods and Services Tax (GST), payroll tax, state transaction tax and so on, which are generated from industries in the economy (Freebairn & Quiggin, 2010). Taxation in mining can be complicated and subject to the existence of multiple government objectives such as maximising government revenue, maximising mineral rents, tax revenue stability, and attracting mining investment.[11] The government invests the mining taxes generated from mineral resources to enhance future economic growth. The government uses the taxes to build better infrastructures to enhance the economic well-being for the country and the community. Appropriate consumption in mineral rents is crucial. Unwise expenditure on mineral taxes can only inhibit a country's economic growth. This is one of the key factors that influence the extent to which the

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[11] The most common taxations in mining are Mining Royalty tax, ad valorem tax, proportional income tax, progressive profit tax and equity sharing arrangement.

economic growth in mineral exporting countries is lagging behind that of the resource deficient countries.[12]

Thirdly, mining taxes generated from the processing of mineral resources can impact far more than just economic growth. The economic well-being of future generations can also benefit from tax revenues through jobs opportunities, apprenticeships and community services. However, a resource boom is not always advantageous to the national economic growth. Economic growth can be inhibited as a result of a resource boom. A resource boom has implications on the real appreciation of exchange rates, which makes other sectors such as manufacturing worse off. The implication of this effect is the so-called Resource Curse or Dutch Disease.

Mineral resources cannot be renewed once the resources are depleted. The depletion of mineral resources restricts economic growth by increasing production costs and restricting the materials available for use to manufacture recyclable goods as well. The advancement of technology is being used to find substitutions for reproducible goods from exhaustible resources. The replacement of reproducible goods can lead to less reliance on exhaustible resources and enhances the sustainable economic development for a nation and general economic well-being. Non-renewable resources and economic growth are determined by the factors such as change in technology, which reduce the costs of production as a result of innovations in technology as mentioned earlier. Imperfect markets are caused by non-competitive price behaviour such as monopoly and monopsony. Other external factors such as financial turbulence and unexpected government policies implementation through which the costs of finished goods produced from mineral resources may not be the key factors in increasing market prices. Additional factors such as pollution and changes in ecosystems can result in irreversible changes in the natural landscape as a result of mining exploitation.

The fast rate of economic growth quickly depleted natural resources such as minerals, forests, and other exhaustible assets. The depletion of natural resources is alarming and the awareness of natural resources depletions has drawn the attention of policymakers to the sustainability of development for future generations. The

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[12] Bond & Malik (2009) and Melhum *et. al* (2006) evidence that proper governance and trade openness are the key factors to stimulate investment climate in resource-rich countries as well as maintained economic growth.

legislatures, hence, have taken action to prevent natural resources being massively exploited in a selfish manner.

2.2.1 The fundamental concepts of resource scarcity

Stiglitz (1974) states that mineral resources are important for human well-being to improve human needs and national economic development. Mineral resources are non-renewable and the depletion of non-renewable resources can drive up mineral prices. Economic growth can be sustained by investing the revenues obtained from mineral resources. Mineral resources need to be exploited in a way in which the revenues can be generated for sustainable development.

Victor (2008) states that many sources, for example Smith (1979) and Barnett and Morse (1963), have confirmed that there were no constraints on economic growth as a result of resource depletion. Victor (2008) states that Barnett and Morse analyse a variety of US natural resources for both prices and production costs. The research findings show that in the U.S. actual prices and actual production costs for natural resources have declined. The finding also shows that there was no depletion of natural resources as the U.S population grew by more than four times and the production output expanded approximately twenty times. West (2011) states that “the massive decrease in copper ore grade was not driven by depletion of higher grade deposit with resulting higher copper prices. It was instead a direct result of innovation that converted massive supplies of previously worthless “waste” rock into valuable ore”. West (2011) also notes that the improvement of technological innovation in extraction and processing in the twenty-first century has significantly shaped the exploitation process of the mining industry by allowing the exploitation of lower grade ores, which couldn’t be utilised in the past. Depletion of mineral resources occurs because the resources are non-renewable. The resources become scarce once the resources are exploited.

Myers and Barnett (1985) state that the resource scarcity is comprised of four factors which are worth noting. These four factors, which impact the scarcity of mineral resources are firstly, resources depletion, high production cost, and innovation; secondly, non-competitive market conditions; thirdly, external disturbances and environment; and fourthly irreversibility of natural resources once exploited.

Resources depletion, high production cost and innovation

Auty and Mikesell (1998) state that there is a controversial argument concerning the world sustainable development among traditional economists and their views about the depletion of mineral resources and the needs of future generations. The study of mineral exploitation can be dated back to at least the early nineteenth century. The demand for mineral resources as a result of the industrial revolution in England had drawn the attention of most of the traditional economists to the future depletion of mineral resources (Myers & Barnett, 1985). Mineral resources utilisation could not be maintained at past rates once the mineral resources were depleted.

In recent economics history, The Club of Rome strongly supports the growth of the utilisation of mineral resources in industrialised countries. The Club of Rome analysed the annual 1970s mineral reserve ratio and concluded that there would be severe shortages of important mineral resources by the year 2000 as a result of resources depletion. The sustainability of mineral resources for the use of future generations had drawn the attention of most of the world's policymakers. Policies, such as restricting mineral exports to support resource non-depletion have been implemented in Australia and Venezuela for iron ore, Canada for uranium, and in the Netherlands for natural gas (Auty & Mikesell, 1998; Radetzki, 1992).

Technology and innovation lower the cost of discovery, extraction costs and mineral processing costs. Technological innovation can minimise the exploitation costs by offsetting the rising prices of mineral resources as a result of depletion. The primary role of technological innovation takes place because of increases in production costs. In particular, the increasing cost of consumer goods motivates mining firms to make substitutions in order to maximise their profits (Macauley, 2005). Technology is defined as the process of production from the beginning stage of extraction, followed by manufacturing and transforming the resources into finished goods. Innovations is defined as the contribution of new ideas to the current outputs to provide greater sophistication and better features. However, over restriction of mineral exploitation can impair the benefits to future generations and thus has uncertain benefits (Radetzki, 1992).

The role of technological innovation is to prevent the exhaustion of natural resources. The justification for investment in technology in natural resources is comprised of three reasons. These are, firstly to replace certain goods made with natural resources; secondly, to improve the capability of machinery, expanding the equipment which is compatible with the latest technology, and encouraging the development of new experimental equipment; thirdly, to generate ongoing innovation in the natural resources market so as to be able to develop and adopt innovative technologies in the face of today's market competition.

The technological innovations in natural resources and economic growth are much debated. Tilton and Landsberg (1999) conduct research based on the changes of the United States (U.S.) copper industry between the 1970s and 1990s. The research shows that technology improvements are crucial to improve the competitiveness of the mining industry. Tilton (2000) states that the conventional economic views on mining competitiveness show that technological innovation is the best way to keep production costs low and maintain national competitiveness. However, Schandl *et. al.* (2010), state that technological innovation is not only concerned with producing or finding substitutions but it is also highly relevant in today's societal development in relation to resource use and the issues of climate change such as greenhouse gas emissions. The improvement of these existing technologies by focusing on the issue of climate change could reduce the heavy reliance on resource use and emissions by eighty per cent (p. 533).

Non-competitive market conditions

One of the greatest impacts of non-competitiveness in the mineral sector is made by the so-called cartels. These are collusive agreements among producers to seek monopolistic control over market prices by restricting mineral outputs. The most successful cartels established in recent times is the Organisation of Petroleum Exporting Countries (OPEC). In the mid-1970s and the early 1980s, the OPEC cartel successfully controlled oil prices by setting minimum oil prices based on the classifications of the qualities and the locations. However, when the oil prices declined in the late 1980s and early 1990s, OPEC still had the ability to maintain oil prices, even though the actual oil prices dropped to the level of the early 1970s.

Jamaica provides another example of producer collusion which occurred during 1974-1975. The Jamaican government had followed their counterparts such as Suriname, the Dominican Republic, and Guinea to increase the tax levy in order to boost the price of bauxite. This decision doubled the price of bauxite imported into the USA. However, the increased tax levy charges had no impact on Jamaica’s bauxite exports (Auty & Mikesell, 1998). History provides proof that the success of cartels in cutting supply and encouraging substitution for the commodity does not exceed more than five years (Radetski, 1992).

Other collusive agreements which are designed to stabilise the mineral prices are called the International Commodity Agreements (ICAs). These agreements have been advocated to conserve mineral prices by consumers and mineral exporting countries because these agreements can benefit both parties. The agreements have raised much controversy by setting agreed prices between consumers and mineral exporting countries. The primary reason which induces the controversies occurring in ICAs is that the mineral prices are often set at unsupportive levels. Thus, the welfare of consumers in mineral producing countries is diminished.

The International Tin Agreement (ITA) was designed and based on the principal of ICA (Auty & Mikesell, 1998). The objective of the ITA was to provide a reserve stock and export quotas for tin producing member countries. The false nature of this agreement became apparent in October 1985 when the world price of tin declined. The corruption that occurred in member governments and the smuggling of tin and trading on the black markets was responsible for the decline in prices.

External disturbances and environment

External disturbances can influence minerals prices and economic growth. Mineral prices may not truly reflect the real costs that society scarifices as a result of mining development. Mineral producing countries have sometimes deferred their mineral exploitation in order to not become excessively reliant on producing a single mineral. This could induce price instability. This can also lead to greater diversification of mineral exploitation. The decisions to defer exploitation taken by governments can discourage foreign and domestic investment. Subsequent deferral of investment can reduce the tax revenue generated from mineral rents and reduce royalty taxes and thus undermine a nation’s economic growth by restricting investment in an industry.

Being heavily reliant on mining development generally has no negative effects for a nation over a long-term period. The mineral rents or royalties taxes collected by a government can be used for other sustainable development purposes, which enable diversification into other industries. Auty and Mikesell (1998) state that growth in the mining industry does not just benefit a single industry, but growth can expand to include another industry by not being totally reliant on production from the mining industry.

Auty and Mikesell (1998) argue that the deferral of mineral production is not a sound policy, neither for an individual mineral exporting country nor groups of mineral exporting countries acting collectively. The policy can stimulate the world's supply of other resources or encourage substitution. However, the policy involves complex issues because of the uncertainty of the world's mineral prices and the expectations of the future generation in regard to today's mineral resources.

Auty and Mikesell (1998) also state that the present generation should only consume the amount of mineral resources required at the present time. The present generation should save and invest a sufficient amount of minerals today for the benefit of future generations to prevent an expanding flow of output in the future. Mineral resources left in the ground need to be invested in factories, infrastructure, exploration, technical research, and education in order to benefit future generations. In other words, the present generations should maintain comparable economic opportunities or increase future per capita output for future generations.

Federal, state and local governments have for a long period regulated for the environmental impacts of mining exploitation. Environmental issues have been a concern for many green environment protectors who want to prevent permanent changes in the appearance of the natural landscape. Some examples are: Johannesburg Declaration agreed by heads of state at the 2002 World Summit on Sustainable Development (WSSD); the Mining Minerals and Sustainable Development (MMSD) report launched by the World Business Council for Sustainable Development (WBCSD) in 2002; and the International Council on Mining and Metals' Sustainable Development Framework (ICMM) in 2003 (Esteves, 2008). These recent developments have impacted the relationship between mining companies and community investment practices.

Irreversible change of natural landscape

The effect on the natural landscape is irreversible once mining exploitation has begun. The impact of mining exploitation can destroy wild life, or result in the extinction of biological species which are the greatest concerns of most environmental activists. The common impacts of mining development are land disturbance, solid waste and acid-mine drainage (UNEP, 2000). Myers and Barnett (1985) state that change in the natural landscape is irreversible. The depletion of mineral resources can cause mineral prices to increase. In addition, depletion of mineral resources can induce technological innovation to find substitutions. However, it must be considered that the natural environment is irreplaceable and may be permanently damaged as a result of mining exploitation. As mentioned in the preceding section, many agencies involved in sustainable development have been established to protect the environment from damage as a result of mining exploitation.

Myers and Barnett (1985) also debate that the natural landscape is becoming more scare as the production of finished goods increases. This is because the value of the natural landscape is not quantified by market prices and the loss of social costs is unable to be reflected fully in the costs of the output of production. Government intervention in the form of implementation of environmental rules and regulations such as mandating pollution control technology and energy efficiency standards (Macauley, 2005) is one of the key prospects in protecting the natural landscape. However, it can also can drive up the costs of outputs, which increases the relative prices of goods, particularly for products, which used significant amounts of natural resources. The above statement is supported by researchers in the twenty first century such as Esteves (2008, pp.39-40) who states that *"the momentum for voluntary social investment by the mining industry has increased dramatically over recent years. Literature on corporate sustainability, the role business in sustainable development, and in the area of corporate social responsibility (CSP) has proliferated"*.

Humphrey (2001) states that the mining industry experiences significant cost pressures when mining operations occur. The pressures intensified towards the new millennium as a result of increased social and environmental demands for sustainable development by many environmental activists: so-called "eco-efficiency". Humphrey (2001) argues that environmental improvements and industry efficiency are strongly linked to each other. There are "win-win" opportunities from sharing between these two elements. These will result in the absence of conflicts between business and the environment. In addition, the absence of conflict will allow businesses to maximise their profit with maximum conservation of the environment simultaneously.

Lambert (2001) states that the universal major concerns recently for sustainable development are protecting irreversible environmental capital, damaging of the natural landscape, air and water pollution, resource depletion, reducing rates of greenhouse gas emission, and recycling and waste limitations. The problems of maintaining global sustainable development entirely depends on the growth of future generations and the demands for resource use. Federal, state and local governments play significant roles in ensuring that global sustainable development is maintained. However, it varies from one country to another. For instance, some countries depend on technological innovation by using renewable energy resources such as wind, geothermal, hydropower, or solar thermal (Macauley, 2005) to achieve sustainable development. These countries are more focused on obtaining supplies from minerals export countries. The mineral producing countries are more focused on sustainable development based on the scarcity of resources as a result of massive production.

Solow (1993) debates the argument of sustainable development in economic well-being and claims that other assets with equal value should be used to replace the used-up resources. Solow (1993) supports the Hotelling theory in which the value of the substituted assets should be equal to the capital gain from the Hotelling rent. Hotelling rent is defined as the difference between the commodity’s market price and the cost of extraction (Auty & Mikesell, 1998, p. 51). The cost of extraction includes the mining development cost and the discovery cost.

2.2.2 The Hotelling Rule (HR) in the exhaustible resources

The sustainability of mineral resources for future generations is at risk because of selfish exploitation and wasteful consumption by current generations and has raised the concern of conservationists (Hotelling, 1931) . Hotelling’s prominent work in natural resource economics addresses resource scarcity. However, HR does not resolve the issues of uncertainty, the possibility of deferring exploitation and market power (Veldhuizen & Sonnemans, 2010) . In the Hotelling theory, there are five main factors, which determine the prices of non-renewable natural resources such as oil: the marginal cost of extraction, the back stop price, the demand of non-renewable natural resources, the ore reserve and the discount rate (Reynolds & Baek, 2012) . The Hotelling Rule supports that only the deferral of mineral production over a period of time can prevent the increase of mineral prices as a result of the increasing resource scarcity (Hotelling, 1931).

In a fully competitive market mining firms face a trade-off between exploiting now and deferring mining exploitation. To be able to meet the equilibrium in a fully competitive market, it makes no difference for mining firms to choose either to invest now, or deferring mining exploitation. The deferral of mining exploitation will not undermine the value of mining exploitation because the resource prices will grow at the rate of interest. The income earned in today's value by mining investment is equal to the future income earned. The only way to make a difference is by increasing resource prices at the rate of interest.[13]

According to the Hotelling model, the increase in non-renewable resource prices minus the marginal extraction costs will increase the rate of interest. As soon as the resources become scarce, the resource prices will increase until the resources near depletion. The demand for the resources must be equal to zero on the date when the exhaustion nears. In other words, the level of prices in non-renewable resources is determined by the requirement of the increase prices to choke off demand when the resource stocks near exhaustion.

In reality, the theory of HR is based on faulty logic and misconception. The HR theory is unreliable and invalid under circumstances which occur in reality (Radetzki, 1992). Balsdon and Deacon (2001) state that the HR has found limited support from most researchers. The lack of success of the Hotelling theory is attributable to the volatility of economic conditions. Factors such as changes in interest rates, extraction technologies, input prices, demand conditions, knowledge about the extent of deposits, tax policy, and degree of monopoly power are primary elements leading to changes in resource stock prices. Veldhuizen and Sonnemans (2010) argue that mining firms will produce large quantity of minerals as long as the resources in the earth's crust are still relatively rich in resource stocks. In other words, massive mining exploitation will lead to a rapid exhaustion of the resources in the ground. This demonstrates the failure of the HR.

The empirical evidence of Reynolds and Baek (2012) further supports the fallacy of the HR, in particular the uncertainties of the discount rate. Reynolds and Baek (2012) state that Hotelling models tend to give economists and the general public the mistaken

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[13] According to HR, the future value of income earned from mining investment will be discounted back to the present value of income earned. There is no difference as to when the mining investment takes place.

impression that the economy is able to conduct intertemporal arbitrage to such a degree that resource problems can be adequately ameliorated.

Radetzki (1992) pinpoints the fallacies of the HR in three major areas. Firstly, the quality of mineral resources varies from one country to another. The quality of mineral resources should be classified so the royalty level for the non-renewable resources can be categorised. In economic theory, the high quality mineral resources, associated with the highest royalty rates will be exploited first, followed by the second grade mineral resources until the resource is depleted. The royalty rate will readjust according to the ore quality of the minerals exploited.

Secondly, as the discovery of new deposits continues over time, the quantity of ore reserves buried in the ground is not known with accuracy and the quality of mineral reserves could vary widely. For instance, miners in the late nineteenth century would not mine copper when the quality was below six per cent, or process low grade iron ore, which had to be transported from long distance places such as Brazil. However, the structure of business has changed in today's mining industry. Ore reserves of as little as 0.5 per cent purity are now considered capable of being processed. In certain cases, the mining companies reduce shipping costs to enable the transport of iron ore from one country to another for steel manufacture (Auty & Mikesell, 1998).

Thirdly, the theory of the HR agrees that the production of mineral resources can be controlled by increasing mineral prices. By deferring or reducing mineral production, mineral resources can be controlled for being over-exploited, which can undermine the economic well-being of intergenerational equity. The HR is not appropriate in an optimum production path for enhancing national and global sustainability as the future rate of production will be unable to meet the global demand due to resource scarcity.

Although there is empirical invalidity of the HR, in reality the theory of HR has still had an influential impact on both theoretical and policy-oriented thinking, particularly with exhaustible resources in the renewable and non-renewable resources sectors (Radetzki, 1992). For instance, the invalidities of the HR about the forecast of long-term oil prices increasing two to three per cent a year in the late 1970s and early 1980s strongly support the false nature of the HR in both the theoretical and empirical approaches. Krautkraemer (1998) states that the implications of basic concept of the HR have not been consistent with empirical studies of mineral prices and the costs of production.[14] The HR is invalid because there has been significant volatility of mineral resources prices over the last one hundred and twenty five years.

The HR is basically applied to non-renewable resources. The non-renewable resources, in particular, are finite. Krautkraemer (1998) states that the finite nature of resources is one of the factors that significantly affects the supply of mineral resources. Some of the implications of the basic HR can be altered when applying more realistic and complex features such as exploration, capital investment, and ore quality to the Hotelling extraction model.

2.3 Contemporary theories of natural resources

The role of natural resources has attracted attention since the industrial revolution occurred in The United Kingdom (U.K.), followed by the development of science and the growth of population. The theory of the scarcity of natural resources and economic growth has been significantly influenced by prominent British classical economists as well as the Neo-classical school of economists in the early nineteenth century. The neoclassical school of economics stated that there are finite natural resources available for human consumption. There is a constraint on economic growth and social welfare as soon as natural resources are depleted. After the neo-classical school of economics, the Conservation Movement in the United States developed. Conservationists have become prominent contributors to contemporary economic literature. The doctrine of the conservation movement is focused on natural resource scarcity and the implications of policy decision making on the development of intergenerational sustainability. The doctrine offers significant, comprehensive, vigorous and influential expression as well as political leadership in current economic literature.

The scarcity of natural resources became an important issue as a result of the rapid growth of the U.S. economy after World War II (WWII). A number of major publications were published in the 1960s and 1970s, for instance *Scarcity and Growth Reconsidered* (Smith, 1979) and *Scarcity and Growth* (Barnett & Morse, 1963). Recently, the study of resource scarcity and economic growth shifted in the mid-1980s to focus more on the rubric of the sustainability of development (Krautkraemer, 2005). The debate in recent economic theory is more concerned about the depletion of natural resources and intergenerational equity in relation to economic well-being. Other

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[14] In broad definition, cost of productions also classify as *in situ* value.

debates concerning exhaustible resources, particularly regarding how royalties will be treated adequately in the real-world mining industry have also raised much concern in recent economic literature (Ravagnani, 2008).

Barnett and Morse (1963) state that the economic literature about natural resources in relation to economic well-being and growth is insufficient. This corresponds with a lack of interest by the majority of economists in relation to subjects such as agricultural economics, energy studies and minerals commodity investigations. Smith (1979) states that three aspects must be addressed when evaluating the scarcity of natural resources. These are, firstly, the externalities that constrain the growth of economies as a result of resource booms; secondly, the technological innovation for recycling or reproducing natural resources being depleted and thirdly, the establishment of monopolies in mineral markets which aim to prevent the over consumption of natural resources.

There are three important elements that are related to natural resources and economic well-being and growth (Barnett & Morse, 1963, p.44). Firstly, the production costs of raw materials, secondly, international diplomatic relations which significantly impact commodities prices in the world market and thirdly, outbreaks of war. The first factor is the most essential because increases in production costs of commodities can inhibit future economic growth. These three elements were carefully considered by most of the economists of the Paley Commission. The commission was established in the 1950s as a result of increasing in raw mineral prices which evoked great public concern about scarcities. The major task of this commission was to “make an objective inquiry into all major aspects of the problem of assuring an adequate supply of production materials for our long-range needs”, and specifically to study :the long-range requirements outlook”(Cooper, 1975, p.238). Other prominent contemporary economists in the discussion of the relation of natural resources to economic growth include Villard (1955) who states that the increase in population growth is as alarming as is the increasing scarcity of resources. Schultz (1956) states that the limitations of natural resources have negative impacts on national economic growth, particularly on the availability of land used by society. This is because of the law of diminishing returns, in which the continuing population growth increases the scarcity of natural resources.

Other important contributions in the field of the relationship between natural resources and economic growth are Eric Zimmermann, Horace Belshaw, Harvey Leibenstein, Richard, R. Nelson, Kenneth Boulding, Everett Hagen, Walt Rostow, A.C. Pigou and Wesley, C. Mitchell. These economists have made significant contributions in the areas of natural resources and economic growth. Their theories are worth noting for current researchers particularly in the areas of sustainable development and resource scarcity.[15] Smith (1979) in *The Scarcity and Growth Reconsidered* states that economic well-being is strongly linked to the quality of the natural environment. There needs to be sound implementation of policies to enable conservation advocates of the natural environment and natural resource utilisation to be in balanced as a result of a high material standard of living.

Apart from public concerns in relation to high-profile natural resource issues and the sustainability of developments, other conservation issues should not be neglected. These include: endangered species, mining in national parks, grazing fees for public ranges, the use of land and conflicts in international natural resource issues. In national conservation issues, the use of land is a distinctive issue, which is faced virtually every day. Land is a resource, which enables humans to produce distinctive goods and services.

Throughout the world, resource issues have been the source of international conflicts regarding the access to particular natural resources, such as water. Other important issues are the mineral resource deposits, which are expected to bolster economic growth and development as well as the manner in which countries should utilise resources to enhance efficiency and sustainability (Brown & Field, 1979).

2.3.1 The analysis of growth models and the study of natural resource economics

Natural resource scarcity has been broadly viewed by most prominent economists throughout the history of economics. However, the scarcity of natural resources had not received significant attention in comparison to capital and labour. Historically, some major economists believed that there was an unlimited supply of natural

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[15] Barnett and Morse (1963) convey a message that the different of economic perspectives in relation to natural resource scarcity and growth are worth noting. This prominence research and the contemporary economists have played significant roles in contributing to the resource economics which cannot be neglected.

resources whereas others believed the natural resources were the major constraint on production.

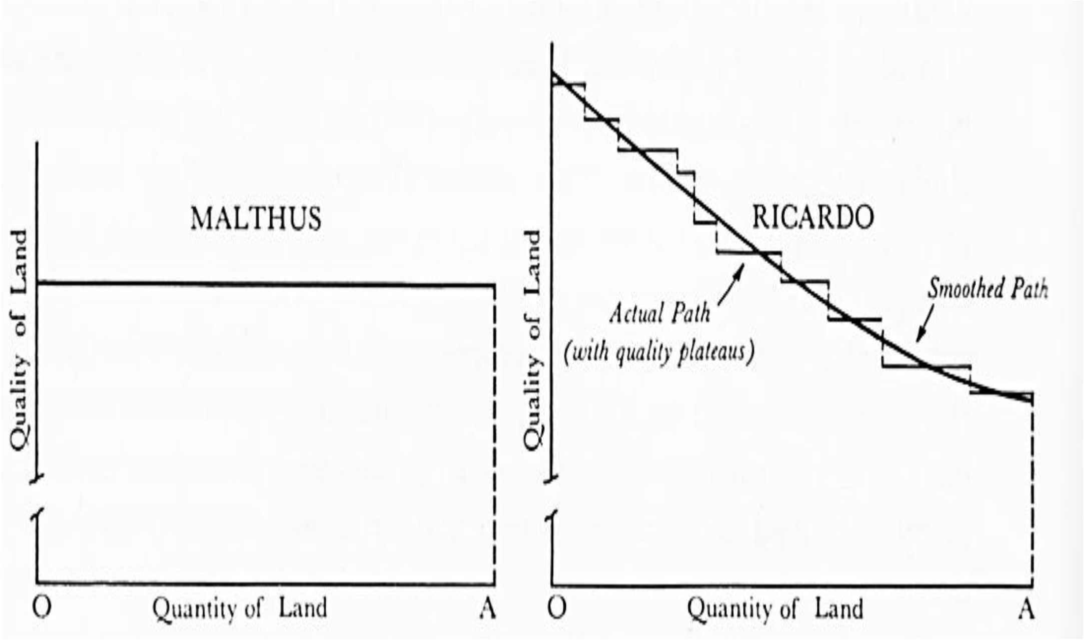
By the early nineteenth century Malthus (1798) and Ricardian (1817) had corrected the misconceptions of classical economics regarding natural resource scarcity and economic growth. The Malthusian and Ricardian ideologies were then elaborated further by Mill (1848). The doctrines of the classical school between the relationship of natural resource scarcity and economic growth were particularly concerned about land. This is because land was absolutely finite and constituted a limit on growth per capita once the limit had been reached (Auty & Mikesell, 1998, Barnett & Morse, 1963).

The concept of the limit to growth in Malthusian theory was influenced by the law of nature called the *'population trap'*. The Malthusian Growth model held that natural resources are limited and that population growth was the main constraint on production and scarcity. Malthus states that the amount of land allocated for agriculture is limited. Continuing population growth was the driving force for the increasing natural resource scarcity resulting from the high demand in land use. The imbalance between population growth and limited availability of land eventually undermined the per capita output and inhibited growth. Resource scarcity is a result of the limits of nature. However, the Malthusian theory has been rejected by mainstream economists (Brander, 2007; Decker & Reuveny, 2005; Dugger & Peach, 2009). Mainstream economists argue that population growth is a barrier to economic abundance. The Malthusian view can be modified by appropriate management and focusing on the role of technological progress.

The David Ricardo version of resource scarcity views that the quality of land can vary the productivity. Ricardo states that the fertile lands can be used before the least fertile lands. Real costs increase when less fertile lands are brought into use and thus the labour-capital cost of output increases to such an extent that there is a decline in economic growth, assuming the technological changes remain constant (Barnett & Morse, 1963).

Overall, the Ricardian version of resource scarcity appears to be more easily understood than Malthus' version. Ricardian diminishing returns take effect as soon as land is brought into use and does not require a specific time horizon and the assumption of limited availability of resources. In relation to industry and growth prospects, Malthus completely ignores the mining industry's relationship to national economic growth. Ricardo's model, takes the mining industry into consideration. Ricardo states that the land used in mining industry varies in fertility. Mined land is part of nature. Economic rents from the poorest mine should be levied equivalent to the fertile mines based on the total production extracted by the labour. The scarcity of mineral reserves and the rapid technological advances for extracting and refining ore grades are based on the same principles as those, which apply to agricultural land (Ricardian, 1817).

Figure 2.1 The Malthus versus Ricardian agricultural land availability

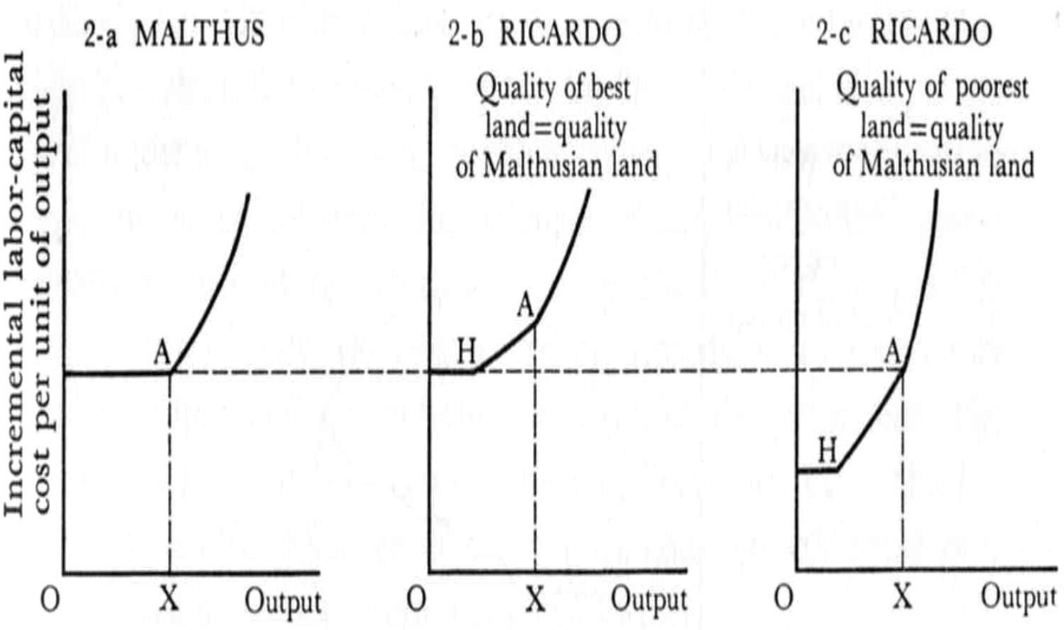


Source: Reproduced from Barnett & Morse, 1963, p. 60

Figure 2.1 above illustrates the availability of agricultural land as measured by both Malthusian and Ricardian models. Both the Malthusian and Ricardian models postulate that the land availability in the earth's crust is limited, being represented in each case by OA.

The Neoclassical school believes that in the economics of scarcity, labour and capital are parameters which are always constant. By contrast, classical economists believe that in reality there are only two inputs natural resources and labour-capital when measuring economic growth. Figure 2.2 below illustrates the economic scarcity effects in both the Malthusian and Ricardian views.

Figure 2.2 The economics of natural resource scarcity effect: Malthusian versus Ricardian



Source: Reproduced from Barnett & Morse, 1963, p. 61

Figure 2.2 panel-a illustrates the Malthusian case in which Malthus assumes that labour-capital cost per unit of output is constant until all land has been employed at point A. The cost per unit of output begins to increase from point A onwards because of the increasing labour-capital required to produce output as a result of limited natural resources. In other words, the economic scarcity effect occurs only until all land is brought in to use which is at point A.

Figure 2.2 panel-b illustrates the Ricardian version of the scarcity effect in which the labour-capital cost per unit of output is constant until the land reaches at point H. The Ricardian scarcity effect begins at point H, as the availability of more fertile land starts declined as more land is brought into use. Once the land is fully employed and reaches point A, the labour-capital cost per unit of output is higher than the Malthusian case.

Figure 2.2 panel-c illustrates the poorest Ricardian land, which will never be brought into use. The economic scarcity effect begins to appear as soon as the most fertile land has been fully employed at point H. The higher labour-capital cost per unit of output begins to rise once the scarcity effect is reached at point A.

In the early twentieth century, the conservation movement was developed by a group of non-economists in the USA. Conservationists state that the over-consumption of natural resources by the current generation were the main constraint to the future generations' productive capabilities. Natural resource scarcities are inescapable. The emergence of the neoclassical growth model started after WWII. These models had as their foundations production functions such as the Cobb Douglas (1928) production function and the Harrod (1939) production function. However, the early stage of the neoclassical growth model had nothing to do with natural resources (Auty & Mikesell, 1998). Basically, the fundamental concept of the neo-classical growth model can be written as the following:

$$Y = F(K, AL)R^h \qquad (2.1)$$

where;

$Y = output$
$K = capital$
$L = labour$
$A = Total\ factor\ productivity$
$R^h = exhaustible\ resource\ which\ is\ homogeneous\ in\ the\ degree\ 1 - h$

In the general growth model, the constraints on domestic investment are the key factors impacting the incomes of the developing nations and holding them at low levels. The Neo-classical economists state that the increase of foreign direct investment, improving the advancement of technology, proper government planning and major policy reforms are the best solutions to removing these hurdles. However, to some extent, these countries have ignored the potential of natural resources by believing that they can purchase resource-based products from the world market at competitive prices by using the revenue they have generated from the export of labour intensive products.

According to Krautkraemer (2005, p. 59), the economic measurement in resource endowment and scarcity consists of three key components: price, extraction cost, and user cost. To satisfy the basic condition for optimal resource extraction, the relationship between three components can be expressed by the following equation:

$$P = C_q + \lambda \qquad (2.2)$$

where;

$P = price\ of\ non-renewable\ resources$
$C_q = extraction\ cost$
$\lambda = user\ cost$

The idea includes the user cost as part of the resource price because it captures the non-extractive economic cost of current depletion such as the opportunity cost of regeneration for a renewable resource and the opportunity cost for future use of a non-renewable resource. Mineral resource prices incur significant uncertainties due to volatility of the resource market. The user cost is one of the fundamental concepts to evaluate how the efficiency of current and future extraction rates would be affected by changes in some of the uncertainty factors (Brown & Field, 1979).

The Club of Rome published in the *Limits to Growth* (Meadow *et al.* 1972) indicated that the threat of resource scarcity as a constraint on national economic growth has raised significant criticism among mainstream economists (Solow, 1974; Hartwick, 1977; Stiglitz, 1979; Toman, 1994), particularly in respect of the impact of resource depletion on intergenerational equity.

Solow (1974) and Stiglitz (1979) both state that technological innovation is necessary to produce replaceable products other than just heavy reliance on the input of natural resources. They state that the marginal productivity of capital can be enhanced and that economic growth can be continued via technological innovation even though there is depletion of natural resources. Smulders (2005) states that in the neoclassical views, finding new resource substitution and technological innovation are the main ways to alleviate the resource scarcity.[16]

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[16] In neoclassical views, the resource substitution is more likely to run into diminishing return, the offsetting of technological innovation is mandatory to sustain economic growth.

Major economists were confident that replacement of natural resources would occur by producing recyclable goods through technological advancement (Auty & Mikesell, 1998). The supplies of natural resources are entirely dependent on the substitution of recyclable goods. The demand for natural resources can be reduced if recyclable goods are sufficient to meet the market demand. The increase in the cost factors of natural resources such as labour costs and capital costs can increase the price of natural resources in the world market. These costs are fully dependent on the demand for natural resources.

The fluctuation in natural resource prices also corresponds to the scarcity of natural resources. These prices are determined by the resource rents earned by the land owners**.** At the equilibrium level, the input prices of the natural resources are equivalent to the marginal products in all sectors. In other words, the abundance of natural resources can impact the world's economic growth. However, this does not inhibit the growth of the individual countries because they are able to seek other replaceable goods from world markets at competitive prices instead of utilising their own local resources.

2.3.2 The abundance of the natural resources and economic growth

The possibility of economic abundance has been considered by major economists from diverse economic perspectives from as early as the nineteen century. Abundance is defined as adequacy. Abundance means human beings are enabled full access to the knowledge, skills, technology, tools, and materials used in the community. In a social context, abundance means everyone has sufficient economic well-being to enable them to improve their living standard (Dugger & Peach, 2009).

Conventional trade theory explains the comparative advantages of certain countries producing and exporting, particular commodities to other countries, while at the same time importing other resources they have shortages of, for national economic development. However, the trade in natural resources had never been well integrated into conventional trade theory. The comparative advantage theory was first formulated by Ohlin (1967) based on the neoclassical growth theory and is solely dependent on the relative scarcities of labour and capital, which is directly influenced by the relative abundance of natural resources.

The theory of the neoclassical growth model states that economic growth occurs by improving efficiency in the basic three-factor model. The three-factor model uses three factors which represent the inputs of the natural resource, labour and capital to analyse the output production function. In the three-factor model countries have a choice to produce either labour-intensive manufactured products or capital-intensive manufactured products; the one that is chosen entirely depends on the labour and capital ratio. Land is another factor which determines the economies of abundance; countries with an abundant amount of land will develop their manufacturing sector to a much higher level of capital per person compared to countries scarce in land. The change in economic growth is solely linked to the changes in labour force and capital formation (Daniel, 1992). Daniel (1992) identifies three approaches in relation to mineral economics and national development: the neoclassical growth theory, the structuralist theory, and Dutch Disease.

In discussing neoclassical growth theory, Daniel (1992) states the constraint on economic growth in the neoclassical growth model is comprised of three elements: the constraints of the domestic savings, the international exchange of mineral resources and the government revenues. These three constraints are linked to one another due to the shift in labour and capital factors in the growth model. For instance, consider that an abundance of labour in an LDN is ready for employment in the mineral sector. If there is insufficient domestic savings to allow sufficient funds to purchase essential mining machinery, then this becomes a constraint on mining exploration.

In neoclassical theory, mineral revenues play a critical role in abolishing these three constraints. Windfall revenues, those generated from mineral exports, are key factors in removing these constraints (Daniel, 1992).

The Structuralists believe that the lack of economic linkages between the mining industry and the rest of the economy caused the decline in mineral exporting countries' terms of trade, particularly for primary commodity exports in relation to the import of manufactured goods. Other structural problems such as production, consumption and fiscal linkages in a nation not only depend on the economic development conditions but are also associated with how wisely the government utilises domestic resources.

The Structuralists see mineral exploitation more as a curse than a blessing. They suggest that the rent generated from mineral resources should be diversified away from development strategies based on primary exports and focused on import substitutions and greater industrialisation.

Resource endowments are not always beneficial to a nation's development. Evidence[17] from different sources indicates that mineral exporting countries, particularly the Least Developed Nations (LDN), experience poor economic performance compared with mineral deficient countries. The income per capita in resource rich LDNs has deteriorated, but their economies have out-performed those of the resource deficient nations. The positions of mineral exporting LDNs with poor economic management are more fragile, and in the most serious case, national economies have completely stagnated or declined.

The oil price shocks in the early 1970s and in late 2008 are the factors, which the world economic down turn can be attributed to. The sharp increase in crude oil prices has significantly impacted the world economic activity. This is seen in the slump in stock markets and decreases in non-fuel mineral prices. However, that these are the only reasons attributable to the poor economic growth in the least developed mineral exporting countries remains dubious. It should be noted that the relationship between the mineral resources and a nation's economic growth is complicated.

Dutch Disease is another modern macroeconomic theory used in the open trading economy, particularly in the analysis of oil booms. One of the key dimensions of Dutch Disease is crowding out or displacing non-mining goods from the export industry (Goodman & Worth, 2008). The primary factor of Dutch Disease is a rising exchange rate that makes the local manufacturing industry worse off. Dutch Disease originally referred to the adverse effects on Dutch manufacturing of the natural gas discoveries of the 1960s, essentially through the subsequent appreciation of the Dutch real exchange rate (Corden, 1984, p. 359). The term Dutch Disease was used by *The Economist* to describe the experience in the Netherlands in 1977. Another example of Dutch Disease occurred with the UK's North Sea Oil from 1979 to 1984 as a result of deficits in oil exports of £2.2b turned into a surplus of £6.6b. The increased oil surplus

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[17] Researchers Ploeg & Poelhekke (2009), Steven & Dietsche (2008), Ding & Field (2005), Auty (2003), Sachs & Warner (1995) and Corden (1984), have demonstrated that resource rich countries in particular, have performed poorly in their economies compared to resource deficient countries. The research demonstrates that the economic parameters such as income per capita, trade policy, government efficiency, sustainable development, investment rates and commodities prices are highly sensitive to economic growth.

had driven up the appreciation of the Sterling Pound. This, and a range of deflationary policies, transformed a surplus of £3.6b from manufactured goods into a deficit of £6.3b (Good & Worth, 2008, p. 204).

Dutch Disease in general undermines the economic growth of a country. However, Dutch Disease can be overcome through technological innovation. Technological innovation is important for discovering, extracting and processing mineral resources in the ground. The invention of new technology or research and development is important for increasing productivity by processing mineral resources into reproducible finished goods for household consumption, and is also the only method to reduce the cost of production as well as to decrease the price of commodities.

Asia-Pacific countries, in particular Australia, have recognised the impact of Dutch Disease since 1976 in the so-called "Gregory effect". Gregory (1976) states that the 1970s mining boom in Australia had made other non-mining sectors such as agriculture, manufacturing and tourism exports worse off. The principle mechanism, which caused the Australian version of Dutch Disease was the impact of the real appreciation of the Australian currency as a result of the mining boom. This adversely affected the non-mining sectors. The majority of the resources in the economy had been absorbed by the mining sector, which undermined economic diversification and led to macro mal-development (Goodman & Worth, 2008; Gregory, 1976).

The Dutch Disease model was first developed by Corden (1984). Corden (1984) uses a model with three sectors the mining sector, the tradeable sector and the non-tradeable sector to analyse the impact of Dutch Disease. The model shows that Dutch Disease impacts on each of the three sectors. The causes of these impacts are the spending effect, a relative price effect and the resource movement effect. The spending effect occurs as a result of a booming sector, which shifts the prices of tradeable sectors to make them less competitive and makes the country's exports outside the booming sector less competitive. The relative price effect occurs when non-tradeable prices in the domestic market increases as a result of increased demand. The resource movement effect occurs when there is a shift of labour and capital from tradeable and non-tradeable sectors to the booming mining sector as a result of the resource boom.

Neoclassical economic theory suggests that mineral exporting countries benefit from the higher prices of natural resources in two ways. Firstly, there are massive revenues inflowing from the exporting minerals through re-investment in projects, which promote development. Secondly, revenue inflows from natural resources due to the real appreciation of exchange rate (Steven & Dietsche, 2008). However, the mineral exporting countries, in particular, are unable to utilise their revenues from the export of natural resources to sustain their countries' development, which prevents them from transitioning into emerging market economies from developing country economies (Steven & Dietsche, 2009). This poor result is known as the resource curse.

Goodman and Worth (2008, p. 202) defined 'the resource curse as the socio-economic disadvantage, political disruption or environmental degradation that results from dependence on extractive industries'. The resource curse phenomena is similar to Dutch Disease, which was much debated in the late 1990s and 2000s based on the experiences of resource rich countries. These countries were enriched with mineral resources but had encountered low-growth development compared to the resource deficient nations. The debate of resource curse was intense in the late 1990s and 2000s driven by rapid economic growth in Asia.

Until recently, much research (Steven & Dietsche, 2008; Torvik, 2009; Coxhead, 2006; and Auty, 1998) has examined the impediments to the growth of the development of mineral resources due to the impact of the resource curse. For instance, the resource boom in Australia has prompted much discussion about the two-tail economies of the mining states and the rest of the country (Garton, 2008). The resource curse occurs when the resource-rich countries achieve lower economic growth than resource-deficient countries. The resource curse can be mitigated if the diversification of economies is implemented by enhancing terms of trade, luring foreign direct investment and achieving better growth rates. Also, particularly in developing nations, high quality institutions leading to good economic policies are key factors, which allow a country turn the curse into a blessing (Yang, 2010).

Three key elements cited as being impacted by the resource curse are:

(1) The social economic impacts caused by changing terms of trade, income volatility, dominance of foreign-owned resource companies and weakened non-resource sectors. The resource boom has occurred in the twenty-first century because of increased demand from the countries of the East and South Asia, the intervention of the US in

the Middle East and early indications of high demand of oil known as ‘peak oil’(Goodman & Worth, 2008, p. 209).

(2) The capture of the politics of regulatory and energy security in mining policy. Mining policy in the twenty-first century has been amended significantly, particularly in native title rights, tax incentives competitiveness, and promoting a self-regulatory approach to conservation protection. Similarly, the concern for energy security has driven much more direct forms of intervention in order to be able to access mineral resources and markets in the region.

(3) There are ecological impacts, which damage the environmental and future economic well-being. The uniqueness of mineral resources and the living environment, in which they are deposited, are values which are effectively priceless, and can never reflect their true value in cash. One of the greatest concern in recent mining development is climate change, particularly the impact on Green House Gas (GHG) emissions. Government plays a critical role in ensuring that mining development is for the good of the community and the environment in which it lives.

2.4 Abundance and scarcity: some empirical considerations

In resource abundance economics, scarcity and growth are critical areas for mainstream economists to debate. Mainstream economists such as Solow (1974). Stiglitz (1974), Hartwick (1974), Toman (1994), Krautkraemer (1998) and Aydin and Tilton (2000) have done much empirical research, which raises a simple empirical question as to whether or not technological progress can overcome diminishing marginal returns. This research question has continued over the years and the research continues today (Krautkraemer, 2005, p. 58). Balsdon and Deacon (2001, p. 5057) consider future research in natural resources and state that “the study of exhaustible resources has largely shifted from optimal extraction and scarcity measurement to the environmental impacts of fossil fuel consumption”.

Bond and Malik (2009) state that there are two reasons for empirical study in relation to natural resources and investment being unsatisfactory. These are that much literature (Mainardi, 1995; Gylfson *et.al.*, 1999; Crowson, 2002; Gylfson & Zoega, 2006) has neglected the investment variable when measuring resource abundance due to volatility and sensitivity of the economy. The previous literature focused on resource scarcity and growth but there has been little research into a more systematic empirical evaluation of the relationship between natural resources and investment.

A significant contribution to the study between relationship resource abundance and economic development was first made by Sachs and Warner (1995). The research of Sachs and Warner (1995) shows that economies with a high ratio of natural resource exports to GDP in 1971 (the base year) tended to have low growth rates during the subsequent period 1971-1989. Sachs and Warner (1995) conclude that the trade policy, income per capita, lack of government and accountability have had negative impacts on economic development in most of the resource-rich countries.

Many researchers (Stijns, 2005; Gylfson & Zoega, 2006; Melhum, *et.al.*, 2006; Berry, 2008; Karnik & Fernades, 2009) have provided evidence that the resource curse has a negative impact on economic growth. Trovik (2009, p. 244) states that "in the last 40 years there is a negative robust correlation between the share of resource exports in GDP and economic growth. This correlation remains even when many other factors are controlled for". The empirical evidence from these researchers indicates that the economies endowed with natural resources tend to grow slower than the resource deficient economies. Those countries with producer friendly institutions could escape any resource curse or Dutch Disease.

The empirical research of Gylfason and Zoega (2006) is worth noting. Their research use a sample of eighty five countries and shows economic growth per capita from 1965 to 1998. Natural resource dependence is measured by the percentage share of natural capital such as physical and human capital. The empirical findings show that natural resources can impact economic growth significantly both directly through macroeconomic variables, as well as indirectly through government policy implications.

Lederman and Maloney (2006) investigate the impact of trade structures, in particular, natural resources, terms of trade and cross industry trade on growth. Lederman and Maloney (2006) developed a panel data over five year periods from 1975 to 1999. Their findings show that trade structure variables such as macro stability, investment, terms of trade, and capital are important determinants of growth rates. The variables mentioned above, which are determined by productivity adversely affect the economic growth and the cross-industry trade generally associated with good economic growth indicators. In summary, the research findings of Lederman and Maloney (2006) show no evidence of a resource curse using the three variables mentioned above.

The impact of resource curse on the economic growth in resource rich countries is significant. Auty (1998, p. 7) states "there is clear evidence that crop-driven resource-rich economies do have an inherently slower growth rate than manufacturing-driven resource-deficient economies". For instance, among the large economy countries, the manufacturing sector expands later in the resource-rich ones and peaks at a level that is 4 per cent of GDP growth, which is lower than the large resource-deficient countries. Among the smaller economies, resource-rich countries have manufacturing sectors that expand their share of GDP of 2-3 per cent, which is lower than in the small resource-deficient countries.

Karnik and Fernades (2009) construct a macroeconomic model to analyse the countries' dependence on the non-renewable resource of oil for The United Arab Emirates (UAE). The macroeconomic model comprises four sectors, which are: the output sector, the government sector, the monetary sector and the external sector. The findings show that resource-rich countries, in particular, require significant economic transformation so that they are not heavily reliant on hydrocarbon sources of revenue for national economic growth.

The empirical findings across various countries show that there is an inverse relationship between economic growth and resource abundance (Berry, 2008). Berry focuses on four countries: Indonesia, Chile, Venezuela and Nigeria and examines the national terms of trade in relation to employment as well as the economic growth. The empirical findings of these four case studies show that the comparative advantages between the nations are the key elements to sustaining economic growth in the primary, secondary and tertiary sectors. However, overall economic growth in these three sectors are solely dependent on the nature of the particular country's business environment, politics and culture.

Bond and Malik (2009) use the cross-country empirical evidence to examine the role of natural resources in explaining long-term differences in private investment based on the share of GDP in a sample of seventy eight developing nations during the period 1970-1998. The findings show a positive impact from the share of fuel exports in total exports and negative impact on fuel exports if a measure of export concentration is taken into consideration. The research also highlights the important role of ethnic diversity, trade openness and the investment capital in a country's private investment shares. Similar to other literature, the paper shows results consistent with the hypothesis that the resource curse will be less significant in countries with more diversified trade structures than in those countries less diversified trade structures.

Market volatilities are key issues in determining the resource curse, particularly output per capita growth in countries that depend heavily on natural resources. A country can turn the curse into a blessing if it is able to mitigate the economic volatility by having a sound financial system, fewer capital account restrictions, openness as well as efficient and effective physical access to world trade (Ploeg & Poelhekke, 2009).

Krautkraemer (2005, p. 58) states that "the recent empirical evidence to date for natural resource commodities is largely in favour of technological progress". Until now, the research has not been fully developed. However, the research in the discovery and development of new ore reserves, capital substitution, technological innovation, and commodity production at least has led a downward sloping price trend for many natural resource commodities.

On the one hand, Victor (2008) argues the original work of Barnett and Morse does not give a clear explanation of the scarcity of non-renewable resources. Victor (2008) states that renewable resources such as commercial fish and forest products can last forever provided the rate of consumption does not exceed the rate of regeneration. Non-renewable resources are dormant assets. Depletion occurs as a result of massive extraction and consumption.

On the other hand, Smith (1979) in *Scarcity and Growth Reconsidered* had renewed interest in the availability of natural resources in relation to material well-being and economic growth. Smith (1979) states that increasing the costs of energy and natural resources are important for ensuring a clean environment and improved health. Prior *et. al* (2011, p. 11) show similar evidence to Smith (1979) and state that social and environmental impacts are factors driving up the costs of mineral production. More inputs of, for instance, energy, water, labour and capital will be required to exploit a large proportion of low grade ores in order to produce the same amount of output that the quality ores produce. This is because of increasing mine surface expansion.

Smith (1978) states that using the relative price index is one of the superior indices in measuring resource scarcity because this factor influences all factors of scarcity. The findings of this study with updated data analysis show that the outcomes of this study alone are not sufficient evidence to draw the same conclusion as the Barnett and Morse study, that is, that there is increasing scarcity of natural resources. The study of Smith shows no evidence of an increasing natural resource scarcity.

Johnson *et.al.* (1980) extended the original work of Barnett and Morse, using the data from the 1957-1970 period. This study shows that the unit labour extraction costs for the agricultural sector and minerals had declined after the period of 1957. The finding shows that scarcity in the mineral sector had declined as a result of substitution between resources. The outcome of this paper shows support for, and consistency with, the Barnett and Morse study.

Krautkraemer (1998) extended the fundamental idea of the Hotelling model by adding some extra factors relating to non-renewable resources, including exploration, capital investment and ore quality based on the basic implications of finite availability for intertemporal allocation. The empirical findings show that these factors can affect price and depletion paths in a number of ways, particularly the discovery of new deposits and technological progress that lowers the cost of extracting and processing non-renewable resources. The study of Krautkraemer (1998) also indicates that the discovery of new deposits and technological progress are key factors in mitigating the impacts of the finite availability of natural resources and reduces their depletion and increasing scarcity.

The study of Krautkraemer (1998) also indicates that the substitution of new materials, through improvements in extraction and processing technologies enable the use of low grade ores and offer greater efficiency in the use of non-renewable resources. Finding new materials is essential to keep pace with increased demand for finite availability through the impacts of growing population and economic development.

Krautkraemer (2005) gives important evidence that the increase of resource scarcity would not drive up the mineral prices. Mineral prices have come down since the early 1980s, and some of these declines are substantial. This is attributed to factors such as substitutions being made, research and development which results in less natural resources used, ore reserves discovered and developed, and new mining methods for recovering resources or reducing the cost of using low grade ores.

The mining industry is more focused on the demands of sustainable development and proceeding to the new era of using e-technologies for improving mining productivity. Humphreys (2001) states that traditionally production growth in the mining industry is affected by three factors: capital inputs, labour inputs and total factor productivity. Total factor productivity is one of the factors used to measure the efficiency of purchased services and energy usage associated with capital and labour inputs. Total factor productivity, in general significantly influences the efficiency of technologies, management systems, labour practices, regulatory practices, economies of scale and ore reserves quality.

The evidence from the US Bureau of the Census data showed that strong productivity growth is usually achieved though sound capital injections in the form of better equipment, larger trucks and shovels, improved rail and port infrastructure. Economy of scale and changes in energy prices are the factors which impact productivity growth in the mining sector (Humphreys, 2001, p. 3). Humphreys (2001) uses historical records to investigate the impact of environmental and social costs on mining productivity. The findings show that the emerging information and communication technologies (ICT) seems to be playing a key role in improving mining productivity growth.

Aydin and Tilton (2000), Krautkraemer (1998), Johnson *et.al* (1980), Barnett and Morse (1963) and others had found that the scarcity of mineral resources can be minimised by facilitating technological innovation, which reduces the cost of extracting and producing mineral resources. Aydin and Tilton (2000) analyse the U.S. copper mining industry over the 1975-1995 period in relation to the labour productivity growth in two aspects; firstly, the change in mining location, and secondly, the change in productivity in mining sites. The study shows support for the hypothesis that the new technology research and development are more important than mineral endowment in changing labour productivity trends and comparative advantages in mining.

Many recent empirical studies (for example Ayres, 2005; Bartos, 2007) have modelled the technological innovations associated with environmental factors (Macauley, 2005). For instance, the invention of the solvent extraction-electrowinning (SX-EW) method for refining copper ore is one of the examples of the significant technological development in the mining industry (Krautkraemer, 2005). New inventions as well as government intervention can impact the prices of inputs and outputs both directly and indirectly to ensure the efficiency of resource use and keep the environmental impact as minimal as possible.

Major empirical studies (Barnett & Morse, 1963; Smith, 1978; Humphreys, 2001; Sullivan *et.al.,* 2001; Krautkraemer, 2005) find no evidence to support the increase of resource scarcity. A tested hypothesis shows little evidence of increasing resource scarcity. Further evidence shows that increasing resource scarcity does not apply to the mineral resource industry. The absence of an increased in natural resource scarcity is mainly attributable to technological innovation, research and development, and reproducing or recycling resources. The empirical studies of Tsur and Zemel (2005) and Reynolds (1999) also support the argument that there is little evidence of increasing resource scarcity.

Tsur and Zemel (2005) use a methodology which enables the complete dynamic characterisation of optimal growth and research and development processes. The findings show that the long run economic growth prospect is determined by production efficiency, learning ability as well as capital-knowledge endowment. For instance a reduction in physical capital due to war outbreak or an increase in immigration to attract highly skilled workers significantly impacts the equilibrium level of the long-term economic growth (Tsur & Zemel, 2005, p.485). According to Tsur and Zemel, a resource-deficient economy devotes a significant amount of its income to backstop research and development to maintain its national economic growth, compared with a resource-abundant counterpart.[18] The objective of encouraging research and development is to sustain economic growth in circumstances in which resources are scarce.

The increasing quantities of minerals extracted have significantly impacted the natural resource prices and user costs have declined simultaneously over a long time period (Reynolds, 1999). This trend is contrary to that predicted by the Hotelling rule as a result of technological innovation. Reynolds (1999) uses an alternative model for

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[18] Tsur and Zemel defined backstop as a resource substitution, e.g., solar energy that substitutes for depleting fossil energy resources (2005, p. 485).

scarcity based on the Mayflower problem to investigate the cost of resource exploration. The explorer for minerals has no information about the total ore reserves contained in the earth's crust. Explorers' information is solely based on the explorers' knowledge of how they search for and extract natural resources. The research findings show that technology can overcome resource scarcity. In fact, the advancement of technology can also drive up mineral prices provided demand for mineral resources is growing faster than technological innovation.

In general, the empirical evidence shows that sound institutional policies, technological innovation and trade openness are closely linked to the productivity of natural resources. The concern about natural resource scarcity could be reduced if natural resources are being consumed in an appropriate manner. Smulders (2005) states "Institutional quality and the correct innovation incentives prove to be essential in transforming resource availability into wealth and coping with problems of resource scarcity" (p. 167).

2.5 Concluding remarks

This chapter summarises a diversity of opinion, popular and professional views in today's world about the importance of natural resources for economic growth and maintenance of society's economic well-being. Concern about the scarcity of natural resources was noted as early as the late eighteenth century by Adam Smith, who stated that natural resource scarcity was one of the main constraints in national economic growth, which limits the possible size of a nation's industrial production. The increased scarcity of natural resources is one of the factors that drive up commodity prices. However, the economic pattern in recent years has shifted towards the global resource use and resource efficiency, particularly in the Asia-Pacific region. The Asia-Pacific region will experience further significant growth during the next three decades, which in the investment of sustainability development made today in this region will fully reflect the future of resource use over the next thirty to fifty years (Schandl & West, 2010).

The concern over the resource availability has become one of the major issues since WWII, following the heavy demand for materials for post war redevelopment. Since that time, the empirical study of Barnett and Morse has played a significant role in contributing to research in natural resource scarcity. The empirical evidence in this pioneering study shows that there is little support in the findings for the hypothesis that there is increasing resource scarcity. The empirical evidence is also consistent with other research studies such as Barnett (1979), Smith (1978), Aydin and Tilton (2000), Krautkraemer (2005), and Prior *et.al.* (2011).

The use of technological innovation in extracting natural resources was demonstrated as early as the nineteenth century by Mill (1848). Mill noted "much as the collective industry of the earth is likely to be increased in efficiency by the extension of science and of the industrial arts" (1848, p. 649). Prior *et. al.* (2011) points out that effective macro-economic policy as well as embracing innovative governance and encouraging mineral exploitation from alternative sources are the key factors ensuring long-term productivity from the abundance of mineral resources. Focusing on the constraints to mineral production as a result of sustainability issues such as social and environmental impacts in mining exploitation is essential to ensure long term mining productivity.

The significant work of Barnett and Morse on resource scarcity has been extended to resource abundance in the late twentieth century as a result of the North Sea oil shock in the Netherlands. Recent literature is more concerned about resource abundance, which can cause two-speed economies as a result of resource booms. The impact of the so-called Dutch Disease as a result of a resource boom is one, which drives up the exchange rate and makes other industries such as manufacturing industries worse off. A **s**ignificant number of studies such as those of Sachs and Warner (1995), Auty (1998), Gylfason and Zoega (2006), and Trovik (2009) have researched resource abundance and indicate that resource deficient economies perform as well as their resource rich counterparts. The findings also suggest resource abundance has negative impact on economic growth. As noted, resource abundance can reduce saving, investment and growth which could result in lowering the level of consumption and output per capita in the long run (Gylfason & Zoega, 2009).

Minerals are not a curse. However, the curse which occurs as a result of the resource boom is mainly caused by the greed of individuals (Wright & Czelusta, 2004). The resource curse is exogenous and can significantly impact national economic growth through macroeconomic avenues as well as through public policies. Wright and Czelusta (2004) state that the prevention of non-renewables resources being over consumed comes through adequate techniques in exploration, technological innovation, and investments. Good institutions and sound macroeconomic policies are vital in determining healthy and robust national economic growth. The development of mineral industries can sustain economic growth by generating wealth from exporting mineral resources. With the sustainable development of natural resources, the environment is conserved for future generations.

Failure to explore mineral resources without appropriate consideration of the environment could damage future national economic activities. Environmental issues are of great concern in the sustainable development of today’s mining industry.

Having discussed the contemporary issues in resource scarcity that are encountered in the mining industry, the next chapter begins with discussion of financial techniques used in mining investment decision making.

Chapter Three

3 Fundamental Framework of Mining Investment Valuation

3.1 Introduction

A review of the literature on the resource scarcity and economic growth was conducted in the preceding chapter. Attention is now given to the fundamental framework of financial techniques in the evaluation of mining projects. The objective of this chapter is to draw attention to the methodological issues in relation to mining project evaluation. This chapter discusses financial techniques that are useful in the mining industry.

Economics defines investment "as the act of incurring an immediate cost in the expectation of future rewards" (Dixit & Pindyck, 1994, p.3). Economic evaluation of an investment is a crucial process in today's business world. Investment evaluation takes place to ensure that the valuation of a particular project is such that a company can generate an investment return at the highest rate possible. Investment in a particular project such as a mining project requires significant project evaluation to determine the economic feasibility. Mining projects, in particular, often have many uncertainties. The uncertainties are usually caused by the very nature of geological reserve estimations, severe problems in forecasting commodity prices and production costs, long evaluation periods during which economic and technological conditions can possibly change, regulatory changes and environmental costs, as well as long lead times.[19]

Investment analysis is perhaps the most important and conscious decision making process for many mining firms. The analysis explains the exact financial position of the project for a mining firm. The results of the analysis may lead the company to invest capital in assets with the anticipation of earning a positive return after a certain period of time. Mining investment decision making is important to determine the

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[19] Mining projects generally have very long lives. It takes several years of intensive effort to discover an ore deposit. The preproduction period of a mining project requires at least 3 to 12 years to be completed. The completion time entirely depends on the mining and processing methods, the size and location of the deposit, and complexity of the operating and environmental licensing procedures.

composition of the company's underlying asset portfolios held, as well as the business risks to the firm.

Investment decision making considers three important factors. Firstly, cost of investment is at least a partially sunk cost. Once an investment has taken place, it becomes irreversible. Secondly, investment decisions incur future uncertainties. The assessment of the probabilities of alternative outcomes is one of the steps in assessing the uncertainties in investment decision making and minimising the investment risks. The third factor relates to the choice of timing. The investment decision should be executed at the most appropriate time.

A feasibility study is the central point of a mining investment project. Feasibility studies are formal procedures to investigate the various relationships in mining projects that could possibly impact mining investment decision making both directly and indirectly. The purpose of a feasibility study is to clarify queries in mining projects by taking accounts of all factors and also ensuring that the project derives acceptable rate of returns.

Investment decisions are ubiquitous. Human beings use investment decisions in their daily lives to make decisions to invest in something better in order to improve their standards of living through the profits generated from the investments. Mining investment is distinct from other industries such as the manufacturing industry. The distinctiveness of the mining industry arises because mining ventures are extremely capital intensive, from the time mining operations commence until a mine closes. Also, mining investment encompasses a few different stages over the duration of the mining process. Significant time periods are required for each stage of this process. Taking the distinctiveness of this business environment into consideration, this chapter discusses fundamental knowledge in mining investment decision making.

The primary role of this research is to investigate mining investment decisions in the Asia-Pacific countries. The research is focused on five countries located in the Asia-Pacific region. These countries are Australia (AUS), Indonesia (INDO), Malaysia (MLY), New Zealand (NZ), and Papua New Guinea (PNG). The research is constructed to consider the mining investment potential in these countries. The Discounted Cash Flow (DCF) utilising Net Present Value (NPV) and Real Options Valuation (ROV) methods will be applied in this research.

Traditionally, NPV and ROV are more acceptable valuation methods to apply in the business world rather than the Internal Rate of Return (IRR), and Payback Period. DCF is the most popular and accepted conventional method used in many companies. Slade (2001) states that the majority of mining company analysts prefer some version of the NPV method, although this method fails to price the flexibility that is inherent in managing risky assets. Peter Monkhouse, the Vice President of BHP-Billiton's Iron Ore Division attacks the use of the NPV method and states that "it systematically undervalues investment returns by up to half its true value" (Wills-Johnson, 2010, p. 97). ROV is still in its infancy but this method is more likely to be the most acceptable method in mining investment valuation analysis in the twenty-first century.

Section 3.2 of the chapter outlines the theoretical approaches in conventional investment analysis. The section explains the differences between investment evaluations in the finance and mining sectors. Section 3.3 outlines the theoretical evaluation approaches in both the DCF NPV and ROV models. The differences between these two approaches are used to distinguish the strengths and weaknesses of the two models. Section 3.4 outlines concluding remarks of this chapter.

3.2 The uniqueness of the mining project investment: A class of project financing

Mining project finance falls within the subject of project finance. Project finance, also called non-recourse or limited recourse finance is a term used to explain a specific type of lending. Lenders or financial institutions assess only the ability of an individual project's financial cash flow to repay the loan. The project's underlying assets are used as collateral. According to Ben Esty, professor of Finance at Harvard Business School, project finance involves the creation of legally independent project company finance with equity from one or more sponsoring firms and non-recourse debt for the purpose of investing in a capital asset (Esty, 2004, p. 13). Project financing deals usually range from USD$100 to USD$500 million (Esty, 2004, p. 38).

To further understand the definition of project finance, John and John (1992, p. 51) define project financing as the "financing of a project by a sponsoring firm where the cash flows of the specific project are earmarked as the source of funds from which the loan will be repaid and where the assets of the project serve as the collateral for the loan". The assets and the cash flows particularly large scale mining projects, are separated from those of the project companies in order to obtain credit appraisal and the loan for the project.

Table 3.1 Worldwide project finance

	2011		201 0		
	US$Bn	Share %	US$Bn	Share %	% Change
Worldwide Total	214.5	100.0	207.4	100.0	3.4
By Country					
India	45.9	21.4	53.2	25.6	-13.7
Australia	23.4	10.9	15.4	7.4	51.8
USA	18.5	8.6	13.5	6.5	36.3
Russia	11.3	5.3	2.8	1.3	310.5
France	11.3	5.3	5.4	2.6	107.8
Spain	10.3	4.8	16.8	8.1	-38.6
UK	10.3	4.8	13.8	6.7	-25.4
Brazil	8.3	3.9	3.1	1.5	170.7
Italy	7.1	3.3	5.4	2.6	31.0
Singapore	6.5	3.0	1.3	0.6	395.4
By Region					
Americas	38.3	17.9	25.6	12.3	49.6
Europe, Middle East & Africa	84.9	39.6	83.8	40.4	1.2
Asia-Pacific (Including Japan)	91.3	42.6	98.0	47.2	-6.8

Source: Austrade, 2012

The most common applications of project financing are in the natural resources sector, such as for mines, pipelines, and oil fields. Project financing is also used in infrastructures investments, such as toll roads, bridges, telecommunication systems, and power plants. Table 3.1 displays global project loan finance for 2010 and 2011. The total for 2011 exceeded the 2010 total by approximately 3%. The total project loan finance for the Asia-Pacific region accounted for USD91.3 billion in 2011 which was slightly less than USD98.0 billion in 2010 when there was a slowing down of the world economy. The Asia-Pacific region still remains the strongest region in total project loan finance in the world. For example, in Australia total project loan finance in 2011 well exceeded the 2010 total, yielding USD23.4 billion. The mining industry accounted for the bulk of Australian project loan finance. The increased demand for total project finance loans in the Asia-Pacific region is attributable to the strong economic development in this region, particularly the strong demand for mineral resources in China and India.

The history of project finance dates back several hundred years. The first project finance was primarily in mining and natural resources projects. It can be traced back to 1299, when the English Crown enlisted a leading Florentine merchant to aid in the development of the Devon silver mines. In the United States, the application of project finance was first developed in the 1930s, when a mining explorer in Texas and Oklahoma used production payment loans to finance oilfield exploration. Project finance began a new era in the 1970s after several large natural resources discoveries. For example British Petroleum (BP) raised $945 million on a project basis in the early 1970s to develop the “Forties Field” in the North Sea. A Freeport Mineral project financed the Ertsnberg copper mine in Indonesia and through Conzinc Rio Tinto of Australia project financed the Bougainville copper mine in PNG (Esty, 2002, p.4).

There has been an upward trend in project financing since the early 1990s, up until the 2008 global financial crisis (Lartey, 2011). The wide use of project financing is mainly attributable to privatisation, deregulation and globalisation across both developed and developing countries. Privatised companies can use project finance to expand their business growth. Policy deregulation can create opportunities for new large scale project investment.

Project financing was scaled back after the 2008 financial downturn. This was attributable to the banks, which needed significant liquidity to improve their financial position after significant profit losses in 2008. For instance, The Royal Bank of Scotland (RBS), the world’s biggest lender of project finance reported the largest ever annual loss in British corporate history totalling £24.1 billion for 2008 (Lartey, 2011, p.21).

Project financing in the mining industry has played a small role relative to other types of projects (Esty & Megginson, 2003). Mining is included in the data for project financing because of the interest of non-governmental organisations (NGOs). Table 3.2 illustrates the distribution by sector of the Multilateral Investment Guarantee Agency's (MIGA) portfolio for fiscal years 2010 and 2011. The MIGA annual report 2011, indicates that the mining industry comprised only 3.3 per cent of the total net exposure compared with other industries such as financial, infrastructure and oil and gas. This is attributable to the majority of mining projects being financed by mining companies themselves. International stock markets also provide another avenue of financing mining projects by raising equity for mining exploration.[20]

Table 3.2 The sectoral distribution of MIGA's portfolio at June 30, 2011 and June 30, 2010

In millions of US dollars	June 30, 2011			June 30„ 2010		
	Gross Exposure	**Net Exposure**	**% of Total Exposure**	**Gross Exposure**	**Net Exposure**	**% of Total Exposure**
Infrastructure	$2,961	$1,694	32.3	$2,302	$1,475	34.3
Financial	4,456	2,341	44.7	4,022	1,855	43.2
Tourism, Construction and Services	193	177	3.4	159	145	3.4
Manufacturing	790	472	9.0	587	341	7.9
oil and Gas	234	195	3.7	468	369	8.6
Mining	243	172	3.3	105	40	0.9
Agribusiness	246	187	3.6	80	73	1.7
	$9,122	**$5,239**	**100.0**	**$7,723**	**$4,296**	**100.0**

Source: The World Bank, MIGA annual report, 2011

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[20] As noted, MIGA is one of the members of the World Bank Group. The objective of MIGA is to provide a political risk insurance scheme for Foreign Direct Investors to invest in the Least-Developed Countries. Projects committed with MIGA are tightly linked with the development goals and priorities of the World Bank. As a result, the mining industry only comprises a small percentage of the sectoral distribution of MIGA's portfolio. The reason to show the MIGA sectoral distribution is to distinguish the differences of the mining sector compared to other industries.

Mining projects are unique by their very nature. Investment in mining projects is capital intensive, environmentally invasive and socially intrusive. Many countries have yet to successfully manage solving the controversial issues related to economic rent and the high external cost of mining projects which convert their mineral endowment into national wealth. These issues have large impacts on surrounding communities. Unfairness in the division of economic rent can cause the outbreak of civil wars. High external costs may undermine the economic well-being of the local communities.

Investment in mining projects is extremely risky. The financial realities of mining show that investment in mining projects in general is not very profitable. Only a small percentage of exploration activity leads to the development of mines. The financing of mining and minerals projects is important and requires careful assessment to determine whether a project is profitable or non-profitable. In assessing mining projects it is necessary to identify and quantify the different levels of risk that separate good decisions from bad ones. Environmental, social, and increasingly, reputational risks are among the many risks. Such risks are among the criteria which banks use to assess the mineral projects.

It takes years to complete a project-finance deal. There are several stages which need to be taken into consideration before an actual project commences. These are the conceptual study, the prefeasibility study and the feasibility study (UNEP, 2001). The first stage is scoping, or a conceptual study which takes place in order to identify general features and order of magnitude of a project, such as examining technical issues requiring further investigation, calculating the cost and time required to undertake further predevelopment, and undertaking the preliminary evaluation of viability, costs and acceptability. A typical conceptual study takes about 2 to 9 months to complete and comprises 0.1 to 1 per cent of the total project cost. [21]

As soon as the information provided by the conceptual study is sufficiently accurate, pre-feasibility studies will take place.[22] Prefeasibility studies have several aims: to assess the possible reserves and approaches to extraction; to identify the techniques and rates of extraction, outline the possible features of the facilities, to develop capital

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[21] This study is usually conducted by company staff using in-house resources.
[22] This type of study is usually led by company staff or entirely subcontracted.

and operating cost estimates; to test the marketability of the commodity, assess the economic conditions and determine what additional efforts are required to enable the pre-development activities to advance. This kind of study takes about 9 to 13 months to complete or comprises 0.2 to 2 per cent of the total project cost.

The final stage is the feasibility study.[23] This is the most serious challenge in mining projects evaluation. A well designed feasibility study will be able to shape the future mining project by securing external funding from financial institutions. Also, a good feasibility study can help to fast track internal final approval.

Feasibility studies have a number of aims: to establish the proven and probable reserves within the overall measured, indicated and inferred resources; to prove the technical feasibility of the mine and extraction methods, defining the characteristics and capacity of the facilities, and estimating the development, capital and operating costs of the mine over the economic life of the resource; to help establish the market for the commodity, investigate the economic sensitivity of the proposed development and set a framework for the implementation of capital investment in the mine

Table 3.3 Predevelopment cost of mining project (AUD$ 000's)

Activity	**Scoping**	**Pre-feasibility**	**Feasibility**
Mine development including geology and hydrology	30-40	40-60	80-100
Extraction or processing	20-30	40-60	80-100
Preliminary Engineering	10-20	40-60	150-300
Cost estimations	5-10	10-15	20-30
Environmental	5-10	30-40	150-350
Site issues – survey, services, geotechnical	Nil	10-20	40-80
Total AUD$ (000's)	**75-120**	**180-275**	**540-1020**

Source: UNEP, 2001,p.33

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[23] In large scale mining companies, feasibility studies are usually conducted by the company's staff specialising in the areas or assigned to consultants or contractors. In the case of small and medium size mining companies, feasibility studies usually are contracted out to a specialist technical consultancy.

development. The duration to conduct a feasibility study will take 1 to 2 years and comprise 4 to 8 per cent of the total project cost.

Table 3.3 illustrates the phases of pre-development costs required for the mining prject evaluation. When interpreting the table, it should be borne in mind that the values displayed only illustrate proportions rather than absolute values. These figures provide a guide to understanding the estimated costs at each preliminary stage of a mining project evaluation before actual mining operation is commenced.

Project finance should be distinguished from conventional corporate finance. Large scale projects involve capital intensity and significant risk. Each project under evaluation requires careful structuring in order to meet the unique needs of each party taking part in the financing project. These include the company undertaking the project, the sponsoring companies or equity holders and the banks.

3.2.1 Project finance versus corporate finance

The concept of project financing is often confused with corporate financing in today's business world. Kensinger and Martin (1988) draw a comparison between the two by classifying the meaning of project finance and corporate finance as follows:

Corporate finance occurs "when a corporation chooses to undertake an investment project, cash flows from existing activities fund the newcomer; and management has the option to roll over the project's capital into still newer ventures within the company later on – without submitting them to the discipline of the capital market" (pp.69-70).

Project finance occurs "when the assets and cash flows associated with each project are accounted for separately. Funding for the new project is negotiated from outside sources, and creditors have recourse only to the assets and cash flows of a specific project. As the project runs its course, furthermore, the capital is returned to the investors, and they decide how to reinvest it" (p.70).

Project financing has emerged as one of the important new financial techniques in modern large scale, highly capital intensive projects. However, research about project finance is limited. The literature on project financing is scarce, out-dated and limited to a few sectors such as energy projects, including oil and gas, telecommunications and power generation facilities. There have been less than fifteen articles which deal directly with project financing published over the last twenty years. These include John and John, 1991; Kleimeier and Megginson, 2000; Esty, 2002; Esty and Megginson, 2003; Subramanian *et.al.*, 2007; Lartey, 2011 and Scannella, 2012.

The increasing use of project finance challenges Modigliani and Miller’s (1958) ‘irrelevance’ proposition. They claim that corporate financing decisions do not impact the value of companies under certain conditions. One of the key assumptions in their irrelevance proposition is that financing and investment decisions are completely separable and independent. Firms can choose to finance their investments through issuing shares, borrowing and spending profits. If this is the case the factors that are traditionally viewed as impacting decision making on financing, such as the firm’s organisational structure and the cost of capital, will have no impact whether a firm finances investment with debt or equity. However, empirical research has shown that corporate financing and project financing lead to different valuations for the same project. According to Yescombe (2002) project finance is different to financing projects. The reason is that projects can be financed in many different ways. A project using project financing involves several parties.

In the developed world, large scale government projects are usually financed by public enterprises; large scale private sector projects are usually financed by corporate financing. In the developing world, most large scale projects are financed by the government through borrowing foreign funds from the international banking market and international institutions such as the World Bank, the International Monetary Fund (IMF) and the Asian Development Bank (ADB).

Subramanian *et.al* (2007) conducted research across forty nations by comparing loans provided to project companies versus loans provided to corporations. The empirical evidence shows that industries with large free cash flows are more likely to utilise project financing than corporate financing. Visconti (2011) states that in managing financial risk, project financing is far more complicated than conventional financing methods. Large scale projects require greater financial sophistication to mitigate the project risks compared with usual corporate financial risks.

The value of mining projects is significantly affected by the number of characteristics not usually important in corporate finance (Samis & Poulin, 1998). The first is the timing of the individual cash flows which has significant impact on the value of money received. Mining projects which have a long lead time before cash flow begins tend to have lower value.

Table 3.4 Key differences of project finance versus corporate finance

Elements	**Project Finance**	**Corporate Finance**
Financing vehicle	Single-purpose project	Multi-purpose project
Type of capital	Finite –time horizon matches life of project	Permanent and indefinite time horizon for equity
Dividend policy and reinvestment decisions	Fixed individual policy – immediate payout; no reinvestment allowed	Corporate management makes decisions autonomous from investors and creditors
Capital investment decisions	Highly transparent to creditors	Opaque to creditors
Financial structures	Highly – tailored structures which cannot generally be re-used	Easily duplicated; common forms
Transaction costs for financing	Relatively higher costs due to documentation and longer gestation period	Low costs due to competition from providers, routinized mechanisms and short turnaround time
Size of financings	Might require critical mass to cover high transaction costs	flexible
Basis for credit evaluation	Technical and economic feasibility; focus on project's assets, cash flow and contractual arrangements	Overall financial health of corporate entity; focus on balance sheet and cash flow
Cost of capital	Relatively higher	Relatively lower
Investors/lender base	Typically smaller group; limited secondary markets	Typically broader participation; deep secondary markets

Source: Comer, 1996, p.6

The second is the uncertainties underlying the economic and physical characteristics of the project. The development of mining projects is dynamic and unique. The structures for evaluating a project are designed and implemented to resolve these uncertainties using information such as grade revelations and price realisations.

The third characteristic is the ability of management to resolve the uncertainties. The ability to be flexible in investment decisions is necessary. Management decision making can significantly impact a project's value because it allows management to avoid bad outcomes and make the best of the investment situation.

Table 3.4 summarises the key differences and characteristics between the two types of financing. It is essential to distinguish these features when evaluating a project.

Comer (1996) and Subramanian *et.al.*, (2007) state that there are four common features of large scale project financing transactions. Firstly, large scale projects usually have a legally independent project company to invest in the project. The structure of the project is used to mitigate the agency cost. Lower agency costs can minimise conflict between owners and related parties. Project financing is usually off balance sheet financing, in which the assets and liabilities of the project company are separated from the sponsor's balance sheet. The project company has no ownership to access internally-generated cash flows of the sponsoring firm, unlike in corporate financing, where the assets and liabilities of the company are part of the company's balance sheet financing.

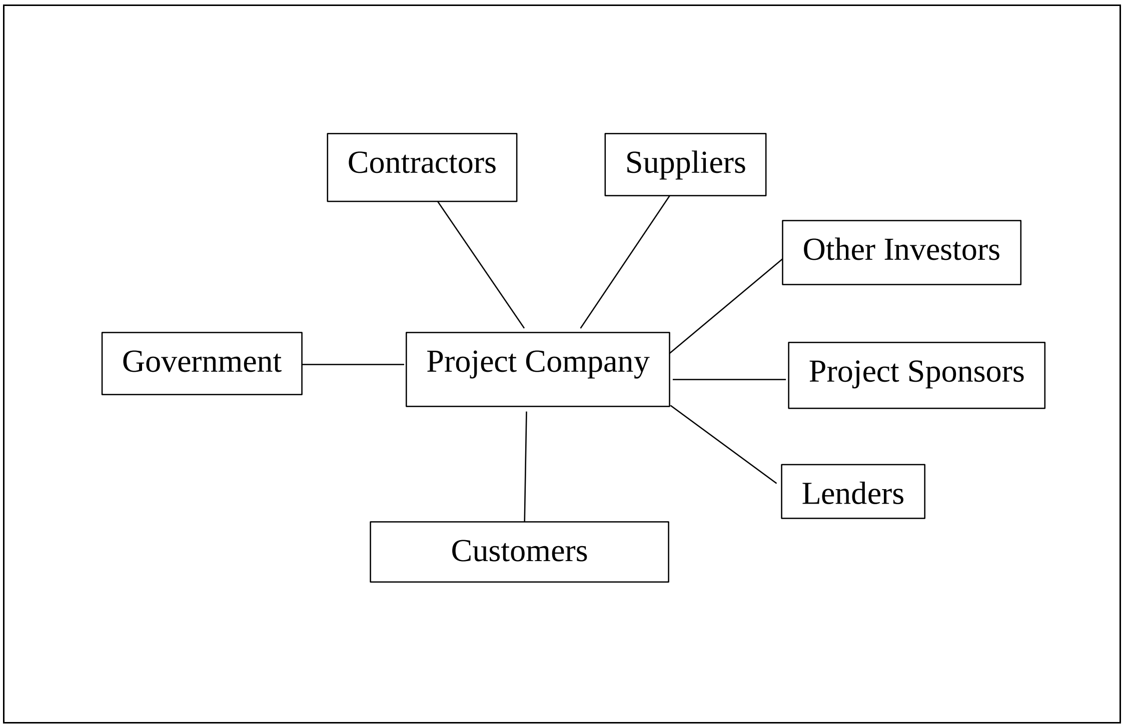
Secondly, investment in large scale projects in mining is usually a long-term illiquid asset. A project company usually invests only in one particular project and the duration of this project is usually significant. In corporate financing projects, a company usually invests in many projects or has a diversified company investment portfolio.

Thirdly, investments in projects are financed with non-recourse debt. A project is usually a standalone project and the debt structure of project financing is completely non-recourse to the sponsors company. In other words, all the interest and loan repayments are from the cash flows generated from the project. By contrast, lenders in corporate finance can generate cash flows and assets from the sponsor company.

Fourthly, the transactions of project financing tend to be highly leveraged compared to public enterprises. Project companies have extremely high debt. The amount of debt usually comprises 65 per cent to 80 per cent of capital in relatively normal cases. The majority of debt is obtained through bank loans. Syndicated lending is common in project financing. Syndicated lending occurs when a collection of lenders from different financial institutions jointly extends a loan to a mining company (Esty & Megginson, 2003).

There are numerous parties involved in the structure of large scale company project financing. Figure 3.1 illustrates the parties involved in a project financing business structure. There are firstly, project sponsors and investors. Project sponsors are separate companies which undertake project investment. These are not used in the mining industry. The sponsor company is generally involved in the construction and the management activities.

Figure 3.1 Simplified project financing structure



Source: Brealey, et.al., 1996, p. 28

Secondly, syndicated lenders such as banks and specialised lending institutions are the source of funds for project investment. Less frequently, companies obtain the investment funds from the bond markets.

Thirdly is the role of government. The government needs to implement a regulatory framework, guarantee currency convertibility, and monitor sustainability issues in the community. For instance, permits may be required from the government for a mining company to build a road or railway for mining exploration.

Fourthly, mining project contractors are usually mining engineering firms or consultants, for which the primary role is to monitor the mining construction, engineering issues, procurements and mining operations.

Mining projects as well as other large scale projects entail significant risk. The primary risks are country and sovereign risks (political risks), industry risks (intense competition within the industry), project and insolvency risks (the adequacy and track-record of the concerned technology and the experience of the project's management), interest rate risks and completion risks.

There are numerous other risks such as customer risks (demand fluctuation), supplier risks (the quality, quantity and availability of utility supplies to generate the projects), sponsor risks (insufficient capital to continue the project), contractor risks (project's schedule delays and budget overruns).

Additional risks including operating risks (regular maintenances of machinery and equipment), product risks (product liability and design patterns), and funding risks (capital falls short as a result of exchange rate fluctuation) are taken into consideration in project evaluation.

Inappropriate risk mitigation can significantly impact a company's cash flow position. This is because risk contamination may significantly undermine a firm's value. The project finance advisor and other parties to structuring the project finance play important roles in mitigating these risks. The responsibility of the project finance advisor is to ensure that these risks are mitigated by allocating risks appropriately to the party who is best suited to be responsible. To determine the project risks, the project finance adviser will usually rate the project risk by assigning credit-rating agencies such as Standard & Poor's and Moody's Investor Services to review the risks of the project based on legal documentation and independent advisers' reports.

Project evaluation is critical to ensuring the long term success of mining companies. Appropriate planning at an early stage of a mining project is essential in order to obtain the greatest scope in exploring alternatives sources, assessing risks and minimising overall project costs while maximising the project upside potential. Financial techniques are becoming crucial in mining project evaluation. The next section discusses in detail the DCF and ROV financial techniques.

3.3 Theory of valuation: financial techniques of mining projects valuation

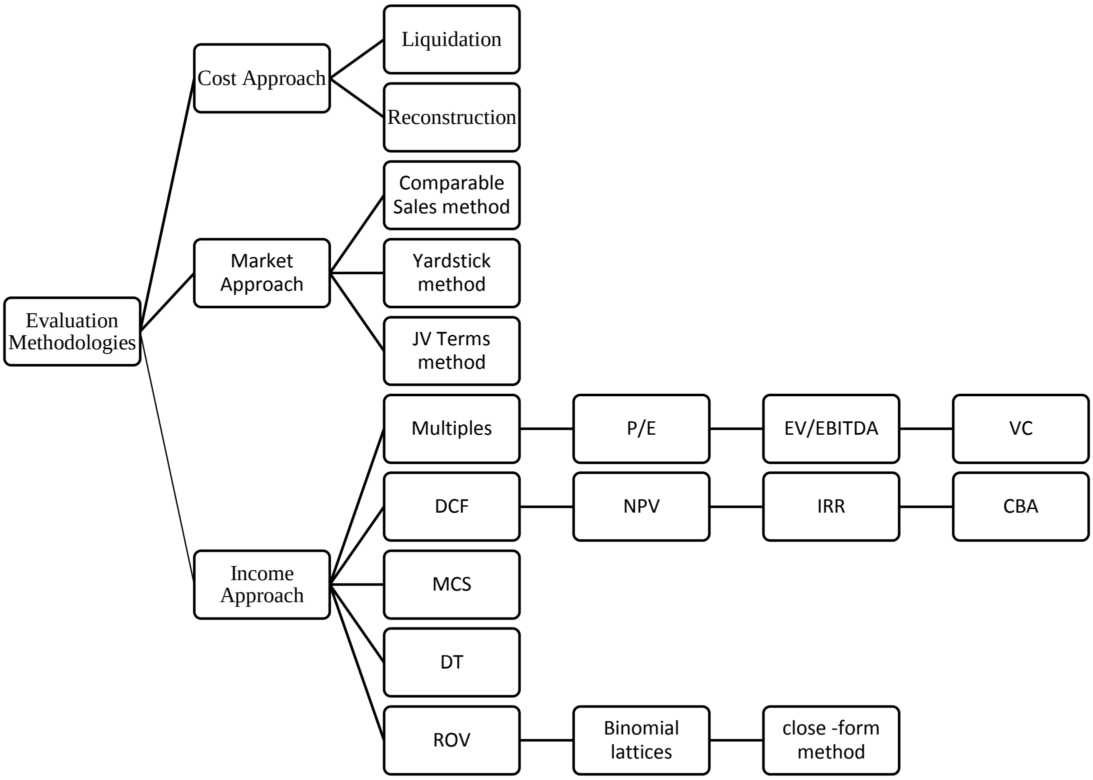
The development of contemporary theory of financial economics over the last 35 years has significantly contributed to the development of valuation theory (Bhattacharya & Constantinides, 2005). The emerging valuation theories over this period includes the general equilibrium theory of Arrow and Debreu (1954); the portfolio selection theory of Markowitz (1952); the equilibrim valuation theory of Sharpe (1964) and Lintner (1965).

Other valuation theories are the non-arbitrage valuation theory of Modigliani and Miller and its application in corporate finance (1958); the intertemporal non-arbitrage valuation theory of Black and Scholes (1973); the intertemporal valuation theory of Merton (1973a); and the asymptotic non-arbitrage theory of Ross (1976).

Conventional valuation theory recognises that the cash flows analysis of mining projects is affected by two fundamental concepts. Firstly, there is the time value of money and secondly, there is uncertainty. The empirical research in the evaluation of mining and other natural resources projects, conducted by Brenan & Schwartz (1985) is worth noting. Brenan & Schwartz state that mining and other natural resource project valuation is made particularly difficult by the high degree of uncertainty and fluctuations in output prices.

Decision making on capital allocation in the mining industry is complex. However, the recent unpredictable levels of volatility in market conditions have made mining investment decision making even more difficult. According to Deloitte Touche (2010) , one of the prominent finance consulting firms, the business cycle and the environment of mining investment decision making will not be the same in the next 10 years as a result of increased demand for mineral resources. In evaluating large scale projects, in particular, there is the need to plan ahead well beyond the market cycles.

Figure 3.2 Project evaluation methodologies



Sources: Gentry & O'Neil, 1984; AIMM, 2001, Mun, 2006; Shafiee, 2010;

Capital budgeting is crucial in mining project decision making. The decision making process in mining projects requires a significant time period to mature. The profitability of the project is one of the primary criteria on which the decision will be based. Profitability is a major objective of mining companies. A mining company is interested in knowing what the present value of future investment in a project is and how long the project will generate returns.

In the scenario of mining project investment, the conventional valuation methodology comprises three widely accepted approaches to estimate the market value of any asset. These are the cost or asset based approach, the market or comparable sales approach and the income or earnings approach. Figure 3.2 above illustrates the three approaches of conventional project evaluation methodology.[24]

The fundamental concept of the cost approach is that a mining company should not purchase a mining property if they can build a mine site of lower construction costs. Gentry and O'Neil (1984) state that the cost approach is rarely applied in the mining industry because the relationship between construction costs and the value of a mining property is imperfect.

The Cost approach comprises two methods: the liquidation and reconstruction methods. The liquidation method is based on the conversion of assets into cash or inventory into accounts receivable in order to reduce the bad debts of the organisation. The reconstruction method is based on current data to evaluate a project, which is not applicable for a future project.

The Market approach is a valuation method in which a property's valuation is determined from the price which comparable property sells for in the market. The market approach comprises three methods. The Comparable Sales approach is designed to evaluate mineral assets based on the market value of the mining property. The Yardstick method is designed to evaluate a mining property based on the known net value of ore reserves. The Joint Venture (JV) method is designed to evaluate a JV mining property based on existing JV agreements.

Roscoe (2002) states that methods using the market approach are acceptable to all types of mining valuation. However, there are some deficiencies in this approach when applied to mining transactions. Firstly, there are limited data for mining properties valuation. Secondly, the fluctuation and uncertainties of production commitments, deferred payments, stock exchanges, production payments and other subtle factors can significantly impact mining valuation.

The income approach includes all fundamental concepts of value estimation that are based on the income generation potential of an asset (AIMM, 2001). The income approach includes the multiple approach, DCF analysis, Monte Carlo Simulation (MCS), decision tree analysis (DTA) and ROV. The valuation of income approach is

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[24] The DCF and ROV methodologies are the main techniques applied in this research. The fundamental concepts of other techniques will only be briefly discussed to better understand the techniques used in project evaluations.

based on the valuation of an estimated asset value by calculating future net earning value generated from the asset then discounting the future earnings to the present time using an appropriate discount rate.

The multiples approach is based on the price to earnings ratio (P/E), enterprise value to earnings before interest, taxes, depreciation and amortization (EV/EBITDA) and venture capital (VC). The multiples approach is used mainly for decisions about start-up business investment funding to forecast future profits in the long-term for a company. The fundamental concept of the multiples approach applies the P/E ratio to determine company value using the market price divided into dividend per share (DPS) and earnings per share (EPS) components. This approach is not commonly used in mining project evaluation.

The most common valuation methods in the income approach are DCF and ROV. Slade (2001) examines project evaluation based on valuing managerial flexibility. An informal survey was conducted by Slade to determine how nonferrous-metal-mining companies evaluate projects. The survey shows that the majority of mining firms use some form of DCF calculation to evaluate projects. Most mining companies use a long-term commodity price and adjusted for risk by using an inflated discount rate. The survey shows that very few mining companies use real-option theory to evaluate mining projects.

DCF and ROV are the most credible techniques used in project evaluation in today's business world according to most authors, for instance Bhappu & Guzman, 1995; Moyen *et.al.*, 1996; Tschabrun, 2005; Samis *et.al.*, 2006; Topal, 2008; Auger & Guzman, 2010; and Sabour & Poulin, 2010.

3.3.1 Conventional discounted cash flows analysis

The traditional DCF valuation or NPV measures the total value of a mining company's net assets using discounted interest rates to adjust for the time value of money. DCF valuation was highly recommended as being one of the acceptable valuation techniques in the 1970s (Myers & Turnbull, 1977). NPV discounted cash flows is a method, which calculates the difference between the total present value of cash inflows and the total present value of cash outflows. The formula for NPV can be written as,

$$\text{Net Present Value} = \sum \text{present value of cash benefits} - \sum \text{present value of cash costs}$$

In measuring the potential wealth creation by companies and the government in the mining industry through investment, NPV of mining investment projects is calculated using the following equation.

$$NPV = \sum_{t=0}^{t} \left(\frac{1}{1+i}\right)^{t} (R_t - OC_t - T_t - K_t) \tag{3.1}$$

where;

NPV = the expected present value of all projects based on after-tax cash flows
i = discount rate for mining projects invested over a period of time t
R = revenues from mine output
OC = operating cost associated with the output in mining
T = tax incurred in the mining project[25]
K = capital expenditure for mining exploration and development
t = years since the beginning of the mining investment

In determining economic viability by NPV, mining investment will only proceed if the NPV of a mining project exceeds zero. By contrast, a mining project yielding a negative NPV should be rejected.

DCF and associated NPV techniques have traditionally been used as major tools for mining project evaluation. However, Martinez and McKibben (2010) state that this technique has the limitation of providing a static view of the project based on averages or expected values, from a mining valuation perspective. The DCF method is unable to deal with project uncertainty and flexibility. Further, Sabour and Poulin (2010) state that the DCF method cannot be relied on for mining investment decision making.

When using the NPV method it is difficult to set a discount rate. One of the characteristic of the DCF-NPV technique is that a single adjusted discount rate is applied to the entire future cash flow to account for all sources of risk, both economic

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[25] Tax (*t*) equals the amount of tax rate multiplied by taxable revenue; tax revenue includes royalties and profit tax.

and technical, such as metal prices, shareholders expectation of returns, ore tonnes and metal quantities. Most importantly, the NPV method is unable to capture the value of management flexibility to respond to commodity price movements. Guj and Garzon (2007) state that using a single adjusted discount rate can be overvalued in more risky mining project compared to less risky ones.

Usually, the adjusted discount rate is estimated as the company's weighted average cost of capital (WACC).[26] The WACC is determined as the weighted average cost of both debt and equity. The equation can be expressed as the following.

$$WACC = \frac{w_e}{w_e + w_d}(k_e) + \frac{w_d}{w_d + w_e}(k_d) \qquad (3.2)$$

where:

$k_e = after\ tax\ cost\ of\ equity$
$k_d = after\ tax\ cost\ of\ debt$
$w_e = equity\ in\ total\ capital$
$w_d = debt\ in\ total\ capital$

Moyen *et.al.* (1996) state that conventional DCF techniques are found to underestimate the value of mining assets. The DCF is only appropriate for valuing safe mining assets. Under conditions of market uncertainty, the DCF fails to make appropriate risk adjustments and fails to price the flexibility that is inherent in managing risky assets. As a result of these limitations, many practitioners have shifted this method towards flexibility financial techniques. ROV is one of the techniques that can be used to eliminate these limitations.

3.3.2 Payback period

The payback period is a simple valuation technique, which does not take the value of money over time into consideration. Large mining companies favour the payback period to evaluate small projects and small mining companies use this technique to evaluate most projects. This technique determines the period of time required to pay back the initial investment from future cash flow. The payback period method is a technique to determine how long a mining company has to wait to obtain back the

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[26] Mining companies usually use after tax cash flows to evaluate a mining project. The calculation of after-tax cash flows in mining projects provides a better basis for market valuation.

initial investment. The shorter time to get back the investment, the better. In mining investment decision making, if the payback period of a mining project is less than the maximum acceptable payback period, the mining project is accepted as a viable investment. By contrast, if the payback period of a mining project exceeds the maximum acceptable payback period, the mining project is rejected.

3.3.3 Internal rate of return (IRR)

IRR, also called the rate of return (ROR) or return on investment (ROI), is the most acceptable technique that is employed in the mining industry for project evaluation. IRR is defined as that discount rate at which NPV equals zero (Torries, 1998). When viewed as the compound interest rate, IRR makes the future value of the investment equal to the future value of the yearly dividends provided those dividends are reinvested at a rate equal to the IRR. In mining project evaluation, the higher the IRR, the more profitable the project.

Unlike the NPV technique, Hartman (1992) defines IRR as the interest rate that equates the sum of the present value of cash inflows with the sum of the present value of cash outflows for a project. The formula of IRR can be written as the following:

$$\sum PV\ cash\ inflows - \sum PV\ cash\ outflows = 0$$
$$NPV = 0 \quad or$$
$$PV\ of\ future\ cash\ flow - initial\ investment = 0$$
$$\sum PV\ cash\ inflows = \sum PV\ cash\ outflows \qquad (3.3)$$

The acceptance or rejection of a mining project using IRR technique is entirely based on comparing the calculated discount rate with the required rate of return, or cut-off rate, established by the mining company.

3.3.4 Real options theory (ROV)

Option theory traditionally is a contract with the opportunity to buy or to sell a commodity on or before an expiry date at a predetermined price. A call option gives mining companies the opportunity to buy commodities on an expiry date at a predetermined exercise price. By contrast, a put option gives mining companies the opportunity to sell commodities on an expiry date at a predetermined exercise price.

There are two common types of options: firstly, an American option is one that can be exercised at any time before the expiration date, secondly, a European option is one that can be exercised only at the option's expiry date.

The formula representing real option theory using Cox, Ross and Rubenstein (1979) binomial model can be written as the following. The binomial model produces the same outcome of the representing underlying project value using the equations (4.16), (4.17) and (4.18) regardless of what types of option is to be estimated (Kodukula and Papudesu, 2006).

$$ROV = \left[\sum_{k=0}^{n}\left(\frac{n!}{k!(n-k)!}\right) \times p^{k}(1-p)^{n-k} \times max(0, u^{k}, d^{n-k}S_{k} - A_{k})\right] \quad (3.4)^{27}$$

where

ROV = *the value of the real option*

n = *the total number of years k*

p = *the risk-neutral probability of being in the upward (u) or downward (d) step size*

S_k = *the pre-period of the current total mineral prices*

A_k = *the pre-period of the total future operation costs*

where *p, u* and *d* can be expressed as follows:

$$u = e^{\sigma\sqrt{\delta t}} \quad (3.4a)$$

$$d = e^{-\sigma\sqrt{\delta t}} \quad (3.4b)$$

$$p = \frac{e^{rf(\delta t)} - d}{u-d} \quad (3.4c)$$

where

σ = *the volatility of the underlying stock, expressed as a percentage of its price*

$\sqrt{\delta t}$ = *the up and down of each time-step size*

rf = *the risk free rate*

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[27] Wills-Johnson (2010) states that the B-S model is of a specific of nature, with limited flexibility. Other models such as the binomial lattice are more commonly used in project evaluation in dealing with flexibility and continuous time.

Myers (1977) incorporates three factors into real option analysis. The first factor in analysing investment in large projects is uncertainty about future cash flows. The second is the irreversibility of investment. Thirdly is the timing of project initiation. ROV is a financial technique incorporating the above factors.

ROV was first adopted in the areas involving commodity production, such as the natural resource industries. Brennan and Schwartz (1985) were the first researchers using ROV empirical research in natural resource industry. The empirical evidence of Brennan & Schwartz shows statistical significance and economic support for using real option theory. Brennan and Schwartz focused on the uncertainties in prices, which occurred in this industry. The uncertainties of commodities prices could significantly impact the total output production. A real option approach is used in the research of Brennan and Schwartz to examine the flexibility and a value on being able to delay investment until optimal timing that occurs in the mining investment. Many leading mining and oil and gas companies are using ROV in their project development (Sick, 1995).

Shafiee (2010) states that ROV is a modern financial technique which enables mining companies to adapt and to amend mining projects under conditions of economic uncertainty and the volatility of future movements in variables. There are several advanced ROV techniques. The most commonly used ROV techniques are: DTA, Binomial Lattice, MCS, partial differential equation and closed form exotic options analysis which are known as the B-S model (Mun, 2006).

3.3.5 Decision tree analysis (DTA)

DTA is a technique originating from operations research and game theory. This technique is another method which is used to analyse the uncertainties in cash flow over a period of time. DTA is a method commonly used to evaluate projects by taking all scenarios, which include the risks associated with unexpected events occurring, into the process of mining investment evaluation. Unlike DCF, DTA is based on each possible decision outcome being identified in the analysis of a project.

In project investment decision making, DTA allows the decision maker to break down large complicated problems into small, concise and simple problems. The NPV outcome produced in this technique enables investors to consider all the options or variables in the investment decision making process in a mining project. Sensitivity analysis of commodity prices, production costs, operating cost and other investment variables are fully reflected in this technique, which enables a mining company to verify which variables impact more than others on the DCF of a mining project.

3.3.6 Monte Carlo simulation (MCS) method

Monte Carlo Simulation (MCS) is another method used to calculate the expected NPV of a project as a measure of its real value. MCS was developed in the 1980s and named after Monte Carlo, Monaco and has been widely used in today's project investment analysis as a result of the availability of sophisticated computer technology. MCS uses the marginal distribution of all the parameters appearing in the NPV formula to examine possible outcomes of the project. The technique uses statistical distribution such as normal, lognormal, triangular, and uniform to analyse the uncertainties parameters within the project (Topal, 2008).

In project evaluation, MCS first develops an appropriate model to evaluate a particular project. MCS then generates a probability distribution from which the MCS program picks the parameter values randomly to determine alternative discounted cash flows and select the most profitable project investment opportunity. The expected NPV of a project is then identified by MCS to enable a mining company to accept or reject investment in the project. MCS can be repeated hundreds or thousands of times, the more simulation done the more closely the calculated value of the project approximates the mean of the underlying distribution.

3.3.7 Close-form, and binomial lattice

Other than DTA and MCS analyses, ROV also uses other forms such as the close-form B-S method and binomial lattice. The close-form method is a relatively simple method to apply in ROV. This method tends to be easy to implement with the assistance of some basic computer programming knowledge. However, the method incorporates a significant level of stochastic calculus in the programming when conducting the analysis.

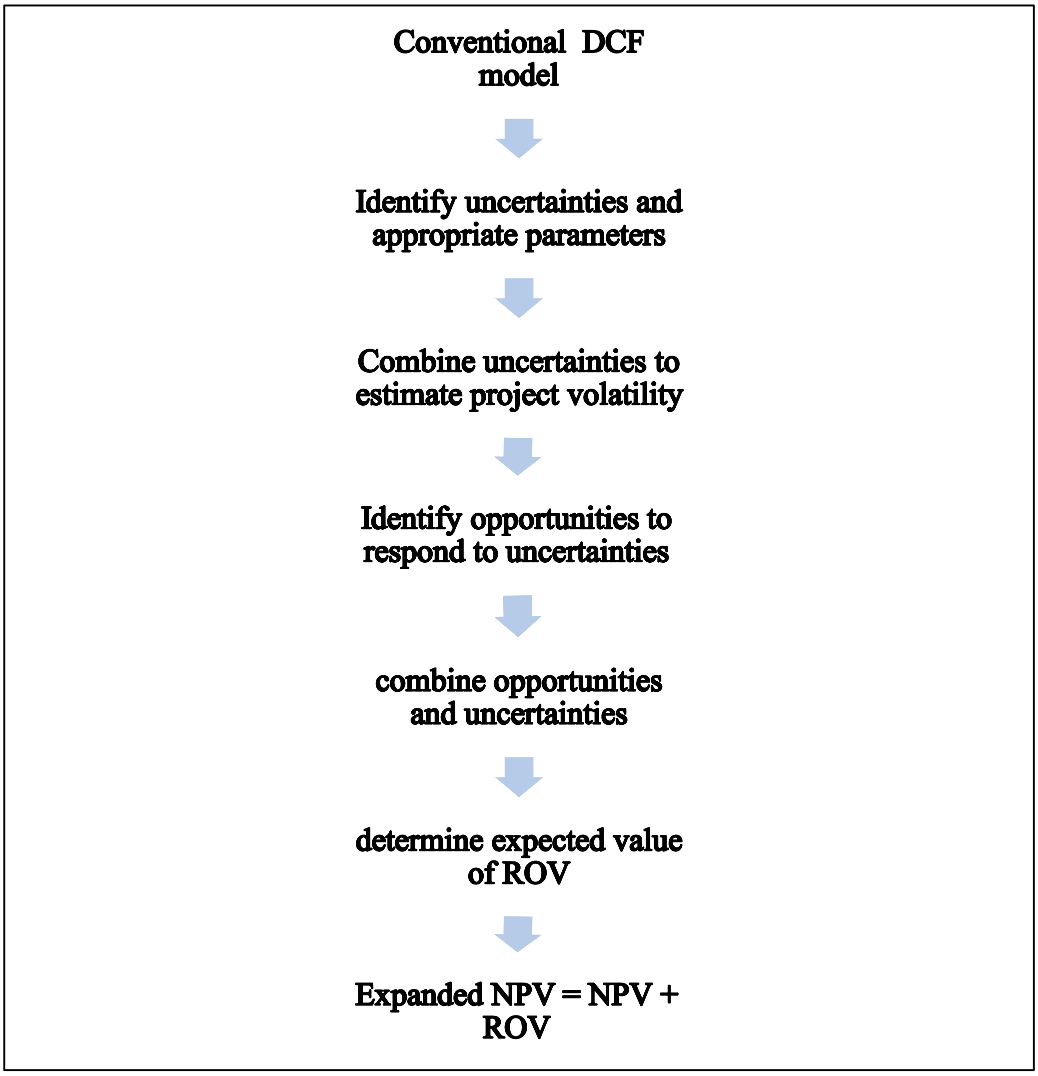
First developed by Cox *et.al.* (1979), the binomial lattice approach can be divided into two different approaches when conducting project evaluation. The first is the use of risk-neutral probabilities, and the second is the use of a market-replication portfolio approach. The asset prices under the binomial option pricing model, in any time period, can move between an upper and lower price level depending on the initial values and changes in the values of the parameters used in the calculations (Damodaran, 2012) . Wills-Johnson (2010) states that using binomial lattice models is the simplest model when applying ROV. This is mainly because binomial lattice models are discrete-time approximations of continuous-time stochastic processes.

Topal (2008) states that the flexibility of ROV is one of the main criteria for mining companies using ROV in project evaluation. The more flexibility around mining project investment strategies, the better. ROV allows a mining company to respond to change by managing future cash flows in ways that will maximise the return to the company.

There are several classifications of embedded options (Hall & Nicholls, 2007). Firstly, there are *expansion options*, where mine expansion causes a higher exercise price in the mining investment. Secondly, there are *contraction options,* which give a mining company the right to reduce the company's assets. Thirdly, there are *abandonment options*, where a mining company has the right to sell company assets for a given price. Fourthly, there are *extension options*, which allow a mining company to extend the life of an asset. Fifthly, there are *deferral options,* which enable a mining company to defer the initial investment in a project. Sixthly, there are *compound options*, which enable a mining company to combine an additional project to the existing options valuation. Finally, there are *rainbow options* in which a project contains a variety of sources of uncertainty.

Martinez and McKibben (2010) state that the use of ROV in mining is different from its use in financial options. ROV in mining deals more with high risk tangible assets. However, the fundamental concepts used in ROV for dealing with uncertainty are the same as those used to calculate financial options. To evaluate a mining project using ROV, there are several procedures. The preliminary stage of project evaluation is to develop a conventional DCF as the primary input into an ROV. The next step is to identify the key sources of uncertainty that could impact a mining project valuation. This can be determined by using appropriate parameters such as economic factors, political stabilities, operating costs and so on.

Figure 3.3 The process of ROV when valuing a mine project



Source: Martinez & McKibben, p. 229

These uncertainties mentioned above are then combined in order to estimate expected volatility in the mining project (in dollar value). Consultants in a mining company can then determine the opportunities using ROV. For example, they may determine if the project can realistically expand, contract, or be abandoned, as well as identifying the key uncertainties and deciding the most appropriate options to be used in the project.

The uncertainties variables can then be combined in a valuation framework using assorted ROV methods such as binomial lattice (particularly for mining projects) to solve and determine the expected value of the real option. The real option value is then added to the DCF model to give the expanded net present value of the project. The process of ROV is summarised in the above Figure 3.3.

From the research perspective, ROV proves to be one of the advanced financial techniques in evaluating mining projects. Using appropriate financial techniques, particularly with the current high level of uncertainty in the world's economy, is extremely useful. Mining companies investing in large scale projects are extremely concerned about the profits they will generate from the investments. Financial techniques with operating flexibility and strategic adaptability such as ROV are thus the most appropriate methods for mining companies to determine investment decisions.

3.4 Concluding remarks

This chapter summarises financial techniques in the context of mining investment decision making. The world's investment climate has shifted towards more large scale project financing rather than corporate financing. This is attributable to the strong demand for mineral resources in Asian countries. Private companies with large scale projects, such as mining companies, favour project financing. Project financing enables mining companies to invest in mining projects by using debt and equity that is particular to each project.

Investment in the mining industry is highly capital intensive. Mining companies are very concerned about investment returns generated from their investment. Financial methods with a significant degree of flexibility and strategic adaptability are highly appropriate. The flexibility is to ensure that the mining company can either enter into or withdraw from the investment as circumstances change, due to the uncertainties that exist in the world's economic climate.

The use of the DCF and ROV methods in mining project evaluation has recently become common. The primary limitation of the DCF method is its reliance on a single-point forecast. ROV is one of the methods where uncertainties in variables, for instance metal prices and ore grades, are used as inputs to compute the cash flow in the model. In the next chapter, attention is given to the empirical studies of DCF and ROV in mining project evaluation.

Chapter Four

4 Part A: A Review of Project Valuation Models

4.1 Introduction

Chapter Two reviews the most relevant literature on the topics of economic development and resource scarcity, noting that the issue of resource depletion has raised much concern in current economic development discussion. Chapter Three outlines the features of project financing and corporate financing, including the types of financial techniques used in mining project evaluation. This chapter gives attention to the empirical methodology for optimal investment decision making as it might be applied in the Asia-Pacific countries.

The aim of this chapter is to describe the methodological issues relating to mining project evaluation. The chapter examines several case studies in order to establish the investment patterns of mining firms operating under uncertainty. A feasibility study of a mining project is normally conducted using the financial techniques discussed in this chapter. The methodology used in this study comprises three approaches. Firstly, there is the profit function model, which is used to explain conditions required for profit maximisation and minimisation of the cost of production for a mining firm to achieve the optimum level of production. Secondly, there is the net present value (NPV) method, which measures the total value of a mining firm’s assets using discounted factors to adjust for the time value of money. Thirdly, there is real options valuation (ROV) analysis, which uses a valuation model to measure a mining firm’s maximum value based on dynamic decision making by taking the risk of the cash flow stream into consideration (Dixit & Pindyck, 1995).

In Part A, the chapter is organised as follows. Section 4.2 describes the theory of profit maximisation for mineral production subject to economic and technology constraints. Section 4.3 describes optimal investment decision making. Section 4.4 describes real options analysis with flexibility and option to delay associated with the timing of the mining project investment in response to a future event. Section 4.5 concludes the chapter.

4.2 Profit maximisation

In neo-classical microeconomic theory, mining firms' business behaviour is characterised by profit maximisation (Kuosmanen *et.al.,* 2010). Mining firms determine both production inputs and outputs with the aim of achieving maximum economic profits (Nicholson, 2005). That is, mining firms choose the production variables[28] $(b_1, \dots, b_n)$ to maximise $R(b_1, \dots b_n) - C(b_1, \dots b_n)$, where R( ) is the firm's revenue function and C( ) is the cost function.

In the profit maximisation model, a simple profit function (π) can be defined as:

$$\pi\ (p, y) = max\ py \qquad (4.1)$$

The letter p represents the vector of all output and input prices. The letter y represents a vector of all output and input quantities in mineral production.

The model in this chapter is adapted from Treadway (1970). Given a case scenario, a mining firm with perfect information and competition, is assumed to invest in a gold mining project represented as a in a country represented as j. The objective of the mining firm is to maximise profits. The mining firm is assumed to produce gold of amount Q_{aj} unit per period, at a gold price of P_{aj}. The mining project produces gold by the application of three variables of production, being a variable factor called labour L_{aj}, capital K_{aj}, and mineral reserves M_{aj}.

Profit maximisation for the mining firm can be written as the following:

$$\max \pi_{aj} = [P_{xaj}(X_{aj}) - (L_{aj}w_{aj} + K_{aj}r_{aj} + M_{aj}s_{aj})] \qquad (4.2)$$

where;

$\pi = \text{profit of a mining firm } a \text{ invested in a country } j$

$P_x = the\ gold\ forward\ price$

$X = the\ quantity\ of\ gold\ produced$

$L = labour$

$K = capital$

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[28] Production variables, $b_1, \dots b_n$ can be any endogenous variables such as labour costs, market prices and capital costs in a competitive market in *N* commodities, indexed n = *1…n*.

$M = gold\ reserves$

$w = wage\ rate$

$r = user\ cost\ of\ capital$

$s = ore\ reserve\ shadow\ prices$

Further, the gold production is subject to the constraint of the production function as follows:

$$X_{aj} = f(L_{aj}, K_{aj}, M_{aj}) \qquad (4.3)$$

Again, assuming that the mining firm a is maximising profit, and profit remains constant over time, the net present value of the mining firm a is $\sum[P_{xaj}(X_{aj}) - (L_{aj}w_{aj} + K_{aj}r_{aj} + M_{aj}s_{aj})]$ where d_{ajt} is the discount rate for firm *a* in country *j* at time *t*.

With the condition of perfect competition, input and output prices are invariant to the actions of the mining firm *a*. The plan of the investment project is made at time *t* = 0. We also assume that price expectations are stationary. The current prices at *t* = 0 are expected to be obtained for the life of the project.

To ensure the mining firm *a* is profit maximising, the first-order condition must be met. To maximise economic profit, the marginal value of mineral production the mining firm produces is equal to the marginal mineral production cost. Substituting in equation 4.2, the maximisation of economic profit by mining firm *a* can be written as the following:

$$\frac{d\pi_{aj}}{dx_{aj}} = P_x - \frac{dL_{aj}}{dx_{aj}}w_{aj} - \frac{dK_{aj}}{dx_{aj}}r_{aj} - \frac{dM_{aj}}{dx_{aj}}s_{aj} = 0 \qquad (4.4)$$

In words, equation 4.4 can be restated as:

$$Mineral\ price = Marginal\ mineral\ production\ cost$$

By partially differentiating equation 4.4, the first-order conditions for a maximum are

$$\frac{d\pi_{aj}}{dL_{aj}} = P_x \frac{df_{aj}}{dL_{aj}} - w_{aj} = 0$$
$$\frac{d\pi_{aj}}{dK_{aj}} = P_x \frac{df_{aj}}{dK_{aj}} - r_{aj} = 0$$
$$\frac{d\pi_{aj}}{dM_{aj}} = P_x \frac{df_{aj}}{dM_{aj}} - s_{aj} = 0 \qquad (4.4')$$

Using equation 4.4', the profit-maximising mining firms should choose these three inputs up to the point at which each of these inputs' marginal contribution to revenue is equal to the marginal cost of utilising these inputs.

The second condition to meet mining firm *a's* profit maximisation objective is that marginal profit is negative beyond the optimal level of x^*_{aj}. Hence, the second equation requires that

$$\frac{d^2\pi_{aj}}{d{x^2}_{aj}} < 0 \qquad (4.5)$$

In the general case, the mining firm uses *N* inputs for a mining production. To satisfy the conditions for the profit function *π(p)*, which corresponds to a production function *f(y)*, there are number of properties derived from the conditions in equation 4.4 and 4.5 and very useful for the mining investment analysis. These include: firstly, homogeneity, which is the profit function is homogeneous of degree one in all prices; secondly, profit functions are non-decreasing in output price *P*, which is a mining firm could always respond to a rise in the price of its output by not changing its input or output plans; thirdly, profit functions are non-increasing in input prices, *y*; fourthly, profit functions are convex in output prices in which the profits obtainable by averaging those available from two different output prices will set at least as large as those obtainable from the average of two prices.

The objective of profit maximisation model is to adopt a "behavioural" approach to studying mining firms' decision making. Mining firms use this model to choose both its inputs and its outputs with the sole goal of achieving maximum economic profits. That is, the mining firm seeks to make the difference between the total revenue and the total cost as large as possible.

In the next section, a static profit maximisation model for mining investment without uncertainties is discussed.

4.3 Optimal investment decision making

The capital used to extract mineral stocks from the ground is one of the inputs required for the development of mining projects. This section presents a profit maximisation model for investment in the mining industry.

In the first scenario, with the absence of economic uncertainty, it is assumed that: mining firms are well managed in a perfectly competitive market; the labour costs and other mining costs are constant for the duration of the project; there are no taxes imposed on this investment; and mining firms can always obtain the desired capital stocks. The model follows the assumptions made by Peterson (1978) and Gould (1968).

Let the a^{th} mining firm select time paths of exploration and extraction in country *j* that maximises the company's present value of all future net cash flows. This present value is given by the integral,

$$Max\, V = \int_0^{\alpha} e^{-R(t)}[P_{x_{1\ldots n}}(t)X_{1\ldots n}(t) - \big(L(t)w(t) + K(t)k(t) + M_{1\ldots n}(t)s_{1\ldots n}(t)\big)]dt \qquad (4.6)$$

where,

$V_{aj} = present\ value\ of\ the\ mining\ firm$

$R(t) = \int_0^t r(\vartheta)d\vartheta = discount\ factor\ at\ time\ zero\ for\ cash\ flows\ to\ be\ received\ at\ time\ t$

$r(t) = the\ discount\ rate\ at\ time\ t$

$P_{x_{1\ldots n}}(t) = price\ of\ minerals\ output\ x_{1\ldots n}\ as\ a\ function\ at\ time\ t$

$X_{1\ldots n} = \ minerals\ output\ 1 \ldots n$

$L(t) = labour\ cost\ at\ time\ t$

$W(t) = wage\ rate\ at\ time\ t$

$K(t) = capital\ at\ time\ t$

$k(t) = user\ cost\ of\ capital\ at\ time\ t$

$M_{1\ldots n}(t) = mineral\ reserves\ 1 \ldots n\ at\ time\ t$

$s_{1\ldots n}(t) = ore\ reserves\ shadow\ price\ at\ time\ t$

For simplification purposes, the equation 4.6 can be expressed as follows

$$Max\ V = \int_0^{\alpha} [P_{x_{1\ldots n}} X_{1\ldots n} - C(t)] e^{-R(t)} dt \qquad (4.7)$$

where,

$C(t) = the\ cost\ at\ time\ t$

$R(t) = the\ discount\ factor$

The cost expression in equation 4.7 is the sum of the mining costs incurred in extracting ore reserves. These include the operating costs of machinery, labour costs and capital costs at the gross investment rate *I* subject to:

$$K_{t+1} - K_t = I_t - \delta K_t \qquad (4.8)$$

Implying that mining investment satisfies

$$I_t = K_{t+1} - (1 - \delta) K_t \quad (4.9)$$

The real user cost *k* represents the real price of capital units p_K, a fixed interest rate *r*, and machinery depreciation rate *δ*. In applying to economic model, the real user cost of mining capital is as follows:

$$k = p_K . (r + \delta - \frac{\Delta p_K}{p_K}) \quad (4.10)$$

The real user cost *k* equals the real price of a unit of *K* multiplied by the real discount rate plus the machinery depreciation used in mining exploration minus the real price capital gain from holding a unit of *K* in each period of *t*.

In the next section, there is a discussion of the impact of tax policy on investment of mining firms.

4.3.1 The impact of tax policy on mining investment behaviour

Generally, most mining project investments are irreversible. In other words, mining companies are unable to disinvest without cost after the investment decision is made

(Alvarez & Koskela, 2008).[29] Mineral reserves and the associated mines are the major form of capital for mining firms. Mineral stocks in the ground can be extracted, refined and traded in the commodity market in the world. Commodities sold in the global market generate revenue for mining firms and government revenue as royalty or income tax from commodities sold.

Taxes represent a substantial cost for mining companies and can certainly impact on corporate investment decisions. The type and level of taxes imposed by the government on mining firms can affect the rate of return on capital of the mining project investment. A stable, predictable, and transparent fiscal regime, therefore, is one of the key factors that a potential mining investor would require. If the tax regime is stable, then there is one less risk that the mining investor has to worry about with their project investment (Saidu, 2007).

In the fiscal regime, Smith (2012, p.3) refers to a broad variety of tax and contractual arrangements, including signature bonus payment, royalties, income tax, production sharing, resource-rent taxes, and state participation. The responsiveness of an investor's plan of exploitation in mining investment depends on the government fiscal policy. These include the scope of exploration and discovery, the timing and scale of initial development, the rate of production and decline, the timing and scale of enhanced recovery operations, the overall resource recovery factor, and the timing of final abandonment.

As Smith (2012) states taxpayers such as mining investors, have ways of adapting to any fiscal regime. Any changes or reforms in fiscal policy can affect the behavioural reactions of mining investors. The pervasive impact of the fiscal system, on the investor as well as the government, can completely change the investment behaviour because this variation can impact the revenue of extractive industries. For this reason, the initiative of this section is to discuss the implication of changes to tax policy and aims to examine the responsiveness of mining firm investment decision making in relation to optimising profits.

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[29] This is because capital used in mining investment is not only industry-specific but also site-specific. Physical capital used in mining firms would be largely re-usable to others in the same industry only if they operate at the same site.

The model in this study is developed from the studies of Hall and Jorgenson (1967) . This model assumes that mining firms encounter external economic influences, which impact on the mining investment decision making.

Assuming that a gold mining firm chooses a mine life T and an extraction gold plan that maximises the expected present value V with taxes included, the net present value can be expressed as the following integral:

$$Max\ V = \int_0^{\alpha} e^{-R(t)}[PX - (Lw + Kk + Ms - \tau))]dt \qquad (4.11)$$

where:

τ = mining taxes[30]

subject to the investment capital accumulation condition in equation 4.8.

The idea of the equation 4.11 comes from the neoclassical theory of production. One of the key aspects of the neoclassical theory is that mining firms maximise their profits and minimise their costs, subject to constraints of the production function that are believed to apply to mining industries. For instance these constraints or the costs are subjected to dependence on the rate of return, the price of investment goods, and the tax treatment of business income. Subject to given factor prices, the profit maximisation model can then be characterised as a solution to solve a nonlinear programming problem.

4.3.2 Timing of the investment decision making

Choosing the right timing is crucial in mining investment decision making. Managerial flexibility is one of the advantages for the mining firm to mitigate investment risks. In the previous section, the researcher assumes that the tax rate is constant for the duration of the mining project and derives the value of a mining project that is shown in equation 4.11. This is the basis for now considering the impact of taxes when managers have flexibility in determining the timing of their mining investment.

Following the example given in the study of Mackie-Mason (1984), the researcher assumes that the mining firm is making incremental mining investment decisions under uncertainty. There is a known quantity of reserves to be produced at a particular site, and the mining firm owns the right to develop the mine and extract the reserves.

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[30] Mining tax could include royalty, corporate tax, and ad valorem tax.

The mining firm is aware of future mineral prices and interest rates fluctuations. Simulation software, @Risk is used to simulate future values of these two variables.

The investment cost used to develop a particular mine site is known and fixed. The mining firm can produce any amount of output per year as they wish up to a capacity constraint, which is represented $\bar{q}$. The mining firm has the flexibility to decide to temporarily shut down the mine, and reopen in the future if conditions warrant doing so. There is a fixed cost incurred if the mining firm decide to close or reopen the mine site. The mining firm can also choose to abandon the mine.

For simplification, the stochastic process of mineral prices can be written as follows:

$$dp = \alpha p dt + \sigma p dz \qquad (4.12)$$

where z is a standard wiener process with unit variance and zero mean; for instance p(t) follows an Ito process. If today's mineral spot price is known, but uncertainty increases as the length of the forecast increases; the variance of $p(s) is\ \sigma^2 p^2 (s - t)$. If $\sigma = 0$ and $\alpha = r$ (rate of interest), (according to the simple Hotelling Rule for exhaustible resource industry equilibrium), mineral rent grow at the rate of interest.

The value of a mining project, $M(x,t;\psi)$ is dependent on an (n x 1) vector of state variables and a control policy functional, $\psi \in \Psi$, Ψ is a compact space. ψ represents a vector of the operating options (e.g., shutdown, delay or re-open the mine site) for the mining firm and t represents the time period. Applying a joint Ito diffusion process, the state variables can be written as follows:

$$dx = \alpha(x, \psi)dt + \sum (x, \psi)dz \qquad (4.13)$$

where α is an (n x 1) vector-valued function, and ∑ an (n x n) matrix-valued function.

To maximise the mining firm's NPV, a firm can use a stochastic dynamic programming to choose the operating, or control variables ψ. The stochastic dynamic programming that is applied in this study will be Dynamic Programming Language (DPL8).

Supposing $\pi^{AT}(x, t; \psi)$ as the after-tax cash, given control policy of ψ, the value of the project which is represented as V(x,ψ,t) using the following equation from Mackie-Mason (1984):

$$\max_{\psi \in \Psi} \left\{ \Pi^{AT} - rV + V_t + \sum_{i=1}^{n} (\alpha_i - \gamma \rho_i \, M^{\sigma i}) V_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{i=1}^{n} \sigma_{ij} V_{ij} \right\} = 0 \quad (4.14)$$

subject to appropriate boundary conditions, where $\rho_i M$ is the instantaneous correlation coefficient between *dzi* and the market return.

Equation (4.14) is one of the simplest models used to solve the value of the underlying project value. Applying the equation (4.14), requires three assumptions: firstly, the existence of a unique maximising control policy, ψ; secondly, the value of the underlying project can be determined from the equation (4.14); and thirdly, the boundary conditions.

The study of Panteghini (2001) is worth noting. He shows that variations in tax rates resulting from changes in government policy affects the rate of return on investments by mining firms. The study also shows that only through tax constancy (to optimise future uncertainties in taxation using option valuation) can the government avoid affecting mining firms' propensity to invest.

As stated above, the goal of a mining firm is to maximise its profits and ensure minimum expenditure in the production of every unit of mineral output (Hall and Jorgenson, 1967). This section summarises the investment timing and the optimal choice of investment for mining firms with policy implications, as well as the flexibility of investment decisions for mining projects. Flexibility enables mining firms to delay the commencement of projects or expand the projects as economic conditions become favourable.

In the next section, attention will be given to the flexibility of mining investment decisions using the real option approach.

4.4 Optimal mining investment decision with flexibility: The real option approach

This section begins by discussing the idea in the context of a simple one period model in which the mining investment decision can be made in only one of two possible periods – invest now or next year. Applying this model, the researcher shows how irreversibility creates an opportunity cost of investing for the mining investor when the future value of the mining project is uncertain. The objective to conduct this study is to see how the value of the option to invest or delay, and the investment decision, depend on the degree of uncertainty over the future value of the underlying mining project.

The standard net present value (NPV) rule, according to Brennan and Trigeorgis (2000) is appropriate to use only with absence of uncertainty. Under the NPV or discounted cash flow approach, mining investment projects should be carried out, if, and only if the discount present value of project net revenue is greater than the investment cost. Otherwise, investment in mining projects should be withheld.

Numerous studies have shown that there are limitations to static discounted cash flows (Myers, 2001, Cobb & Charnes, 2007, Guthrie, 2009). Moyen *et.al.* (1996, p. 63) stated: *"many practitioners claim to be dissatisfied with traditional net present value techniques. In particular, it is often found that such calculations undervalue mining assets"*. The discounted cash flow ignores the flexibility of mining firms to respond when market conditions deviate from their expectation.

The shortcomings of the conventional discounted cash flow method, with its lack of managerial flexibility, have induced other practitioners to search for other valuation methods that enable mining firms to make project investment decisions with flexibility when market uncertainty occurs (Dixit & Pindyck, 1995). The real option approach is one of the primary enhanced decision-making frameworks. This allows mining company managers to add value to their firms by taking advantage of flexibility in this valuation method (Lander & Pinches, 1998).

Mun (2006) states that real options theory is used to evaluate a company's physical or real asset. In mining investment, the most common real option used is the option to invest or defer investment. There are also the options to abandon a given mining project, or to switch to increased or decreased production outputs or inputs. However, choices to use appropriate types of real options model completely depend on the project itself.

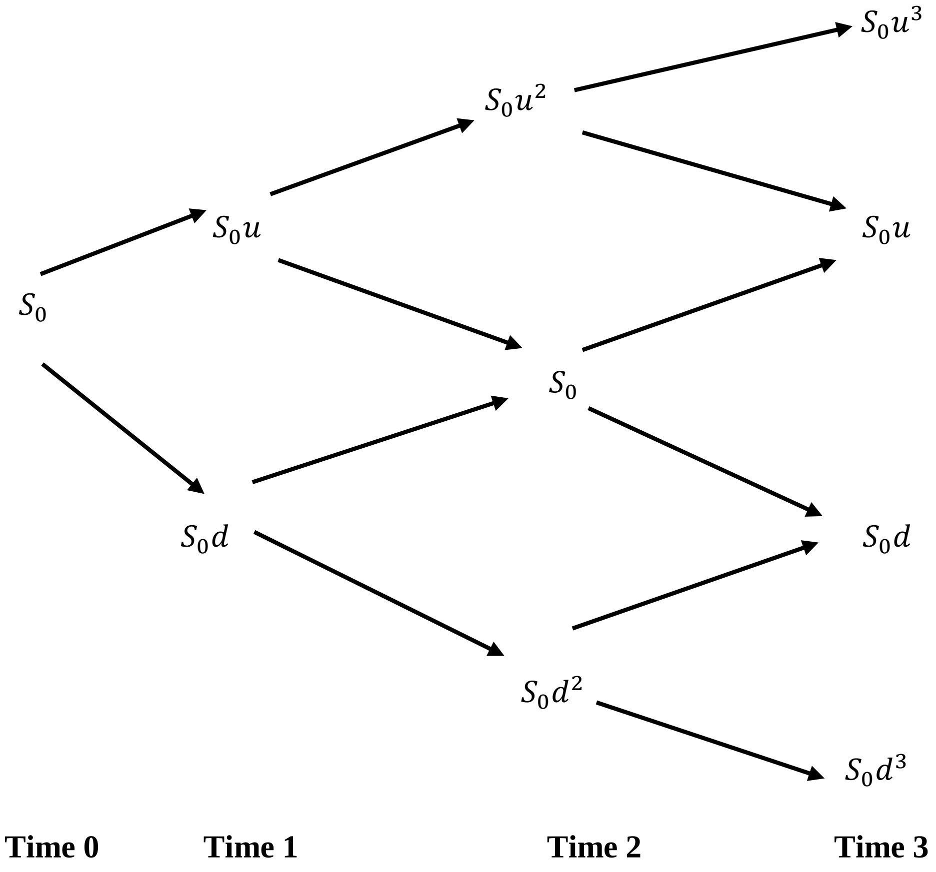
The type of real options used in this study is the option to wait or defer investment. Other types of real options are outside the scope of this study. The reason for using this type of real options is that they enable mining firms to wait for better information before an investment decision is made. For example, mining firms may only commit to mining projects and make decisions after the government announces the tax policy.

The real options approach in this section uses the Cox, Ross and Rubenstein (1979) binomial lattice model. Will-Johnson (2010) uses the binomial lattice model as it is simpler for capturing real options theory than the Black-Scholes (1973) model. The simple reason is that binomial lattice models are based on discrete time approximation for continuous time stochastic processes.

4.4.1 The real options approach: binomial lattice model

Figure 4.1 shows the binomial model in the form of a branching tree. S_0 represents the initial value of the underlying project NPV. In time 1, the lattice either goes up or down, and the lattice continues to go either up or down, following time increments. The up or down movements are commonly represented by *u* and *d* factors, where *u* is > 1 and *d* is < 1; such that *u* = 1/*d*. The magnitude of these factors relies on the volatility of the underlying asset, which is output price uncertainty in this study.

Figure 4.1 A binomial tree model



Following the binomial model in Figure 4.1, the model comprises of two nodes in time 1, which indicate the possible underlying asset value (S_0u, S_0d) at the end of that time period. In time 2, the time step in the model results in three nodes and the underlying project values are ($S_0u^2, S_{0,}\ S_0d^2$). In time 3, the time step in the model results in four nodes and the underlying project values are ($S_0u^3, S_0u, S_0d, S_0d^3$). The time step can be as many steps as possible and the last node represents the range of possible outcomes of the project's value at the end of the option life.

The binomial model used in this study follows the pioneering work of Cox *et.al.,*(1979). The method they apply uses statistical probability theory to develop a binomial lattice approach to evaluate option pricing based on discrete form of mathematics.[31] Copeland and Antikarov (2001) state that the binomial model, in general, is more flexible than a stochastic partial differential equation when solving option pricing problems.

As mentioned, to formulate a binomial lattice model, there are two steps. The first step is to formulate an up and down equation, which uses discrete time simulation to calculate the path size in the model based on the underlying mining project's value. The second step is to evaluate the model based on probability calculation. The advantage of the second step is that it enables the calculation of the value of a mining project. Mun (2006) states that the first and second steps of the binomial model show consistency when applied to all real options binomial modelling regardless of complexity.

Consider an example given in the study of Brandao, *et.al.*, (2005) , and suppose that a mining investment project has an unknown value *ROV* and that there is a replicating mining project portfolio of an amount *A*. This replicating portfolio consists of market-traded stock with a current price *S* and of *B* dollars invested in a risk-free bond that pays an interest rate *rf*. Also, with all economic uncertainties taken into consideration, it is assumed that mining firms make similar assumptions to those make in Section 4.3. Mining firms now encounter uncertainties because of external factors impacting the mining investment decision making.

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[31] In the practitioner perspective, discrete-form mathematics is algebraic in nature and easier to understand than the differential equations of stochastic calculus.

Also consider a well-managed, risk-averse mining firm is in a perfectly competitive industry; the labour cost is a quasi-fixed factor; there are taxes imposed by the government. Capital costs for mineral exploration are convex costs. The mining firm can always obtain the desired capital stock and the ore reserves are identified.

The binomial lattice model is a model where the value of the underlying asset can increase *(Su)* and decrease *(Sd)* in value by a set of proportions over each period of time with a given risk-neutral probability, *q*, dependent upon the volatility of the mineral prices.

Applying a simple one-period model, Equation (4.15) can be used to evaluate the American style call option and the value of this mining project in time 1 from now is be $AS_u + B(1 + r^f)$ and $AS_d + B(1 + r^f)$ in the up and down states respectively. The researcher also assumes that the values of the project in these same up and down states are known. For the portfolio value of A and B to replicate the value of the project in each of the up and down states exactly, the appropriate values of *A* and *B* must be derived by solving a system of two equations in two unknown variables, $ROV_u = AS_u + (1 + r^f)B$ and $ROV_d = AS_d + (1 + r^f)B$, which yield $A = (ROV_u - ROV_d)/((u - d)S)$ and $B = (uROV_d - dROV_u)/((u - d)(1 + r^f))$. If the values of *A* and *B* are replicating portfolio for the project at the end of the period, according to the basic no-arbitrage argument of finance theory, the current price, AS+B must be the value of the project *ROV*. As noted, the expression of *A* and *B* excludes the risk-neutral probability of p. However, the solution of p is easily obtained by using the relationship *V=AS+B.*

Using the theoretical perspective, the basic set up of the binomial lattice model can be expressed as follows:

$$ROV = \left[\sum_{k=0}^{n} \left(\frac{n!}{k!(n-k)!}\right) \times p^k (1-p)^{n-k} \times max(0, u^k d^{n-k} S_k - A_k)\right] \quad (4.15)$$

where;

$ROV\ = the\ value\ of\ the\ real\ option$

$n = the\ total\ number\ of\ years\ k$

$p = the\ risk - neutral\ probability\ of\ being\ in\ the\ upward\ (u) or\ downward\ (d)\ step\ size$

$S_k = the\ pre - period\ of\ the\ gold\ NPV, which\ remains\ after\ each\ period\ of\ gold\ mining$

$A_k = the\ pre - peiod\ of\ the\ total\ future\ operating\ costs$

where p, u and d can be expressed as follows:

$$u = \exp(\sigma * \sqrt{dt}) \qquad (4.16a)$$

$$d = {}^{1}\!/_{u} \qquad (4.16b)$$

$$p = \frac{\exp(\mathrm{r}^{f} * dt) - d}{u - d} \qquad (4.16c)$$

where;

$dt = the\ length\ of\ time\ period\ between\ states\ (in\ equation\ 4.15)$

$r^{f} = the\ risk\ free\ rate$

$\sigma = the\ volatility\ of\ the\ underlying\ stock, expressed\ as\ a\ percentage\ of\ its\ price$

In conducting the basic form of binomial model application, the expected present value of the ROV binomial lattice model is entirely dependent on the value of u and d in the case of risk neutrality. The up and down node calculated using volatility as well as the number of years of the mining project operation are used to determine the up and down values.

The next section presents an analysis using a single period option to wait.

4.4.2 The option to wait/defer investment

Option to delay is one of the important features when dealing with an investment policy and an option to expand the scale of operations. The intention of mining investors choosing the option to delay is to maximise the value of their project.

In the literature, Smit and Ankum (1993) state that the deferment of project investment caused by market uncertainty creates flexibility for mining firm investment decision making[32]. Mining projects are capital intensive and have long lead times. The use of options to delay or defer mining project investment is extremely important for mining firm’s investment decision making under economic uncertainty, such as that caused by tax policy changes. Under such uncertainty, mining firms may have an incentive to wait or to defer their mining project investment until economic conditions are more conducive to investment.

Under the call option, the mining project investment has an underlying asset at the current present value of expected cash inflows S_k, as described in equation 4.15, with

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[32] Under investment timing strategy, Smit and Ankum (1993) state that the timing of investment is similar to the timing of exercise of a call option when the project reaches maturity.

the project exercise price, which is the necessary investment expenditure, A_k. To properly define this, the deferral investment of mining project can be written as follows:

$$Expected\ NPV = max(0, S_k - A_k) \qquad (4.17)$$

In other words, when the call option is at maturity, if no further delay is possible, the NPV of the mining project value is equal to the expected NPV when $S_k - A_k$ is positive. Otherwise, the project value is become zero.

The strategy of using deferring options allows mining firms or equity holders the right, but not the obligation, to make the investment in the future. Mining managers will wait and make the investment if the future project value turns out to exceed the necessary investment value at that time. The option to wait is another form of a call option on the gross project value S_k, with an exercise price equal to the required outlay in year k, A_k.

An investment decision that is based on the net value of the real option mentioned above can be expressed using the following equations:

$$S_k - A_k > 0, \qquad \text{invest} \qquad (4.18a)$$

$$S_k - A_k < 0, \qquad \text{wait or abandon} \quad (4.18b)$$

Mining firms can use the equation (4.18) to choose the maximum of the mining project value subtract the required investment cost, or zero.

McDonald and Siegel (1986) consider the appropriate timing for mining investors to decide whether or not to build the plant and at what point the mining firm is optimal to pay a sunk cost I in return for a project expected future cash flows whose value is V. The value of V represents a discounted expected cash flow at time t and follows geometric Brownian motion:

$$dV = \alpha V dt + \sigma V dz \qquad (4.19)$$

where dz is a standard Wiener process. When undertaking the investment decision, the mining firm knows the present value of the project, but the expected future values are lognormally distribute with variance that grows linearly with the time in the future. For the mining firm therefore V represents the market value of a claim on the stream of net cash flows that arise from installing the investment project at time t.

As with an example applied in Dixit and Pindyck (1994), the researcher examines the optimal timing of an irreversible mining investment project for the mining firm, beginning with the initial mining investment project in which V follows (4.19). The mining firm receives the payoff value at time *t*, which is $V_t - I$. To determine the value of the mining investment opportunity, that is the value of the option to invest which is represented by *F(V)*, the mining firm maximises the expected present value as follows:

$$F(V) = max\varepsilon E[(V_t - I)]e^{-\rho t} \qquad (4.20)$$

where *E* represents the expectation, *t* represents the unknown future time period that the mining investment is made, ρ represents the discount rate, and the maximisation of the mining project's value is subject to equation (4.19) for dV.

The condition of $\alpha < \rho$ is applied as otherwise the integral in equation (4.19) can be indefinitely larger when *t* is larger. In the stochastic case, with $\sigma > 0$, the mining firm seeks to find at which point it is optimal to invest *I* in return for an asset worth *V*. This is done by finding a critical value V^* such that the investment decision takes place once $V \geq V^*$

To evaluate mining investment opportunity and the optimal investment decision rule, the researcher will let *F(V)* be the value of the mining firm's option to invest. As mentioned earlier, discussion of this methodology follows the study as applied in Dixit and Pindyck (1994).

Considering a mining project portfolio in which the mining investor decides to hold the option to invest, which is worth *F(V)*, and go short $n = F'(V)$ unit of the project (or equivalently, of the mining project or portfolio *x* that is perfectly correlated with *V*). In the portfolio of the mining investment, the value of this investment project can be written as $\Phi = F - F'(V)V$. The investment project is dynamic as the project's NPV value, *V* changes, the project's NPV value of *F'(V)* may change from one short interval of time to the next. As a result, the composition of the investment project portfolio will be changed. Over each short interval of length *dt*, the researcher assumes that the value *n* is constant.

When the investment project portfolio is in the short position, the project will require the payoff value of $\delta VF'(V)$ each time period; otherwise rational mining investors will not enter into the long side of the transaction. Mining investors holding a long position in the mining project will demand the risk-adjusted return μV. μV equals the capital gain αV *plus* the dividend stream of δV. In the short position, it includes *F'(V)* unit of the project, which will require paying out $\delta VF'(V)$. Taking this payment into account, the total return from holding the mining project portfolio over a short time interval *dt* can be written as follows:

$$dF - F'(V)dV - \delta VF'(V)dt \qquad (4.21)$$

Using Ito's Lemma, the integration of *dF* can be written as the following:

$$dF = F'(V)dV + \frac{1}{2}F"(V)(dV)^2 \qquad (4.22)$$

To estimate the total return of the mining investment project, this can be written as follows:

$$\frac{1}{2}F"(V)(dV)^2 - \delta VF'(V)dt \qquad (4.23)$$

From equation (4.19) for *dV*, the mining investor identifies that $(dV)^2 = \sigma^2V^2dt$. The return of the mining project portfolio therefore stated as follows:

$$\frac{1}{2}\sigma^2V^2F"(\mathrm{V})\mathrm{dt}\text{-}\delta\mathrm{VF'}(V)dt \qquad (4.24)$$

Note that the return on the equation (4.24) is risk-free. To avoid arbitrage possibilities, the equation (4.24) must equal $r\Phi dt = r[F - F'(V)V]dt$:

$$\frac{1}{2}\sigma^2V^2F"(V)dt - \delta VF'(V)dt = r[F - F'(V)V]dt \qquad (4.25)$$

Dividing through by *dt* and rearranging, the equation (4.25) gives the following differential equation that *F(V)* must satisfy:

$$\frac{1}{2}\sigma^2V^2F"(V) + (r-\delta)VF'(V) - rF = 0 \quad (4.26)$$

Besides, the future value of *F(V)* must also satisfy the following boundary conditions:

$$F(0) = 0 \quad (4.27a)$$

$$F(V^*) = V^* - I \quad (4.27b)$$

$$F'(V^*) = 1 \quad (4.27c)$$

Condition (4.27a) arises from the observation that if the project's value of *V* goes to zero, it will stay at zero. The occurrence of *V = 0* is because of an implication of the stochastic process in equation (4.19). The option to invest for the mining project investment will not exercise or wait when $V = 0$.

Equations (4.27b) and (4.27c) come from consideration of the optimal mining investment. V^* is the critical value at which it is optimal to invest. Upon financing the mining project, equation (4.27b) is the project value the mining firm receives a net payoff, which is $V^* - I$. Equation (4.27c) is the "smooth pasting" condition.[33] The mining company can either continue its current mining operation or terminate the operation. The equation suggests if $F(V)$ were not continuous and smooth at the critical exercise point V^*, one could do better by exercising the project value at a different point.

Note that equation (4.26) is a second-order differential equation. However, there are three boundary conditions that must be satisfied, which are equations (4.27a) – (4.27c). The reason is that the position of the first boundary $(V = 0)$ is known. The position of the second boundary is not, which the "free boundary" V^* must identify. That needs the third condition.

There is another usefulness of equation (4.27b). The equation can be rewritten as $V^* - F(V^*) = I$. It indicates that when the mining project investment is being invested, it gets the project value V, but the mining firm gives up the opportunity cost or option to invest. The value is $F(V)$. The net gain of the opportunity cost, therefore, is $V = F(V)$. The critical value V^* is where this net gain equals the direct or tangible cost of investment, I Equivalently, the researcher can rewrite the equation as $V^* = I + F(V^*)$, setting the mining project value equal to the full cost (direct cost plus opportunity cost) of making the mining investment.

To find the value of $F(V)$, the researcher must solve equation (4.26) subject to the boundary conditions (4.27a) – (4.27c). To satisfy the boundary conditions of (4.27a) the solution for $F(V)$ must take the form:

$$F(V) = AV^{\beta_1} \quad (4.28)$$

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[33] Smooth pasting condition suggests that the mining investment decision can be determined by the mining firm choosing to either continue or terminate its mining operation. This means that the mining firm continues the project operation by waiting for better information and the flow payoff is zero. If the project is chosen to terminate, the project will be investing, and the termination payoff of the project's present value is the expected future cash flows minus the cost of investment.

where A is a constant that is yet to be determined, and $\beta_1 > 1$ is a known constant value, and this value depends on the parameters $\sigma, \rho, and\ \delta$ of the quadratic differential equation.

Since the second-order homogeneous differential equation (4.26) is linear in the dependent variable F and its derivatives, the general solution can be expressed as a linear combination of any two independent solutions. Applying the function AV^{β} by substitution that it satisfies the equation provided β is a root of the quadratic equation

$$\frac{1}{2}\sigma^2\beta(\beta - 1) + (\rho - \delta)\beta - \rho = 0 \quad (4.29)$$

The two roots are

$$\beta_1 = \frac{1}{2} - \frac{(\rho - \delta)}{\sigma^2} + \sqrt{\left[\frac{(\rho - \delta)}{\sigma^2} - \frac{1}{2}\right]^2 + \frac{2\rho}{\sigma^2}} > 1 \quad (4.30),$$

and

$$\beta_2 = \frac{1}{2} - \frac{(\rho - \delta)}{\sigma^2} - \sqrt{\left[\frac{(\rho - \delta)}{\sigma^2} - \frac{1}{2}\right]^2 + \frac{2\rho}{\sigma^2}} < 0 \quad (4.31).$$

So the general solution to equation (4.26) can be written as follows:

$$F(V) = A_1V^{\beta_1} + A_2V^{\beta_2},$$

Where A_1 and A_2 are constants to be determined. In this study, the boundary condition (4.27a) implies that $A_2 = 0$, leaving the solution in equation (4.28).

Applying equation (4.28), except that now r replaces ρ in the quadratic equation for the exponent β_1, which can be written as follows: [34]

$$\beta_1 = \frac{1}{2} - \frac{(r - \delta)}{\sigma^2} + \sqrt{[\frac{(r - \delta)}{\sigma^2} - \frac{1}{2}]^2 + \frac{2r}{\sigma^2}} \quad (4.32).$$

The remaining boundary conditions (4.27b) and (4.27c), can be used to solve the two remaining unknown variables: the critical value, V^* and the constant A at which it is

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[34] The researcher can use either the contingent claims solution or a dynamic programming solution, under the assumption of risk-neutrality to solve the mining investment problem. These two methods generate the same outcome according to Dixit and Pindyck (1994).

optimal to invest. By substituting (4.28) into (4.27b) and (4.27c) and rearranging, the equation now can be written:

$$V^* = \frac{\beta_1}{\beta_1 - 1} I, \qquad (4.33)$$

and

$$A = \frac{(V^* - I)}{(V^*)^{\beta_1}} = \frac{(\beta_1 - 1)^{\beta_1 - 1}}{[(\beta_1)^{\beta_1} I^{\beta_1 - 1}]} \qquad (4.34)$$

Equations (4.28), (4.29) and (4.30) give the value of the mining investment opportunity and the optimal investment rule, that is, the critical value V^* at which the mining firm is able to use for optimisation in their investment decision.

Next, the theory of contingent claims valuation outlined in equation (4.19) is followed. Let *x* be the price of dynamic portfolio mining project perfectly correlated with *V*, and denote by ρ_{xm} the correlation of *x* with the market portfolio. Since *x* associates with V, $\rho_{xm} = \rho_{Vm}$. In this case, the researcher assumes that the portfolio of this mining project pays no dividends, and the entire return is from capital gains. Then *x* evolves according to

$$dx = \mu x dt + \sigma x dz \qquad (4.35)$$

where μ, the drift rate, is the expected rate of return from holding the portfolio of the mining project. According to the Capital Asset Pricing Model (CAPM), μ represents the portfolio of the mining project systematic (non-diversifiable) risk. The fundamental condition of equilibrium from the CAPM states that

$$\mu = r + \emptyset \rho_{xm} \sigma \qquad (4.36)$$

where *r* is the risk-free rate, and $\emptyset$ is an aggregate market parameter (the market price of risk) that is exogenous. ρ_{xm} is the coefficient of correlation between returns on the particular mining project, represented as *x* and the whole market portfolio *m*. Thus, μ is the risk-adjusted expected rate of return that the mining firm would expect to use if the mining investor is to own the mining project.

The researcher also assumes that α, the expected percentage rate of change of *V*, is less than the risk-adjusted return μ. The mining firm would never invest if this were not the case. No matter what the current level of V is the mining company would be better off waiting and just holding on to its option to invest.

As noted, the parameter δ plays a significant role in this model. The parameter of δ is helpful to draw upon the analogy of call option theory in the application of the mining project investment activities. If the value of V were the mining project value, δ would be the dividend rate. The expected total return of the mining project would be$\mu = \delta + \alpha$, that is, the dividend rate plus the expected rate of capital gain. A decision to exercise the option depends on the δ. If the dividend rate δ were zero, a call option on the project investment would always be held to maturity, and never exercised prematurely. This is because the entire return on the particular mining project is captured in its price movements, and hence by the call option, there is no cost incurred to keep the option alive. By contrast, if the dividend rate δ is positive, there is an opportunity cost to keeping the option alive rather than exercising it. In this case, the opportunity cost is the dividend stream that has forgone by holding the option.[35]

The parameter δ can be interpreted in different ways as well. For instance, δ could reflect the process of entry and capacity expansion by competitors, which is outside the scope of this thesis. Or it can only reflect the cash flow from the mining project. If the mining project infinitely lives, then equation (4.19) can represent the development of V during the operation of the mining project, and δV is the rate of cash flow that the project yields.

The investment problem of this study, μ is the expected rate of return from owning the completed project investment. This parameter μ is the equilibrium rate established by the capital market and includes an appropriate risk premium. If $\delta > 0$, the expected rate of capital gain on the mining project is less than μ. δ, therefore, would be an opportunity cost of deferring the project, and instead keeps the option to invest alive. If δ were zero, there would be no opportunity cost to keep the option alive, and one would never invest, no matter how high the NPV of the mining project. This is the objective as to why the researcher assumes $\delta > 0$. Intuition suggests that if δ is enormous, the option value will be subtle. This is because of the opportunity cost of

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[35] Since δ is a proportional dividend rate, the higher the project NPV, the greater is the flow of dividends. At some high project NPV, the opportunity cost that has forgone dividends becomes sufficient enough to exercise the option.

waiting is large. As $\delta \to \infty$, the option value tends to be zero; in effect, the only choice of the mining investor is to invest now or never, and the standard NPV rule again will be applied.

The characteristics of the optimal investment rule and the value of the investment opportunity, as given by equations (4.28), (4.32), (4.34), and (4.35) help to illustrate the empirical result using the standard option pricing models. These equations also show how outcomes depend on the values of the various parameters.

These equations reflect an important point demonstrating that $F(V)$ increases when σ increases, as does the critical value V^*. Investment projects with greater uncertainty can increase the value of mining firms' investment opportunity. However, for that very reason, uncertainty can decrease the amount of actual investing that mining companies will do. As a result, when commodity markets or the economic climate becomes more uncertain, the project ROV can go up, even though mining companies do less investing and perhaps produce a lesser amount of mineral resources.

The dependence of V^* on σ, also shows a direct relationship. The study in Dixit and Pindyck (1994) is worth noting. The study shows the interrelationship that V^* increases dramatically with σ.[36] Mining investment, in particular is highly sensitive to volatility in project values, irrespective of investors' or managers' risk preferences, and irrespective of the extent to which the riskiness of V is correlated with the market (p.153).

Mining firms can be risk-neutral in any investment activities that they are conducting. Stochastic changes in V can also be completely diversifiable as well. However, an increase in σ will still increase V^*. Because of this reason, commodity price volatility tends to depress mining investment.

4.5 Concluding remarks for Part A

In Part A, the methodology used in this thesis for examining investment decisions in mining firms is discussed. The methodology focuses on the way mining companies react to uncertainty in output prices.

Investment in any large scale projects can be delayed. The mining firms have an incentive to delay their irreversible investment decisions. By delaying the mining firm

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[36] The volatility factor, σ will discuss further in Part B.

has the opportunity to wait for new information to arrive about prices, costs, and other market conditions before committing to investment. A strategic approach to the timing of investment decision is essential for mineral projects. This is because mining firms have to bear enormous capital costs and are exposed to the volatility of commodity markets that impact on the company’s profit. Mineral resources can be viewed as providing options to produce the resource and should be valued accordingly. The two commonly used approaches, the NPV and ROV methods, are used to examine mining firm investment decision making in dealing with uncertainty.

Part B: Mining Investment during Price Uncertainty

4.6 Review the concepts of commodity price uncertainty

Mining revenue is a critical factor in determining whether or not to invest in a mining project. The primary source of mining revenue is the ore bodies or ore reserves, which are classified as more or less valuable for mining investors (Alford, *et.al.*, 2010). Mining firms decisions on how much capital to invest, the timing of investments, the mine production capacity, expansion potential, and plant processing capacity are determined completely by information on mineral prices (Caro, *et.al.*, 2010).

Commodity prices are one of the most volatile variables in determining the profit of a mining project. In this part of the chapter, much attention is given to the variation of commodity prices, especially with regard to the optimal timing of a mining firm's investment.

The mean reversion (MR) model is used to forecast the future mineral prices before MCS is conducted. Monte Carlo simulation (MCS) stochastic tool is used to identify the distribution of prices based on the expected mean and standard deviation. MCS is used for the valuation of American-type options in this study (Longstaff & Schwartz, 2001). The main feature of MCS identifies uncertainty variables before the event trees can be developed. MCS is one of the methods used to identify risk sensitivity, which enables mining investors to capture the most significant uncertain variables that could affect their investment decisions.

The remainder of the chapter in Part B is organised as follows: in Section 4.7 provides background on stochastic process models, in Section 4.8 describes the model used to value uncertainty in commodity prices, and the chapter concludes in Section 4.9.

4.7 Background studies of the stochastic modelling

Economic viability in today's mining industry is highly dependent on sound company planning and management. A key decision support system, which mining firms can successfully apply to resolve their investment planning and management problems is optimisation techniques. These techniques include: ore-body or reserve estimation; the design of optimum pits; the determination of optimal production planning; the determination of optimal mine operation layouts; the determination of machinery maintenance and replacement policies; the determination of an efficient mine site redevelopment program; the determination of the best choice of machinery, such as truck and loaders for the mining operations; and the design and efficient operation in the issues of transportation and logistics network to support the mining operations (Caccetta, 2010, p. 547).

The use of optimisation decision support models in large-scale mining projects has been extensively studied. For instance, these techniques have been applied in the copper resource sector by Mondschein and Schilkurt (1997), Caldentey and Mondschein (2003) and Caldentey, *et.al.,* (2007). Epstein, *et.al.,* (1999) examine techniques used in the renewable forestry industry and these techniques are applied in the studies of crude oil industry by Baker and Ladson (1985) , Dyer, *et.al.*, (1990), and Gibson and Schwartz (1990).

The advantage of using these optimisation decision techniques is that mining firms are able to evaluate their investment projects by choosing the projects that have short-term and long-term profitability. Caldentey, *et.al.,* (2007) states that most of these models use state variables, such as commodity market prices and mineral demand, as independent variables to determine the mining firm’s investment decisions.

When applying a mineral extraction rate to the real options model, the researcher takes into consideration uncertainties, such as change of commodity price, production cost, investment expenditure, geological properties, ore deposits, unexpected delay of the operation, and capacity constraints (Ghoddusi, 2010). These uncertainties are relevant when applied to the concept of capacity expansion in a real options model, and they are also important in the context of analysing mining investment and the production decisions of the mining firms.

When dealing with uncertainty in the real options model, Schwartz and Smith (2000) state that the stochastic model of commodity prices plays a significant role when evaluating mining project investment. Stochastic processes in modelling price variables evolve in either discrete or continuous time in an unpredictable or partially random way. Stochastic price behaviour can be done with either a Geometric Brownian Motion (GBM) (Brennan & Schwartz, 1985; McDonald & Siegel, 1986) especially in the short-term, or with a mean reversion (MR) model (Ozorio, *et.al.*, 2013) in the long-term.

In early studies of stochastic models in relation to price risks, researchers usually assumed that commodity prices followed a “random walk” (described by GBM).[37] By applying the stochastic process and assuming that commodity prices had a simple random walk model, the researcher simulates commodity prices to forecast the net present value (NPV). Accordingly, the random walk model is used to forecast commodity prices based on the fluctuation of daily mineral prices traded in the commodity market; variations of commodity prices in the random walk process have a mean value equal to zero (Enders, 2004).

GBM was initially used to model stochastic markets (Mun, 2006). Mun (2006) states that the GBM is the most commonly used process stochastic model due to its simplicity and wide-ranging applicability (p. 272). GBM is a process that does not follow any simple deterministic rule, such as “a commodity price will increase *X* per cent every year”. The path of stock prices in the share market is often used as an example of a GBM process because the path is stochastic in nature and cannot be predicted with any certainty. When applying the GBM model the researcher expects that commodity prices grow at a trend with the variance of future commodity spot prices which is also expected to remain constant. It assumes that a small increase in commodity prices in one time period causes a small increase for all future forecasted commodity prices.

Alternatively, several researchers examined the use of MR price model when evaluating commodity price risks in the mining industry (e.g., Laughton & Jacoby, 1993; Dixit & Pindyck, 1994; Cortazar & Schwartz, 1994; and Smith & McCardle, 1999). In the long-term, for most commodity prices, there is some mean-reversion in prices. However, there is also uncertainty about the market commodity price equilibrium to which the commodity price reverts when applying the mean-reverting price model. When applying this model, the researcher needs to find an average commodity base price, which is required in this study to determine the best-case scenario for the timing of the investment.

4.7.1 Geometric Brownian motion model

A Wiener process, also called geometric Brownian motion (GBM) is a continuous-time stochastic process, which is comprised of three features. Firstly, the GBM is a

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[37] GBM model was first used in the Black-Scholes (B-S) option pricing formula by Black & Scholes (1973) for evaluating stock price uncertainty.

Markov process, which means that the probability distribution for all future commodity prices depends on the current commodity prices. Secondly, the GBM has independent increments. It means that the probability distribution for any changes of time interval no matter how small the time interval is. Thirdly, the process is normally distributed. The process can be changed over any infinite time interval with a variance that increases linearly within the time interval (Pindyck, 2001).

These three Markov's properties are particularly important in modelling GBM. This is because the GBM model is only based on current information to forecast the future path of the process. The GBM process is used in most of the contingent claim analysis literature to simulate stock spot prices (Caldentey, *et.al.,* 2007).[38] The Black and Scholes (1973) (B-S) model is a prominent research model that incorporates a GBM closed-form solution for the share market. Other examples of the application of the GBM model are to the stochastic process of price risks and uncertainties in mathematical finance (see Merton, 1973b and Samuelson, 1965).

Several researchers, such as Schwartz and Smith (2000) and Smith and McCardel (1999), apply GBM models to prices of mining commodities, with mining firms having the flexibility to open or close projects or increase or decrease the rate of production based on the fluctuations of commodity prices (Caldentey *et.al.*, 2007). Schwartz (1997) finds that stochastic models, such as GBM, are important for valuing financial contingent claims on the mineral resources, particularly when conducting an analysis of the investment project at the stage of mineral extraction or expansion of mineral production capacity. Mining firms must choose the optimal timing of investment carefully in order to be successful in the natural resource industry. One of the objectives in this study is to investigate the ability to use option to delay in an irreversible mining investment project, which can profoundly affect the decision to invest.

The empirical study of Dixit and Pindyck (1994) is worth noting because they used copper spot prices to compare GBM and the mean-reverting hypothesis for the last two hundred years. They are not able to reject the mean-reversion hypothesis. They also

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[38] GBM model also used in modelling security prices, as well as interest rates, wage rates, output prices, and other economic and financial variables.

find that the null hypothesis of GBM can be rejected when only thirty to forty years of data are included.

Brekke and Schieldrop (2000) use GBM to study the option to invest in a flexible technology that enables mining firms to adapt to future changes when shocks occur. Mining firms have the flexibility to choose either a pure technology that uses only one capital stock or a flexible technology that enables mining firms to change between capital stocks. The study demonstrates the option to choose the flexible technology gives firms a significant reduction in expected fuel costs. Mining investments are irreversible, and the economic conditions are stochastic, so the flexibility of mining investments is highly significant. Understandably, in the absence of the flexible technology, mining firms are more reluctant to invest.

Using the GBM model to forecast oil prices, Smith and McCardle (1999) discretise this process by using a decision tree and dynamic programming models to describe the sequence of decision making and the resolution of uncertainties over time. The empirical finding of this study is that the option pricing and decision analysis approaches are equally replicated.

Other studies applying the GBM model include Kamrad and Ernst (2001) who use a contingent claims methodology, commonly used in financial analysis, to formulate a production control model that features by market and process uncertainty. They find that market risk is largely described by the commodity prices and process uncertainty is significantly correlated with the random variability that causes variation in output yields.

4.7.2 Mean reverting processes

The simplest MR stochastic process is also known as an *Ornstein-Uhlenbeck process*. An MR stochastic process model is another version of the Markov stochastic process, but does not have independent increments. The MR model suggests that prices and returns are eventually drawn back to the long-term average to which the current spot price must revert. This average price can be a historical average of the commodity price or another relevant average in the resource sector.

The concept of an MR model originates in microeconomics theory. The MR model states that when the commodity prices fall below the long-term average price, the demand for commodities will increase while the supply of mineral production will decrease. In practical terms, the factor that determines the change in demand of mineral resources is the mineral price variation: as mining revenue declines because of the lower commodity prices, mining investors probably decide to defer their investment or close the less efficient mining sites, causing mineral resources to be in short supply (Bastian-Pinto, *et.al.,* 2010). Based on this theory, the researcher applies the MR model in this study based on 50 years of commodity prices to forecast future returns from the investment project.

With respect to empirical studies using MR, Schwartz (1997) studies three variations of a mean-reverting stochastic behaviour model of commodity prices into a one-factor, two-factor or three-factor model. Variables used in these models are copper, gold and crude oil prices. The first model is a simple one-factor model using the logarithm of the commodity spot price - the model that is applied in this study. The second model includes the convenience yield of the commodity, and the third model includes interest rates. These three models are each assumed to follow a mean-reverting process. The study compares the value and the investment rule for simple mining investment projects, concluding that the valuation of mining investment projects and the investment optimisation rule are significantly dependent on the volatility process for the underlying factors.

Other studies, such as Hahn and Dyer (2008) develop a method by constructing recombined binomial lattices to a model underlying one-factor stochastic processes that were mean-reverting. Bastian-Pinto *et.al.,* (2010) develop a non-censored binomial lattice model for a mean-reverting process to evaluate real option pricing, which shows the importance of stochastic processes for uncertainty of the underlying project value and the effect it has on changing the real option value.

Pindyck (2001) finds that the use of stochastic processes, such as GBM, MR, and Ito's Lemma, are becoming more and more common and widely used in the fields of economics and finance.[39] These stochastic models offer a new approach for analysing investment timing and option valuation problems in the mineral resource industry.

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[39] Pindyck (2001) states that Ito's Lemma process is important in deriving an optimal investment rule because it enables differentiating and integrating functions in GBM.

In the next section, the MCS method is applied to simulate the commodity price in order to find the optimal investment rule of critical prices.

4.7.3 Monte Carlo simulation (MCS)

Monte Carlo simulation (MCS) is named after the famous gambling city in Monaco. The concept of MCS is to simulate thousands of possible mining project scenarios based on calculation of the mining project NPV for each scenario using the DCF method and then analysing the probability distribution of the NPV results. MCS is a type of parametric simulation, where specific distributions (for example, normal, triangular and lognormal) and parameters (for example mean and standard deviation) are required before a simulation can begin.

MCS is an approach to valuing options, such as traditional finite difference and binomial lattices. MCS has many advantages when applied to mining project valuation, in particular to managing risk and optimising investment. For instance, the option valuation used in MCS is path dependent and can have multiple stochastic factors. From a practical perspective, the design of MCS is well suited in today's business world, particularly in high-risk project investment evaluation. The computer programming set up in this simulation software is well equipped to deal with decision making analysis for mining firms and allows significant gains in computational speed and efficiency.[40]

In practice, the MCS method is used for risk analysis, risk quantification, sensitivity analysis, and prediction. Prior to conducting ROV analysis, using binomial decision tree analysis, simulation models such as MCS are crucial steps for solving difficult and complex but practical problems with great ease.

Figure 4.2 shows the implementation process and tools for option valuation. For conducting the ROV analysis in this study, the researcher follows a system dynamic programming model, which is a discrete time binomial decision tree analysis to conduct a project valuation in the mining industry. In application of the system dynamic model, MCS is used to evaluate mining projects without options, using a DCF

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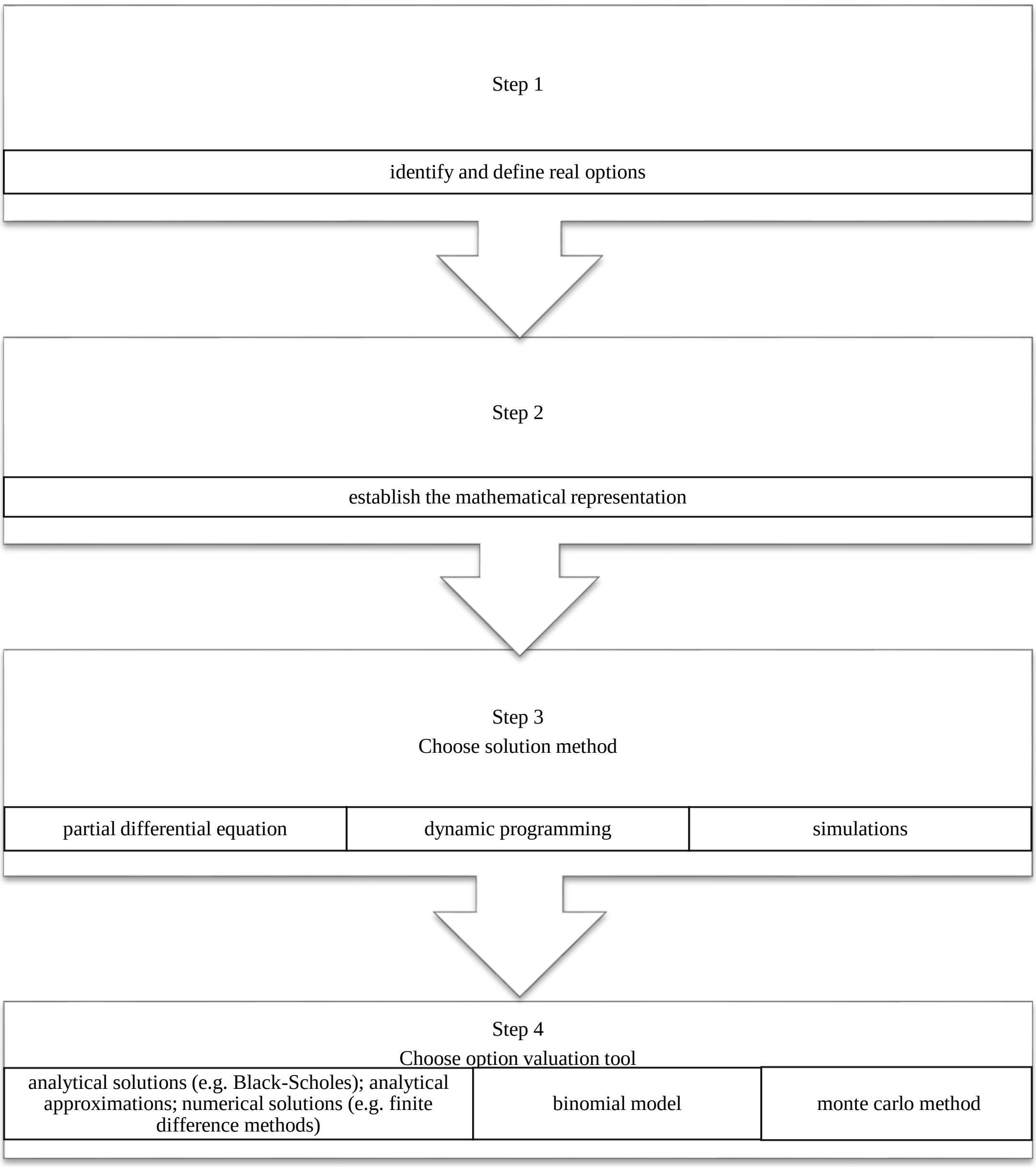
[40] Longstafff and Schwartz (2001) state that the use of simulation models is one of the most simple, transparent and flexible methods in empirical research.

analysis and calculating the expected NPV. This study follows the steps applied in the study of Amram and Kulatikala (1999).

Figure 4.2 Implementation process and tools for option valuation



Source: Amram and Kulatilaka, 1999, p.108

Prior to the building of the binomial decision tree, MCS is used to select a range of variable values that have high uncertainty, such as discount rates, commodity prices, and tax rates by randomly picking these values from the probability distribution then using these values for the event. Each event can produce associated results and can have a forecast. Forecasts are events (usually with formulas or functions) that use an important output of the model for simulation purposes.

MCS is one of the simulator tools which can combine many uncertainty variables into one by running them through a single spreadsheet. In binomial decision tree analysis, Brandao and Dyer (2005) state that MCS is performed with the objective by combining all uncertain variables into one single distribution after the stochastic process to determine the value of the project. Copeland and Antikarov (2001) find that with software programs, such as Crytal Ball or @Risk, using MCS is an important step in constructing the binomial lattice event tree. To conduct an empirical analysis in this study, the MCS is applied to generate distribution of the commodity prices before constructing an event tree to find the optimal investment rule in critical prices.

As mentioned earlier, the process that the researcher follows to construct a value-based event binomial tree lattice is simple and straight-forward. Firstly, the model starts with a present value spreadsheet using expected free cash flow to estimate present value based on discounting present value for time value of money at weighted average cost of capital (WACC). Secondly, model uncertainty variables are specified in order to capture autocorrelation and cross-sectional correlations so the researcher can decide how confidence interval can change over time. Thirdly, MCS is applied with thousands of iterations to generate the lognormal probability distribution NPV and calculate relevant statistically valid confidence intervals for decision making. Fourthly, the last step constructs PV lattice with cash flows reinvested following GBM.

As stated at the outset, investment in mining projects can be risky and volatility in mineral price is one of the significant factors with which mining managers are most concerned in evaluating projects. The use of MCS analysis is a powerful tool in estimating the stochastic properties that drive volatility. In this case, MCS is applied to estimate the standard deviation of rates of return based on the distribution of present values.

Researchers who have used the MCS include Merton (1976) and Cox and Ross (1976). They apply the MCS to allow stochastic variables to follow a general stochastic process. Heath, *et.al.,* (1992) conduct a study in MCS using non-Markovian processes. This study follows these researchers' application in highlighting a new investment approach which deals with the timing decision in mining investment.

The key feature of this method simulates the volatility process of the underlying project NPV. The simulation method is similar to the binomial lattice model, which applies risk-neutral probabilities to discount the option values based on simulation outcomes at the riskless rate. In the following section, the study focuses on estimating the volatility factor of the underlying risky mining project and how to use it to build a binomial decision tree.

4.7.4 Estimating volatility

Volatility in commodity prices is an important factor that affects mining option values. The objective of applying the MCS is to estimate the project's volatility, and build an event tree using the binomial model.

In ROV theory, "volatility is a measure of the variability of the total value of the underlying asset over its lifetime. It signifies the uncertainty associated with the cash flows that comprise the underlying asset" (Kodukula & Papudesu, 2006, p. 86). The volatility factor (σ), which is needed to build binomial decision trees is the standard deviation of the natural logarithm of cash flow return.

The logarithmic cash flow returns method, MCS, project proxy approach, market proxy approach and management assumption approach are among the methods used to estimate volatility. The logarithmic cash flow returns method is simple to use. This method is based on the simple mathematics calculation. The variability of the future cash flows is used to compare the current cash flows or historical stock indexes. The cash flow relative returns are then generated into the logarithmic relative returns in estimating the underlying asset value.

As discussed in the previous section, there are multiple variables, such as revenues, costs and discount factor when using the MCS approach. These factors contribute to the present value of the project cash flows that comprise the underlying asset value. These variables can be simulated using MCS over the project life because of volatility.

In estimating volatility, MCS conducts numerous simulations based on the chosen input data and then calculates the volatility factor across simulations. The input data can be generated based on the historical information, such as stock indexes and interest rates, or based on management estimates. There are many input variables that contribute to the project's cash flow. However, only a few variables have the most impact, for example, commodity prices and tax rates. The advantage of using MCS is that there is a distribution showing the percentile of the outcome. The percentile distribution is then used to evaluate the sensitivity of the real option value of the mining project.

The project proxy approach is an indirect approach to estimate the volatility factor of the underlying mining project value. The feature of this method is that it uses data as a proxy based on the information from the historical project. The method assumes that the historical data of a previous project in some way contains relevant world market information.

The market proxy approach is a method using comparable indexes, such as the closing stock price of a publicly traded company that has a similar cash flow profile and risk to make a comparison. This method compares the companies' liquid and non-liquid assets, provided the comparable market, sector, or industry-specific data are available.

Management can also predict the volatility based on their subjective best guesses. Best guesses are usually a combination of management's optimistic, pessimistic, and average expected payoffs for a given mining project.

In this study, the logarithmic stock prices returns approach or the logarithmic cash flow returns approach and the MCS are applied. The volatility factor using the logarithmic cash flow returns approach is estimated using the following equation:

$$Volatility = \sqrt{\frac{1}{1-n}\sum_{i=1}^{n}(y_i - \bar{y})^2} \qquad (4.37)$$

where *n* is the number of Ys, and $\bar{y}$ is the average Y value.[41]

Prior to developing a binomial decision tree model, the procedures mentioned above are essential steps in ensuring the prescribed parameters required to build the decision tree binomial model are determined. The binomial model is discussed extensively in Chapter 6.

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[41] Y represents the natural logarithm of cash flow returns.

4.8 The model

4.8.1 The measurement of commodity price with uncertainties

Stochastic models of mineral prices in the resource sector have an important role when evaluating commodity related mining projects (Schwartz & Smith, 2000). GBM and mean-reversion models are the two most common stochastic models used to model uncertainties in the real option model (Kobari, *et.al.*, 2014), with a majority of studies using stochastic models to evaluate mining projects assuming that commodity prices follow a "random walk" as described by Geometric Brownian Motion (GBM) (Brennan & Schwartz, 1985; Paddock, *et.al.*, 1998; Smith & McCardle, 1999).

Even though the commodity prices, such as copper and coal, are often modelled using the GBM method, researchers believe that, to some extent, these mineral prices should somehow be related to long-term marginal production cost (Dixit & Pindyck, 1994). In other words, in the short-term, commodity prices might fluctuate randomly up and down in response to economic uncertainties, such as wars or civil revolutions, or in response to changes in government mineral policies. However, in the long-term, commodity prices are drawn back toward the marginal cost of production. Thus, a mean-reversion process is utilised for modelling commodity prices in the applications in the next chapter.

There are a number of multi-factor commodity models apply to modelling the uncertainty of commodity prices (see Cartea & Figueroa, 2005; Jaimungal & Surkov, 2011). Schwartz's (1997) one-factor geometric mean reversion (GMR) model is able to capture the pricing uncertainties when applying ROV. This model is particularly useful when modelling a spot price process forecast for over 30-year periods. There are many studies which support the idea of commodity prices following mean reversion process (Gibson & Schwartz, 1990; Dixit & Pindyck, 1994; Schwartz, 1997; Hahn & Dyer, 2008; Aleksandrov & Espinoza, 2009). These studies find that commodity prices tend to revert to the equilibrium level in the long-term.

The model in this study assumes that the mining project under consideration is a mine that will produce a single commodity mineral and that spot prices follow the stochastic process written as the following:

$$dS_t = \kappa\,(\mu\text{-}\ln S_t)Sd_t + \sigma S dZ_t \qquad (4.38)$$

where κ is the speed of reversion, μ is the level of mean reversion, σ is the volatility of commodity prices, Z_t is the increment of a Wiener process. Defining $X_t = \ln S_t$ and applying *Ito's Lemma*, the log price process follows the Ornstein-Uhlenbeck stochastic process also called arithmetic MR process, which can be written as follows:

$$dX_t = \kappa(\alpha - X_t)dt + \sigma dW_t \qquad (4.39)$$

where

$$\alpha = \mu - \frac{\sigma^2}{2\kappa} \qquad (4.40)$$

Note that the expected change in X in equation (4.39) depends on the difference between $\alpha - X_t$. In other words, the mean-reverting process is based on α. If X is greater than α, then *X* is more likely to fall. If *X* is less than α, then *X* is more likely to rise.

Equation (4.39) is the continuous-time version of the first-order autoregressive (AR1) process in discrete time. The equation is particularly useful in the limiting case when $dt \rightarrow 0$. The AR1 process can be written as follows:

$$X_t - X_{t-1} = \bar{X}(1 - e^{-\kappa}) + (e^{-\kappa} - 1)X_{t-1} + \epsilon_t \qquad (4.41)$$

where unit root tests can be used to test econometrically for mean reversion, which requires $k > 0$.

4.9 Concluding remarks

In this chapter, the real options model is discussed as it is used in this study to examine the impact of uncertainty in commodity prices. Uncertainty in commodity prices is crucial in determining the profitability of investment in mining projects for mining investors.

Using a real options pricing technique, the model is presented here for valuing the investment decisions when commodity price uncertainties occur. This is a discrete time mean reverting process (MR) model that can be used to examine price variation in the mining industry. Using either discrete time or continuous time framework to model variables are extensively applied in theoretical finance, empirical finance, and financial econometrics, both in academia and industry (Alizadeh, *et.al.,* 2001).

The real options approach in this study takes account of the stochastic process in economic variables (for example uncertainty in commodity prices) when undertaking mining investment decision making. The real options model, particularly MCS incorporating binomial decision tree analysis, is a significant achievement in dealing with these issues in the financial market.

The next chapter presents an empirical analysis using a static discounted cash flows analysis. The researcher discusses mining project investment when uncertainty is not taken into account.

Chapter Five

5 A Static Model of Mining Project Evaluation

5.1 Introduction

In Chapter Four the researcher outlines standard neoclassical investment theory in relation to the investment behaviour of profit maximisation of mining firms. Profit maximising and cost minimising are key factors in determining the revenue of the project investment. In order to achieve the most lucrative revenue at minimum cost, it is necessary to apply an investment strategy to the mining project. This investment strategy allows the mining investors to decide the right timing of their project investment decisions. Choosing and using appropriate investment strategies, as well as capital budgeting analyses, can completely change the entire mining investment process.

Capital budgeting analysis is one of the most traditional and standard static methods or strategic approaches for evaluating a project's feasibility. This method is favoured by the majority of mining companies and is particularly important when evaluating large scale mining projects, which usually have a long lead time. A mining firm's decision needs to be based on this evaluation outcome to determine whether to invest or disinvest the project.

The valuation concept of capital budgeting analysis is used to evaluate the present value of the future mining investment, as well as the projects profits. The traditional discounted cash flow (DCF) or net present value (NPV) method that was advocated by Irving Fisher in 1907 remains at selecting investments that maximise the market value of a firms existing equity. The expected return on the investment in this standard approach must be greater than the initial expenditures that were incurred in the mining project.

The traditional investment rule states that if a mining project sustains a significant profit, it will usually be granted permission to proceed with a mining investment. However, mining investment using the traditional static DCF can only decide on the investment as an all-or-nothing strategy. There are some shortcomings with this traditional static method, such as lack of operating flexibility and a tendency to underestimate the real strategic value. In practical terms, however, the traditional approach is still one of the preferred methods for performing a project evaluation (Arnold & Nixon, 2011).

In a project evaluation, the static DCF method uses two economic forces, risk or cost versus reward or benefit to determine the profits of a mining project. Revenue generated from the mining investment is expected to generate cash flow from the investment and also to cover the cost of the investment.

An application of the static DCF approach for project valuation follows the pioneering work of Modigliani and Miller (1958) (hereafter MM). The prominent MM approach is an important milestone in the finance literature for the value of a firm that is funded with a combination of debt and equity. This method is applied in a mining project evaluation in which the static DCF focuses on the combination of debt and equity used for funding a mining project and the cash flow calculation. This standard approach assumes that the decisions made in mining project evaluation are static. As a consequence, managers will not alter their level of production in response to the investment they made and will continue the mine operation until the entire mine life is ended.

In this chapter, the researcher discusses the empirical evidence on the static capital budgeting methods that affect mining investment decisions making. The rest of the chapter is organised as follows: Section 5.2 comprises some static empirical models and data collection; Section 5.3 contains the forecasting and simulating of a discount rate; Section 5.4 consists of the analysis using the DCF method; Section 5.5 discusses the empirical result of the NPV in mining investment in the Asia-Pacific region and Section 5.6 is the conclusion.

5.2 Empirical models and methods of estimation

In this section, the researcher discusses the estimation of the DCF model, which was introduced in Chapter Five. The purpose of this model is to perform the static tasks of traditional DCF project valuation. These tasks included working out the entire cash flow and finding the most profitable project in the region, then conducting a sensitivity analysis of the most sensitive variables that could affect the profit of the project.

5.2.1 Description of the DCF model

The purpose of estimating the project's NPV is to determine the viability of mining projects. When all benefits and costs can be expressed in a cash amount, the formula of NPV can be written as:

Net present value = ∑ *present value of cash benefits* - ∑ *present value of cash* costs

To reiterate, the NPV method is one of the most reliable and simple methods used in capital budgeting because it accounts for the time value of money by using discounted cash flows. The NPV estimation is the present value of net cash flows generated by a mining project including salvage value minus capital investment expenditures on the project.

As noted, the simple NPV is the sum of net present values minus the capital expenditures, excluding the tax flow. However, in the static cash flow analysis on mining project investment, there are usually tax consequences regardless of whether there are cash in-flows or cash out-flows. Ignoring tax implications can substantially impact the outcome of cash flow or a company's NPV. This study uses the variation of tax flow to determine the viability of the mining project as a result of tax flow change. The tax flow that apply to this study range from 25 percent to 35 percent. Information about tax flow are accessed from the government's taxation office or Inland Revenue of the particular country.

The software packages used for analysis are Matlab, @Risk simulator software and dynamic programming language 8, specifically (DPL 8). Firstly, Matlab and @Risk simulator is used for simulating discount rates. The historical data used for simulating discount rates is obtained from the individual country's Central Bank website. Secondly, @Risk simulator software is then used to forecast the mining project's NPV with tax implications. The value of NPV associated with other assumptions in mineral prices, costs structures and taxes are simulated using @Risk simulator software by one thousand iterations simulation. Simulation in @Risk simulator identifies the margin of the NPV based on a standard normal probability distribution, which determine the exact NPV. Mining investors then decide whether to proceed with the mining project or abandon it.

There are many different sources used to obtain information that is necessary for cash flow analysis. In this study, the primary source of data is mining companies' annual reports. The mining site used for Australia is the Daunia Mine for open-cut coal under BHP Billiton Mitsubishi Alliance; the Indonesian is the Tembang Gold Mine Project operating under Sumatra Copper and Gold company; the New Zealand site is the Eastern and Buller coal project working for Bathurst Resources Limited; the Malaysian site is the Mengapur Mine project produced by the Monument Mining Limited located in Vancouver, Canada; and the Papua New Guinean site is the Wafi-Golpu mining project under the operation of the Australian mining giant, Newcrest and Harmony Gold Mining Company Ltd.

These five selected mining projects have its uniqueness and characteristics. For instance, Daunia coal mine project in Queensland, Australia is the major mining projects, which is expected to produce 4.5m tonnes per annum of coking coal as well as created extensive local infrastructures and job opportunities. Tembang gold mine project is one of the flagship gold-silver mining project in Sumatra, Indonesia. Mengapur gold mine project is a project, which defined the historical polymetallic resources in the full bankable feasibility study in Malaysia's mining industry. Buller coal project in Bathurst, New Zealand is home to some of the world's most valuable hard coking coal used for steel making and The Wafi-Golpu tenements host one of the highest grade porphyry copper systems in South-East Asia, in particular, the Golpu deposit. A spectacular of these features have led the researcher to use these selected mining projects to conduct the responsiveness of mining investors' behaviour in this study.

Thriving economic growth and its endowment of mineral resources of the Asia-Pacific region is the primary reason to conduct a mining investment analysis in this region. The Asia-Pacific region is one of the most diverse in the world in terms of GDP per capita, the size of the economy, technology, specialisation and factor endowment (Lee & Heshmati, 2009). The International legal firm, DLA Piper (2012) states that international private capital is increasingly injected into the Asia-Pacific countries after the Asian Financial Crises in 1997. In 2014, a growing number of mining projects in the Asia-Pacific are operated and funded by private mining companies. The study of mining investment in Asia-Pacific countries is two-fold. Firstly, the opportunities that exist for the development of mining, resources and infrastructures in this region are impressive because these five countries have abundant mineral resources in the ground.[42] Secondly, these five countries have significant coal and gold producers, such as Australia, Indonesia and Papua New Guinea.

The estimation of mineral production in the cash flow follows the annual mineral production from individual mining projects, as indicated in the mining companies' annual report. In relation to cash flow, the researcher assumes that mining companies had a constant mineral production rate over the entire life of the mining project. The average ore grade and the minerals recovery are both determined in percentages and multiplied by the annual production in order to obtain the total production being extracted. The amount of ore grade is obtained from mining company's pre-feasibility study report. These mineral resources and estimated reserves are in compliance with the Joint Ore Reserves Committee (JORC) code.[43]

The NPV of a mining project comprises mining costs, processing costs, refining costs and miscellaneous costs, royalty rates, and machinery depreciation. The data used for calculating the cost structure are obtained from mining companies' annual reports. Of the mining projects in this study, some are joint ventures and the other mining companies are operated by the mining firm itself.

Measuring total sales revenue and total costs are crucial prior to analysing the cash flow. The cash flow analysis requires using an appropriate discount rate. Calculation of the discount rate is based on the average of the interest rate obtained for each country, which includes the seven percent of the mining cost discount factor.

Estimating the appropriate discount rate is a necessary step to ensure that the evaluation of the mining project is as accurate as possible. In the next section, attention is given to the analysis of the discount rate simulation of the mining project.

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[42] The reason why New Zealand is included in this study is because the New Zealand government is keen to increase its mining investment activities in coal, petroleum and gas projects. Crown Minerals of New Zealand is a government agency, which governs the mining acts and permits in New Zealand. The agency also assists the New Zealand government to maximise the gains from the development of mineral resources, in line with the Government's objectives for energy and economic growth.

[43] The JORC code is the Australasian code for reporting of exploration results, mineral resources and ore resources, prepared by the Joint Ore Reserves Committee of The Australasian Institute of Mining and Metallurgy, Australian Institute of Geoscientists and Mineral Council of Australia (JORC).

5.3 Estimating and forecasting discount rates

Discount factors are the connection between future and today's project values. Choosing appropriate discount rates is always an important decision for mining investors and requires patience. The lower the discount rate, the more likely the investment project is delayed. In contrast, the higher the discount factors, the more likely the investment will proceed.

In determining the discount factors, it is important to use the appropriate discount rate when determining the 'fair' value of a mining project. Rudenno (2012) states that the mining project with a discount rate or hurdle rate that meets the minimum market expectation adds value to the company if a positive NPV is achieved. The discount rate in this study is set at 12 per cent for the entire life of the project. Interest rates forecasting is based on the mean-reverting model using nominal interest rates. The reason for setting the project's discount rate at twelve per cent is to allow for some contingencies that might occur after the mine site begins. Rudenno (2012) states that mining firms often select hypothetically high discount rates. These discount rates are dependent on the riskiness of the mining project and the mining location and country.

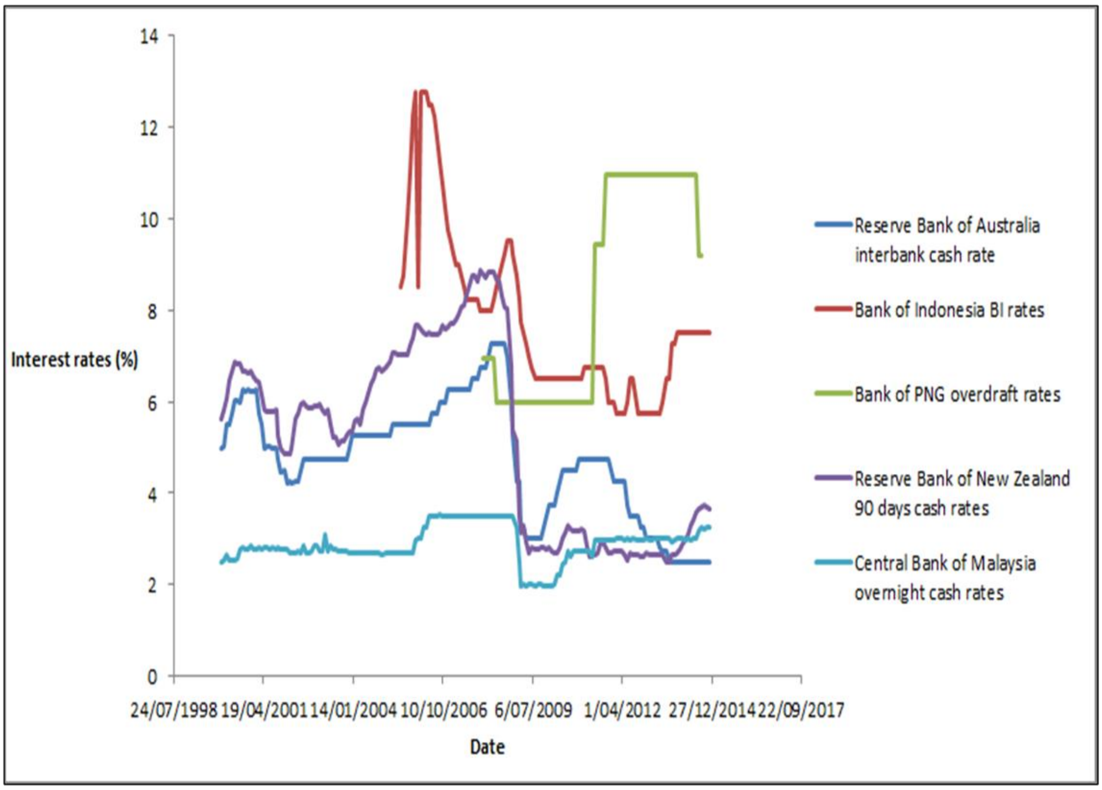
Calculating a project's NPV value is a common method for mining investors' decision making. Cox *et.al.* (1985) and Ingersoll and Ross (1992) claim that the level of interest rate volatility is important as the mining firm's investment decision. The importance of interest rate volatility is intense when mining firms use an internal rate of return (IRR) to evaluate their project investment. Tolis *et.al.* (2010) state that the value of the interest rate and IRR that trigger an investment decision increases if the volatility is significant.

Calculating a project's NPV requires an appropriate discount rate determination. Kodukula and Papudesu (2006) state that the magnitude of risk (cash flow uncertainty), private risk, and market risk are discount factors for a given cash flow stream. Therefore, mining investors should first consider uncertainties associated with the mining project cash flow stream when making the decision to invest. For instance, if the mining investment is associated with certainty regardless of private risk or market risk on a cash flow stream, a risk-free rate will apply. In contrast, if there is uncertainty associated with the mining project valuation, the mining investor should then consider how the private risk or market risk influences their investment decisions.[44]

Mining project investment usually involves both private and market risks. On the one hand, private risks, such as investment cost and capital expenditure, need to be given serious consideration before decisions are made. On the other hand, market risks such as exchange rate volatility and commodity price fluctuations in the world market, can also significantly impact on the entire process of the investment project.

Applying the appropriate discount rates is critical. Many academics and practitioners argue that if a cash flow stream is only applied to a private risk without the existence of market forces, a risk-free rate should apply. Investments in mining and oil and gas attract higher market risks, and so a proportional risk premium should be added to the risk-free rate in order to discount the market-driven project cash flows at a rate that is equivalent to the risk level of the project (Kodukula and Papudesu, 2006).

Figure 5.1 The historical interest rates of the Asia-Pacific countries



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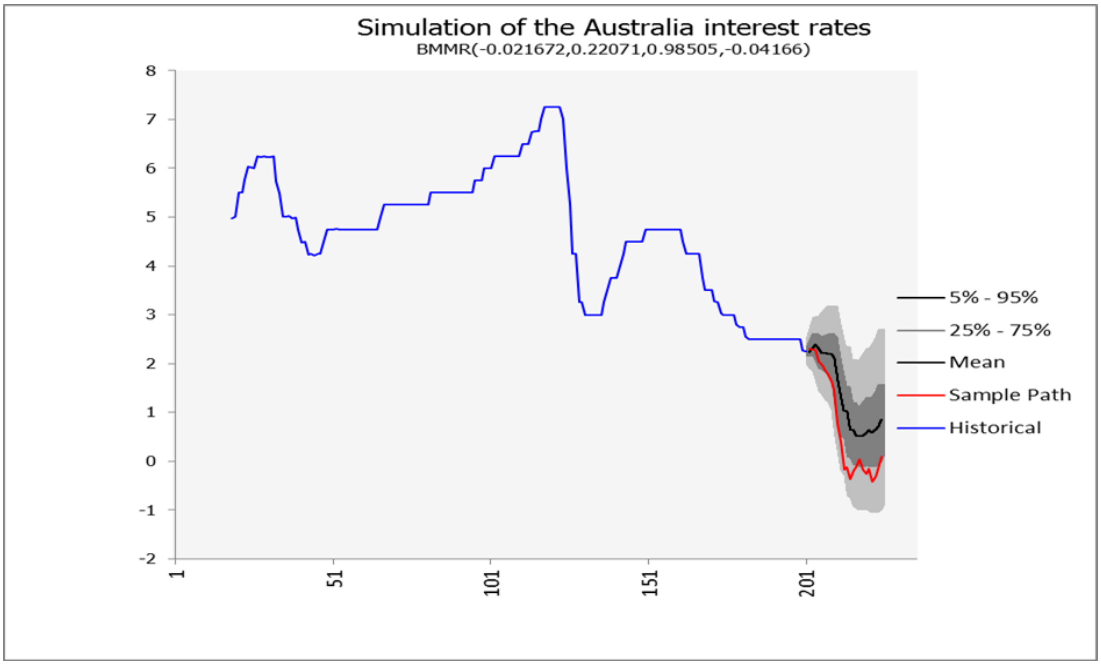
[44] Private risks are related to the efficiency of a company to complete a project on time as well as the effectiveness and the efficacy of the technology to the new product produced in the market. Market risks such as commodity price are the risks inherent in the value of a traded security.

In this study, the researcher uses the mean reverting model (MR) to simulate the discount rate factor so as to examine the value of the mining investment opportunity and the optimal investment rule when *V* (the NPV of the mining project) is in a mean reverting process (Dixit and Pindyck, 1994). In other words, in the short term, commodity prices will fluctuate randomly up and down; in the long term, commodity prices will be drawn towards the marginal production costs.

This study applies the MR model to forecast the mining company's discount rates that necessary for the mining project investment. The characteristic of this study is to examine the optimal investment rule by comparing the present value that would result from immediate investment with the value of waiting. The MR model used to simulate interest rates in this study, therefore, is deemed more appropriate. Figure 7.1 shows the historical interest rates of the Asia-Pacific countries based on monthly data from January 2000 until November 2014. The purpose of Figure 5.1 is to show the historical interest rates movement in Asia-Pacific countries prior to conducting the interest rates simulation.[45]

Figure 5.2 Simulation of the Australia interest rates



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[45] Using Matlab application, the historical interest rates simulation shows similar outcome as replicated in Excel worksheet. As a reiteration, simulations of the past interest rates using Matlab will not show and the study will proceed to the section of interest forecasting.

The figure also shows that Australia, Malaysia and New Zealand had the least volatility in interest rate fluctuation, except during the period of the GFC. Countries such as Indonesia and Papua New Guinea, with their lack of transparency of government policies, had interest rate fluctuations that are either high or stayed constant. The higher interest rates can be attributable to these countries' macroeconomics uncertainty, high administration costs of banks in rural areas, limited bank competition, and low incentives to attract deposits for retail banks to increase their investment opportunity rather than purchasing government bonds (IMF, 2008).

Simulating interest rates can be a difficult task. Variation in the interest rates can change the entire project's revenue and may result in deferring or abandoning the investment project. The study uses Central Banks official cash rate (OCR) for interest rate simulations. The OCR is the standard rate of interest applied by the majority

Figure 5.3 Simulation of Indonesia interest rates

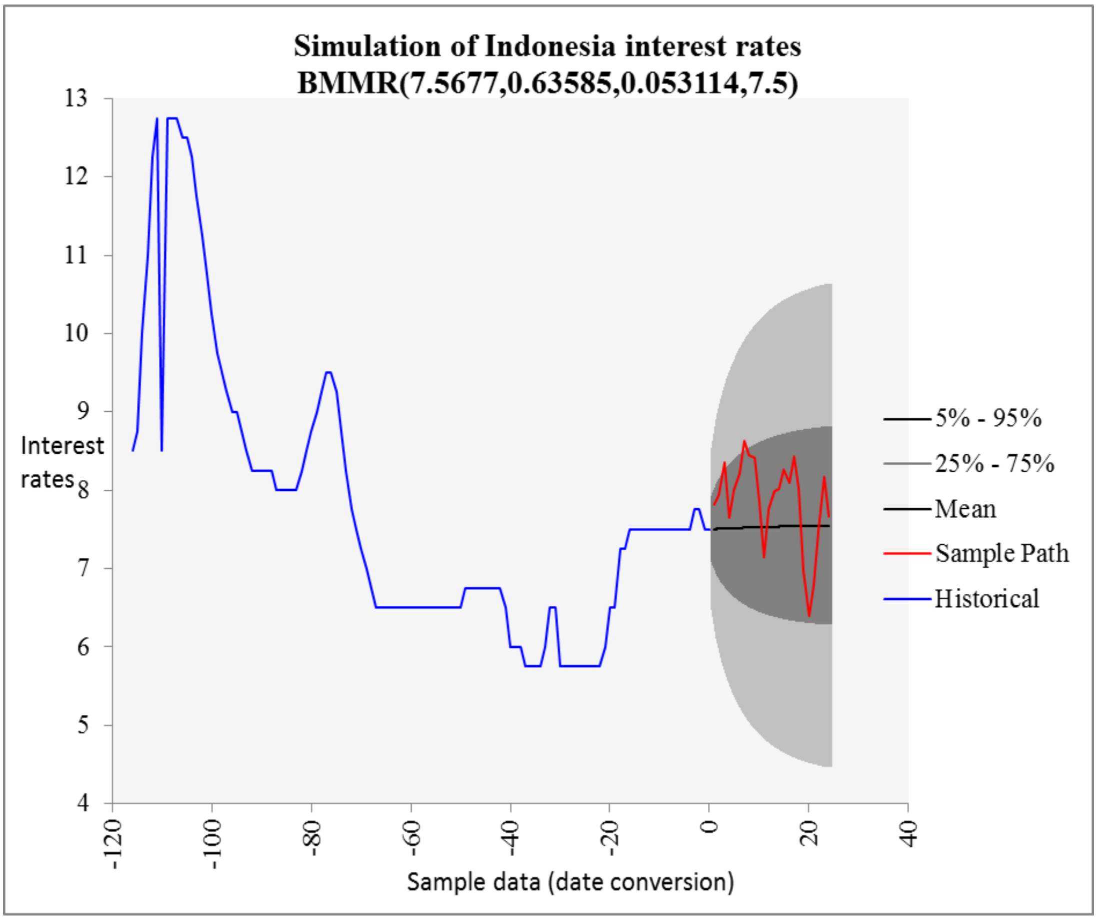

Figure 5.4 Simulation of Malaysia interest rates

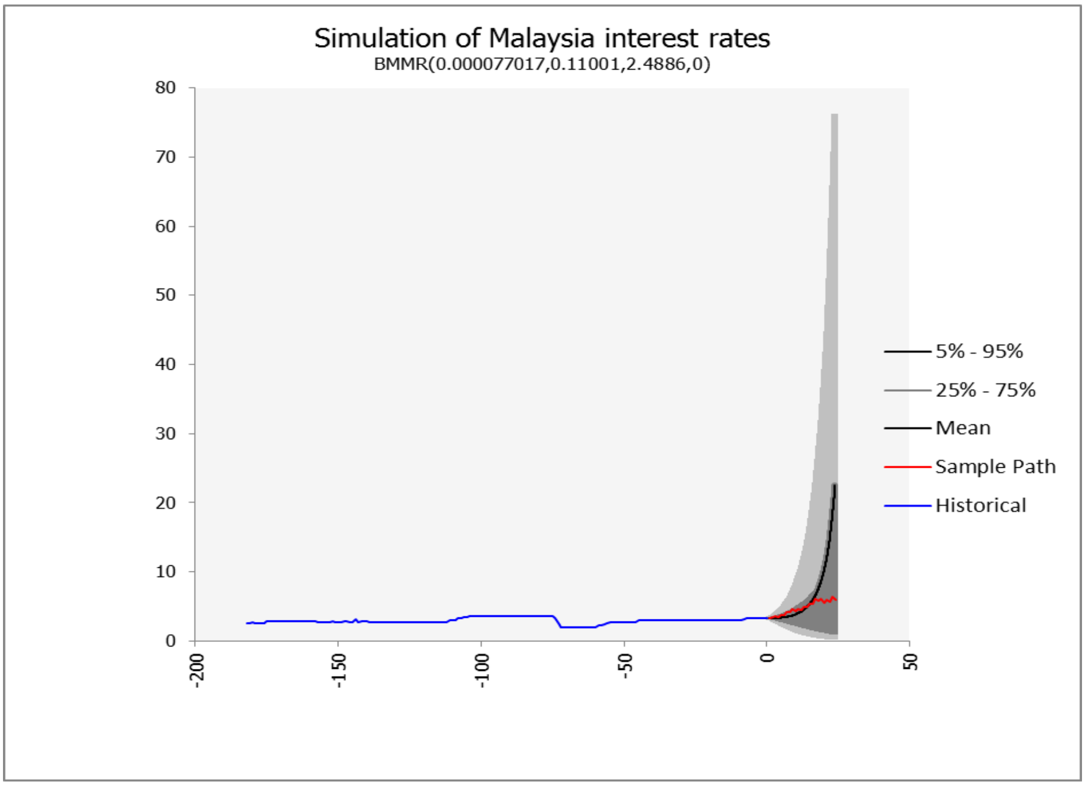

Figure 5.5 Simulation New Zealand interest rates

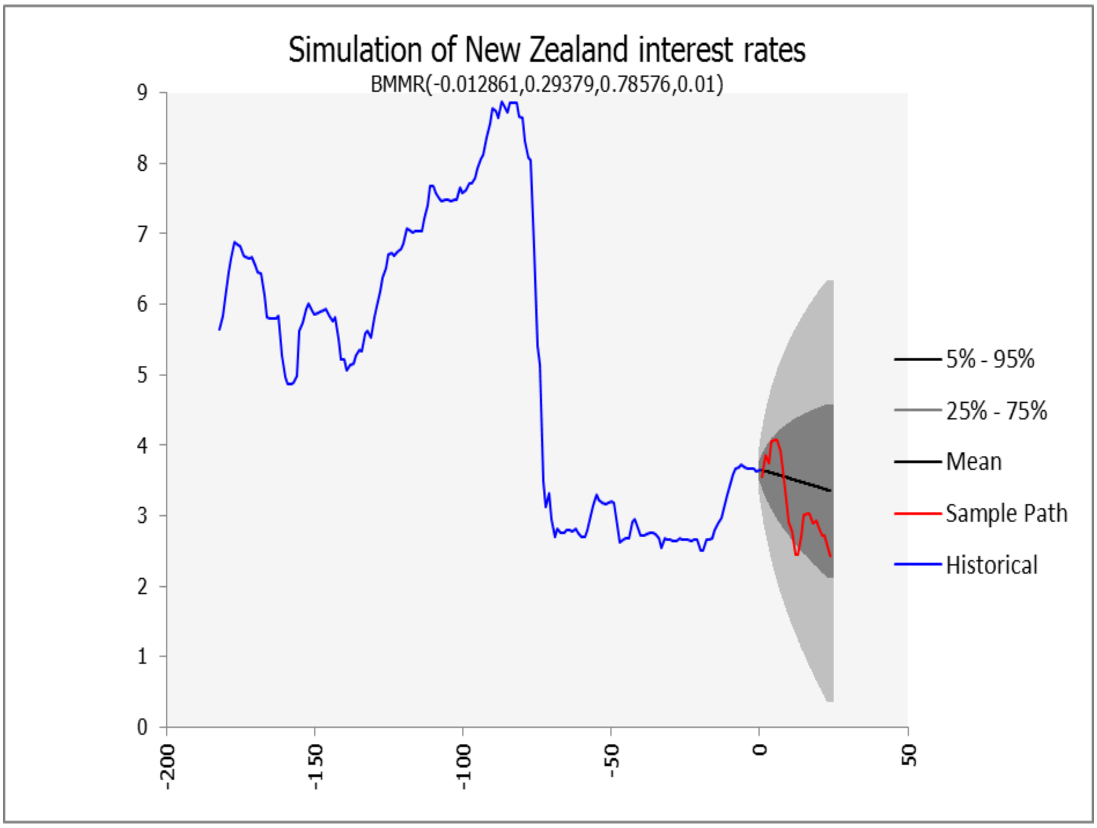

Figure 5.6 Simulation of Papua New Guinea interest rates

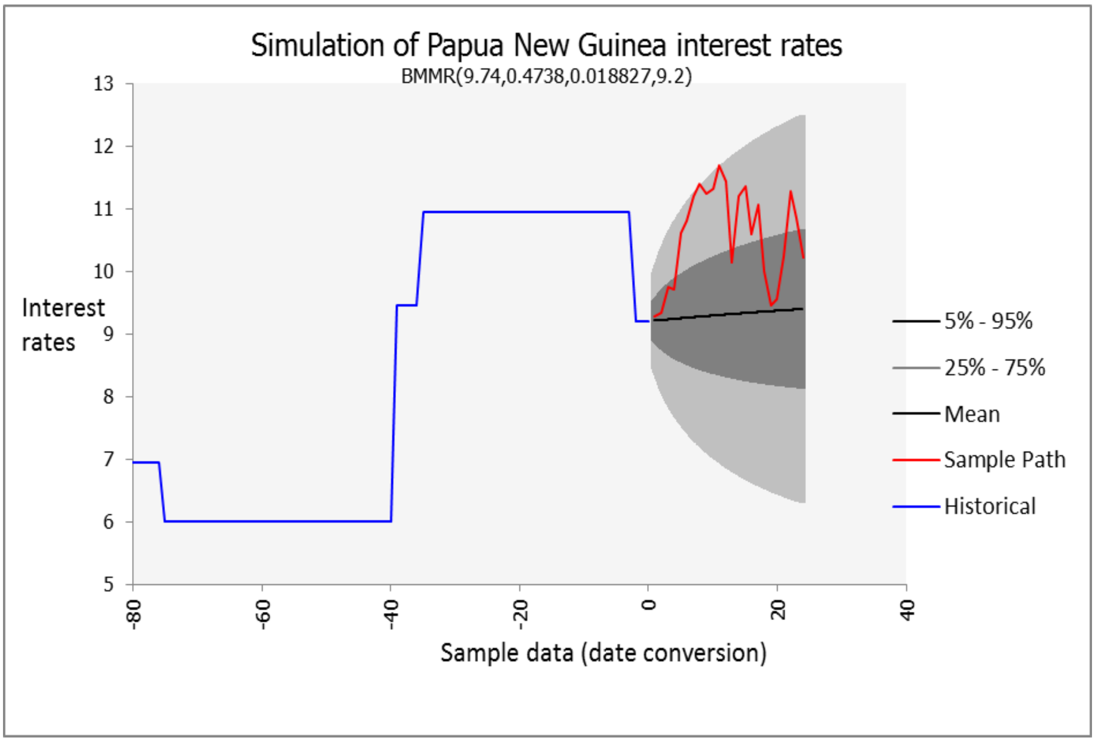

Table 5.1 Forecasted nominal interest rates of Asia-Pacific countries (in percent, per annum)

Date	Australia	Indonesia	Malaysia	New Zealand	Papua New Guinea
Apr-15	2.24	7.50	3.25	3.64	9.21
May-15	2.31	7.51	3.26	3.63	9.22
Jun-15	2.39	7.51	3.28	3.62	9.23
Jul-15	2.30	7.51	3.30	3.61	9.24
Aug-15	2.21	7.52	3.34	3.59	9.25
Sep-15	2.21	7.52	3.38	3.58	9.26
Oct-15	2.20	7.52	3.46	3.57	9.27
Nov-15	2.20	7.52	3.54	3.56	9.28
Dec-15	2.11	7.53	3.66	3.54	9.28
Jan-16	1.69	7.53	3.80	3.53	9.29
Feb-16	1.35	7.53	3.99	3.52	9.30
Mar-16	1.03	7.53	4.21	3.50	9.31
Apr-16	1.03	7.53	4.51	3.49	9.32
May-16	0.65	7.54	4.85	3.48	9.33
Jun-16	0.64	7.54	5.31	3.47	9.33
Jul-16	0.52	7.54	5.84	3.45	9.34
Aug-16	0.52	7.54	6.58	3.44	9.35
Sep-16	0.51	7.54	7.43	3.43	9.36
Oct-16	0.57	7.54	8.63	3.41	0
Nov-16	0.64	7.54	10.07	3.40	0
Dec-16	0.59	7.55	12.08	3.39	0
Jan-17	0.64	7.55	14.59	3.38	0
Feb-17	0.72	7.55	18.30	3.36	0
Mar-17	0.87	7.55	22.82	3.35	0

Central Banks in the region. The interest rate decisions made by each Central Bank are different. For example, the OCR in Australia and Malaysia are published on a daily basis, and the board meeting held on monthly basis. Interest rates for 90-day bills in New Zealand are published on a weekly basis. The OCR in New Zealand is reviewed eight times a year by the Reserve Bank of New Zealand. The OCR in Indonesia and Papua New Guinea are published on a monthly basis based on the monthly decision made by the monthly Central Bank's Board meeting. The inconsistency of data availability for discount rates measurement can change the simulation outcome significantly.

Indonesia and Papua New Guinea encounter simulation difficulties. During the analysis process, the researcher converts these data from stationary to non-stationary due to the availability of sample data in these two countries. Data access from the Bank of Indonesia is available from 2005 until the current date. Meanwhile, the Bank of Papua New Guinea provides data access from 2010 until September 2014 and the bank has not released current data since then.

By converting the historical interest rates into individual country basis (in blue solid line), Figures 5.2 -5.6 show that interest rates for Australia, Indonesia, Malaysia and New Zealand declined significantly over the period of GFC. Interest rates after the Global Financial Crisis (GFC) in these four countries are considerably stagnant, with interest rates dropping between 2 and 6 per cent. Papua New Guinea is the only country that kept the interest rate above 6 per cent during the GFC. It also had the highest rate in the region at 11 per cent for over two years.

Table 5.1 shows the forecasted nominal interest rates, percent per annum for Australia, Indonesia, Malaysia, New Zealand and Papua New Guinea. Australia, Malaysia and Papua New Guinea have the highest forecasted nominal interest rates. Given the last forecasts for Australia, Malaysia and Papua New Guinea, the researcher believes that in the current extreme uncertainty economic trend in particular Australia will have lower interest rates compared to others. The current lower commodity prices and crude oil prices are the major factors attributed to such a level forecasted nominal interest rates.

In the context of Malaysia, the introduction of a 6 percent goods and services tax in April is putting pressure on domestic prices, while import costs are rising after the ringgit slumped 15 percent this year also contributed to the extremely high forecasted nominal interest rates. A sharp declined in ringgit as the fastest inflation in a year fuelled speculation interest rate will increase.

Papua New Guinea currently experience similar political issues to Malaysia. Issues such as corruption, government cash flow problem and exchange rate rationing are the major problems, which have driven such extreme high forecasted interest rate.

Using this information, the following section discusses the simulation of interest rates that are necessary for the mining project investment analysis.

5.3.1 Interest rate simulation[46]

As noted above, the static discounted cash flow is commonly used valuation method for discounting future cash flows back to the present value. To discount back to the future value of money, Diez-Canedo *et.al.,* (2003) state that both future cash flows and payment dates must be identified. This is particularly important when applying appropriate discount rate factors to estimate the NPV.

The discount rate factor is the variable used in DCF analysis to determine the net present value of future cash flows. The discount factor in DCF shown in Table 5.1 considers not only the time value of money, but also the risks and market uncertainties in relation to the temporal structure of future cash flows. In other words, the greater the uncertainty of the mining project, the higher discount rate applies. As a result of this consensus estimation, risk adjusted discounted factor is applied for a risky mining project, with the adjustment based upon some measure of the mining project risk.

There are two ways to conduct the interest rate simulation in this study. Firstly, the researcher can use the Hull-White/Vasicek (HWV) Gaussian Diffusion Mean Reverting Model with drift available from Matlab. The basic model derived from

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[46] Simulation is a method used to examine the consequences of continuous risk of high volatility variables from a project investment (Damodaran, 2007).

Stochastic Differential Equations (SDE) mean-reverting with drift can be written as the following:

$$dS_t = a(L - S_t)dt + \sigma_t S_t dW_t \quad (5.1)$$

where σ_t is a volatility or standard deviation, W_t is a Wiener process, $W_t \equiv N\left(0, \sqrt{t}\right)$ and follows the normal distribution. Secondly, the researcher can use the non-geometric Brownian motion (BM) processes, which is BM with mean reversion (BMMR) available in the @Risk simulator for forecasting. These two approaches generate the same outcome regardless of which software is used.

One of the objectives for using the mean reversion (MR) model in this study is to simulate future interest rates. Based on historical interest rates, the final outcome of this model tends to fluctuate interest rates in such a way that they revert back to the long-term equilibrium point (Swishchuk, 2005). An MR process follows the concept of microeconomics.

Figures 5.2-5.6 (in red solid line) above show the simulation of interest rates in the Asia-Pacific region. The figures show that simulation of interest rates for these Asia-Pacific countries reverted back to the equilibrium point, which is from day zero. Interest rates are calculated based on the number of days over the life of the project.

Table 5.1 summarises and forecasts the future interest rates for mining project investment. The table shows that interest rate fluctuations in Asia-Pacific countries are steady, except in Australia and Malaysia. The volatile interest rate fluctuations can attributed to factors such as Australia’s extreme low record of current commodity prices, such as iron ore, which cause the economy to flatten, and uncertainty of Malaysia’s economic conditions, such as political tension and a large stock of domestic debt held abroad (The World Bank, 2015). These conditions impact mining investment decisions directly and indirectly.

These figures also show that interest rates fluctuation in Indonesia, New Zealand and Papua New Guinea are steady when simulations are conducted, due to their Central banks’ interest rate decisions. However, interest rates variation for Australia and Malaysia are unstable with Malaysia’s being the most volatile among these five Asia-

Pacific countries. Variation of these interest rates are attributed to the fast economic growth in Malaysia and the Central Bank of Malaysia's attempt to curb the risk of financial imbalances in that country (Chong, 2014).

Having discussed the simulation of interest rates using @Risk simulator, the researcher next presents the empirical evidence for a deterministic cash flow analysis in mining investment decision making.

5.4 The empirical results

McDonald and Siegel (1986) state that the optimal NPV rule of investment in the project should be invested when the value of the project, *V* is greater than *I*. The model developed by McDonald and Siegel is one of the most basic continuous-time of irreversible investment models used in mining project evaluation. This method is usually applied in static discounted cash flow analysis, in which the decision is based on positive or negative values of NPV.

One of the primary rules of the traditional capital budgeting is that the allocation of resources among mining investment projects should be on a long-term basis. The concept of traditional capital budgeting theory is to make an immediate investment outlay in order to help the mining firm achieves its investment objective. In applying this simple investment rule, the theory implies a simple concept in which mining firm should maximise their investment revenue or minimise their capital investment expenditure when an investment project is being considered. The following section discusses the analysis of the static DCF in which the changes in tax rates is the main issue for mining investors to determine their investment decisions.

5.4.1 The analysis of DCF

In measuring the potential wealth creation by companies and governments investing in the mining industry, the NPV of the mining investment projects is calculated using the following equation:

$$NPV = \sum_{t=0}^{t} (\frac{1}{1+i})^{\mathrm{t}}(R_t - \mathrm{OC}_t - \mathrm{T_t} - \mathrm{K_t}) \qquad (5.2)$$

where;

NPV
$= the\ expected\ present\ value\ of\ all\ projects\ based\ on\ after\ tax\ cash\ flows$
$i = discount\ rate\ for\ mining\ projects\ invested\ over\ the\ period\ of\ t$
$R = revenues\ from\ mine\ \ output$
$OC = operating\ cost\ associated\ with\ the\ output\ in\ mining$
$T = Tax\ flow\ incurred\ in\ the\ mining\ project$[47]
$K = capital\ expendure\ for\ mining\ exploration\ and\ development$
$t = years\ since\ beginning\ of\ mining\ investment$

A deterministic DCF, without managerial flexibility, is used to evaluate a mining project's investment in the five Asia-Pacific countries and is discussed in this section. This study applies to mining projects that are currently operating in these countries.

In order to demonstrate the DCF calculation, the researcher initially has to establish the year the mining project should commence operation. In other words, the total years of mining are calculated using the following formula:

$$\frac{Total\ mineral\ reserves}{Total\ production} \qquad (5.3)$$

The information in equation (3) is obtained and calculated by using the mining companies' annual reports. The DCF calculation can then be carried out by establishing how many tonnes of minerals are mined each year after the mining project commences. The mineral production is calculated from information available in the annual reports. The average ore grade and recovery are based on the assumption demonstrated in the webinar's tutorial, which is shown in the Matlab and also data available in the mining company's annual report. In practice, the estimation of these mineral reserves complies with the Joint Ore Reserves Committee (JORC) code.[48]

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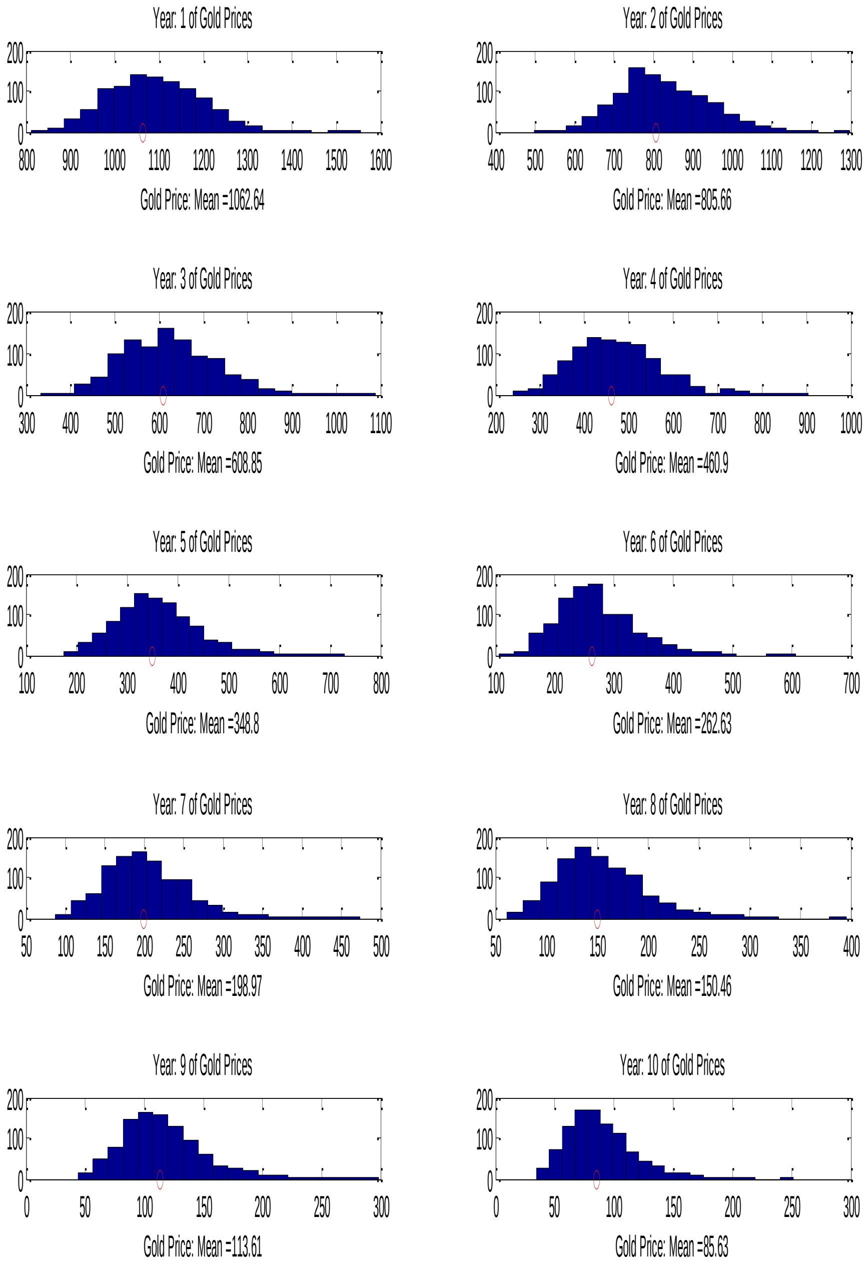
[47] Tax flow (t) equals the amount of tax rate multiplies taxable revenue; tax revenue includes royalties and profit tax.

[48] Recovery in mining defines as the percentage of precious of valuable metal in the ore that is recovered by metallurgical extraction. The recovery and ore grade are based on the researcher own estimation by applying information contain in the mining company's annual report.

Figure 5.7 Forecasted gold prices[49]



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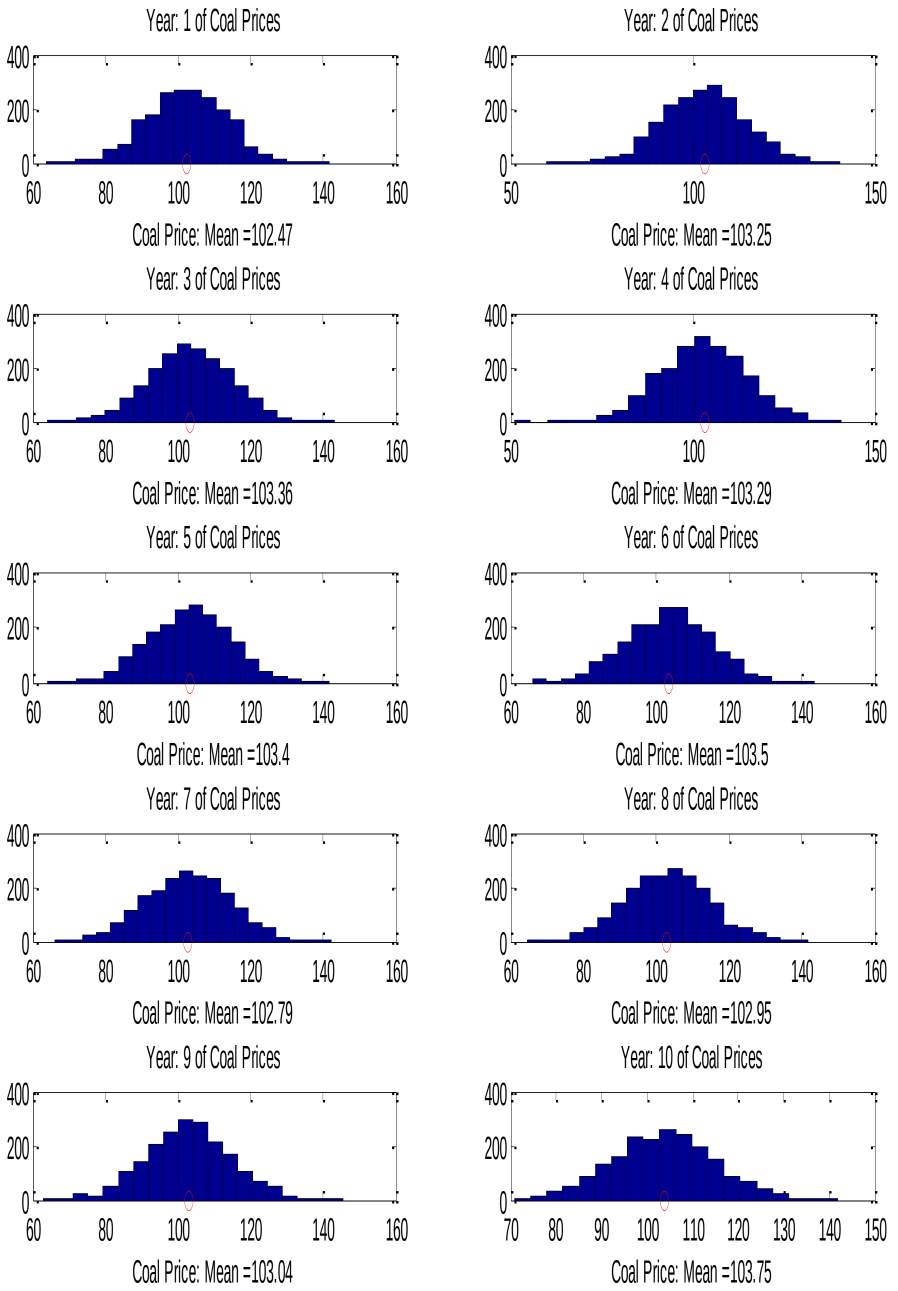
[49] The researcher applies the Matlab to find the forecasted commodity prices to calculate DCF. In the next chapter, timing flexibility in commodity price is discussed.

Figure 5.8 Forecasted coal prices



The HWV Gaussian Diffusion Mean Reverting model is used to forecast coal and gold prices. The model simulates the historical coal and gold prices from 1997 to 2013. The calibrate parameters required to simulate the historical data is the discrete-time form model shown in equation (5.1). These variables can then use Monte Carlo simulation to simulate the SDE object in order to generate multiple log price paths using 1000 iterations. The number of years affected for the future forecasted mineral depends on the life of the mining project. These future forecasted commodity prices are applied to the DCF model for the static mining investment analysis. Figures 5.7 and 5.8 show the forecasted 10 year periods of gold and coal prices with an annual interest rate of 12 percent. These two figures provide an example of the method used to forecast the commodity prices that are needed for DCF analysis.

Estimating cost expenditures in the DCF analysis is straightforward. In general, capital cost expenditures are applied into the DCF model based on the data collection from each mining company's annual report and the allocation of each component of the cost of investments in the entire mining process. Mining costs, royalties, refining and other costs, as well as contingencies are the major cost payment components used in the DCF analysis in this study. In most cases, data available for capital cost expenditures in the annual report are in the total amount of the entire project investment. When conducting DCF analysis, the total cost expenditures in this study are applied then divided by the number of years the mining project operates.[50]

Simulating the discounting factor is also a necessary step in determining the NPV. Matlab is used to find the discounting factor that requires the DCF analysis.[51] It comprises several stages prior to determining the discounting factor. Firstly, interest rate historical data needs to be simulated by using Microsoft access and excel work files. Secondly, the script needs to be well written using the codes in Matlab.

As mentioned early, the interest rate simulation uses the HWV mean reversion model. Simulation of the interest rates based on the number of years, specifically as *y* of the operating mining project is the time, or specifically, *t*y*. The letter *t* is represented by the number of workday days in a year, which is 252 working days using 1000 iterations.

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[50] Due to some countries not indicating royalty data in their annual report, mining royalties are only shown in Malaysia and Indonesia. However, tax policy is one of the main concerns in which is examined throughout the thesis. Therefore, the royalty rate will not be examined in detail in the analysis and is only minor data.

[51] The complexity of the Matlab in regard the scripts writing has made the researcher to switch to @Risk simulator to conduct the next step of the analysis.

The mean of the interest rate is used in this study to determine the discounting factors. The codes required for determining the discounting factor are as follows:

Table 5.2 The discounting factors calculation

```
r = mean (simIR, 2)/100;
c= 0.07;
discFactor = exp(-(r+c).*(1:size(simIR,1)’/252);
discFactory = discFactor(252:252:end);
```

Table 5.2 shows the Matlab codes used to determine the discount factors. The letter *r* is a mean of interest rate discount factor and the letter *c* is the mining cost discount factor, which is 7 percent. The seven percent interest rate that the mining cost incurs is to ensure the precaution of the mining investors in their project investment in the event of unforseen economic conditions. These two variables are necessary in order to find the discounting factor for calculating NPV.

After conducting these essential steps the NPV can be calculated. Applying a simple excel form to calculate the DCF, Figures 5.9 to 5.23 show the NPV for the mining investment analysis in the Asia-Pacific region.

The analysis of these figures is to examine the mining investment by considering the variation of tax flows in this region. The fiscal rates that apply in this study is a tax flow range between 25 and 35 percent. Importantly, the objective of this analysis is to discuss the investment behaviour in the mining industry as a result of the variation in fiscal tax flows in which flexibility is not taken into account. The DCF tables of these five countries are Tables 5.3-5.5 for Australia, Tables 5.6-5.8 for Indonesia, Tables 5.9-5.11 for Malaysia, Tables 5.12-5.14 for New Zealand, and Tables 5.15-5.17 for Papua New Guinea.[52]

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[52] The DCF for Australia, Malaysia and New Zealand has split into two tables for each tax flow. This is because these countries have mining projects over twenty-year periods, and it is difficult to demonstrate the DCF calculation into a single form table.

Table 5.3 NPV of Daunia coal mine project investment in Australia at 25 percent tax flow

Production Period	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
oal Production (000's tonnes)		45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00
Waste (tonnes)											
Stripping ratio											
Average Ore grade		0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Recovery		0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Coal produced (tonnes)		26190.00	26190.00	26190.00	26190.00	26190.00	26190.00	26190.00	26190.00	26190.00	26190.00
oal Price (US$/ metric tonne)		81.12	72.75	65.32	59.00	53.29	48.03	42.91	38.72	34.85	31.63
Sales revenue		2124532.80	1905322.50	1710730.80	1545210.00	1395665.10	1257905.70	1123812.90	1014076.80	912721.50	828389.70
Capital gain -Salvage Value											
Less: Mining Cost (000's)		-13630.00	-13630.00	-13630.00	-13630.00	-13630.00	-13630.00	-13630.00	-13630.00	-13630.00	-13630.00
Processing Cost		-3190.00	-3190.00	-3190.00	-3190.00	-3190.00	-3190.00	-3190.00	-3190.00	-3190.00	-3190.00
Royalty											
Refining Cost and other cost		-8700.00	-8700.00	-8700.00	-8700.00	-8700.00	-8700.00	-8700.00	-8700.00	-8700.00	-8700.00
Depreciation		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operating Profit before Tax		2099012.80	1879802.50	1685210.80	1519690.00	1370145.10	1232385.70	1098292.90	988556.80	887201.50	802869.70
Less: Income Tax (25%)		-524753.20	-469950.63	-421302.70	-379922.50	-342536.28	-308096.43	-274573.23	-247139.20	-221800.38	-200717.43
Operating Profit After Tax		1574259.60	1409851.88	1263908.10	1139767.50	1027608.83	924289.28	823719.68	741417.60	665401.13	602152.28
Depreciation											
Capital Expenditure	-50000.00										
ndiscounted Net Cash Flow	-50000.00	1574259.60	1409851.88	1263908.10	1139767.50	1027608.83	924289.28	823719.68	741417.60	665401.13	602152.28
Discount factor (12%)	1.10	0.89	0.79	0.70	0.62	0.55	0.49	0.43	0.38	0.34	0.30
Cash Flow Present Value	-50000.00	1398764.40	1111521.35	883511.04	706238.76	563908.76	449479.25	355244.02	283073.67	224762.94	179726.18
Cumulative Cash Flow	-50000.00	1348764.40	1061521.35	833511.04	656238.76	513908.76	399479.25	305244.02	233073.67	174762.94	129726.18
et Present Value ($ Million	5766863.09										

Production Period	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
oal Production (000's tonnes)	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00
Waste (tonnes)										
Stripping ratio										
Average Ore grade	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Recovery	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Coal produced (tonnes)	26190.00	26190.00	26190.00	26190.00	26190.00	26190.00	26190.00	26190.00	26190.00	26190.00
oal Price (US$/ metric tonne)	28.14	25.48	23.07	20.35	18.12	16.23	14.61	13.08	11.57	10.48
Sales revenue	736986.60	667321.20	604203.30	532966.50	474562.80	425063.70	382635.90	342565.20	303018.30	274471.20
Capital gain -Salvage Value										
Less: Mining Cost (000's)	-13630.00	-13630.00	-13630.00	-13630.00	-13630.00	-13630.00	-13630.00	-13630.00	-13630.00	-13630.00
Processing Cost	-3190.00	-3190.00	-3190.00	-3190.00	-3190.00	-3190.00	-3190.00	-3190.00	-3190.00	-3190.00
Royalty										
Refining Cost and other cost	-8700.00	-8700.00	-8700.00	-8700.00	-8700.00	-8700.00	-8700.00	-8700.00	-8700.00	-8700.00
Depreciation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operating Profit before Tax	711466.60	641801.20	578683.30	507446.50	449042.80	399543.70	357115.90	317045.20	277498.30	248951.20
Less: Income Tax (25%)	-177866.65	-160450.30	-144670.83	-126861.63	-112260.70	-99885.93	-89278.98	-79261.30	-69374.58	-62237.80
Operating Profit After Tax	533599.95	481350.90	434012.48	380584.88	336782.10	299657.78	267836.93	237783.90	208123.73	186713.40
Depreciation										
Capital Expenditure										
ndiscounted Net Cash Flow	533599.95	481350.90	434012.48	380584.88	336782.10	299657.78	267836.93	237783.90	208123.73	186713.40
Discount factor (12%)	0.26	0.23	0.21	0.18	0.16	0.14	0.13	0.11	0.10	0.09
sh Flow Present Value (NPV)	141363.21	113057.92	89715.27	70000.56	54957.18	43285.20	34256.96	26791.42	20749.44	16455.56
Cumulative Cash Flow	91363.21	63057.92	39715.27	20000.56	4957.18	-6714.80	-15743.04	-23208.58	-29250.56	-33544.44

Table 5.4 NPV of Daunia coal mine project investment in Australia at 30 percent tax flow

Production Period	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Coal Production (000's tonnes)		45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000
Waste (tonnes)																					
Stripping ratio																					
Average Ore grade		0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Recovery		0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Coal produced (tonnes)		26190	26190	26190	26190	26190	26190	26190	26190	26190	26190	26190	26190	26190	26190	26190	26190	26190	26190	26190	26190
Coal Price (US$/ metric tonne)		81.12	72.75	65.32	59	53.29	48.03	42.91	38.72	34.85	31.63	28.14	25.48	23.07	20.35	18.12	16.23	14.61	13.08	11.57	10.48
Sales revenue		2124532.8	1905322.5	1710730.8	1545210	1395665.1	1257905.7	1123812.9	1014076.8	912721.5	828389.7	736986.6	667321.2	604203.3	532966.5	474562.8	425063.7	382635.9	342565.2	303018.3	274471.2
Capital gain -Salvage Value																					
Less: Mining Cost (000's)		-13630	-13630	-13630	-13630	-13630	-13630	-13630	-13630	-13630	-13630	-13630	-13630	-13630	-13630	-13630	-13630	-13630	-13630	-13630	-13630
Processing Cost		-3190	-3190	-3190	-3190	-3190	-3190	-3190	-3190	-3190	-3190	-3190	-3190	-3190	-3190	-3190	-3190	-3190	-3190	-3190	-3190
Royalty																					
Refining Cost and other cost		-8700	-8700	-8700	-8700	-8700	-8700	-8700	-8700	-8700	-8700	-8700	-8700	-8700	-8700	-8700	-8700	-8700	-8700	-8700	-8700
Depreciation		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Operating Profit before Tax		2099012.8	1879802.5	1685210.8	1519690	1370145.1	1232385.7	1098292.9	988556.8	887201.5	802869.7	711466.6	641801.2	578683.3	507446.5	449042.8	399543.7	357115.9	317045.2	277498.3	248951.2
Less: Income Tax (30%)		-629703.84	-563940.75	-505563.24	-455907	-411043.53	-369715.71	-329487.87	-296567.04	-266160.45	-240860.91	-213439.98	-192540.36	-173604.99	-152233.95	-134712.84	-119863.11	-107134.77	-95113.56	-83249.49	-74685.36
Operating Profit After Tax		1469308.96	1315861.75	1179647.56	1063783	959101.57	862669.99	768805.03	691989.76	621041.05	562008.79	498026.62	449260.84	405078.31	355212.55	314329.96	279680.59	249981.13	221931.64	194248.81	174265.84
Depreciation																					
Capital Expenditure	-50000																				
Undiscounted Net Cash Flow	-50000	1469308.96	1315861.75	1179647.56	1063783	959101.57	862669.99	768805.03	691989.76	621041.05	562008.79	498026.62	449260.84	405078.31	355212.55	314329.96	279680.59	249981.13	221931.64	194248.81	174265.84
Discount factor (12%)	1.1	0.88852207	0.78839584	0.69903108	0.61963406	0.54875819	0.48629716	0.4312681	0.38180059	0.33778564	0.29847298	0.26492358	0.23487631	0.20671127	0.18392891	0.16318319	0.14444876	0.12790231	0.1126713	0.0996976	0.08813273
Cash Flow Present Value	-50000	1305513.44	1037419.93	824610.304	659156.174	526314.838	419513.963	331561.082	264202.096	209778.748	167744.436	131938.994	105520.729	83734.2527	65333.8576	51293.3665	40399.5154	31973.1634	25005.326	19366.1399	15358.5235
Cumulative Cash Flow	-50000	1255513.44	987419.926	774610.304	609156.174	476314.838	369513.963	281561.082	214202.096	159778.748	117744.436	81938.9944	55520.7288	33734.2527	15333.8576	1293.36647	-9600.48458	-18026.8366	-24994.674	-30633.86	-34641.476
Net Present Value ($ Million)	5315738.88																				

Table 5.5 NPV of Daunia coal mine project investment in Australia at 35 percent tax flow

Production Period	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Coal Production (000's tonnes)		45000	45000	45000	45000	45000	45000	45000	45000	45000	45000
Waste (tonnes)											
Stripping ratio											
Average Ore grade		0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Recovery		0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Coal produced (tonnes)		26190	26190	26190	26190	26190	26190	26190	26190	26190	26190
Coal Price (US$/ metric tonne)		81.12	72.75	65.32	59	53.29	48.03	42.91	38.72	34.85	31.63
Sales revenue		2124532.8	1905322.5	1710730.8	1545210	1395665.1	1257905.7	1123812.9	1014076.8	912721.5	828389.7
Capital gain - Salvage Value											
Less: Mining Cost (000's)		-13630	-13630	-13630	-13630	-13630	-13630	-13630	-13630	-13630	-13630
Processing Cost		-3190	-3190	-3190	-3190	-3190	-3190	-3190	-3190	-3190	-3190
Royalty											
Refining Cost and other cost		-8700	-8700	-8700	-8700	-8700	-8700	-8700	-8700	-8700	-8700
Depreciation		0	0	0	0	0	0	0	0	0	0
Operating Profit before Tax		2099012.8	1879802.5	1685210.8	1519690	1370145.1	1232385.7	1098292.9	988556.8	887201.5	802869.7
Less: Income Tax (35%)		-734654.48	-657930.875	-589823.78	-531891.5	-479550.785	-431334.995	-384402.515	-345994.88	-310520.53	-281004.4
Operating Profit After Tax		1364358.32	1221871.63	1095387.02	987798.5	890594.315	801050.705	713890.385	642561.92	576680.975	521865.305
Depreciation											
Capital Expenditure	-50000										
Undiscounted Net Cash Flow	-50000	1364358.32	1221871.63	1095387.02	987798.5	890594.315	801050.705	713890.385	642561.92	576680.975	521865.305
Discount factor (12%)	1	0.88852207	0.78839584	0.69903108	0.61963406	0.54875819	0.48629716	0.4312681	0.38180059	0.33778564	0.29847298
Cash Flow Present Value	-50000	1212262.48	963318.503	765709.568	612073.59	488720.921	389548.679	307878.148	245330.518	194794.552	155762.691
Cumulative Cash Flow	-50000	1162262.48	913318.503	715709.568	562073.59	438720.921	339548.679	257878.148	195330.518	144794.552	105762.691
Net Present Value ($ Million)	4865711.71										

Production Period	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Coal Production (000's tonnes)	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000
Waste (tonnes)										
Stripping ratio										
Average Ore grade	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Recovery	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Coal produced (tonnes)	26190	26190	26190	26190	26190	26190	26190	26190	26190	26190
Coal Price (US$/ metric tonne)	28.14	25.48	23.07	20.35	18.12	16.23	14.61	13.08	11.57	10.48
Sales revenue	736986.6	667321.2	604203.3	532966.5	474562.8	425063.7	382635.9	342565.2	303018.3	274471.2
Capital gain - Salvage Value										
Less: Mining Cost (000's)	-13630	-13630	-13630	-13630	-13630	-13630	-13630	-13630	-13630	-13630
Processing Cost	-3190	-3190	-3190	-3190	-3190	-3190	-3190	-3190	-3190	-3190
Royalty										
Refining Cost and other cost	-8700	-8700	-8700	-8700	-8700	-8700	-8700	-8700	-8700	-8700
Depreciation	0	0	0	0	0	0	0	0	0	0
Operating Profit before Tax	711466.6	641801.2	578683.3	507446.5	449042.8	399543.7	357115.9	317045.2	277498.3	248951.2
Less: Income Tax (35%)	-249013.31	-224630.42	-202539.155	-177606.275	-157164.98	-139840.295	-124990.565	-110965.82	-97124.405	-87132.92
Operating Profit After Tax	462453.29	417170.78	376144.145	329840.225	291877.82	259703.405	232125.335	206079.38	180373.895	161818.28
Depreciation										
Capital Expenditure										
Undiscounted Net Cash Flow	462453.29	417170.78	376144.145	329840.225	291877.82	259703.405	232125.335	206079.38	180373.895	174265.84
Discount factor (12%)	0.26492358	0.23487631	0.20671127	0.18392891	0.16318319	0.14444876	0.12790231	0.1126713	0.0996976	0.08813273
Cash Flow Present Value	122514.781	97983.5339	77753.2347	60667.1535	47629.5546	37513.8357	29689.366	23219.2312	17982.8442	15358.5235
Cumulative Cash Flow	72514.7806	47983.5339	27753.2347	10667.1535	-2370.44542	-12486.1643	-20310.634	-26780.7688	-32017.156	-34641.476

Table 5.6 NPV of Tembang gold mine project investment in Indonesia of at 25 percent tax flow

Production Period	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
gold Production ('000 o/z)		146	146	146	146	146	249	249	249
Waste (tonnes)									
Stripping ratio									
Average Ore grade		0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Recovery		0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
gold produced (ounces)		89.79	89.79	89.79	89.79	89.79	153.135	153.135	153.135
gold Price (US$/oz)		1447	1501	1547	1609	1662	1715	1766	1824
Sales revenue		129926.1	134775	138905.1	144472	149231	262627	270436	279318.2
Capital gain -Salvage Value									
Less: Mining Cost (000's)		-9520	-9520	-9520	-9520	-9520	-8750	-8750	-8750
Processing Cost		-2720	-2720	-2720	-2720	-2720	-2500	-2500	-2500
Royalty (per o/z)		-431	-431	-431	-431	-431	-431	-431	-431
Refining Cost and other cost		-1360	-1360	-1360	-1360	-1360	-1250	1250	1250
Depreciation		-	-	-	-	-	-	-	-
Operating Profit before Tax		115895.1	120744	124874.1	130441	135200	249696	260005	268887.2
Less: Income Tax (25%)		-28973.8	-30186	-31218.5	-32610	-33800	-62424	-65001.4	-67221.8
Operating Profit After Tax		86921.35	90557.8	93655.6	97830.8	101400	187272	195004	201665.4
Depreciation		-	-	-	-	-	-	-	-
Capital Expenditure	-40000								
Undiscounted Net Cash Flow	-40000	86921.35	90557.8	93655.6	97830.8	101400	187272	195004	201665.4
Discount factor (12%)	1	0.9315	0.8678	0.8083	0.753	0.7014	0.6534	0.6087	0.567
Cash Flow Present Value	-40000	80967.24	78586.1	75701.82	73666.6	71121.9	122363	118699	114344.3
Cumulative Cash Flow	-40000	40967.24	38586.1	35701.82	33666.6	31121.9	82363.3	78699	74344.3
Net Present Value ($ Million)	415450.28								

Table.5.7 NPV of Tembang gold mine project investment in Indonesia of at 30 percent tax flow

Production Period	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Gold Production (000's o/z)		146	146	146	146	146	249	249	249
Waste (tonnes)									
Stripping ratio									
Average Ore grade		0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Recovery		0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
Gold produced (o/z)		89.79	89.79	89.79	89.79	89.79	153.135	153.135	153.135
gold Price (US$ o/z)		1447	1501	1547	1609	1662	1715	1766	1824
Sales revenue		129926.1	134775	138905.1	144472	149231	262627	270436	279318.2
Capital gain -Salvage Value									
Less: Mining Cost (000's)		-9520	-9520	-9520	-9520	-9520	-8750	-8750	-8750
Processing Cost		-2720	-2720	-2720	-2720	-2720	-2500	-2500	-2500
Royalty		-431	-431	-431	-431	-431	-431	-431	-431
Refining Cost and other cost		-1360	-1360	-1360	-1360	-1360	-1250	-1250	1250
Depreciation		-	-	-	-	-	-	-	-
Operating Profit before Tax		115895.1	120744	124874.1	130441	135200	249696	257505	268887.2
Less: Income Tax (30%)		-34768.5	-36223	-37462.2	-39132	-40560	-74909	-77251.6	-80666.2
Operating Profit After Tax		81126.59	84520.7	87411.89	91308.8	94640	174787	180254	188221.1
Depreciation									
Capital Expenditure	-40000								
Undiscounted Net Cash Flow	-40000	81126.59	84520.7	87411.89	91308.8	94640	174787	180254	188221.1
Discount factor (12%)	1	0.9315	0.8678	0.8083	0.753	0.7014	0.6534	0.6087	0.567
Cash Flow Present Value (NPV)	-40000	75569.42	73347	70655.03	68755.5	66380.5	114206	109720	106721.3
Cumulative Cash Flow	-40000	35569.42	33347	30655.03	28755.5	26380.5	74205.7	69720.5	66721.35
Net Present Value ($ Million)	365355.03								

Table 5.8 NPV of Tembang gold mine project investment in Indonesia of at 35 percent tax flow

Production Period	0	1	2	3	4	5	6	7	8
	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Gold Production (000's o/z)		146	146	146	146	146	249	249	249
Waste (tonnes)									
Stripping ratio									
Average Ore grade		0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Recovery		0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
Gold produced (o/z)		89.79	89.79	89.79	89.79	89.79	153.135	153.135	153.135
Gold Price (US$ o/z)		1447	1501	1547	1609	1662	1715	1766	1824
Sales revenue		129926.1	134775	138905.1	144472	149231	262627	270436	279318.2
Capital gain -Salvage Value									
Less: Mining Cost (000's)		-9520	-9520	-9520	-9520	-9520	-8750	-8750	-8750
Processing Cost		-2720	-2720	-2720	-2720	-2720	-2500	-2500	-2500
Royalty		-431	-431	-431	-431	-431	-431	-431	-431
Refining Cost and other cost		-1360	-1360	-1360	-1360	-1360	-1250	-1250	1250
Depreciation		-	-	-	-	-	-	-	-
Operating Profit before Tax		115895.1	120744	124874.1	130441	135200	249696	257505	268887.2
Less: Income Tax (35%)		-40563.3	-42260	-43705.9	-45654	-47320	-87393	-90126.9	-94110.5
Operating Profit After Tax		75331.83	78483.5	81168.18	84786.7	87880	162302	167379	174776.7
Depreciation									
Capital Expenditure	-40000								
Undiscounted Net Cash Flow	-40000	75331.83	78483.5	81168.18	84786.7	87880	162302	167379	174776.7
Discount factor (12%)	1	0.9315	0.8678	0.8083	0.753	0.7014	0.6534	0.6087	0.567
Cash Flow Present Value (NPV)	-40000	70171.6	68107.9	65608.24	63844.4	61639	106048	101883	99098.39
Cumulative Cash Flow	-40000	30171.6	28107.9	25608.24	23844.4	21639	66048.2	61883.3	59098.39
Net Present Value ($ Million)	316401.10								

Table 5.9 NPV of Mengapur gold mine project investment in Malaysia at 25 percent tax flow

Production Period	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12
gold Production (000's o/z)		52982	52982	52982	52982	52982	52982	52982	52982	52982	52982	52982	52982
Waste (tonnes)													
Stripping ratio													
Average Ore grade		0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Recovery		0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
gold produced (ounces)		29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064
gold Price (US$/oz)		1455	1502	1554	1610	1658	1720	1791	1837	1902	1960	2029	2093
Sales revenue		42553023.12	43927588.13	45448383.46	47086163.04	48489974.11	50303230.1	52379700.6	53725019.6	55626013.7	57322285.44	59340263.86	61212011.95
Capital gain -Salvage Value													
Less: Mining Cost (000's)		-5934	5934	5934	5934	5934	5934	5934	5934	5934	5934	5934	5934
Processing Cost		-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967
Royalty		-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132
Refining Cost and other cost		-159	-159	-159	-159	-159	-159	-159	-159	-159	-159	-159	-159
Depreciation		-	-	-	-	-	-	-	-	-	-	-	-
Operating Profit before Tax		42531831.12	43918264.13	45439059.46	47076839.04	48480650.11	50293906.1	52370376.6	53715695.6	55616689.7	57312961.44	59330939.86	61202687.95
Less: Income Tax (25%)		-10632957.8	-10979566	-11359764.9	-11769209.8	-12120162.5	-12573476.5	-13092594.2	-13428923.9	-13904172.4	-14328240.4	-14832735	-15300671.99
Operating Profit After Tax		31898873.34	32938698.1	34079294.59	35307629.28	36360487.58	37720429.6	39277782.5	40286771.7	41712517.3	42984721.08	44498204.89	45902015.96
Depreciation													
Capital Expenditure	-13670032												
Undiscounted Net Cash Flow	-13670032	31898873.34	32938698.1	34079294.59	35307629.28	36360487.58	37720429.6	39277782.5	40286771.7	41712517.3	42984721.08	44498204.89	45902015.96
Discount factor (12%)	1	0.9054	0.8201	0.7433	0.6738	0.6098	0.5523	0.5007	0.4531	0.4098	0.3715	0.3363	0.3042
ash Flow Present Value (NPV	-13670032	28881239.92	27013026.31	25331139.67	23790280.61	22172625.33	20832993.2	19666385.7	18253936.2	17093789.6	15968823.88	14964746.31	13963393.26
Cumulative Cash Flow	-13670032	15211207.51	13342993.9	11661107.26	10120248.2	8502592.919	7162960.84	5996353.27	4583903.84	3423757.18	2298791.471	1294713.895	293360.8462
Net Present Value ($ Million)	40192941												

Production Period	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23
gold Production (000's o/z)	52982	52982	52982	52982	52982	52982	52982	52982	52982	52982	52982
Waste (tonnes)											
Stripping ratio											
Average Ore grade	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Recovery	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
gold produced (ounces)	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064
gold Price (US$/oz)	2170	2230	2313	2383	2495	2545	2658	2769	2868	2964	3085
Sales revenue	63463958.88	65218722.72	67646146.03	69693370.51	72968929.68	74431232.9	77736038.1	80982351.2	83877711.6	86685333.7	90224107.44
Capital gain -Salvage Value											
Less: Mining Cost (000's)	5934	5934	5934	5934	5934	5934	5934	5934	5934	5934	5934
Processing Cost	-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967
Royalty	-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132
Refining Cost and other cost	-159	-159	-159	-159	-159	-159	-159	-159	-159	-159	-159
Depreciation	-	-	-	-	-	-	-	-	-	-	-
Operating Profit before Tax	63454634.88	65209398.72	67636822.03	69684046.51	72959605.68	74421908.9	77726714.1	80973027.2	83868387.6	86676009.7	90214783.44
Less: Income Tax (25%)	-15863658.7	-16302349.7	-16909205.5	-17421011.6	-18239901.4	-18605477.2	-19431678.5	-20243256.8	-20967096.9	-21669002.4	-22553695.9
Operating Profit After Tax	47590976.16	48907049.04	50727616.52	52263034.88	54719704.26	55816431.7	58295035.6	60729770.4	62901290.7	65007007.27	67661087.58
Depreciation											
Capital Expenditure											
Undiscounted Net Cash Flow	47590976.16	48907049.04	50727616.52	52263034.88	54719704.26	55816431.7	58295035.6	60729770.4	62901290.7	65007007.27	67661087.58
Discount factor (12%)	0.2752	0.2498	0.2268	0.2058	0.1858	0.1684	0.1534	0.1385	0.1252	0.113	0.1028
Cash Flow Present Value (NPV)	13097036.64	12216980.85	11505023.43	10755732.58	10166921.05	9399487.09	8942458.46	8411073.2	7875241.59	7345791.822	6955559.803
Cumulative Cash Flow	-572995.771	-1453051.56	-2165008.98	-2914299.83	-3503111.36	-4270545.32	-4727573.95	-5258959.21	-5794790.82	-6324240.59	-6714472.61

Table 5.10 NPV of Mengapur gold mine project investment in Malaysia at 30 percent tax flow

Production Period	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11
gold Production (000's o/z)		52982	52982	52982	52982	52982	52982	52982	52982	52982	52982	52982
Waste (tonnes)												
Stripping ratio												
Average Ore grade		0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Recovery		0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
gold produced (ounces)		29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064
gold Price (US$/oz)		1455	1502	1554	1610	1658	1720	1791	1837	1902	1960	2029
Sales revenue		42553023.12	43927588.13	45448383.46	47086163.04	48489974.11	50303230.1	52379700.6	53725019.6	55626013.7	57322285.44	59340263.86
Capital gain -Salvage Value												
Less: Mining Cost (000's)		-5934	5934	5934	5934	5934	5934	5934	5934	5934	5934	5934
Processing Cost		-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967
Royalty		-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132
Refining Cost and other cost		-159	-159	-159	-159	-159	-159	-159	-159	-159	-159	-159
Depreciation		-	-	-	-	-	-	-	-	-	-	-
Operating Profit before Tax		42531831.12	43918264.13	45439059.46	47076839.04	48480650.11	50293906.1	52370376.6	53715695.6	55616689.7	57312961.44	59330939.86
Less: Income Tax (30%)		-12759549.3	-13175479.2	-13631717.8	-14123051.7	-14544195	-15088171.8	-15711113	-16114708.7	-16685006.9	-17193888.4	-17799282
Operating Profit After Tax		29772281.78	30742784.89	31807341.62	32953787.33	33936455.08	35205734.3	36659263.6	37600986.9	38931682.8	40119073.01	41531657.9
Depreciation												
Capital Expenditure	-13670032											
Undiscounted Net Cash Flow	-13670032	29772281.78	30742784.89	31807341.62	32953787.33	33936455.08	35205734.3	36659263.6	37600986.9	38931682.8	40119073.01	41531657.9
Discount factor (12%)	1	0.9054	0.8201	0.7433	0.6738	0.6098	0.5523	0.5007	0.4531	0.4098	0.3715	0.3363
Cash Flow Present Value (NPV)	-13670032	26955823.93	25212157.89	23642397.03	22204261.9	20694450.31	19444127	18355293.3	17037007.2	15954203.6	14904235.62	13967096.55
Cumulative Cash Flow	-13670032	13285791.52	11542125.48	9972364.616	8534229.492	7024417.897	5774094.62	4685260.89	3366974.75	2284171.21	1234203.212	297064.1415
Net Present Value ($ Million)	16552695											

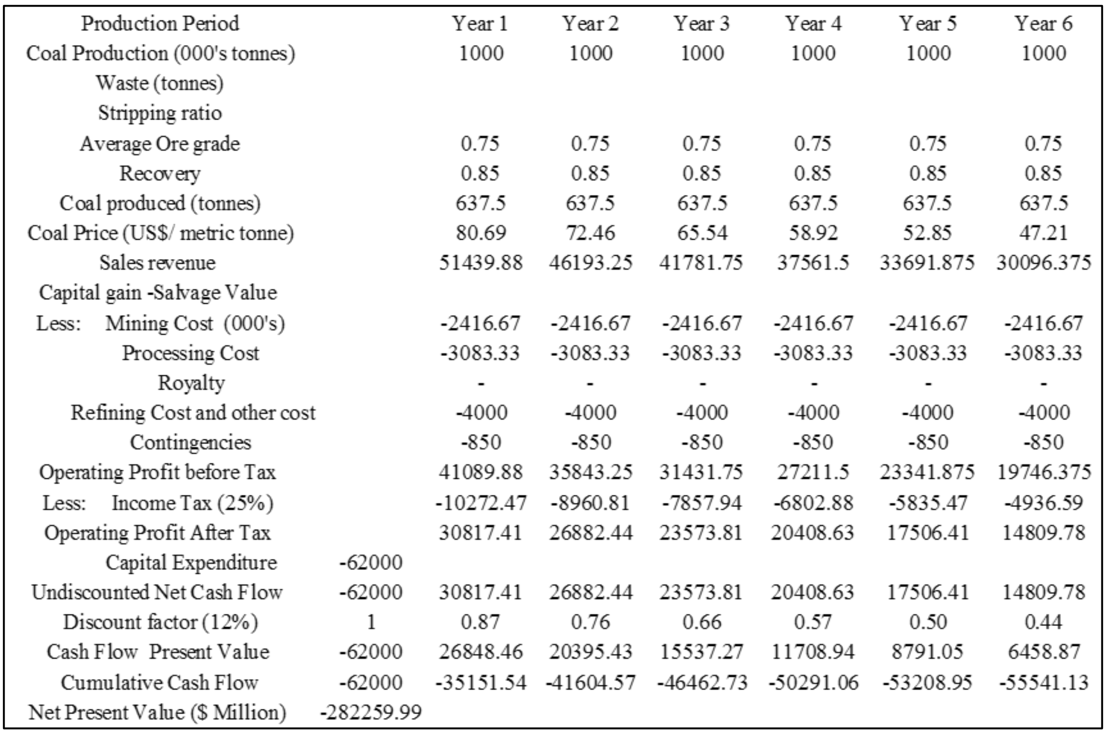
Production Period	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23
gold Production (000's o/z)	52982	52982	52982	52982	52982	52982	52982	52982	52982	52982	52982
Waste (tonnes)											
Stripping ratio											
Average Ore grade	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Recovery	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
gold produced (ounces)	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064
gold Price (US$/oz)	2170	2230	2313	2383	2495	2545	2658	2769	2868	2964	3085
Sales revenue	63463958.88	65218722.72	67646146.03	69693370.51	72968929.68	74431232.9	77736038.1	80982351.2	83877711.6	86685333.7	90224107.44
Capital gain -Salvage Value											
Less: Mining Cost (000's)	5934	5934	5934	5934	5934	5934	5934	5934	5934	5934	5934
Processing Cost	-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967
Royalty	-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132
Refining Cost and other cost	-159	-159	-159	-159	-159	-159	-159	-159	-159	-159	-159
Depreciation	-	-	-	-	-	-	-	-	-	-	-
Operating Profit before Tax	63454634.88	65209398.72	67636822.03	69684046.51	72959605.68	74421908.9	77726714.1	80973027.2	83868387.6	86676009.7	90214783.44
Less: Income Tax (30%)	-19036390.5	-19562819.6	-20291046.6	-20905214	-21887881.7	-22326572.7	-23318014.2	-24291908.2	-25160516.3	-26002802.9	-27064435
Operating Profit After Tax	44418244.42	45646579.1	47345775.42	48778832.56	51071723.98	52095336.2	54408699.9	56681119.1	58707871.3	60673206.79	63150348.41
Depreciation											
Capital Expenditure											
Undiscounted Net Cash Flow	44418244.42	45646579.1	47345775.42	48778832.56	51071723.98	52095336.2	54408699.9	56681119.1	58707871.3	60673206.79	63150348.41
Discount factor (12%)	0.2752	0.2498	0.2268	0.2058	0.1858	0.1684	0.1534	0.1385	0.1252	0.113	0.1028
Cash Flow Present Value (NPV)	12223900.86	11402515.46	10738021.87	10038683.74	9489126.315	8772854.62	8346294.56	7850334.99	7350225.49	6856072.367	6491855.816
Cumulative Cash Flow	-1446131.55	-2267516.95	-2932010.54	-3631348.67	-4180906.1	-4897177.79	-5323737.85	-5819697.42	-6319806.92	-6813960.04	-7178176.59

Table 5.11 NPV of Mengapur gold mine project investment in Malaysia at 35 percent tax flow

Production Period	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11
gold Production (000's o/z)		52982	52982	52982	52982	52982	52982	52982	52982	52982	52982	52982
Waste (tonnes)												
Stripping ratio												
Average Ore grade		0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Recovery		0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
gold produced (ounces)		29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064
gold Price (US$/oz)		1455	1502	1554	1610	1658	1720	1791	1837	1902	1960	2029
Sales revenue		42553023.12	43927588.13	45448383.46	47086163.04	48489974.11	50303230.1	52379700.6	53725019.6	55626013.7	57322285.44	59340263.86
Capital gain -Salvage Value												
Less: Mining Cost (000's)		-5934	5934	5934	5934	5934	5934	5934	5934	5934	5934	5934
Processing Cost		-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967
Royalty		-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132
Refining Cost and other cost		-159	-159	-159	-159	-159	-159	-159	-159	-159	-159	-159
Depreciation		-	-	-	-	-	-	-	-	-	-	-
Operating Profit before Tax		42531831.12	43918264.13	45439059.46	47076839.04	48480650.11	50293906.1	52370376.6	53715695.6	55616689.7	57312961.44	59330939.86
Less: Income Tax (35%)		-14886140.9	-15371392.4	-15903670.8	-16476893.7	-16968227.5	-17602867.1	-18329631.8	-18800493.4	-19465841.4	-20059536.5	-20765828.9
Operating Profit After Tax		27645690.23	28546871.68	29535388.65	30599945.38	31512422.57	32691039	34040744.8	34915202.1	36150848.3	37253424.94	38565110.91
Depreciation												
Capital Expenditure	-13670032											
Undiscounted Net Cash Flow	-13670032	27645690.23	28546871.68	29535388.65	30599945.38	31512422.57	32691039	34040744.8	34915202.1	36150848.3	37253424.94	38565110.91
Discount factor (12%)	1	0.9054	0.8201	0.7433	0.6738	0.6098	0.5523	0.5007	0.4531	0.4098	0.3715	0.3363
Cash Flow Present Value (NPV)	-13670032	25030407.93	23411289.47	21953654.38	20618243.19	19216275.28	18055260.8	17044200.9	15820078.1	14814617.6	13839647.36	12969446.8
Cumulative Cash Flow	-13670032	11360375.52	9741257.057	8283621.971	6948210.784	5546242.875	4385228.4	3374168.51	2150045.67	1144585.23	169614.9537	-700585.612
Net Present Value ($ Million)	-7087550.4											

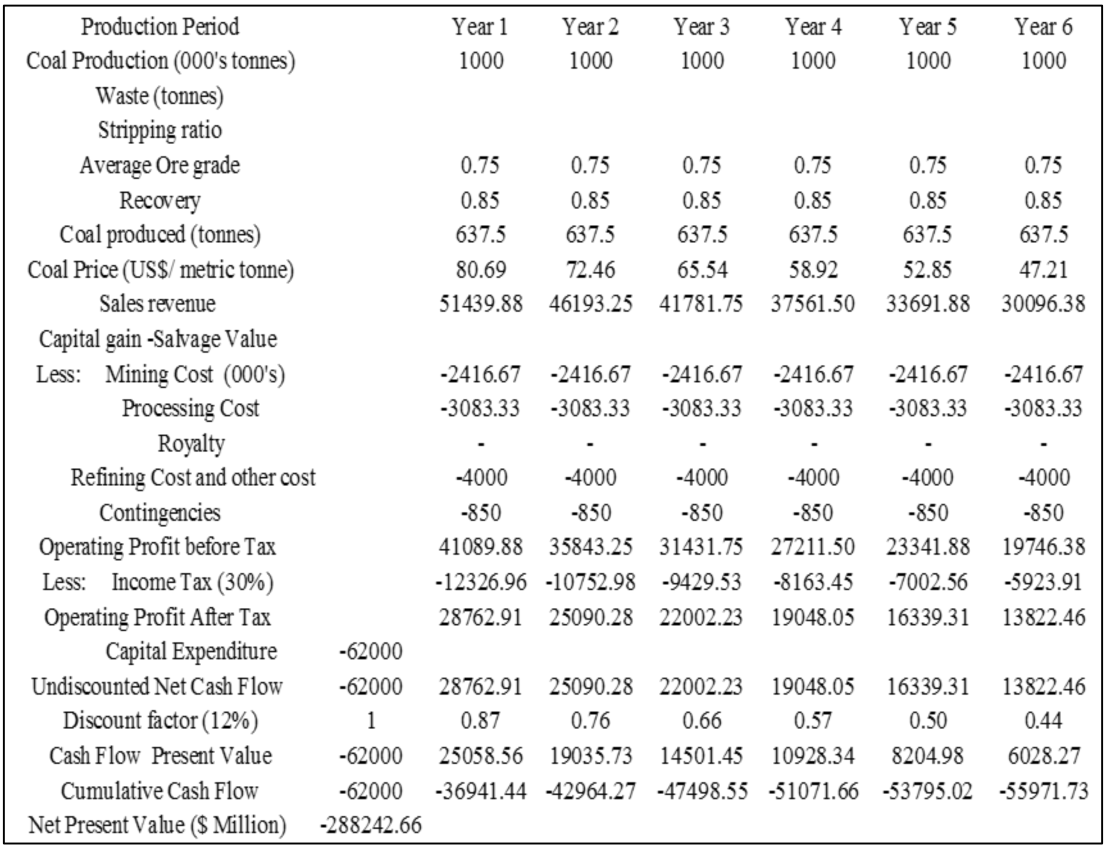
Production Period	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23
gold Production (000's o/z)	52982	52982	52982	52982	52982	52982	52982	52982	52982	52982	52982
Waste (tonnes)											
Stripping ratio											
Average Ore grade	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Recovery	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
gold produced (ounces)	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064	29246.064
gold Price (US$/oz)	2170	2230	2313	2383	2495	2545	2658	2769	2868	2964	3085
Sales revenue	63463958.88	65218722.72	67646146.03	69693370.51	72968929.68	74431232.9	77736038.1	80982351.2	83877711.6	86685333.7	90224107.44
Capital gain -Salvage Value											
Less: Mining Cost (000's)	5934	5934	5934	5934	5934	5934	5934	5934	5934	5934	5934
Processing Cost	-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967	-10967
Royalty	-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132	-4132
Refining Cost and other cost	-159	-159	-159	-159	-159	-159	-159	-159	-159	-159	-159
Depreciation	-	-	-	-	-	-	-	-	-	-	-
Operating Profit before Tax	63454634.88	65209398.72	67636822.03	69684046.51	72959605.68	74421908.9	77726714.1	80973027.2	83868387.6	86676009.7	90214783.44
Less: Income Tax (35%)	-22209122.2	-22823289.6	-23672887.7	-24389416.3	-25535862	-26047668.1	-27204349.9	-28340559.5	-29353935.6	-30336603.4	-31575174.2
Operating Profit After Tax	41245512.67	42386109.17	43963934.32	45294630.23	47423743.69	48374240.8	50522364.2	52632467.7	54514451.9	56339406.3	58639609.24
Depreciation											
Capital Expenditure											
Undiscounted Net Cash Flow	41245512.67	42386109.17	43963934.32	45294630.23	47423743.69	48374240.8	50522364.2	52632467.7	54514451.9	56339406.3	58639609.24
Discount factor (12%)	0.2752	0.2498	0.2268	0.2058	0.1858	0.1684	0.1534	0.1385	0.1252	0.113	0.1028
Cash Flow Present Value (NPV)	11350765.09	10588050.07	9971020.304	9321634.902	8811331.578	8146222.15	7750130.66	7289596.78	6825209.38	6366352.912	6028151.829
Cumulative Cash Flow	-2319267.32	-3081982.34	-3699012.11	-4348397.51	-4858700.83	-5523810.26	-5919901.75	-6380435.63	-6844823.03	-7303679.5	-7641880.58

Table 5.12 NPV of Buller coal mine project investment in New Zealand of at 25 percent tax flow



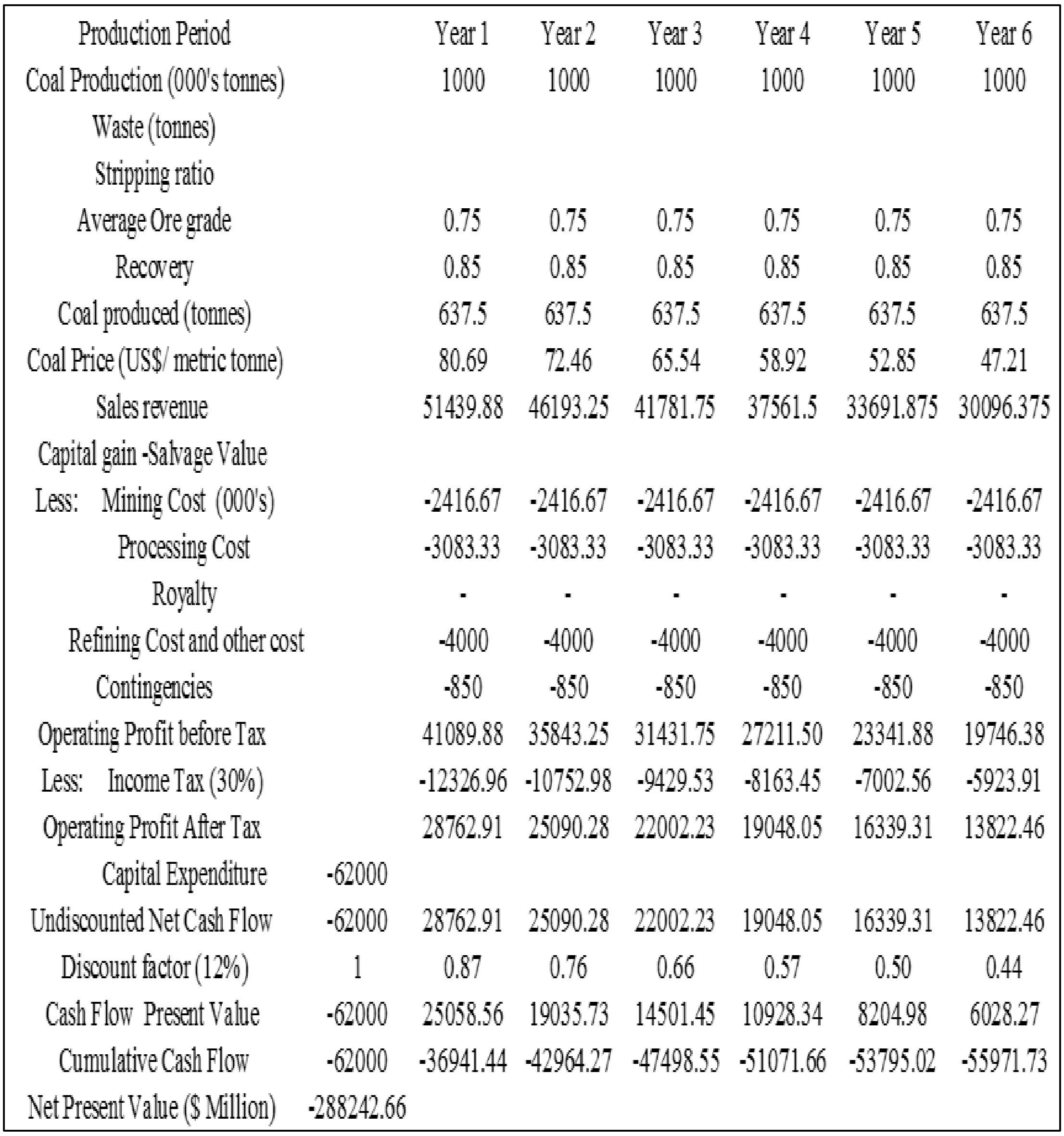
Production Period		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Coal Production (000's tonnes)		1000	1000	1000	1000	1000	1000
Waste (tonnes)							
Stripping ratio							
Average Ore grade		0.75	0.75	0.75	0.75	0.75	0.75
Recovery		0.85	0.85	0.85	0.85	0.85	0.85
Coal produced (tonnes)		637.5	637.5	637.5	637.5	637.5	637.5
Coal Price (US$/ metric tonne)		80.69	72.46	65.54	58.92	52.85	47.21
Sales revenue		51439.88	46193.25	41781.75	37561.5	33691.875	30096.375
Capital gain -Salvage Value							
Less: Mining Cost (000's)		-2416.67	-2416.67	-2416.67	-2416.67	-2416.67	-2416.67
Processing Cost		-3083.33	-3083.33	-3083.33	-3083.33	-3083.33	-3083.33
Royalty		-	-	-	-	-	-
Refining Cost and other cost		-4000	-4000	-4000	-4000	-4000	-4000
Contingencies		-850	-850	-850	-850	-850	-850
Operating Profit before Tax		41089.88	35843.25	31431.75	27211.5	23341.875	19746.375
Less: Income Tax (25%)		-10272.47	-8960.81	-7857.94	-6802.88	-5835.47	-4936.59
Operating Profit After Tax		30817.41	26882.44	23573.81	20408.63	17506.41	14809.78
Capital Expenditure	-62000						
Undiscounted Net Cash Flow	-62000	30817.41	26882.44	23573.81	20408.63	17506.41	14809.78
Discount factor (12%)	1	0.87	0.76	0.66	0.57	0.50	0.44
Cash Flow Present Value	-62000	26848.46	20395.43	15537.27	11708.94	8791.05	6458.87
Cumulative Cash Flow	-62000	-35151.54	-41604.57	-46462.73	-50291.06	-53208.95	-55541.13
Net Present Value ($ Million)	-282259.99						

Table 5.13 NPV of Buller coal mine project investment in New Zealand of at 30 percent tax flow



Production Period		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Coal Production (000's tonnes)		1000	1000	1000	1000	1000	1000
Waste (tonnes)							
Stripping ratio							
Average Ore grade		0.75	0.75	0.75	0.75	0.75	0.75
Recovery		0.85	0.85	0.85	0.85	0.85	0.85
Coal produced (tonnes)		637.5	637.5	637.5	637.5	637.5	637.5
Coal Price (US$/ metric tonne)		80.69	72.46	65.54	58.92	52.85	47.21
Sales revenue		51439.88	46193.25	41781.75	37561.50	33691.88	30096.38
Capital gain -Salvage Value							
Less: Mining Cost (000's)		-2416.67	-2416.67	-2416.67	-2416.67	-2416.67	-2416.67
Processing Cost		-3083.33	-3083.33	-3083.33	-3083.33	-3083.33	-3083.33
Royalty		-	-	-	-	-	-
Refining Cost and other cost		-4000	-4000	-4000	-4000	-4000	-4000
Contingencies		-850	-850	-850	-850	-850	-850
Operating Profit before Tax		41089.88	35843.25	31431.75	27211.50	23341.88	19746.38
Less: Income Tax (30%)		-12326.96	-10752.98	-9429.53	-8163.45	-7002.56	-5923.91
Operating Profit After Tax		28762.91	25090.28	22002.23	19048.05	16339.31	13822.46
Capital Expenditure	-62000						
Undiscounted Net Cash Flow	-62000	28762.91	25090.28	22002.23	19048.05	16339.31	13822.46
Discount factor (12%)	1	0.87	0.76	0.66	0.57	0.50	0.44
Cash Flow Present Value	-62000	25058.56	19035.73	14501.45	10928.34	8204.98	6028.27
Cumulative Cash Flow	-62000	-36941.44	-42964.27	-47498.55	-51071.66	-53795.02	-55971.73
Net Present Value ($ Million)	-288242.66						

Table 5.14 NPV of Buller coal mine project investment in New Zealand of at 35 percent tax flow



Production Period		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Coal Production (000's tonnes)		1000	1000	1000	1000	1000	1000
Waste (tonnes)							
Stripping ratio							
Average Ore grade		0.75	0.75	0.75	0.75	0.75	0.75
Recovery		0.85	0.85	0.85	0.85	0.85	0.85
Coal produced (tonnes)		637.5	637.5	637.5	637.5	637.5	637.5
Coal Price (US$/ metric tonne)		80.69	72.46	65.54	58.92	52.85	47.21
Sales revenue		51439.88	46193.25	41781.75	37561.5	33691.875	30096.375
Capital gain -Salvage Value							
Less: Mining Cost (000's)		-2416.67	-2416.67	-2416.67	-2416.67	-2416.67	-2416.67
Processing Cost		-3083.33	-3083.33	-3083.33	-3083.33	-3083.33	-3083.33
Royalty		-	-	-	-	-	-
Refining Cost and other cost		-4000	-4000	-4000	-4000	-4000	-4000
Contingencies		-850	-850	-850	-850	-850	-850
Operating Profit before Tax		41089.88	35843.25	31431.75	27211.50	23341.88	19746.38
Less: Income Tax (30%)		-12326.96	-10752.98	-9429.53	-8163.45	-7002.56	-5923.91
Operating Profit After Tax		28762.91	25090.28	22002.23	19048.05	16339.31	13822.46
Capital Expenditure	-62000						
Undiscounted Net Cash Flow	-62000	28762.91	25090.28	22002.23	19048.05	16339.31	13822.46
Discount factor (12%)	1	0.87	0.76	0.66	0.57	0.50	0.44
Cash Flow Present Value	-62000	25058.56	19035.73	14501.45	10928.34	8204.98	6028.27
Cumulative Cash Flow	-62000	-36941.44	-42964.27	-47498.55	-51071.66	-53795.02	-55971.73
Net Present Value ($ Million)	-288242.66						

Table 5.15 NPV of Wafi-Golpu gold mine project investment in Papua New Guinea at 25 percent tax flow

Production Period	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13
gold Production (000's o/z)		550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00
Waste (tonnes)														
Stripping ratio														
Average Ore grade		0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Recovery		0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
gold produced (ounces)		297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99
gold Price (US$/oz)		1455.00	1511.00	1561.00	1613.00	1656.00	1716.00	1768.00	1830.00	1900.00	1968.00	2019.00	2098.00	2155.00
Sales revenue		433575.45	450262.89	465162.39	480657.87	493471.44	511350.84	526846.32	545321.70	566181.00	586444.32	601641.81	625183.02	642168.45
Capital gain -Salvage Value														
Less: Mining Cost (000's)		-965.00	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48
Processing Cost		-650.00	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48
Royalty		-	-	-	-	-	-	-	-	-	-	-	-	-
Refining Cost and other cost		-2795.00	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84
Contingencies		-435.00	0.00	-	-	-	-	-	-	-	-	-	-	-
Operating Profit before Tax		429165.45	449538.09	464437.59	479933.07	492746.64	510626.04	526121.52	544596.90	565456.20	585719.52	600917.01	624458.22	641443.65
Less: Income Tax (25%)		-107291.36	-112384.52	-116109.40	-119983.27	-123186.66	-127656.51	-131530.38	-136149.23	-141364.05	-146429.88	-150229.25	-156114.56	-160360.91
Operating Profit After Tax		321874.09	337153.57	348328.19	359949.80	369559.98	382969.53	394591.14	408447.68	424092.15	439289.64	450687.76	468343.67	481082.74
Depreciation														
Capital Expenditure	-9800.00													
Undiscounted Net Cash Flow (x 1000)	-9800.00	321874.09	337153.57	348328.19	359949.80	369559.98	382969.53	394591.14	408447.68	424092.15	439289.64	450687.76	468343.67	481082.74
Discount factor (12%)	1.00	0.80	0.63	0.50	0.40	0.32	0.26	0.20	0.16	0.13	0.10	0.08	0.07	0.05
Cash Flow Present Value (NPV) (x 1000)	-9800.00	257788.96	213384.49	175661.91	144591.84	118185.28	98499.76	79628.49	65474.16	54665.48	45290.76	37542.29	30723.34	24439.00
Cumulative Cash Flow	-9800.00	247988.96	203584.49	165861.91	134791.84	108385.28	88699.76	69828.49	55674.16	44865.48	35490.76	27742.29	20923.34	14639.00
Net Present Value ($ Million) (x 1000)	1199434.26													
Production Period		Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25	Year 26
gold Production (000's o/z)		550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00
Waste (tonnes)														
Stripping ratio														
Average Ore grade		0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Recovery		0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
gold produced (ounces)		297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99
gold Price (US$/oz)		2233.00	2290.00	2385.00	2475.00	2568.00	2663.00	2788.00	2870.00	2989.00	3111.00	3202.00	3300.00	3422.00
Sales revenue		665411.67	682397.10	710706.15	737525.25	765238.32	793547.37	830796.12	855231.30	890692.11	927046.89	954163.98	983367.00	1019721.78
Capital gain -Salvage Value														
Less: Mining Cost (000's)		-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48
Processing Cost		-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48
Royalty		-	-	-	-	-	-	-	-	-	-	-	-	-
Refining Cost and other cost		-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84
Contingencies		-	-	-	-	-	-	-	-	-	-	-	-	-
Operating Profit before Tax		664686.87	681672.30	709981.35	736800.45	764513.52	792822.57	830071.32	854506.50	889967.31	926322.09	953439.18	982642.20	1018996.98
Less: Income Tax (25%)		-166171.72	-170418.08	-177495.34	-184200.11	-191128.38	-198205.64	-207517.83	-213626.63	-222491.83	-231580.52	-238359.80	-245660.55	-254749.25
Operating Profit After Tax		498515.15	511254.23	532486.01	552600.34	573385.14	594616.93	622553.49	640879.88	667475.48	694741.57	715079.39	736981.65	764247.74
Depreciation														
Capital Expenditure														
Undiscounted Net Cash Flow (x 1000)		498515.15	511254.23	532486.01	552600.34	573385.14	594616.93	622553.49	640879.88	667475.48	694741.57	715079.39	736981.65	764247.74
Discount factor (12%)		0.04	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
Cash Flow Present Value (NPV) (x 1000)		21236.75	17280.39	13951.13	11825.65	9346.18	7551.63	6412.30	5511.57	4138.35	3682.13	3003.33	2432.04	1987.04
Cumulative Cash Flow		11436.75	7480.39	4151.13	2025.65	-453.82	-2248.37	-3387.70	-4288.43	-5661.65	-6117.87	-6796.67	-7367.96	-7812.96

Table 5.16 NPV of Wafi-Golpu mine project investment in Papua New Guinea at 30 percent tax flow

Production Period	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13
Gold Production (000's o/z)		550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00
Waste (tonnes)														
Stripping ratio														
Average Ore grade		0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Recovery		0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Gold produced (o/z)		297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99
gold Price (US$ o/z)		1455.00	1511.00	1561.00	1613.00	1656.00	1716.00	1768.00	1830.00	1900.00	1968.00	2019.00	2098.00	2155.00
Sales revenue		433575.45	450262.89	465162.39	480657.87	493471.44	511350.84	526846.32	545321.70	566181.00	586444.32	601641.81	625183.02	642168.45
Capital gain -Salvage Value														
Less: Mining Cost (000's)		-965.00	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48
Processing Cost		-650.00	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48
Royalty		-	-	-	-	-	-	-	-	-	-	-	-	-
Refining Cost and other cost		-2795.00	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84
Contingencies		-435.00	-	-	-	-	-	-	-	-	-	-	-	-
Operating Profit before Tax		428730.45	449538.09	464437.59	479933.07	492746.64	510626.04	526121.52	544596.90	565456.20	585719.52	600917.01	624458.22	641443.65
Less: Income Tax (30%)		-128619.14	-134861.43	-139331.28	-143979.92	-147823.99	-153187.81	-157836.46	-163379.07	-169636.86	-175715.86	-180275.10	-187337.47	-192433.10
Operating Profit After Tax		300111.32	314676.66	325106.31	335953.15	344922.65	357438.23	368285.06	381217.83	395819.34	410003.66	420641.91	437120.75	449010.56
Depreciation														
Capital Expenditure	-9800.00													
Undiscounted Net Cash Flow (x 1000)	-9800.00	300111.32	300111.32	300111.32	300111.32	300111.32	300111.32	300111.32	300111.32	300111.32	300111.32	300111.32	300111.32	300111.32
Discount factor (12%)	1.00	0.80	0.63	0.50	0.40	0.32	0.26	0.20	0.16	0.13	0.10	0.08	0.07	0.05
Cash Flow Present Value (NPV) (x 1000)	-9800.00	240359.15	199158.86	163951.11	134952.38	110306.26	91933.11	74319.93	61109.22	51021.11	42271.38	35039.47	28675.12	22809.74
Cumulative Cash Flow	-9800.00	230559.15	189358.86	154151.11	125152.38	100506.26	82133.11	64519.93	51309.22	41221.11	32471.38	25239.47	18875.12	13009.74
Net Present Value ($ Million) (x 1000)	1102241.44													
Production Period		Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25	Year 26
Gold Production (000's o/z)		550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00
Waste (tonnes)														
Stripping ratio														
Average Ore grade		0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Recovery		0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Gold produced (o/z)		297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99
gold Price (US$ o/z)		2233.00	2290.00	2385.00	2475.00	2568.00	2663.00	2788.00	2870.00	2989.00	3111.00	3202.00	3300.00	3422.00
Sales revenue		665411.67	682397.10	710706.15	737525.25	765238.32	793547.37	830796.12	855231.30	890692.11	927046.89	954163.98	983367.00	1019721.78
Capital gain -Salvage Value														
Less: Mining Cost (000's)		-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48
Processing Cost		-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48
Royalty		-	-	-	-	-	-	-	-	-	-	-	-	-
Refining Cost and other cost		-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84
Contingencies		-	-	-	-	-	-	-	-	-	-	-	-	-
Operating Profit before Tax		664686.87	681672.30	709981.35	736800.45	764513.52	792822.57	830071.32	854506.50	889967.31	926322.09	953439.18	982642.20	1018996.98
Less: Income Tax (30%)		-199406.06	-204501.69	-212994.41	-221040.14	-229354.06	-237846.77	-249021.40	-256351.95	-266990.19	-277896.63	-286031.75	-294792.66	-305699.09
Operating Profit After Tax		465280.81	477170.61	496986.95	515760.32	535159.46	554975.80	581049.92	598154.55	622977.12	648425.46	667407.43	687849.54	713297.89
Depreciation														
Capital Expenditure														
Undiscounted Net Cash Flow (x 1000)		300111.32	300111.32	300111.32	300111.32	300111.32	300111.32	300111.32	300111.32	300111.32	300111.32	300111.32	300111.32	300111.32
Discount factor (12%)		0.04	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
Cash Flow Present Value (NPV) (x 1000)		19820.96	16128.37	13021.06	11037.27	8723.10	7048.19	5984.81	5144.13	3862.46	3436.65	2803.11	2269.90	1854.57
Cumulative Cash Flow		10020.96	6328.37	3221.06	1237.27	-1076.90	-2751.81	-3815.19	-4655.87	-5937.54	-6363.35	-6996.89	-7530.10	-7945.43

Table 5.17 NPV of Wafi-Golpu gold mine project investment in Papua New Guinea at 35 percent tax flow

Production Period	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13
Gold Production (000's o/z)		550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00
Waste (tonnes)														
Stripping ratio														
Average Ore grade		0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Recovery		0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Gold produced (o/z)		297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99
Gold Price (US$ o/z)		1455.00	1511.00	1561.00	1613.00	1656.00	1716.00	1768.00	1830.00	1900.00	1968.00	2019.00	2098.00	2155.00
Sales revenue		433575.45	450262.89	465162.39	480657.87	493471.44	511350.84	526846.32	545321.70	566181.00	586444.32	601641.81	625183.02	642168.45
Capital gain - Salvage Value														
Less: Mining Cost (000's)		-965.00	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48
Processing Cost		-650.00	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48
Royalty		-	-	-	-	-	-	-	-	-	-	-	-	-
Refining Cost and other cost		-2795.00	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84
Depreciation		-435.00	-	-	-	-	-	-	-	-	-	-	-	-
Operating Profit before Tax		428730.45	449538.09	464437.59	479933.07	492746.64	510626.04	526121.52	544596.90	565456.20	585719.52	600917.01	624458.22	641443.65
Less: Income Tax (35%)		-150055.66	-157338.33	-162553.16	-167976.57	-172461.32	-178719.11	-184142.53	-190608.92	-197909.67	-205001.83	-210320.95	-218560.38	-224505.28
Operating Profit After Tax		278674.79	292199.76	301884.43	311956.50	320285.32	331906.93	341978.99	353987.99	367546.53	380717.69	390596.06	405897.84	416938.37
Depreciation														
Capital Expenditure	-9800.00													
Undiscounted Net Cash Flow (x 1000)	-9800.00	278674.79	292199.76	301884.43	311956.50	320285.32	331906.93	341978.99	353987.99	367546.53	380717.69	390596.06	405897.84	416938.37
Discount factor (12%)	1.00	0.80	0.63	0.50	0.40	0.32	0.26	0.20	0.16	0.13	0.10	0.08	0.07	0.05
Cash Flow Present Value (NPV) (x 1000)	-9800.00	223190.64	184933.23	152240.32	125312.92	102427.24	85366.46	69011.36	56744.27	47376.75	39251.99	32536.65	26626.90	21180.47
Cumulative Cash Flow	-9800.00	213390.64	175133.23	142440.32	115512.92	92627.24	75566.46	59211.36	46944.27	37576.75	29451.99	22736.65	16826.90	11380.47
Net Present Value ($ Million) (x 1000)	1005309.91													
Production Period		Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25	Year 26
Gold Production (000's o/z)		550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00	550.00
Waste (tonnes)														
Stripping ratio														
Average Ore grade		0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Recovery		0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Gold produced (o/z)		297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99	297.99
Gold Price (US$ o/z)		2233.00	2290.00	2385.00	2475.00	2568.00	2663.00	2788.00	2870.00	2989.00	3111.00	3202.00	3300.00	3422.00
Sales revenue		665411.67	682397.10	710706.15	737525.25	765238.32	793547.37	830796.12	855231.30	890692.11	927046.89	954163.98	983367.00	1019721.78
Capital gain - Salvage Value														
Less: Mining Cost (000's)		-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48	-276.48
Processing Cost		-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48	-236.48
Royalty		-	-	-	-	-	-	-	-	-	-	-	-	-
Refining Cost and other cost		-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84	-211.84
Depreciation		-	-	-	-	-	-	-	-	-	-	-	-	-
Operating Profit before Tax		664686.87	681672.30	709981.35	736800.45	764513.52	792822.57	830071.32	854506.50	889967.31	926322.09	953439.18	982642.20	1018996.98
Less: Income Tax (35%)		-232640.40	-238585.31	-248493.47	-257880.16	-267579.73	-277487.90	-290524.96	-299077.28	-311488.56	-324212.73	-333703.71	-343924.77	-356648.94
Operating Profit After Tax		432046.47	443087.00	461487.88	478920.29	496933.79	515334.67	539546.36	555429.23	578478.75	602109.36	619735.47	638717.43	662348.04
Depreciation														
Capital Expenditure														
Undiscounted Net Cash Flow (x 1000)		432046.47	443087.00	461487.88	478920.29	496933.79	515334.67	539546.36	555429.23	578478.75	602109.36	619735.47	638717.43	662348.04
Discount factor (12%)		0.04	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
Cash Flow Present Value (NPV) (x 1000)		18405.18	14976.34	12090.98	10248.89	8100.02	6544.75	5557.33	4776.69	3586.57	3191.18	2602.89	2107.77	1722.10
Cumulative Cash Flow		8605.18	5176.34	2290.98	448.89	-1699.98	-3255.25	-4242.67	-5023.31	-6213.43	-6608.82	-7197.11	-7692.23	-8077.90

Tables 5.3-5.17 show the calculation of the traditional DCF. When the tax flow is set at 25 per cent, the mining project invested in Malaysia generates much higher profits than the other four countries. The analysis shows that investment in the mining project and the revenue are mainly dependent on the total production of mineral produced. The more minerals that are produced the higher the profit for mining investors.

The DCF analysis among these five countries shows that mining project investment in New Zealand is the least profitable, which can be attributed to high investment costs. As well, ore reserves contained in the ground were not as concentrated as other countries. Due to high investment costs, New Zealand mining investors require five years to repay the funds they borrowed for the mining project investment, whereas the other countries only require six to twelve months to repay the investment cost.

The life of the project investment in New Zealand is shorter than the other four countries. Allens (2015) states that the life of a mining project depends on the following four factors: firstly, the lease of mining projects is usually granted for periods of 15-25 years and subject to extension; secondly, the consumption and demand for minerals determines the mining project's life; thirdly, the transparency of government policies such as changes in government could result in a switch of the mining project's ownership or changes in the taxation system; fourthly, the operation of the total life of mining project is based on the economic and social impacts; for example, the life of mining project will be shorter if the economic and social impacts to the local community are significant.

As noted in Crown Minerals New Zealand (2014), it is important for the New Zealand government to set a key role by reviewing and updating mining legislation, providing useful information for mining investors, and consulting the mining investors as well as the community before the key mining decisions are made. Based on the four factors listed above, the life of the mining project in New Zealand is determined by the land leases for mining investors to open the mine and the significance of the economic and social impacts.

A critical aspect of this analysis is that the fiscal tax flow rate can affect mining investors' decisions as a result of the reduction in their investment revenues. The figures above imply that mining investors can only rely on hands-on information to make their investment decisions if flexibility is not taken into account. The viability of the mining project investments in the Asia-Pacific region can be difficult for mining investors if the tax flow increase to 30 and 35 percent. Alternatively, increasing the tax flow can add an extra cost burden to the investment in the country in which minerals are not the primary exports.

The study also evidences that countries endowed with mineral resources such as Australia, Indonesia and Papua New Guinea are among the countries that can offer better NPV for mining investors when the tax rates change. Substantial production rate seems to offset the high investment cost as a result of tax flows change. Without accessing flexibility, the outcome of this analysis concludes that the variations in tax flows can benefit countries endowed with mineral resources and which rely on minerals as the primary exports.

In the next section the researcher assigns a probability distribution and identifies two uncertain variables. This activity is to further analyse the NPV using the @Risk simulator in the static case in order to determine the viability of the mining project.

5.5 The empirical evidence of mining investment without flexibility

In the previous section, the researcher presented the static DCF cash flow method to examine an evaluation of a mining project using a traditional Excel worksheet. From a practical view point, the above analysis can be transformed in probability distribution using @Risk software to evaluate the mining projects' NPV value in the five countries.

In this latter analysis, assigning a probability distribution and uncertain variables are two key factors in identifying risks and their impact on mining project investment (Cohen & Stone, 2008). This analysis uses the Normal probability distribution because it is one of the most widely known continuous probability distributions. Normal distribution is renowned for its bell shape, which is used to describe many natural phenomena (Charnes, 2007).

The high risk mining project should be modelled with probability distributions by identifying a range of uncertain variables, such as commodity prices and tax rates. The purpose of using probability distributions is to identify the risks of these uncertain variables, which can impact the NPV of the mining investment. In this study, the researcher used @Risk software to conduct a static cash flow analysis by applying the normal probability distribution sets at 90 percentile certainty. Accordingly, the 10th, 50th and 90th percentile are common methods used for defining uncertain variables in the high risk mining project evaluation. Conceptually, the 10th percentile is the lowest value that the researcher believes the uncertain variable is likely to reach, the 50th percentile is the most likely value the uncertain variable will reach, and the 90th percentile is the highest value that the researcher thinks the uncertain variables will reach in the mining investment operation (Mao-Jones, 2012). This percentile indicates the robustness of a mining project. The purpose of using the 90th percentile in this study is to ensure that enough scope is available above the 90th for highly unlikely scenarios, such as 'Acts of God'. To testify the robustness of these outcomes, the NPV values in these five countries in Microsoft Excel are correlated to the NPV values simulated using @Risk.

Figure 5.9 NPV simulations for Daunia coal mine project in Australia

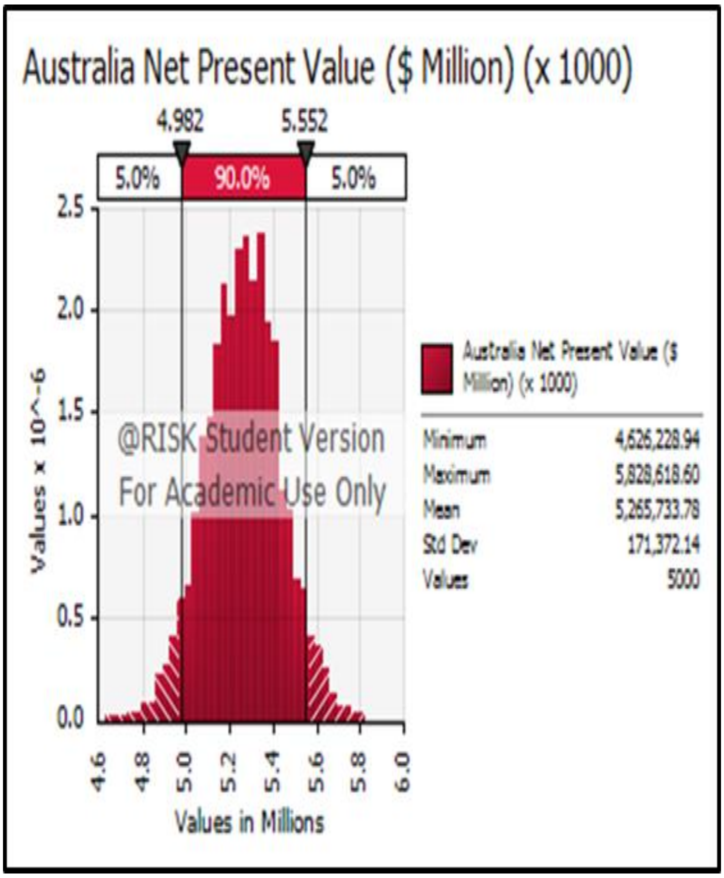


Figure 5.10 NPV simulations for Tembang gold mine project in Indonesia

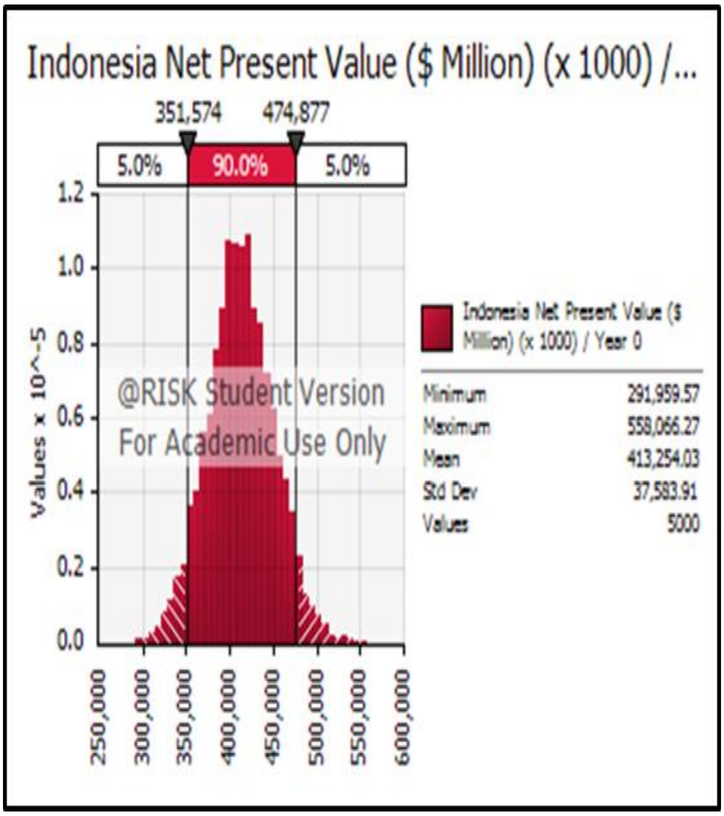


Figure 5.11 NPV simulations for Mengapur gold mine project in Malaysia

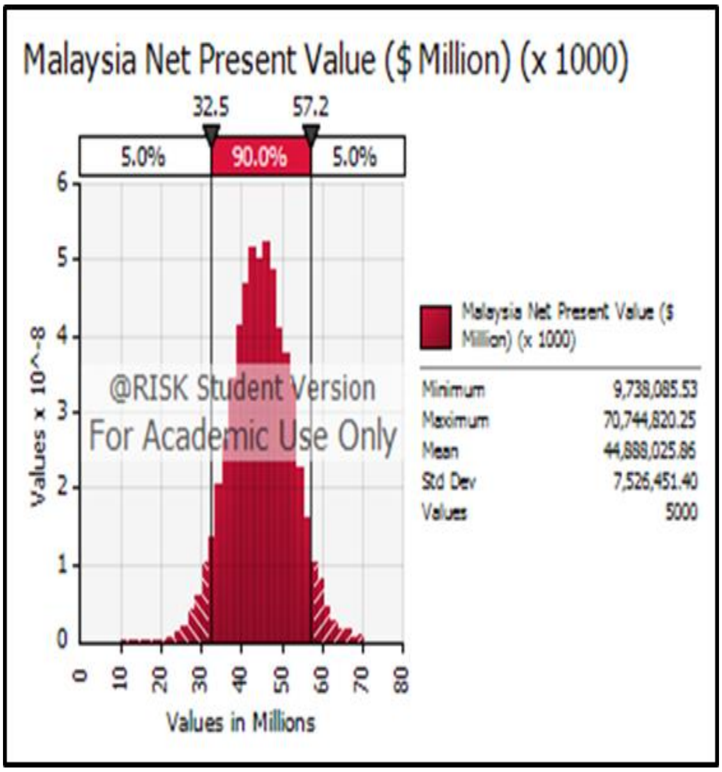


Figure 5.12 NPV simulations for Buller coal mine project in New Zealand

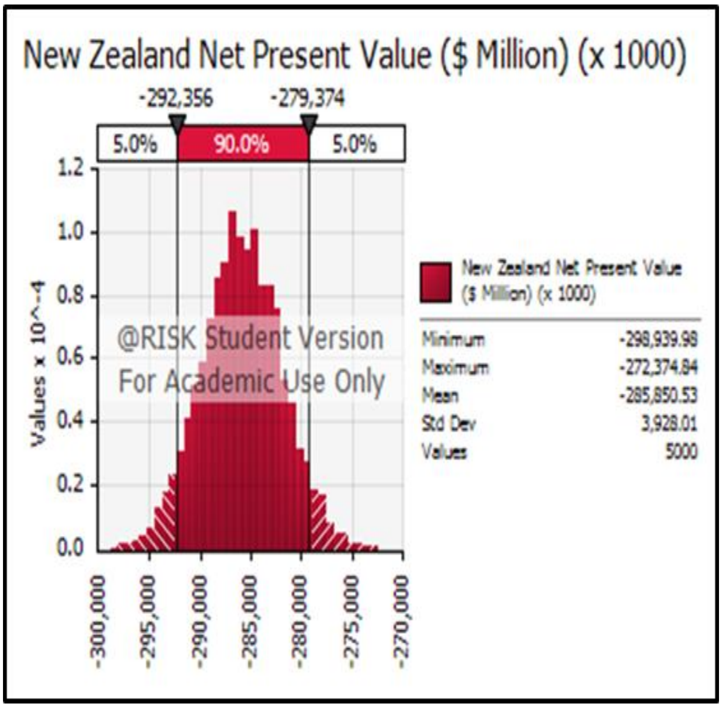
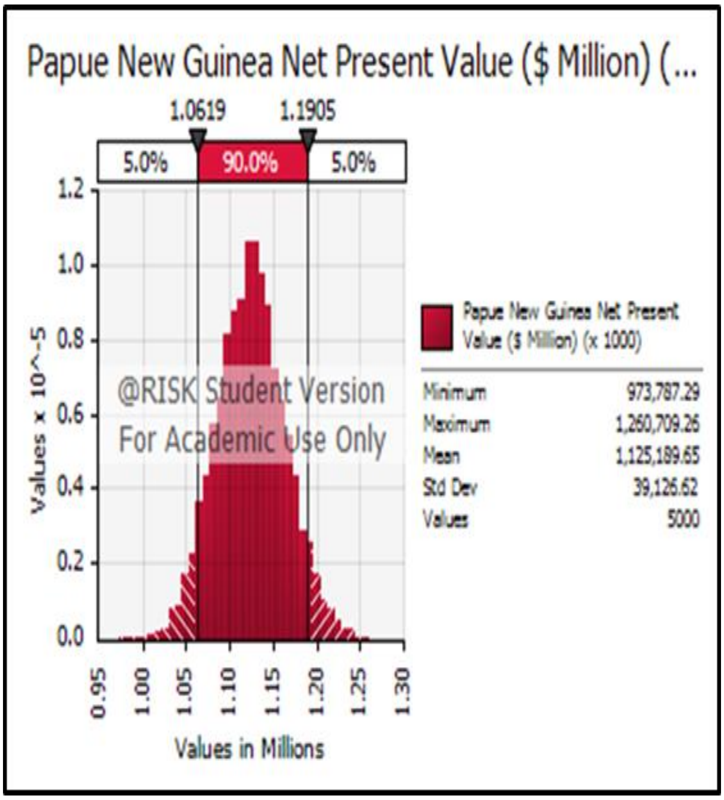


Figure 5.13 NPV simulations for Wafi-Golpu gold mine project in Papua New Guinea



When the investment is undertaken with certainty, the model development is straight-forward for MCS simulation purposes. Under static conditions, the researcher assumes that variables such as mineral prices and total costs are highly volatile. The objective of using these variables is because commodity prices and costs are the most volatile variables that could impact the NPV value significantly.

This static DCF analysis is compatible with the research undertaken by Detert and Kotani (2013). Their research used the volatility of coal price as a main variable to determine the basic potential stochastic processes. Not surprisingly, uncertainty and volatility are two of the common conditions encountered by the majority of resource companies when a project's feasibility is being considered. One of the major revenues of resource companies come from the commodity price (Damodaran, 2009).

Simulations of NPV projects among the five countries in the Asia-Pacific region, Malaysia has the highest NPV of the project investment in the region, which worth USD$44m.[53] The primary reason for Malaysia achieving a significant amount of NPV value is because of its high production rate compared to other countries. Based on this information, Malaysia's mining and other operating costs, are similar to countries such as Indonesia and Papua New Guinea.

Indonesia is endowed with some of the highest mineral resources in the world. However, it achieved the lowest NPV. This could be attributed to the low production of gold as indicated in cash flow. With 90 percentile certainty as shown in Figure 5.10, there is a 5 per cent chance of mining investment in Indonesia falling below USD$3.5m and 5 per cent chance of the investment going above USD$4.8m. The researcher believes that the calculation of NPV in Indonesia is underestimated. This is because risks are not taken into account when the DCF method is used.

Australia, one of the world's advanced economies abundant with mineral resources and heavily reliant on mineral exports has experienced a resource boom in the last ten years and achieves reasonable returns. As shown in the cash flow, mineral production in Australia is substantial, at 26190 tonnes a year. However, the substantial mining

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[53] Estimation of dollar is based on the US constant dollar. Sullivan *et.al.,* (2000, p.1) state "constant dollars are dollars in which effects of changes in the purchasing power of the dollar over time have been removed. Constant dollars, therefore, have comparable purchasing power in different time periods and are on equivalent terms".

costs and other related mining expenses are the primary reason that the investment in Australia was not as lucrative as the investment made in Asia.

The International Energy Agency (IEA), as reported in Mining Australia, believed that mining investment in Australia especially larger projects in resource sectors would hold back plans in 2013 as a result of high investment costs. Commitments to new mining projects in Australia have slowed dramatically since 2013.

Shipp (2012) from the Institute of Public Affairs of Australia expresses similar views, claiming that competition in the mining industry in Australia is increasingly intense due to high mining costs, which discourage any mining activities in the country and encourage mining investors to seek offshore investment. For instance, the set up cost for iron ore mining in Australia has doubled over the last five years to almost USD$195 per tonne. At the same time, the implementation of a mining tax and a price for carbon by the Australian Government, had significant impacts on the mining investment activities in Australia (Peterson & Cullen, 2012).

In recent years, competition in mining investment in Australia has been intense compared to Asian counterparts. For instance, because labour and capital costs are cheaper in other Asian countries, mining investors are likely to reconsider their investment in Australia. Complexity and strict government rules and regulations in Australia are also factors from investing in Australia.

Based on the simulation and with the absence of flexibility, the return for mining investment in Australia is more profitable than its closest neighbour, New Zealand after deducting essential mining expenses and capital expenditures. Mining investment in the Asia-Pacific region is profitable based on the simulation, with the exception of New Zealand. Based on the traditional static discounted cash flow, mining investment in New Zealand should be abandoned straight away without further consideration. Among other countries in the region, the mining project in New Zealand has an extremely short mining life.

The entire life of the project is less than ten years.[54] However, mining projects undertaken in other mineral resource countries experience longer project life than New Zealand.

Another factor that impacts on the project life in New Zealand can be attributed to the ore reserves. Not surprisingly, the quality and the quantity of ore reserves play a crucial role in determining the entire life of a mine project works. Hoover (2008) states that the life of a mining project is eventually dependent on the pace of mining site development. Shaft-sinking is a critical point in determining how soon the project is ended as a result of minerals depletion[55].

The above simulations are based on 5000 iterations of the Monte Carlo simulation. Damodaran (2007) states that in order to achieve the high accuracy of simulation results, it is better to run simulations for as many iterations as possible. To check the robustness of NPV values based on this statement, the researcher conducts a simple test by changing to 100,000 steps simulation for both Australia and New Zealand. Not surprisingly, NPV values using the 100,000 iterations simulation achieves higher NPV values than the 1000 iterations simulation. For instance, by setting 90 per cent certainty, Australia's NPV value is between $4,912,563.96 (minimum value) and $5,633,421.61 (maximum value). New Zealand the only country to achieve a negative NPV value, also produces a higher NPV. By changing this simulation, New Zealand's NPV value is now between $(289,315.9) and $(282,416.89) in negative value.

When applying this static DCF model into Dynamic Programming Language (DPL), the same result is replicated in the cash flow model using excel. Figure 5.14 shows an example of the NPV for the Australia mining project evaluation using DPL when the investment does not include any uncertainty. However, the primary objective of this

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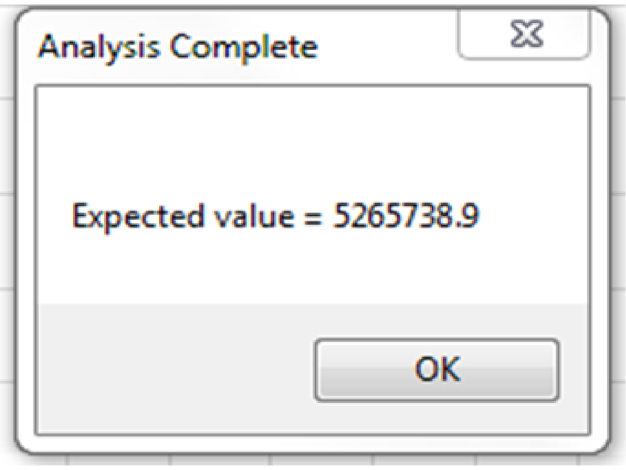
[54] Minerals in New Zealand are gold, silver, titanomagnetite iron sand, coal, and petroleum. The main reason for the shorter life of mining projects in New Zealand is attributable to the late development of resource industry 2009. Since 2009, the government of New Zealand began to undertake an extensive work program, streamline and deregulate the complexity of New Zealand's mining acts to ensure the resource industry was developed at a robust regime both nationally and internationally. For instance, the New Zealand Government amended the Crown Mineral Acts 1991 in 24 May 2013, which suited the resource industry development that it urgently needs in the twenty-first century (New Zealand Petroleum & Minerals, 2014).

[55] As noted, the new technology innovation such as shaft-sinking equipment for mining can be deepened at least 400 feet a year on an existing mine site to explore the ore body. The quickest the mine operated, the fastest the ore body is depleted and the project is ended earlier as expected.

chapter focuses on mining investment without flexibility. Therefore, MCS is the key point for evaluation purpose for mining investment.

Figure 5.14 A deterministic model using DPL application



Analysis Complete

Expected value = 5265738.9

The analysis in this section addresses the empirical results of overall NPV values in five countries used in this study. In the next section, attention will be given to the empirical analysis in terms of policy implications for mining project investment.

5.5.1 Net present values and policy analyses in the Asia-Pacific region

In the previous section, attention was given to mining firms' profit maximisation based on the net present value valuation. This static method was based on the one-off decision without considering flexibility. In the static NPV rule, if the NPV's is positive, the mining project definitely proceeds. Otherwise, the mining project is withdrawn.

Mineral deposits are diverse and are spread across the globe. Mining investors have a range of countries to choose from. Decisions on mining investment are surely based on the jurisdiction that can offer attractive tax flow rate, such as tax holiday scheme, to lure mining investors. Cottarelli (2012) states that fiscal tax rates affect mining investment decisions at all stages – this includes exploration, development, and production. The impact of a tax policy regime in mining investment can be complicated. In return, countries with mineral endowment, such as Australia, Indonesia and Papua New Guinea, must offer an attractive and conducive tax rate to mining investors.

Menezes (2001) claims that an effective fiscal tax regime is an important step for mining investors when considering their investment choice during the pre-feasibility studies. Mining investors often choose countries that offer attractive tax flow rates as their first choice in mining investment decisions. For instance, Canada is one of the most successful countries, in offering a competitive and attractive fiscal regime to mining investors (Menezes, 2001).

As noted above, policy uncertainty is one of the factors that can affect the investment decision. The choice of government policies is crucial in determining the investment decisions in a country. In the next subsection, the researcher discusses policy uncertainty without option. The objective of conducting this study is to shed light on government policy uncertainty which can deter investors from deciding to invest in the mining sector.

5.5.1.1 The model of government subsidy and tax policy measurement

Government policies play a key role in determining mining investments in a country. Otto *et.al.*, (2006) state that taxation is a complex matter and any poor or ill-conceived taxation policy decisions from a government can dramatically impact industry in the country.[56]

A government may implement a mining tax system to ensure that the tax revenue obtained from mining investors benefits the local community as well as the nation's economy, while simultaneously encouraging investment in the mining sector (Mitchell, 2009). Tax subsidies such as tax credits, tax deductions, tax exemptions, and lower tax rates offered by the government are financial incentives for mining investors. Increased taxes are financial disincentives to discourage mining investment activities as planned due to the government changing the allocation or configuration of mineral resources. In certain circumstances, governments change mining policies to achieve a better economic outcome in their policy decisions making (Lazzari, 2005). One example is the five year tax break implemented by the Malaysian Government, in which mining companies and investors are permitted tax relief, regardless of profits and losses. This policy is designed to attract mining investors to Malaysia.

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[56] Changes in taxation policies are particularly important to the mining sector. This is because the resource sector is extremely sensitive to tax-imposed effects, which involves extremely high cost structure and depends on market-driven demand and fluctuations of commodity price.

Transparency of government policies is an important factor in attracting project investment in a country. Freebairn (2012) states that in Australia during 2008-2009, the mining sector contributed at least six percent of federal government revenues. These revenues can be doubled up for both the Commonwealth and the State governments as a result of a booming in the resource sector. During the investment expansion stage, these funds are used for investments to expand transport and other physical infrastructure in that region. Mining investment, therefore, can sustain economic growth and create jobs for local regional communities and alternatively helps to develop regional infrastructures such as schools, roads and hospitals.

Governments urgently need significant policies to attract mining investment. A government can implement tax credit incentive schemes to encourage mining firms to invest in the country. Alternatively, the government can implement a tax deduction or tax break to encourage mining investment. This study aims to investigate the credibility of tax relief policies.

If the government pays tax subsidy s_{ajt}, per unit of mining project invested at time *t*, the mining investor can maximise their project's NPV in time *t* using the model in Chapter Five was follows:

$$Max\, V_{ajt} = \int_0^T [P_{x_{1\ldots n}aj} X_{1\ldots naj} e^{\alpha T} - C(I)_{aj}] e^{-RT} + s_{ajt} \qquad (5.4)$$

The equation (5.4) is applied to estimate the government subsidies in time T. The objective of estimating this model is to examine the responsiveness of mining investors when the tax credit is implemented in the mid-stream of a project investment. The researcher assumes that tax credits will be imposed by responsible governments over the period of a mining investment, and the researcher examines the impact of NPV in relation to tax credit changes. How do tax credits over the period of the project impact the investment decision of mining firms and by how much will the value of NPV change as a result of tax credits? Discussions of the tax policy with flexibility will be conducted in the next chapter. To some extent, the analysis of NPV in the mining project enables the mining investors to replicate a position where mining investment profit is maximised after tax deductions.

This section discusses the impacts of mining investment decisions when tax credits are imposed on mining investors. However, a similar model with the tax rates change can also apply in the model either by increasing the tax subsidy or reducing the tax rate. If tax credits apply, this variable will be added at the end of the model because tax credits can boost the mining investment. By contrast, the variation of tax rates can cause uncertainty and discourage mining investment. Therefore, tax rates is part of investment costs and deem to subtract from the mining project.

Fiscal policies can either increase tax subsidies or reduce tax rate and any variation of these policies can significantly change the mining investment decision. The imposition of tax credits or changes to the tax rates is completely dependent on the regulatory decisions of the current economic climate. The researcher believes that the variation of tax rates in general have a significant impact on the mining investment rather than the imposition of tax credits. Davidson’s (2012) study concludes that the mining industry pays substantial tax on project investment rather than receiving substantial tax credits from the government. In general, the mining industry is not a large beneficiary of the government subsidy or special privileges. Therefore, the mining project investment is used the variation of tax flows to conduct an analysis in this study.

Attention is now given to evaluating policy implications without an option value. The analysis examines the volatility of policy implications and assumes there are no uncertainties at this stage. Investment decisions are totally based on policy implications set by the government.

The empirical study is conducted using the @Risk simulator to investigate the variation of tax rates in response to the mining project investment in the static case. There are several uncertain variables, such as income tax rate, operating profit after tax and cumulative cash flow, which the researcher uses to simulate the NPV output variable.[57] The researcher identifies that these three variables are close together. There must be a combination of income tax rate and operating profit after tax or cumulative cash flow to conduct a simulation. Otherwise, the simulation certainly cannot be carried out. The @Risk simulator only generates sound outcome in the mining

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[57] The researcher implies income tax in this study as another form of corporate tax or company tax.

investment if these three uncertain variables are identified and none of these variables can be simulated separately.

Figure 5.15 Simulation of the Australia's Daunia coal mine project investment at 25 percent tax flow

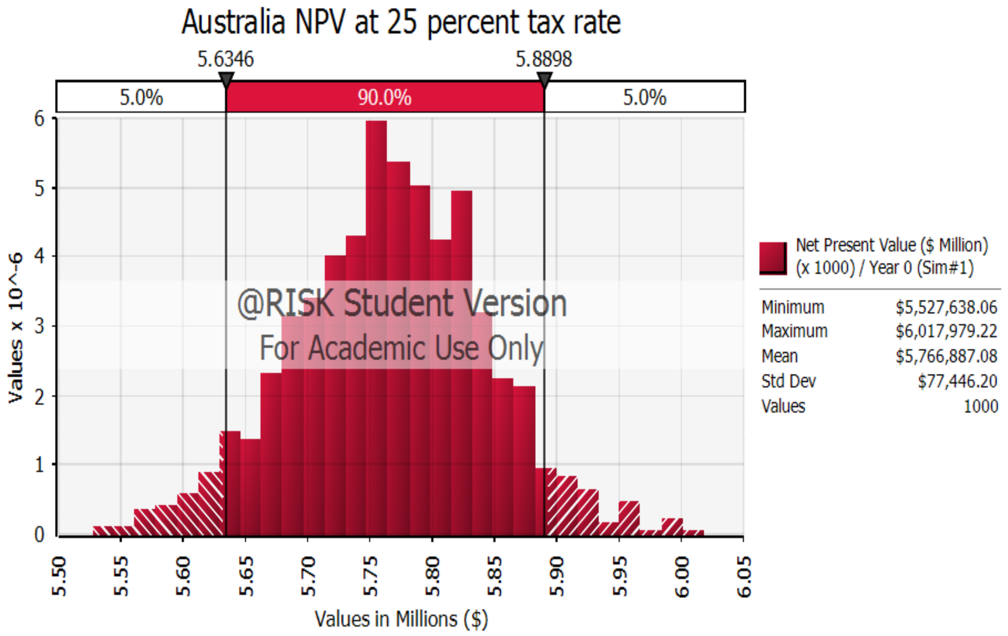


Figure 5.16 Simulation of the Australia's Daunia coal mine project investment at 30 percent tax flow

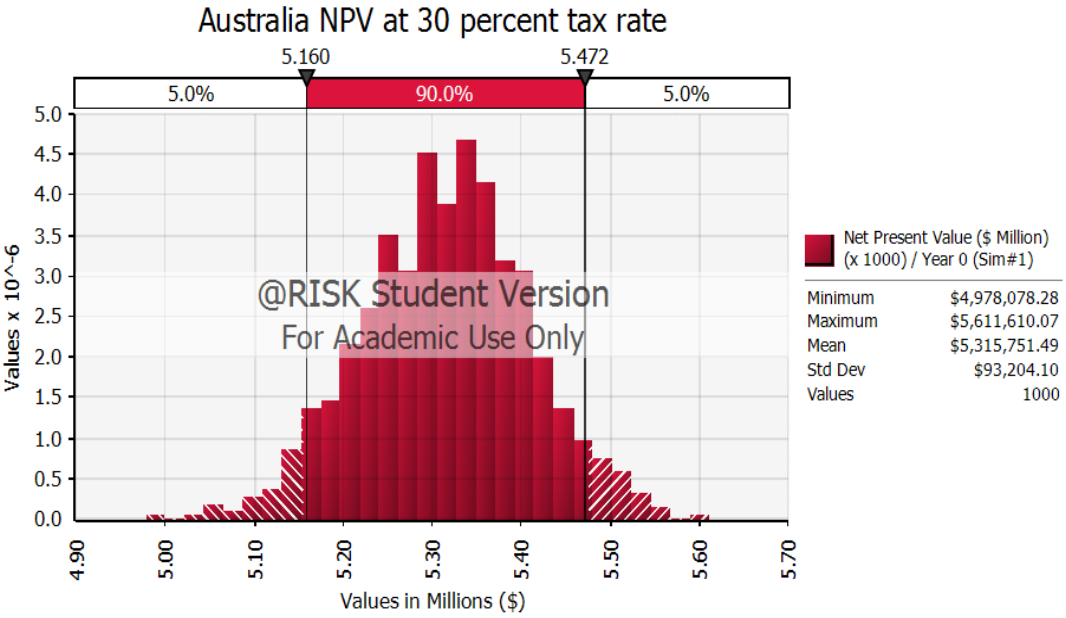


Figure 5.17 Simulation of the Australia's Daunia coal mine project investment at 35 percent tax flow

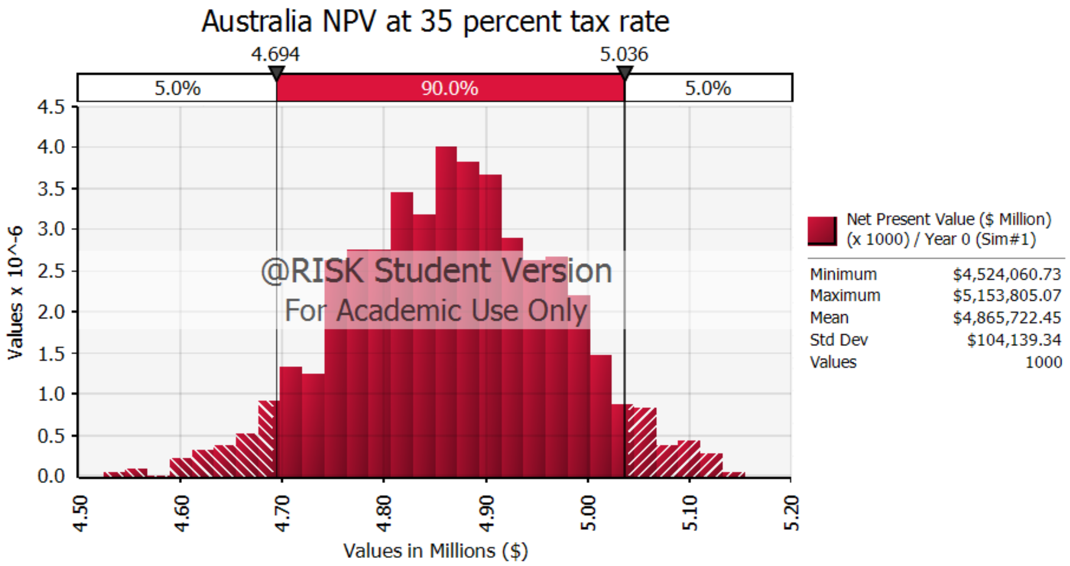


Figure 5.18 Simulation of the Indonesia's Tembang gold mine project investment at 25 percent tax flow

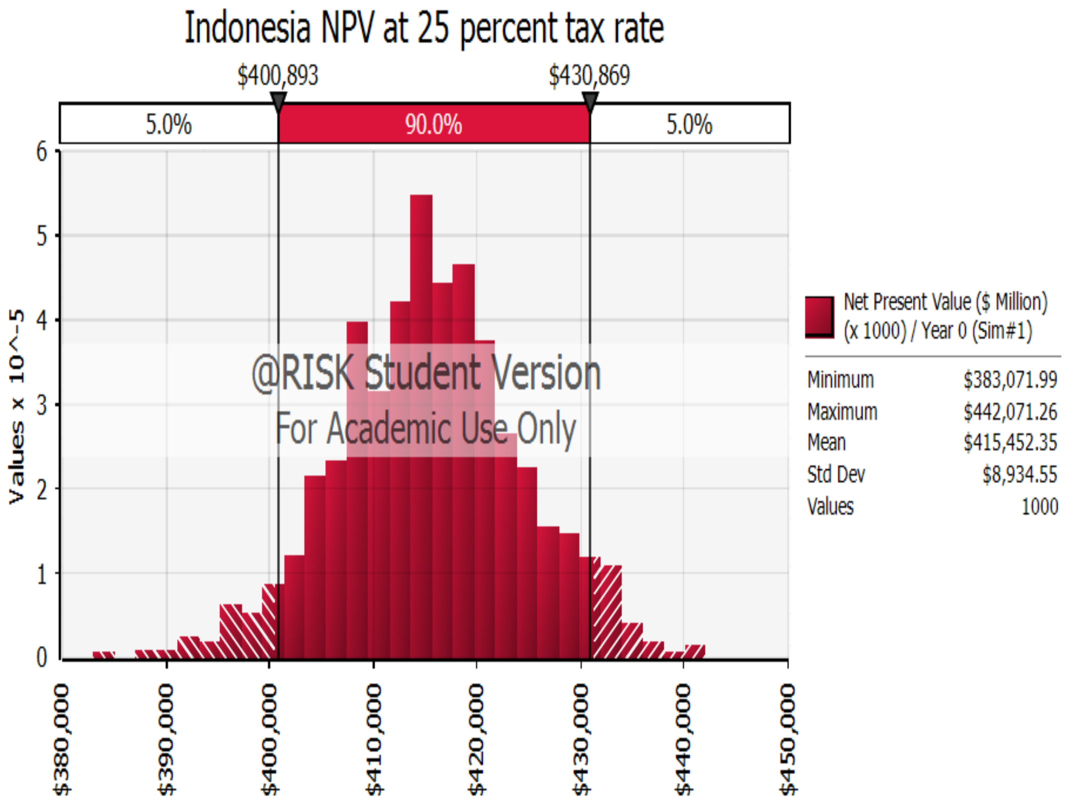


Figure 5.19 Simulation of the Indonesia's Tembang gold mine project investment at 30 percent tax flow

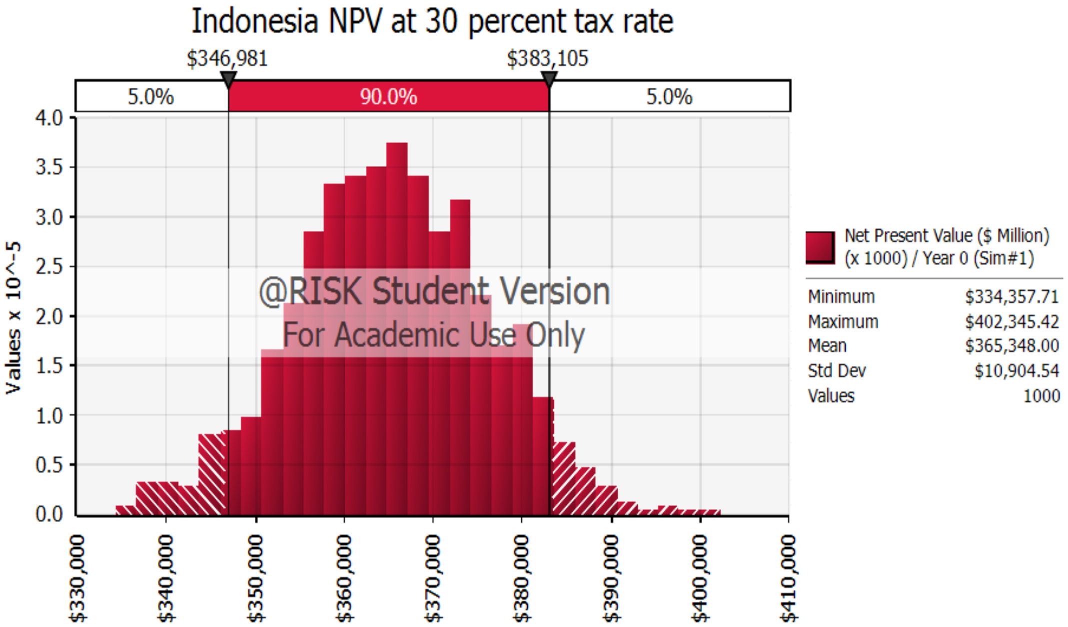


Figure 5.20 Simulation of the Indonesia's Tembang gold mine project investment at 35 percent tax flow

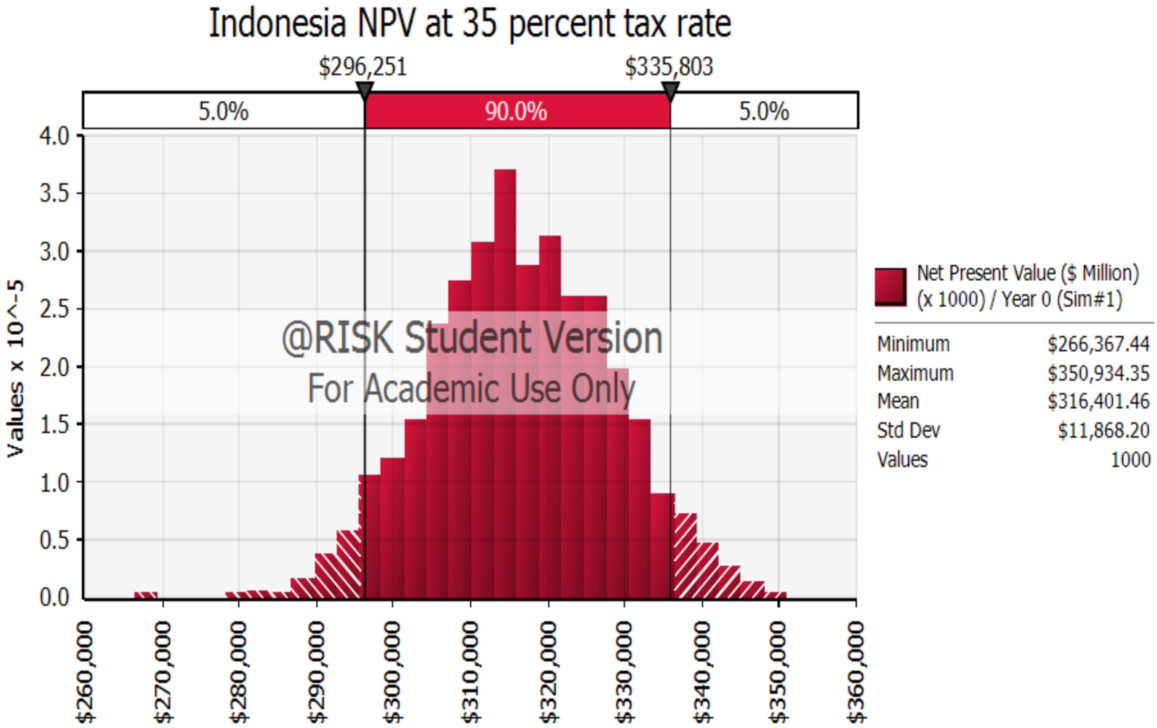


Figure 5.21 Simulation of the Malaysia's Mengapur gold mine project investment at 25 percent tax flow

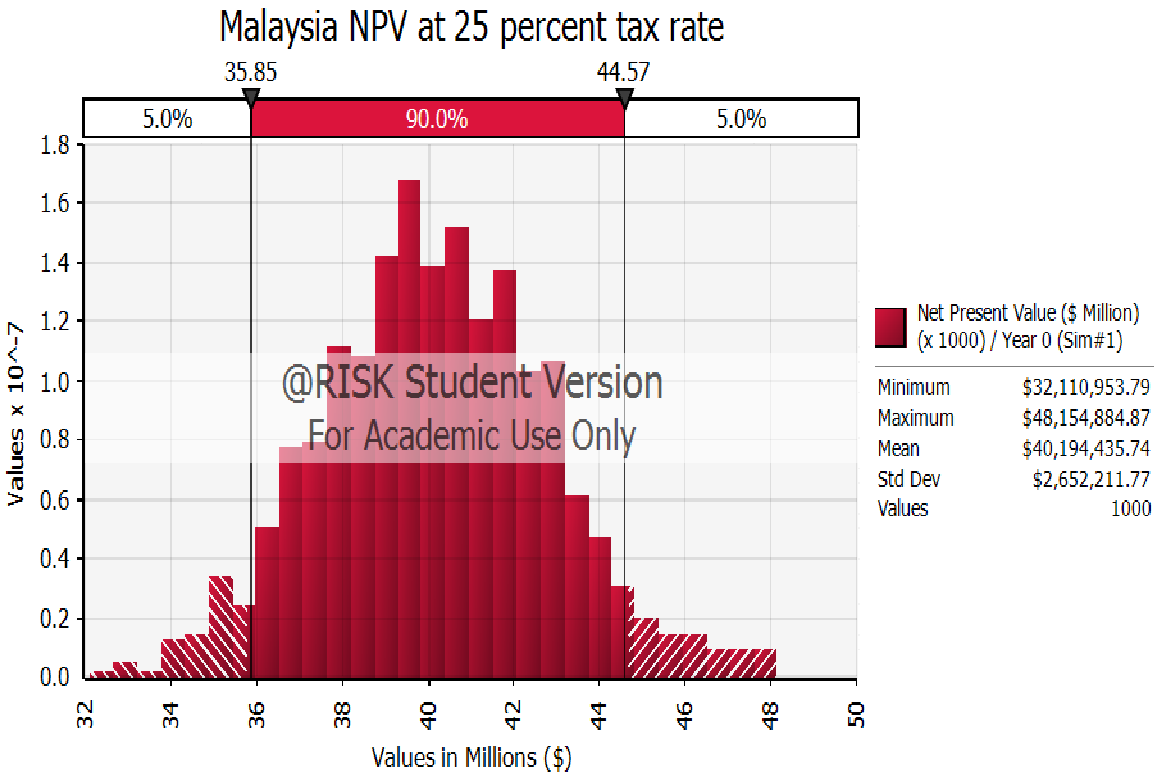


Figure 5.22 Simulation of the Malaysia's Mengapur gold mine project investment at 30 percent tax flow

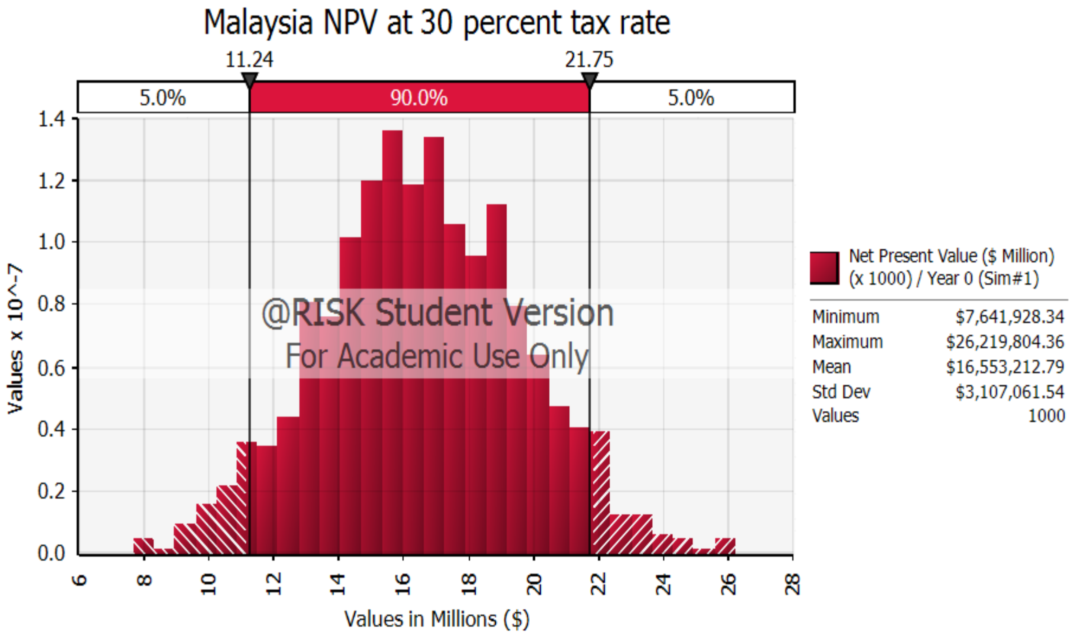


Figure 5.23 Simulation of the Malaysia's Mengapur gold mine project investment at 35 percent tax flow

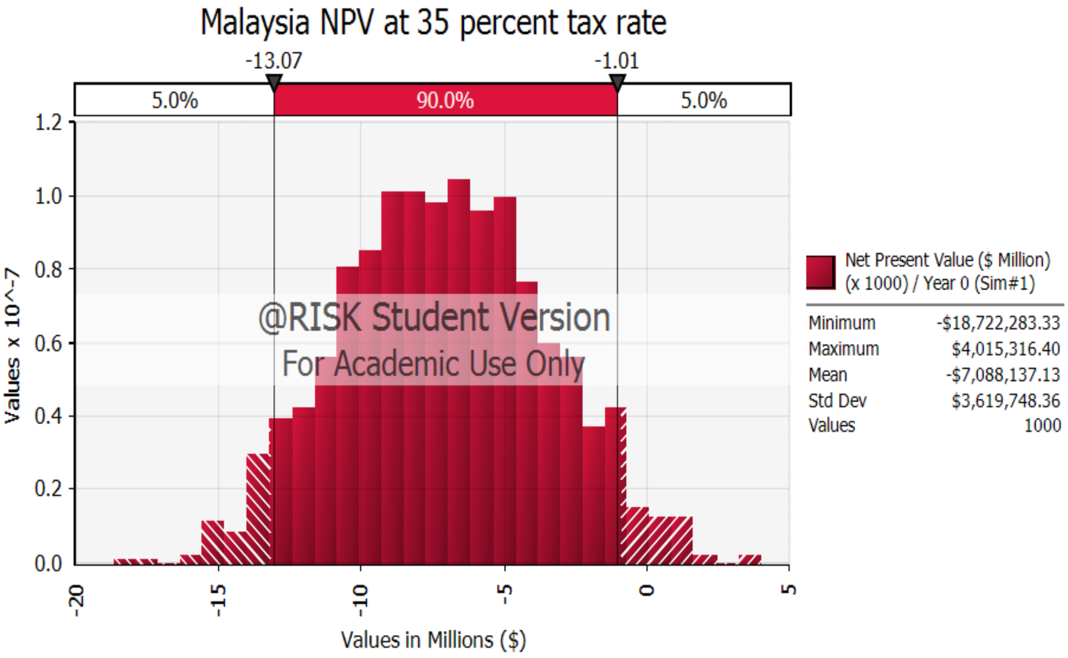


Figure 5.24 Simulation of the New Zealand's Buller coal mine project investment at 25 percent tax flow

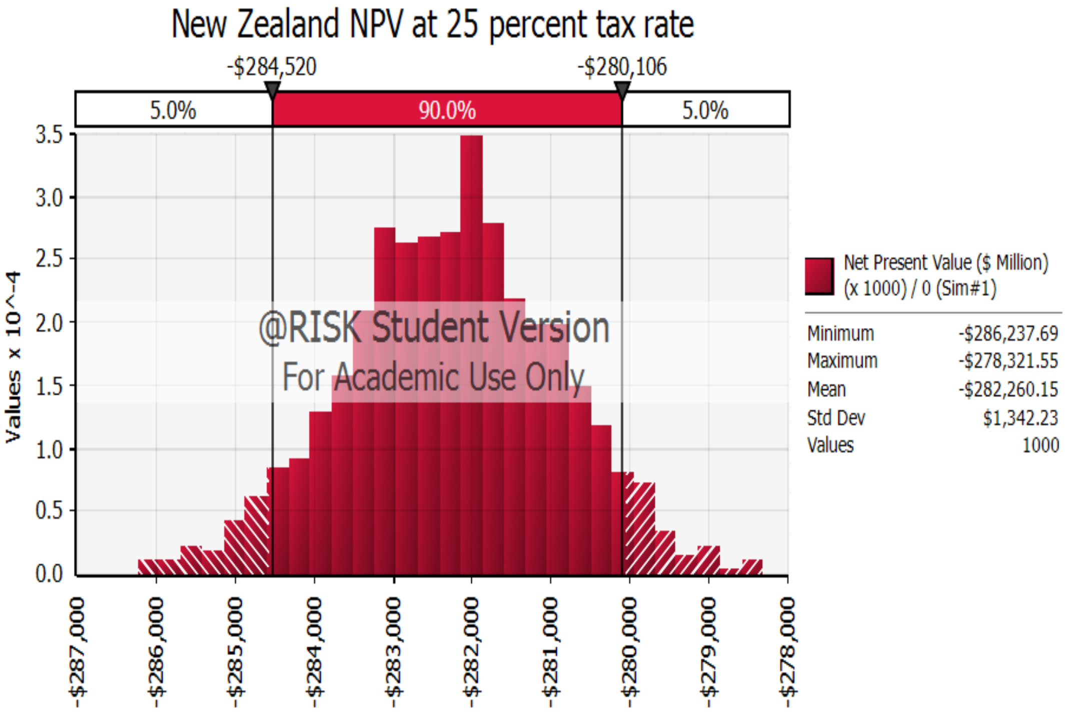


Figure 5.25 Simulation of the New Zealand's Buller coal mine project investment at 30 percent tax flow

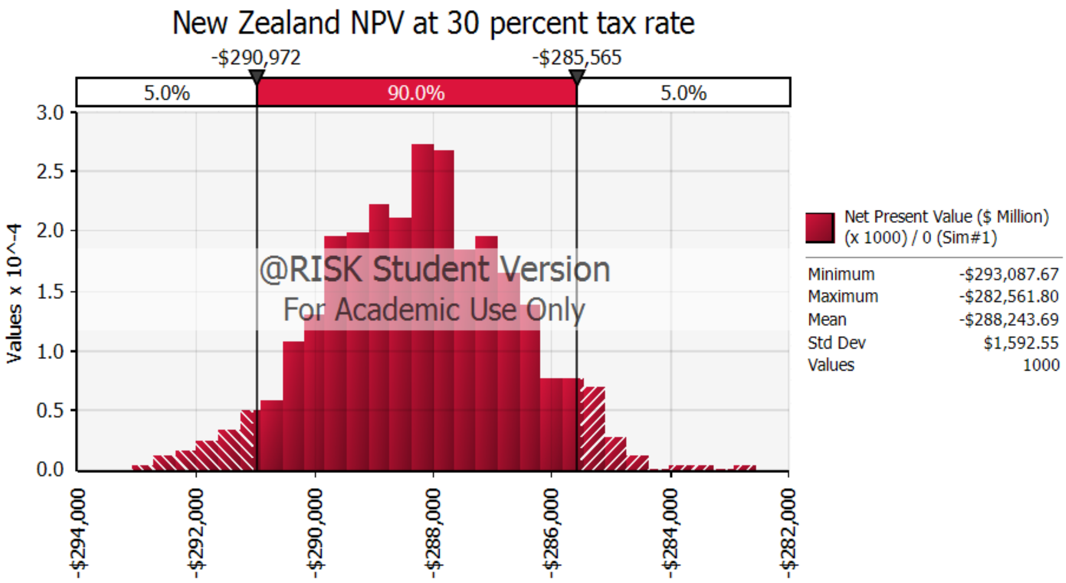


Figure 5.26 Simulation of the New Zealand's Buller coal mine project investment at 35 percent tax flow

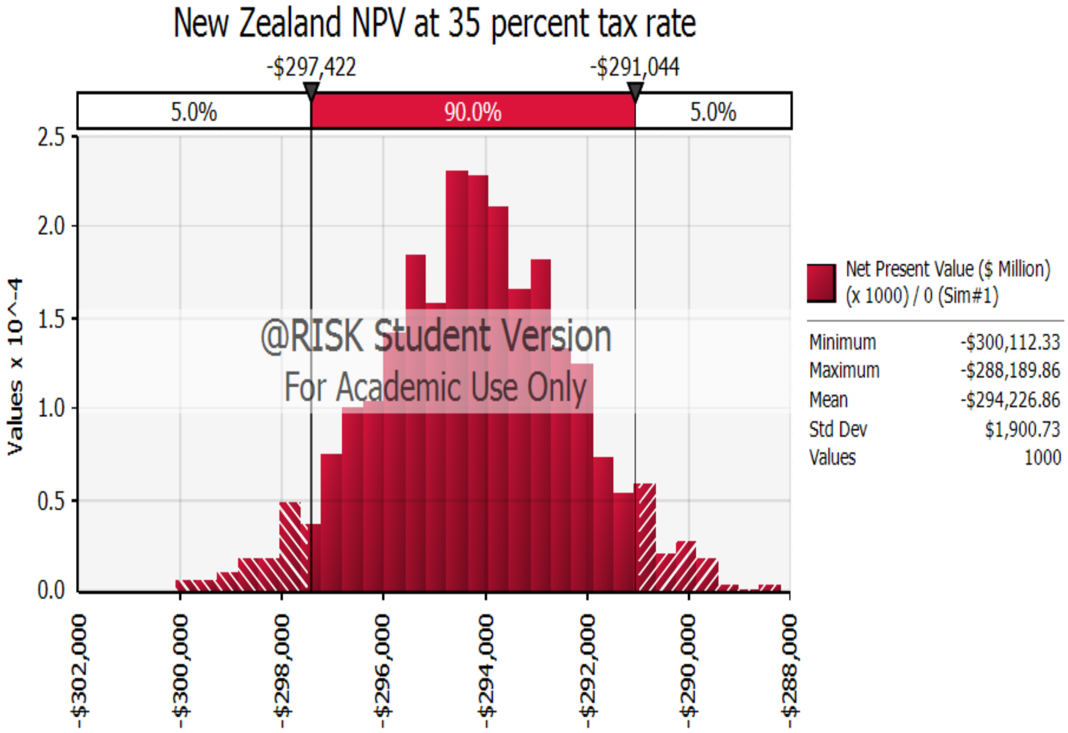


Figure 5.27 Simulation of the Papua New Guinea's Wafi-Golpu gold mine project investment at 25 percent tax flow

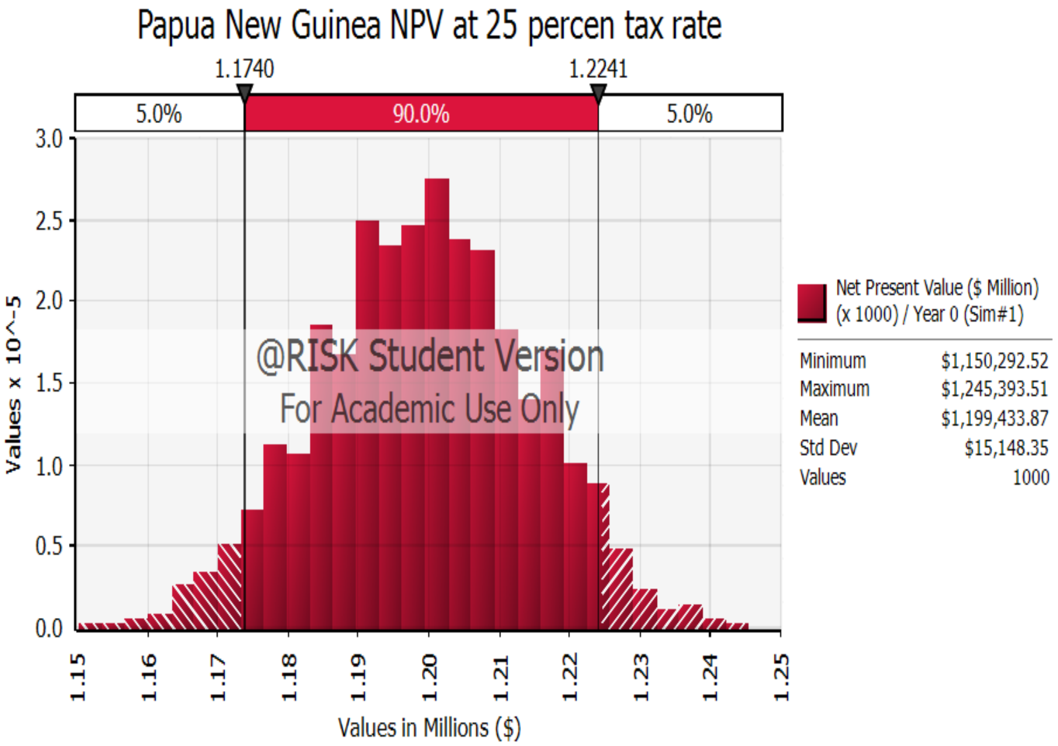


Figure 5.28 Simulation of the Papua New Guinea's Wafi-Golpu gold mine project investment at 30 percent tax flow

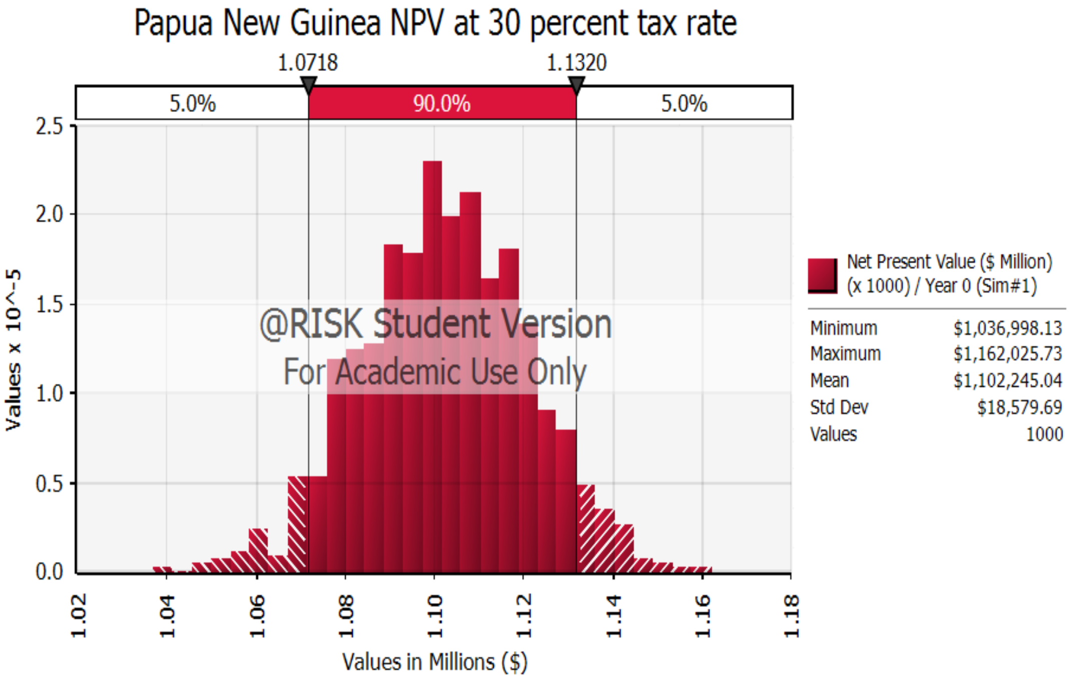
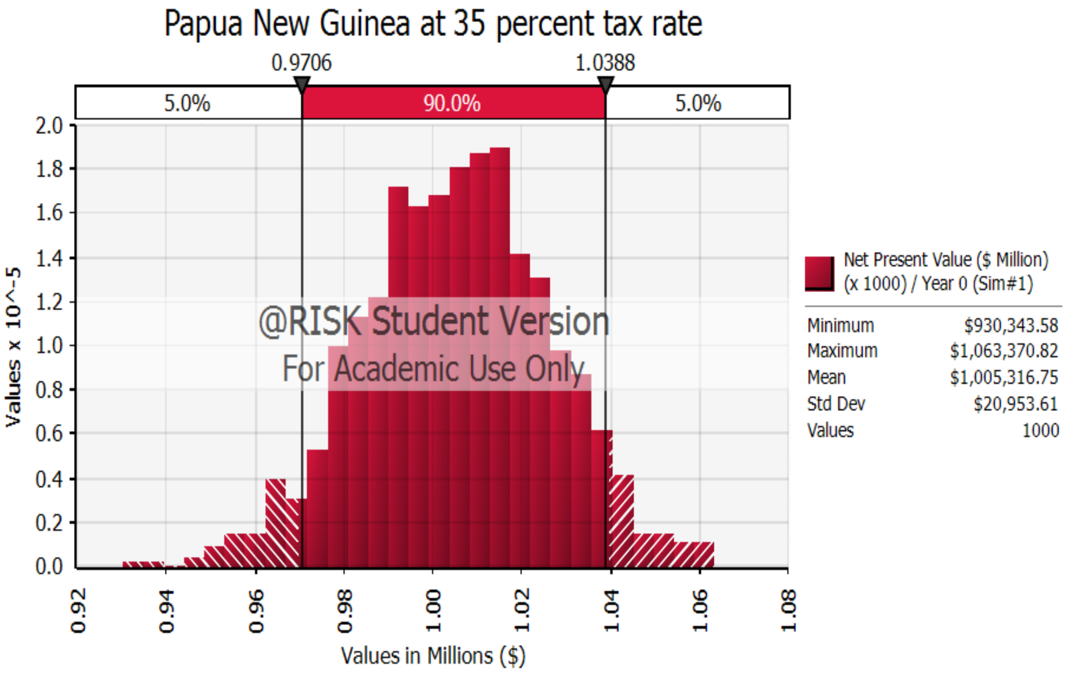


Figure 5.29 Simulation of the Papua New Guinea's Wafi-Golpu gold mine project investment at 35 percent tax flow



Figures 5.15-5.29 show the sensitivity of the NPV for five selected mining projects as a result of the variation in tax flows in the Asia-Pacific countries' mining investment decisions.[58] The outcomes show that the change of tax flow rates certainly can impact on the entire mining project investment decisions in the region. The analysis once again shows that mining investors who invest in countries endowed with mineral resources have considerable advantage over project investment in countries with limited mineral resources. The higher tax flow rate jeopardises investment profit in countries with limited minerals.

The empirical analysis also shows that tax flows uncertainty significantly reduces investors' profit in their project investment. However, if the investment project targets countries with abundant mineral resources such as Australia, Indonesia and Papua New Guinea, the scenario changes when mineral production is expanded to offset the high tax rates.

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[58] The normal probability distribution in Figures 5.15-5.29 indicates that the maximum and the minimum values in which the mining investors can use to decide the profitability of the project investment. Project investment decisions can be made based on this analysis using the static DCF method.

Table 5.18 shows the summary of the project NPV as a result of the change in tax flow rates. This table summarises the outcomes replicated by the probabilities distributions in the above figures of the five countries in the Asia-Pacific region.

Table 5.18 Summary of the project NPV based on the variation of tax flows ($ million)[59]

Tax flow at 25 per cent	Australia Daunia coal mine project	Indonesia Tembang gold mine project	Malaysia Mengapur gold mine project	New Zealand Buller coal mine project	Papua New Guinea Wafi-Golpu gold mine project
NPV minimum value	$5,485,883	$389,833	$32,369,173	-$286,494	$1,149,059
NPV maximum value	$5,997,952	$439,529	$48,762,42	-$277,981	$1,243,487
NPV mean	$5,766,911	$415,447	$40,191,453	-$282,261	$1,199,436

Tax flow at 30 per cent	Australia Daunia coal mine project	Indonesia Tembang gold mine project	Malaysia Mengapur gold mine project	New Zealand Buller coal mine project	Papua New Guinea Wafi-Golpu gold mine project
NPV minimum value	$4,992,288	$333,938	$6,767,905	-$293,573	$1,048,004
NPV maximum value	$5,643,637	$401,893	$28,249,993	-$282,761	$1,165,665
NPV mean	$5,315,778	$365,356	$16,554,383	-$288,243	$1,102,243

Tax flow at 35 per cent	Australia Daunia coal mine project	Indonesia Tembang gold mine project	Malaysia Mengapur gold mine project	New Zealand Buller coal mine project	Papua New Guinea Wafi-Golpu gold mine project
NPV minimum value	$4,340,215	$283,484	-$20,251,173	-$303,030	$921,235
NPV maximum value	$5,247,442	$362,707	$4,080,625	-$289,383	$1,083,280
NPV mean	$4,865,703	$316,390	-$7,085,746	-$294,224	$1,005,309

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[59] Corporate tax rate is the only variable used when applying a static DCF method in this study, with the exclusion of Malaysia, which the royalty tax rate is included in this study.

Similar to previous empirical outcomes, with the absence of uncertainty, the case of Buller coal mine project in New Zealand shows that its investment is negative, which can be entirely abandoned. The priority of investment decisions should be given to the other mine projects in the rest of the four countries, which generate higher NPV values.

In the scenario of the tax flow at 25 percent and 30 percent, the project investment in Malaysia is one of most profitable investment made by the mining investors. The simulation shows that the NPV of Mengapur gold mine project in Malaysia is the highest compared to other countries in the region. In the static case, there are no issues which suggest the mining investors should ignore the project investment in any particular country.

However, when Malaysia's tax flow increases to 35 percent, there is a dilemma in the decision making relating to the project investment in this country. In the static approach the mining investors certainly abandon this investment project, even though the maximum NPV value for Mengapur gold mining project is profitable. In other words, the mining investors could miss a potential 'golden opportunity' by relying on hands-on information without applying the strategy of flexibility. The evidence shows that the strategy of flexibility plays a crucial role in the mining project. The fallacy of the static DCF has become one of the critical points raised in a majority of the literature. Most studies argue that the NPV approach does not take uncertainties into consideration. As a result of these shortcomings, a new modern, sophisticated approach, with real options model is developed in order to supplement a dissatisfaction with this static DCF method. A discussion of this matter is developed in the next chapter.

5.6 Concluding remarks

In this chapter the deterministic NPV approach is adopted. In particular, the high volatility variables such as commodity prices and tax flow rates using five selected mining projects are considered in this study. The study concludes that mining investors who apply the DCF may not receive important information that can generate better revenue for their project investment. The traditional static DCF approach, which does not take flexibility into account, is one of the biggest fallacies of using this method.

This approach has been long studied in the literature about inflexibility when dealing with high risks mining projects. Because of the inflexibility of one-off decisions, mining investors can only rely on current information to decide whether the investment is to go ahead or be abandoned. However, by making the one-time investment decision to invest or not, mining investors can lose out; arguably, they should wait for better information before making the decision to invest. By adopting project flexibility and choosing a real optimal timing investment, mining investors can avoid missing out on any future investment opportunities in their project investment analysis.

In the next chapter, the researcher will address and further develop the shortcomings of the static decision model. Attention will be given specifically to accessing the flexibility investment decision making model, which is a real options valuation model. In applying this approach, mining investors have the opportunity and the flexibility to make investment decisions. Determining the optimal investment rule is crucial. Using the optimal investment rule, mining investors can decide on the critical price at which the investment decision will be made.

Chapter Six

6 Optimal Timing of Investment and the Real Options Model

6.1 Introduction

In the previous chapter, attention is given to the investment decision making of mining firms with an absence of flexibility, where mining investors make their investment decisions based only on the availability of current information. When using the traditional discounted cash flow analysis, mining firms rely on this information to decide whether the investment project should proceed or be completely abandoned.

Because of the rigidity of the traditional DCF method, mining firms could miss out on beneficial information that would enable them to make better investment decisions in the future. Given that flexibility in mining project investment decisions is crucial, the real options model has become one of the new paradigms for making decisions, particularly for large scale investment projects in the resource industry.

Investment in the resource sector entails high capital intensity and is firm specific (Pindyck, 1990). Investment expenditure in this industry is usually irreversible and is a sunk cost. By taking sufficient time to delay their investment, mining firms can wait for new information about prices, costs, and other market conditions prior before committing to their investment project.

Irreversibility has significant implications for overall mining investment behaviour. For example, irreversibility makes investment extremely sensitive to various forms of investment risks, such as uncertainty over the future commodity prices and operating costs that determine cash flow. For the mining investment itself, uncertainty over the future interest rate, as well as uncertainty over the total mining cost and timing problems, are also factors that increase the exposure to loss from the investment irreversibility.

In the context of policy implications, the purpose of the government in implementing policy stimulation is to encourage mining investment as a whole, stability in the country’s economy as well as credibility of the national financial position rather than just implementing tax incentives or interest rates to encourage mining investment.

However, changes in government policies can significantly undermine mining investors’ confidence. This is because the uncertainties of government policies can significantly shift the mining companies’ profits. These uncertainties, such as the volatility of economic conditions may induce a temporary or permanent shut-down of a project as a result of a sharp fall in profits. Relying on the optimisation theory is one of the key factors for mining firms to determine appropriate timing of investment when uncertainties occur.

The remainder of the chapter is organised as follows: in Section 6.2 the researcher discusses the optimal timing of commodity prices. In Section 6.3 the researcher describes the model and data collection. In Section 6.4 the researcher outlines the empirical outcomes of real options valuation (ROV) and the optimal timing of mining project investment and Section 6.5 concludes the chapter.

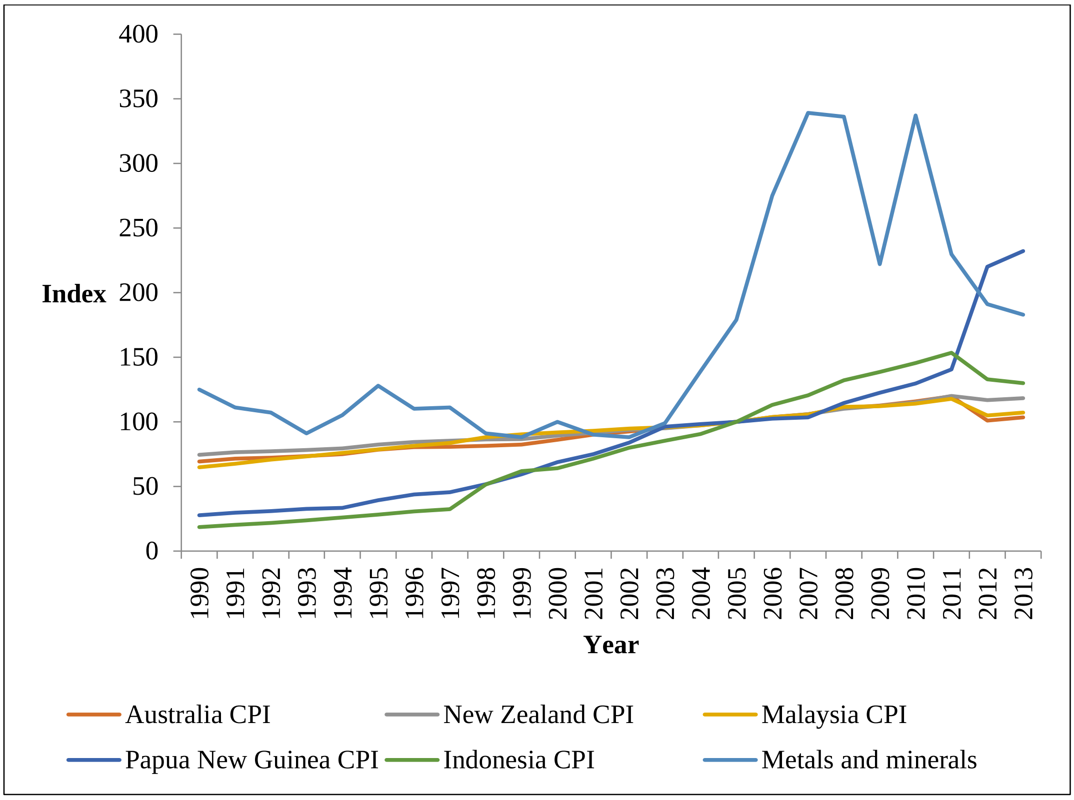
6.2 The optimal timing of commodities price

The world metals commodities market is comprised of precious and non-precious metal. These include ferrous and non-ferrous metals, which are traded at different prices. Mineral price is one of the most volatile variables in mining investment. Fluctuation of mineral price is the key factor in determining the profitability of mining project investment. According to Damodaran (2012), mineral prices fluctuate based on the basic concept of market demand and supply, as with business cycles. In other words, mineral prices will move up and down over time.

Mineral prices in the world commodity market are determined not only by the current level of mineral demand and supply. They are also dependent on the availability of stocks as well as the scarcity of that mineral. Any variation of demand and supply that induces a change in the inventories in the world commodity market has an impact on short-term price movements (Rudenno, 2012). If one commodity price is driven too high in the short term, then the country will have to substitute with other cheaper commodities that can compensate. By contrast, if demand for a commodity falls and prices are below expectation, then mines will close and production will fall.

Scarcity, the commodity grade, and the difficulty in locating and processing minerals are the main factors that determine the movement of commodity prices. A lower grade of a commodity will trade at a lower price in the world commodity market. As a result of resource depletion, mining firms have to use advanced technology to extract mineral resources in extremely difficult locations. As a consequence, difficulty in mineral extraction due to resource depletion will increase commodity prices in the world market. In other words, commodity prices in a very competitive international market fluctuate according to the world economic activities such as the market demand, supply and the stocks level.

Figure 6.1 Asia-Pacific countries CPI and Metal Price Index, 1990-2013[60] [61]



In Figure 6.1, the researcher presents Asia-Pacific countries Consumer Price Index (CPI) and the previous Metal Price Index, which have been plotted since 1990.[62] The figure shows that there is a tremendous decline of metal prices caused by the Global Financial Crisis (GCF) in 2007 and that the movement of mineral prices received by mining companies are volatile in the immediate post-GFC period. Since then, the

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[60] As noted, CPI in these five Asia-Pacific countries is based on the year 2005 = 100. All CPI values are relative to that year until 2011. CPI after 2011 is obtained from other official websites such as Central Bank in that country.

[61] CPI in New Zealand is based on index number = 1000.

[62] As noted, although CPI is not the best data to reflect the metal prices, it does reflect a fundamental trend of increasing metal prices in an inflationary environment over times.

movement of mineral prices has had a downward trend. The trend seems to be for prices to return to normal, following the same movement as the CPI.

The figure also shows that the increase in the CPI for Papua New Guinea (PNG) is much higher than the other Asia-Pacific countries. One of the reasons for this is the high inflationary pressure, which occurred due to strong economic performance that continued until 2010, supported by resurgent minerals production and investment in new projects (The World Bank, 2011).

In the profit side, mining investors always take the price according to the international market. For instance, there may be unexpected economic circumstances, such as price shocks caused by the fluctuation of mineral prices in the international commodity market, which mining investors have no power to control. Mining investors can use the future or hedging contracts to mitigate the future uncertainty of mineral prices. However, using future or hedging contracts can be costly.

As a result, forecasting the future commodity price is the key issue in determining the profitability of an investment project. However, the forecasting can only determine the most probable outcome based on current information at the time the forecast is made.

Mitigating uncertainties in project investment is important, particularly the fluctuation of commodity prices. Having an understanding of these uncertainties can provide mining investors some assurance about their investment decisions. This includes using the optimal timing in determining the best mining investment outcome based on mineral pricing. In this section, the researcher aims to apply the concept of the optimal timing using the mean reverting (MR) model to develop an empirical analysis in mining investment.

As discussed in Chapter 4, the MR model is applied to determine commodity future prices using the commodity spot prices. Following the MR model application in previous literature (e.g., Dixit, 1994; Schwartz, 1997; Schwartz & Smith, 2000), it assumes that mineral prices should model as a mean reverting process. As a repetition, the model is defined as the following:

$$dS_t = \kappa\,(\mu\text{-}\ln S_t)Sd_t + \sigma S dZ_t \quad (6.1)$$

where κ is the speed of reversion, μ is the level of mean reversion, σ is the volatility of commodity prices, which are gold and coal prices in this study, and Z_t is the increment of a Wiener process.

The common MR model applies to modelling stochasticity of commodity prices (Mun, 2006). Finding the critical value of $V^*,$ at which it is optimal to invest in a project investment, is crucial in this study. The variable V^* is used to determine the project's NPV.

Mining commodity prices always show greater volatility than any other primary product industry. The variation of these prices is considered to be a reflection of resource availability (Tilton, 2003). In the resource industry, mining production decisions as well as the rate of mineral production are highly dependent on commodity prices (Modirroosta, 2013).

The booms and busts in the mining sector are not a new phenomenon. Fluctuations of commodity prices in the mining sector have occurred for over 150 years (Stuermer, 2013). These long-term fluctuations, due to the dynamic effects of demand and supply shocks, can significantly impact fiscal and macroeconomic policies on both developed and developing resource rich countries (World Trade Organisation, 2010; IMF, 2012).

The study aims to use mineral trigger prices to find an optimal timing for mining investors to invest based on the investment rule provided.[63] Determining trigger prices help mining investors to decide the best possible investment timing in their decision making. The critical value can then be used to reflect the optimisation of mining investment behaviour for the mining investor.

The study of Dixit and Pindyck (1994) is worth noting. They apply the optimal investment rule by using two variables, V and V^* to determine the worthiness of the investment decision. The viability of the mining project investment is determined only when the value of V is larger than the critical value of V^* and that greater than I, which is represented as the investment cost. Using this optimal investment rule, mining firms can use the options to delay to decide their project investment prior to committing their

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[63] Trigger prices in this study refer as commodity shadow prices; it is a base price at which mining investors believe their profit can maximise when the investment project is undertaken.

resources. Through delaying the investment decision, mining investors can add value to their project until new information arrives.

Factors such as depletion of reserves, new ore reserve discoveries, and technical change are the key forces that reflect the movement of mineral prices (Bloch & Sapsford, 2011). Fluctuations in the commodity prices can reflect by changing these factors. Zhang *et.al.,* (2014) find that moderate volatility of mineral prices also convey some information to mining investors giving them an incentive for postponing their investment until better future mineral price information arrive.

In some cases, fluctuations or shocks in commodity trigger prices can be significant but only apply on the factors of production such as labour, capital and land.[64] To a certain degree, the impact can vary (Bhattacharyya & Williamson, 2013). This effect is often referred to as ‘Dutch Disease’, discussed in the literature review in Chapter Two.

To determine the risk of mineral price uncertainties in relation to optimal timing of mining project investment, the researcher conducts an empirical analysis in the next section.

6.3 Model and data collection

To conduct an empirical analysis in mineral price uncertainties, the researcher uses data from online secondary data resources. Similar to Chapter 5, data are primarily collected from Index Mundi, The World Bank, International Monetary Fund (IMF) and government websites, such as central banks for interest rate collection.

To simulate mineral price uncertainties, the analysis uses @Risk software and Syncopation software DPL 8 decision programming language. Commodity prices first use @Risk software to simulate forecasting future price then DPL 8 is applied to solve the ROV. As noted, DPL 8 is a system dynamic model to solve the ROV using strategic decision tree analysis. This software is used to evaluate mineral price uncertainties

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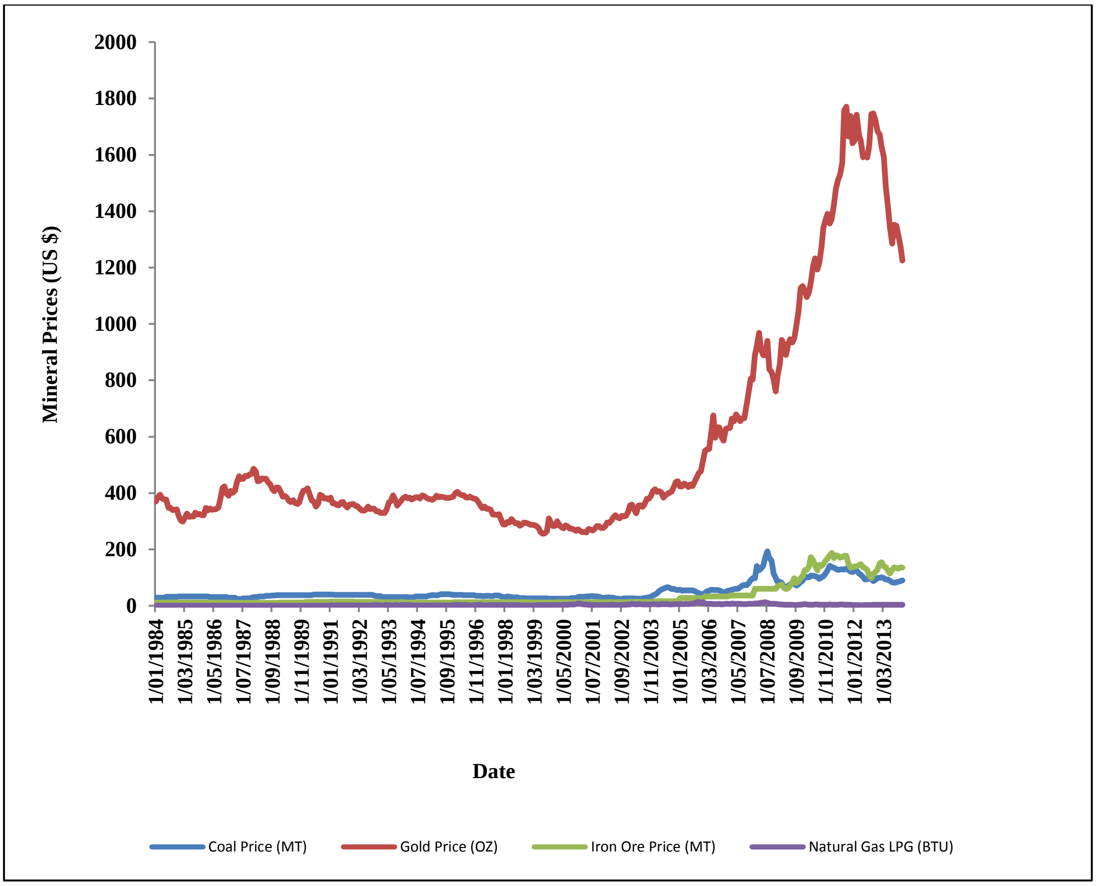
[64] According to the study of Stuermer (2013), there are three different types of shock to commodity prices. Firstly, ‘supply shocks’ occur due to unexpected event changes in the supply of commodities. Secondly, ‘world output-driven demand shocks’ occur due to unexpected strong demand of commodities in the world market as a result of an unexpected strong economic growth (e.g. a strong demand of the Australian commodity in the Asia market in the first decade of the 2000s). Thirdly, ‘other demand shocks’, which are not related to the other two shocks mentioned above.

based on the investment timing and has been used extensively in previous literature for modelling risky projects (e.g., Smith & McCardle, 1999; Brandao, *et.al.*, 2005; Tan *et.al.*, 2009; and Tan *et.al.*, 2010). In the next section, a simulation of coal and gold price model is discussed.

6.3.1 Commodity prices simulation

Having discussed the movement and fluctuation of commodity prices, the researcher now attends to the simulation of commodity prices for mining investment. Using Monte Carlo simulation (MCS) at @Risk software, the researcher finds the critical value that the mining investor uses this value to maximise the expected NPV of the project.

Figure 6.2 The historical trend of mineral and energy prices.



Source: Indexmundi, 2014

The study uses two commodities, coal and gold, to find a critical value that the mining investor invests in their project. These two commodities are among the most important mineral resources that the five Asia-Pacific countries have produced. For instance, the Wafi-Golpu Gold mine in PNG, owned by the Wafi-Golpu Joint Venture, which is a subsidiary of Newcrest Mining Limited and Harmony Gold Mining Company Limited of South Africa; and the Mengapur-Selinsing Gold mine in Malaysia owned by the Canadian mining company, Monument Mining Limited. These gold mine projects are the major and largest mining sites in these countries economy.

As stated throughout this thesis, commodity prices are variables that play a significant role in mining project evaluation. Figure 6.2 indicates the fluctuation of the historical prices in commodities and energy prices over thirty year periods. This fluctuation is particularly important in the feasibility and operation stages (Shafiee, 2010).

The commodity prices data for forecasting are obtained from the World Bank. The coal price data is collected from early January 1970 until August 2014 and the gold price data from January 1960 until August 2014. Selecting an appropriate stochastic model is a crucial step in the process of mining investment (Miranda & Brandao, 2013). The stochastic process has a direct impact on the behaviour of the ROV, which can affect the entire decision making. In this study, the researcher uses fifty-year periods to forecast commodity prices because commodity prices tend to revert to a long-term average price (Ozorio *et.al.,* 2013).

Flexibility and timing are two major interests in this study. Mining investors can use flexibility to defer their option in order to maximise their project value by waiting for better information.

Table 6.1 Monthly average projected prices for gold

Months	USD/Ounce
SEPT-2014	1294.99
OCT-2014	1297.89
NOV-2014	1301.39
DEC-2014	1305.00
JAN-2015	1308.64
FEB-2015	1312.29
MAR-2015	1315.95
APR-2015	1319.60
MAY-2015	1323.27
JUN-2015	1326.93
JUL-2015	1330.59
AUG-2015	1334.27
SEPT-2015	1337.93
OCT-2015	1341.61
NOV-2015	1345.29
DEC-2015	1348.98
JAN-2016	1352.65
FEB-2016	1356.35
MAR-2016	1360.04
APR-2016	1363.74
MAY-2016	1367.44
JUN-2016	1371.14
JUL-2016	1374.84
AUG-2016	1378.55

Table 6.2 Monthly average projected prices for coal

Months	USD/PER(M/T)
SEPT-2014	68.09
OCT-2014	70.58
NOV-2014	69.92
DEC-2014	70.65
JAN-2015	74.40
FEB-2015	75.75
MAR-2015	75.91
APR-2015	73.79
MAY-2015	74.89
JUN-2015	73.53
JUL-2015	72.07
AUG-2015	70.77
SEPT-2015	69.98
OCT-2015	68.53
NOV-2015	66.44
DEC-2015	66.67
JAN-2016	67.51
FEB-2016	68.29
MAR-2016	68.19
APR-2016	68.11
MAY-2016	68.29
JUN-2016	68.00
JUL-2016	68.37
AUG-2016	68.23

This is because fluctuations of mineral prices in the world market can impact the total project value significantly. Modelling mineral price uncertainties using decision tree analysis gives the investor a better chance of getting higher value for the mining project.[65]

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[65] In this study, the researcher uses decision tree analysis to identify the best possible NPV outcome of the mining investment project. Determination of NPV is based on variation of commodity prices in which uncertainties in commodity prices induce the change in total value of the mining project.

In a practical matter, flexibility is the key criteria that mining managers take into consideration both informally and intuitively. Smith and McCardle (1999) state that mining managers incorporating flexibility in their project investment activities can most likely improve the accuracy of the project valuation and maintain its consistency across different managers within the mining company. These contentious debates have been argued to a great extent in the literature (for example, Dixit & Pindyck, 1994).

In a deterministic case, the mining decision in relation to commodity prices fluctuation takes three steps into account. Firstly, the mining company's decision is based on the base price of the commodity. Secondly, the mining company assumes that the project should go ahead, or wait for future information, or be abandoned. Thirdly, the company begins to simulate the model to determine the project's NPV. Tables 6.1 and 6.2 above illustrate the forecasted coal and gold prices for the next twenty-four months.

Based on historical data over fifty year periods available from the World Bank, Table 6.1 and 6.2 show the average monthly movement of coal and gold prices. The forecasted results show that the value of precious metals such as gold is continuing to rise. However, there is significant volatility of coal prices due to demand and supply of coal in the world market. The forecast shows that coal price is likely to ease after 2015.

Figure 6.3 Gold price simulation

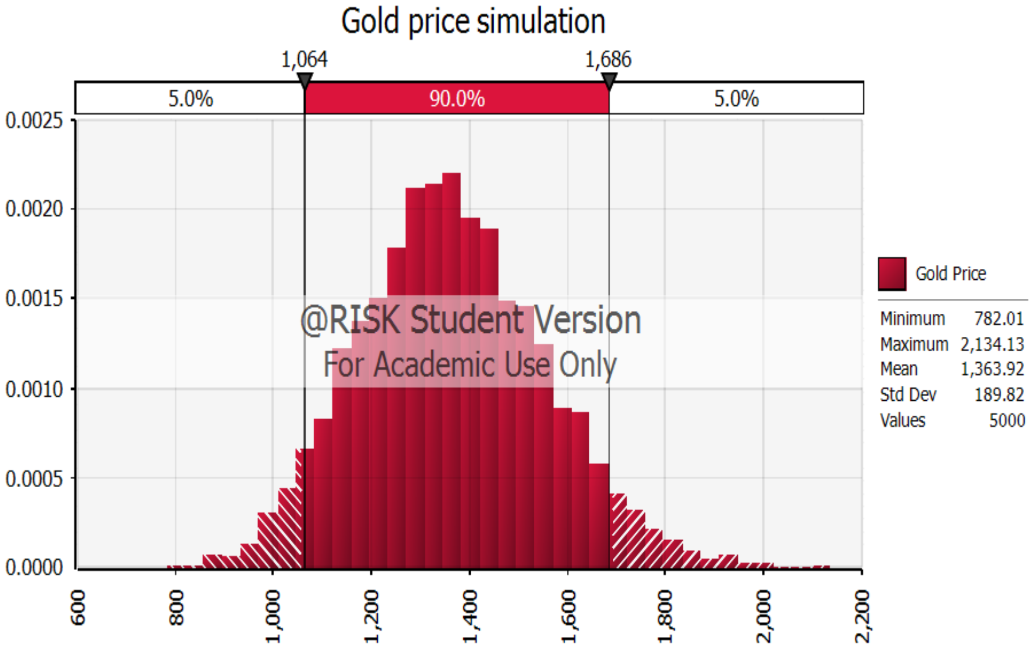
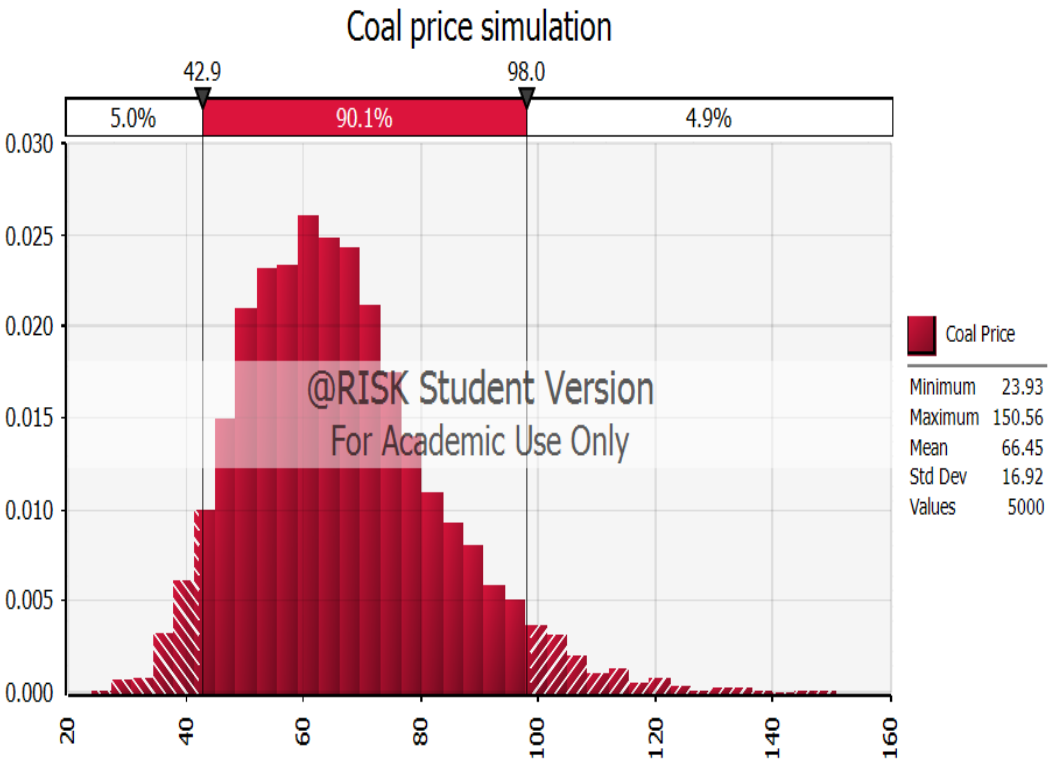


Figure 6.4 Coal price simulation



These average monthly coal and gold prices can then be simulated by using @Risk software MCS with 5000 iterations. The MCS is based on equation 6.1, and using the prices in Tables 6.1 and 6.2. Figures 6.3 and 6.4 show the simulation of these two prices.

Using MCS with 5,000 iterations, the gold price simulation shows that for the gold mining project, there are 5 percentiles that the gold price fall below USD1064 per ounce and 5 percentiles that the gold price go up above USD1686 per ounce, providing the mining investor sets their investment target at 90 percentile.

For a coal mining project, the simulation shows that with a 90 percentile target in the coal mining project, the coal price will have a 5 percentile chance to fall below USD42.90 per m/t and a 5 percentile chance to go up above USD98.00 per m/t.

The key point of running this simulation is to obtain the forecasted gold and coal prices in which the critical value V^* can be used by the mining firm to make a decision in their mining investment. To determine the critical value, the researcher adopts a simple example as conducted in Dixit and Pindyck (1994) to find the value of option to invest, as well as the investment rule for a mining investment.

To calculate the option to invest, the researcher applies a basic risk-free portfolio in which the mining firm held the option and sold short some minerals. In today's mining project portfolio at t=0, the value is

$$\Phi_0 = FV_0 - nP_0 \qquad (6.2)$$

where Φ_0 is denoted as the return from holding the mining project portfolio at time 0; FV_0 is denoted as the value of the investment opportunity at time 0; and nP_0 is represented a short selling position for a commodity by borrowing from another producer, or by going short in the futures market at time 0.

If the project value in t=1 depends on the future price of P_1, the value of the mining project portfolio is

$$\Phi_1 = FV_1 - nP_1 \qquad (6.3)$$

where $\Phi_1$is denoted as the return from holding the mining project portfolio at time 1; $FV_1$is denoted as the value of the investment opportunity at time 0; and $nP_1$is represented a short selling position for a commodity by borrowing from another producer, or by going short in the futures market.

In equations (6.2) and (6.3), the value of the mining project depends on the commodity price of P at time 0 and 1. The letter of n is represented the risk-free rate of the mining project portfolio in which mining investor could obtain a short position by borrowing from another mining producer, or by going short in the futures market. The value of the mining project, Φ_1 is independent of what happens to the P. In this case scenario, the objective to set the risk-free rate for the mining project portfolio is to ensure that the project value is independent of whether the P goes up or down in t=1.[66] By setting the mining project portfolio's return equal to the risk-free rate, the researcher is then able to determine how the value of the option and the decision to invest depend on the

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[66] Since the mining project is risk-free, the rate of return that the mining investor can earn by holding the project portfolio will be the risk-free rate of interest. If the return of the mining project portfolio is higher than the risk-free rate, speculators or arbitrageurs can earn unlimited amounts of money by borrowing at the risk-free rate and buying the portfolio. By contrast, if the return of the mining project portfolio is less than the risk-free rate, speculators or arbitrageurs can earn money by selling short the portfolio and investing the funds at the risk-free rate.

initial commodity price, P_0 on the magnitudes of the up and down movements in price at t=1, and on the probability q that the price will rise next year.

In determining the value of option to invest in mining investment in t=1, the calculation is based on the construction of a risk-free portfolio, which requires that the mining investor can hold the option and sell short number of commodities. In t=0, the value of the project is denoted in equation (6.2). In t=1, the value of the mining project depends on the commodity price of P_1. In simple mathematical form, the value of the mining project in t=1 is

$$FV_1 = \sum_0^\infty \frac{P_1}{(1.1)^t} = 11P_1 \qquad (6.4)$$

Assuming that the risk-free discount rate is at 10 per cent per annum (p.a.) and the initial capital expenditure for setting up the mining project is USD8500m. The mining manager expects that the investment will only go ahead if the project value exceeds USD8500m.

The purpose of the researcher applies the risk-free discount rate at 10 per cent p.a. in this study is to ensure that the portfolio of mining investment is risk-free, that is, so that the project value for next year is independent of whether the price of the commodity goes up or down. Since the portfolio is risk-free, mining investors know that the rate of return one can earn from holding it must be the risk-free rate of interest. If the return on the portfolio were higher than the risk-free rate, arbitrageurs could earn unlimited amounts of money by borrowing at the risk-free rate and buying the portfolio. By contrast, if the portfolio’s return were less than the risk-free rate, arbitrageurs could earn money by selling short the portfolio and investing funds at the risk-free rate. As a result, by setting the portfolio’s return at 10 percent p.a. equal to the risk-free rate, mining investors be able to find the current value of the investment opportunity, which is derived in equation (6.3).

To maximise the future value of FV_1, the project value in t=1 can derive as $FV_1 = \max[0, 11P_1 - 8{,}500]$. The mining manager also assumes that there is a 50 per cent chance the price will go up and a 50 per cent chance the price will go down. If the price P_0 is in the range where it may go up next year, that is, if $P_1 = 1.5P_0$, the investment would be worth going ahead; otherwise the investment would have to defer if the price went down. In this case, if the investment is to go ahead, the equation (6.2) can be derived as

$$\varPhi_1 = 16.5P_0 - 8500 - 1.5nP_0 \quad (6.5)$$

There is also 0.5 probability chance of the commodity price going down. If the commodity price is falling, the investment will not take place, in which case the equation can be derived as

$$\varPhi_1 = -0.5nP_0 \quad (6.6)$$

To calculate these two scenarios, the researcher assumed that the commodities price had a 0.5 chance to go up and down, which is *n*, which means the risk-free portfolio can be derived as

$$n = 16.5\text{-}8500/P_0 \quad (6.7)$$

In order to calculate the return of the investment, the short position would require a payment of $0.1nP = 1.65P_0 - 850$. Since the mining investment return is $6.6P_0 - F_0 - 3400$, and is risk-free, the return must be equal to $0.1\varPhi_0 = 0.1F_0 - 1.65P_0 + 850$. Solving for FV_0, the option value to invest is:

$$FV_0 = 7.5P_0 - 3868 \quad (6.8)$$

Applying equation (6.8) in order to find the critical price of P_0, the intrinsic value of the option investment rule is shown in Table 6.3:

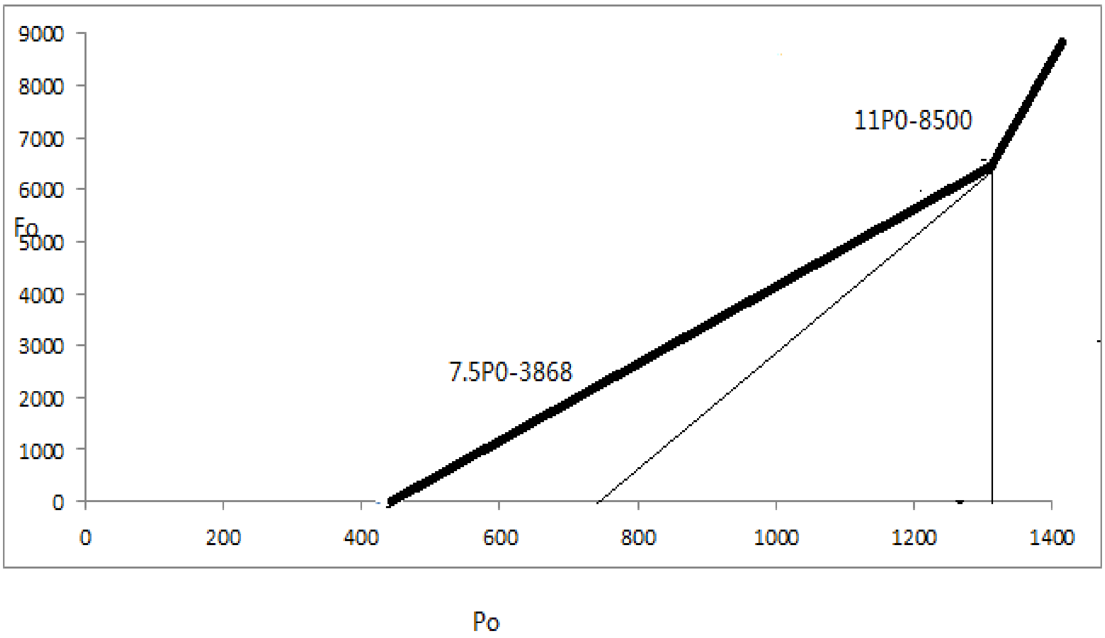
Table 6.3 The gold critical price of option to invest and the investment rule

$P_0 \leq 425$	$F_0 = 0$	Never invest
$425 < P_0 \leq 1323$	$F_0 = 7.5P_0 - 3868$	Invest in period 1 only if price goes up
$P_0 > 1323$	$F_0 = 11P_0 - 8{,}500$	Invest in time 0

Following a simple calculation, as depicted in Dixit and Pindyck (1994), Table 6.3 shows that if the commodity price is below USD425, the mining investment can be abandoned. If the value of commodity price is between 425 < P_0< 1323, the mining investor should wait for better future information and invest if the price goes up. If $P_0 > 1323$, the mining investor should make the decision immediately.

In Figure 6.5, the researcher has plotted F_0 option to invest as a function of P_0 price. Figure 6.5 shows that the mining investor has a choice to invest today or not invest at all. The option to invest would be worth the maximum of zero and $11P_0 - 8500$ if the option is exercised immediately. In other words, the net present value (NPV) of today's project value will be less than USD8500.

Figure 6.5 Change the initial gold price to determine the value of option to invest



The mining investor would invest today as long as$11P_0 > 8500$, that is, the value of $P_0 > USD772$. When $P_0 > 1323$, it is optimal to invest now rather than wait. The intrinsic value of the option to invest is then $11P_0 - 8500$ and is shown as a solid line for values of P_0 greater than USD1323. However, if the option value to invest is worth more than$11P_0 > 8500$, the option should not be exercised, at least until next year when better information is available for the mining investor.

Figure 6.5 shows that F_0 is a convex function of P_0. In this case, if the investment decision is made today, then the mining firm has the right to exercise its project up to the optimal exercise point, which is USD1323. The figure also shows that as long as $P_0 > USD772$, the project investment should begin to invest immediately.

Applying the similar method as above, if the cost of the investment, I, for the coal mining project at USD1000, the coal price to decide if the investment project goes ahead will be above USD61 per tonne. Mining investors should consider their coal mining investment project in period 1 only if the coal price has gone up to between USD61 and USD73. The mining investor should prepare the worst and the best case scenarios in which their coal mining project should be abandoned immediately if the coal price is below USD61. Otherwise, the coal mining project should invest immediately if the coal price reaches USD73 per tonne and above. Table 6.4 demonstrates the changing of coal price that can impact the investment decision of the coal mining investor.

Table 6.4 The coal critical price of option to invest and the investment rule

$P_0 \leq 61$	$F_0 = 0$	Never invest
$61 < P_0 \leq 73$	$F_0 = 7.5P_0 - 455$	Invest in period 1 only if price goes up
$P_0 > 73$	$F_0 = 11P_0 - 1{,}000$	Invest in time 0

Having discussed uncertainty of commodity prices in relation to optimisation of the project investment, the researcher now conducts an empirical analysis of real options valuation.

6.4 Real option analysis

As discussed in the previous section, timing is the key factor for mining investors to determine their investment decisions. The advantage of the ROV method is having the opportunity to access its flexibility. Choosing the right timing with flexibility offers a significant advantage for mining investors. In using the ROV approach, mining investors are able to choose options to wait, options to expand, options to contract and many other options to determine investment decisions that will suit their flexibility. Among these options strategies, the option to wait or the deferring option will be emphasised in this study.

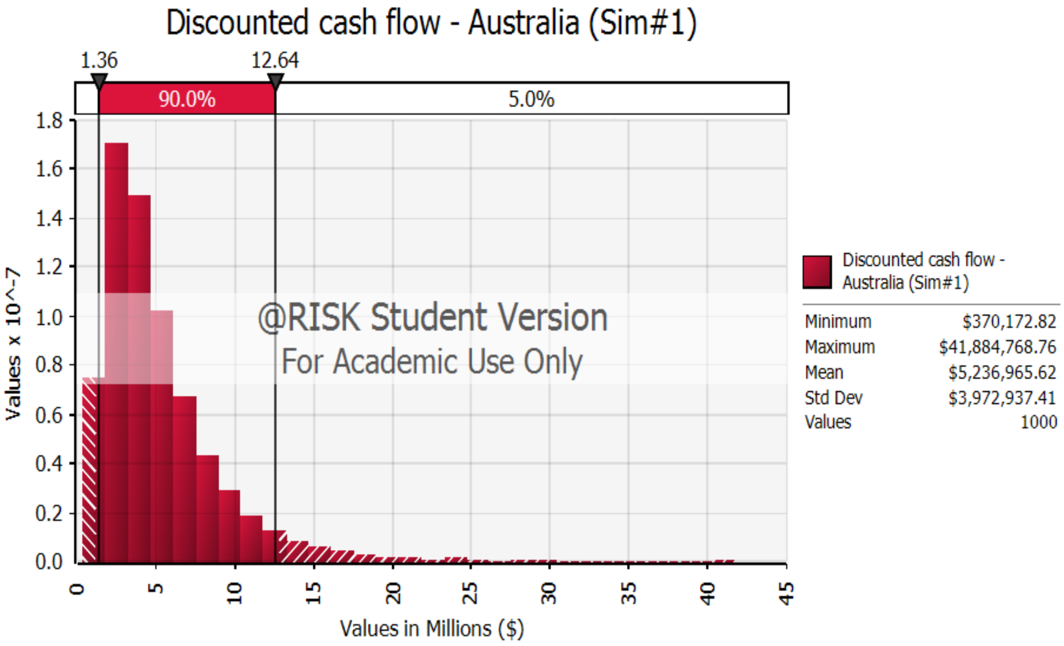
6.4.1 The empirical evidence of using real option valuation

In this section, the researcher uses the strategy of the deferring option to estimate highly volatile variables. The study is based on the analysis of selected project investments in the Asia-Pacific countries. The important feature of using the deferring option is to enable the mining investor to have an option to invest by waiting rather than making the investment decision immediately.

Waiting has its value, particularly in large scale mining project investments. The objective of this study is to construct a case scenario in which the investor has an option to defer for a year, and the project's value has a volatility rate of 40 per cent. What would the project value be worth if the deferring option applies, assuming that investment cost is increasing over time and the risk free rate is set at 12 per cent?

Following the model set up in the @Risk software simulator, the option valuation in this study valued in three simulations using 1000 iterations. Prior to conducting the option value simulation, the first step is to simulate the future value, which is V of the mining project, using a lognormal model; the second then is to calculate the cash flow from the option by deferring the time of option value using the formula at @Risk as *Max(V-exp(.12)*current investment cost,0)*; and the last step is to calculate the discounted cash flow from the option.[67] The option valuation can then be determined based on the mean of discounted cash flow to decide whether or not the investment should be exercised.

Figure 6.6 Option to invest for the Daunia coal mine project in Australia



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[67] The current investment cost is varied and based on the total capital expenditure (CPEX) of an initial set up cost for a selected project investment.

Figure 6.7 Option to invest for the Tembang gold mine project in Indonesia

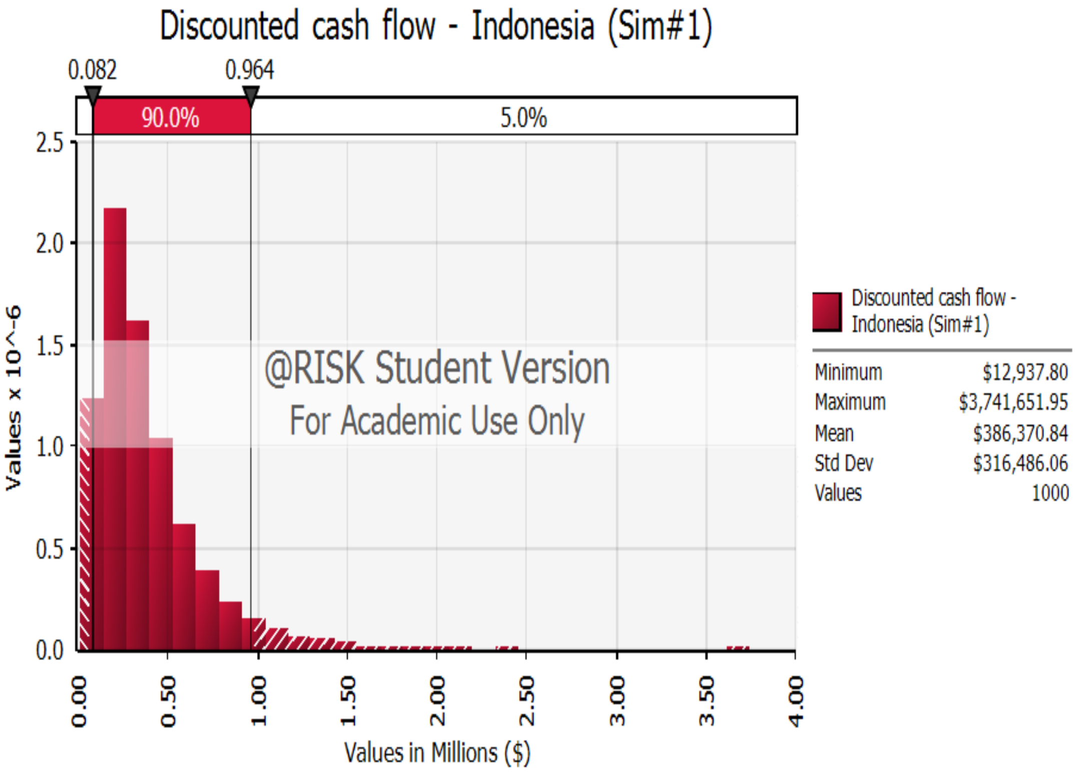


Figure 6.8 Option to invest for the Mengapur gold mine project in Malaysia

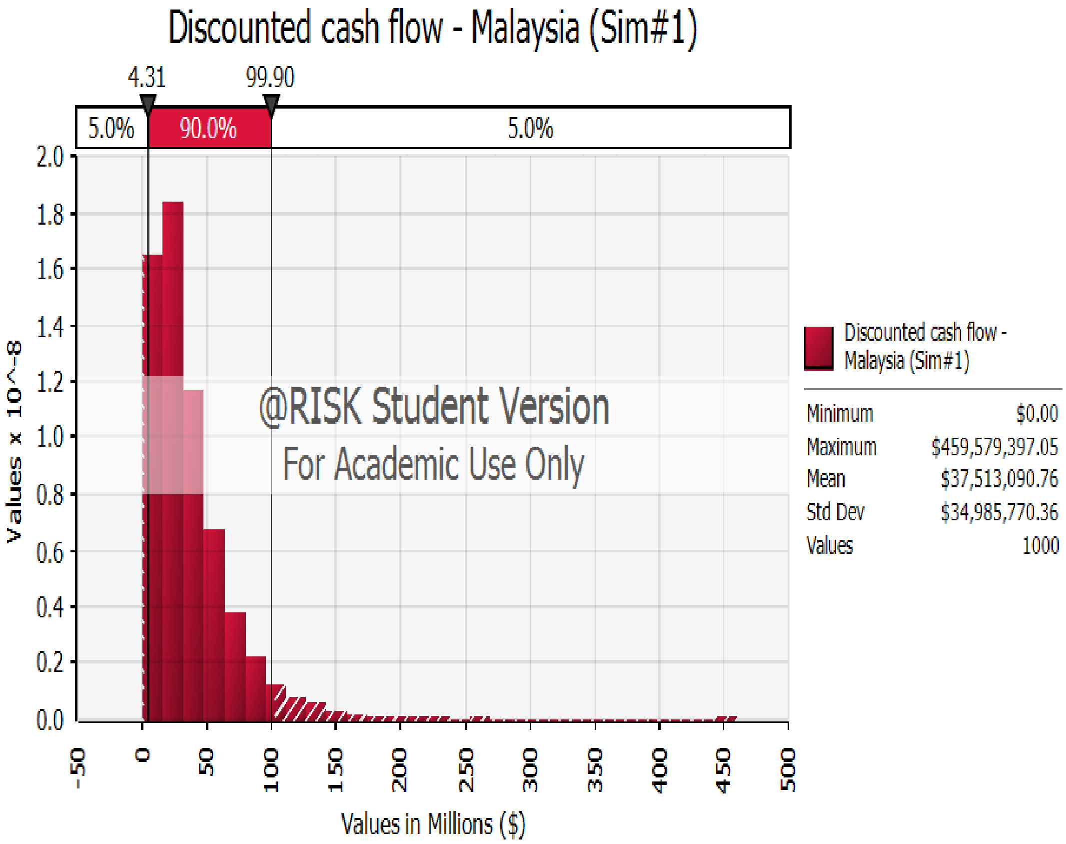


Figure 6.9 Option to invest for the Eastern and Buller coal mine project in New Zealand

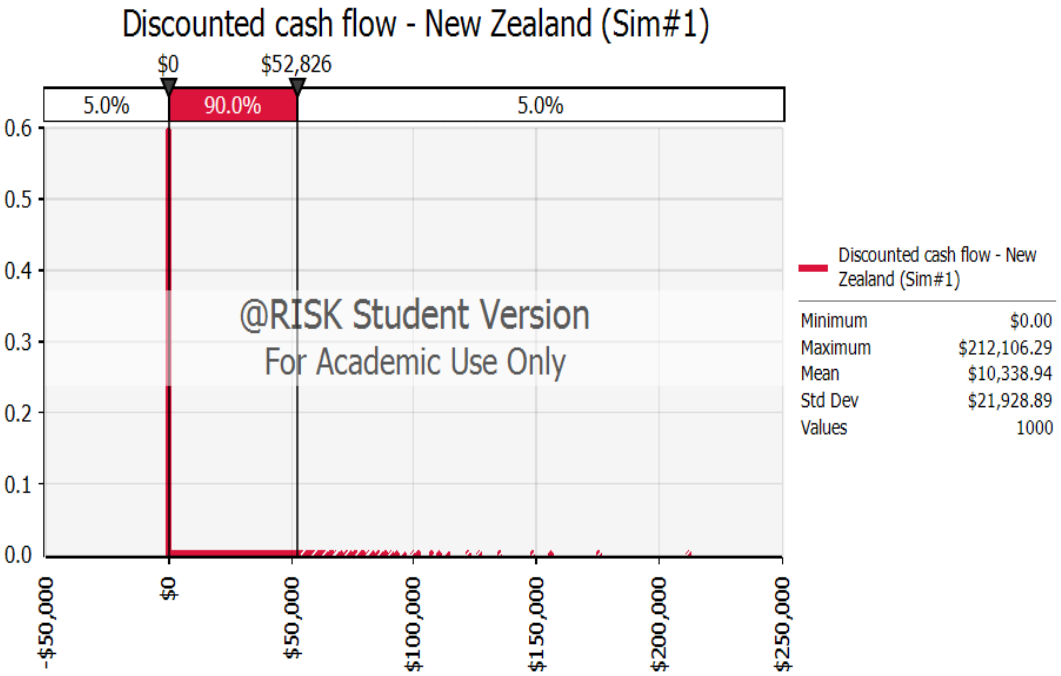
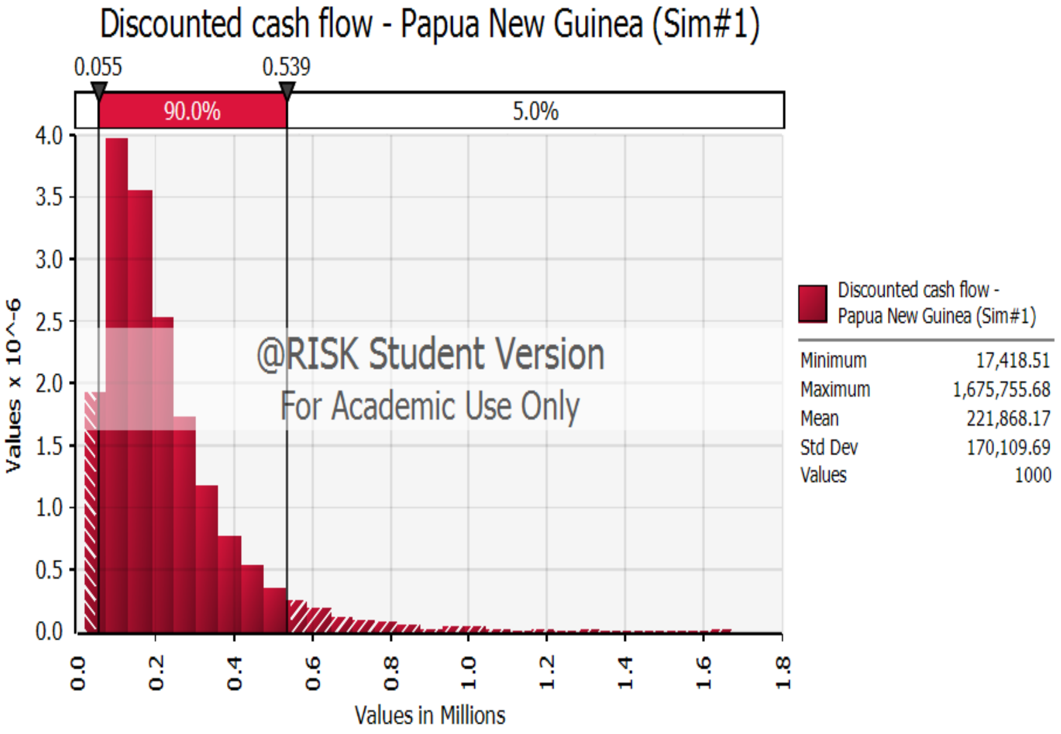


Figure 6.10 Option to invest for the Wafi-Golpu gold mine project in Papua New Guinea



Figures 6.6 - 6.10 illustrate the option to invest for a selected mining project investment in the Asia-Pacific countries by estimating the volatility rate.[68] For investment decisions, the mining investor assumes that there are three possible case scenarios: the mining firm believes there is a 30 per cent, 40 per cent or a 50 percent chance of uncertainty that could affect the mining investment.

As mentioned above, the model is used to estimate the uncertainty of mining investments. To decide whether the investment should go ahead or be deferred until the following year, the decision to exercise the option is based on the numbers of 1 and 0. If the simulator software shows the numbers 1, it means that the option should be exercised; otherwise the project investment should defer for another year until the better option value is obtained.

On the one hand, the findings show that project investment activities in Australia, Indonesia, Malaysia and Papua New Guinea are robust. Mining project investment activities undertaken in these countries are close to 1. In general, mining project investment in these countries is lucrative and profitable based on the particular time of the project simulation. Findings using the @Risk software simulator show that the expected average return of mining project investment from these resource rich countries is positive.

On the other hand, there is an exception case for Buller coal mine project in New Zealand, which tells a completely different story than the other countries. This is because mining project investment in New Zealand has not achieved negative NPV. In using the option valuation based on the volatility rate, the finding shows that there is less than a 5 per cent probability chance to exercise the option value for the project investment in New Zealand. In this case, the mining investor should defer their mining project investment in New Zealand rather than invest immediately, until investment conditions have improved.

To further elaborate the above analysis for each individual mining project in these five countries, the researcher believes that rationality for investment decisions is critical. Testing for rationality of mining firm investment behaviour in the copper industry,

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[68] The volatility rate in this study refers to the uncertainty in tax policy matters.

Auger and Guzman (2010) state that investment timing is one of the most important factors to ensure the investment process is a success.

Their findings show that more than half of mining investors are missing opportune times, such as low price periods, for their mining project investment decisions. Missing the right timing for investment decisions can be attributed to mining firms not being fully rational when investing in a mining project. Another factor that contributes to mining investors missing out on the right time is neglecting the standard investment criteria, which is to disregard commodity price uncertainty when undertaking an investment decision.

As a result, the objective in this study is to deliver sufficient information using timing optimisation for mining investors to decide the best outcomes for their investment decisions making. The optimal timing is a simple investment rule that enables mining investors to determine the best timing of the mining investment. Under this condition, mining investors are able to choose to either invest or disinvest their investment in midstream if profits are unable to be sustained.

The empirical evidence offers in this study is similar to the study in Auger and Guzman (2010). However, the primary purpose of this study is to estimate the volatility rate using real options valuation. In most of the finance literature, estimating the volatility rate has been difficult (Alizadeh *et.al.,* 2002). Therefore, the researcher conducts an empirical study by estimating the volatility rate in order to find the right timing decision for a mining project investment that can significantly impact the expected rate of return for the project's NPV.

When estimating volatility, the researcher applies the logarithmic stock prices returns approach or the logarithmic cash flow returns approach to estimate the volatility factor, as discussed in the previous chapter. This method is used to calculate a volatility factor that is based on the variability of the future cash flows comparable to the current cash flows or historical stock indexes. The cash flow relative returns are then generated into the logarithmic relative returns that are used in estimating the underlying asset value. Stock markets indexes in the Asia-Pacific region are applied in this method in order to estimate the volatility factor. Data for stock indexes are downloaded from Yahoo Finance's stock market website. The volatility factor is estimated by using the following equation:

$$Volatility = \sqrt{\frac{1}{1-n}\sum_{i=1}^{n}(y_i - \bar{y})^2}$$

where n is the number of Ys, and $\bar{y}$ is the average Y value.[69]

In determining volatility factors, the Monte Carlo simulation (MCS) is a powerful technique to estimate the stochastic properties of the variable that drives volatility (Copeland & Antikarov, 2001). By identifying stochastic variables, MCS can estimate the standard deviation of rates of return (based on the distribution of present values) using the @Risk simulator and then the event decision tree binomial lattice is developed. Brandao *et.al.,* (2005), Tan *et.al.,* (2009) and Miranda and Brandao (2013) are among the researchers who have used this method to evaluate a mining project investment based on dynamic decision tree analysis.

A decision tree binomial lattice, using the ROV approach, is a well-known method for tracking uncertainty in a mining project investment. This approach is used for the underlying asset value by applying the optimal investment rule to determine the project value. In this context, the empirical research of Ihli *et.al.,* (2013) is worth noting. Their study shows that the ROV approach offers better decision behaviour for farmers than the static discounted cash flow analysis.

Applying the similar concept in the study of Ihli *et.al.,* (2013), the researcher finds that the volatility rate impacts the aggregate NPV of mining investment decisions. The empirical evidence in this study shows that a high volatility rate offers better option values, particularly in investing in high risk projects.

From the practitioner's perspective, an inspiration of this study is to understand mining investors' investment and disinvestment behaviour. This thesis also helps to gain insights into the dynamics of how uncertainty factors, such as changes in tax policy as well as fluctuation of commodity prices, affects the investment decision behaviour. As stated above, understanding the timing and investment behaviour using the deferring option is imperative to forecast and adapt changing economic conditions. This is particularly important when the future returns of the mining investment are uncertain.

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[69] *Y* represents the natural logarithm of Cash Flow Returns.

This section concludes the timing and investment behaviour using the deferring option, which is inspired by previous and current research in optimal timing investment using ROV analysis (for example Brennan & Schwartz, 1985; McDonald & Siegel, 1986; Miranda & Brandao, 2013; Kobari *et.al.*, 2014). As mentioned above, deferring investment has its value, particularly when there is uncertainty of the future conditions. The development of ROV has become widely recognised by most of the industry practitioners as the powerful investment tools to capture investment uncertainty. In the next section, the researcher conducts an investment analysis using the binomial model in conjunction with the Dynamic Programming Language version 8 (DPL8).[70]

6.4.2 The empirical evidence using the binomial approach

In the previous section, the researcher discusses the option value of the mining project investment when uncertainty of the future conditions occurs. Option pricing is extremely sensitive to the level of volatility of the project's NPV. Therefore, an important feature of conducting this empirical analysis is to examine an optimisation timing of investment decisions; by deferring an investment project, the mining firm has the opportunity to achieve better NPV rather than invest now. In this section, the researcher extends this analysis further by using a binomial decision tree analysis.[71]

As previously mentioned, there is a major criticism in regard to the static DCF approach in which this approach had neglected managerial flexibility. In other words, the project's decision is not affected by future decisions of the mining firm. Unlike the ROV method, managerial flexibility is fully taken into consideration during the execution of a project so that the expected returns of the project are maximised or the expected losses are minimised.

Solving ROV problems are complicated. This is because application of ROV involves significant mathematical complexity. As a result of this issue, a discrete time binomial lattice model is applied in this study. Brandao *et.al.*, (2005) state that both binomial

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[70] Guthrie (2009) states that dynamic programming language is a method that breaks down a complex multi-period optimisation problem into a sequence of simpler project investment problem. The mining firm is able to make a decision based on that date when the action is taken. The advantage of this approach is that the past information can be summarised by the state nodes that the mining project is currently in and the future information can be summarised by the market values of the mining firm after up and down moves.

[71] A decision tree analysis is used to analyse the investment decision that may be available to the mining firm at each point in time. The decision will then be summarised and made by the mining firm based on these outcomes.

lattice and the corresponding binomial tree give the same outcome as in the binomial model resulting from moving down and then up in value using risk-neutral probability.

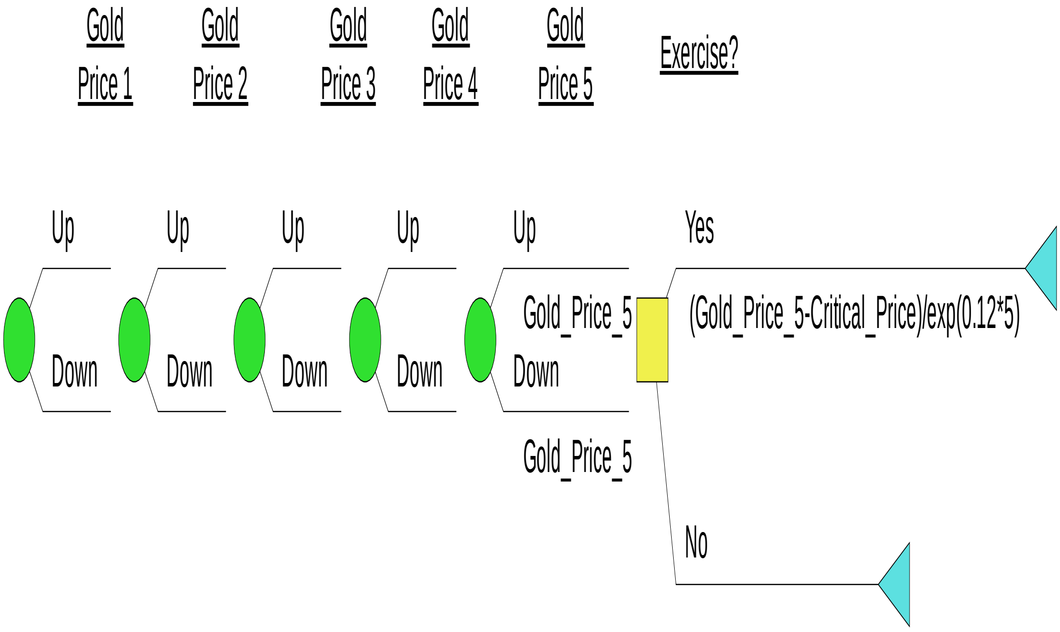
Prior to conducting a binomial decision tree analysis, there are two scenarios, which the researcher needs to be aware: the first scenario is without uncertainty, and the second scenario is using the binomial lattice decision tree model to solve an ROV problem in a mining project investment. As noted, the option values without uncertainty are discussed in Chapter 5. However, the former is re-examined in order to show that the binomial decision trees analysis gives a similar outcome, as shown in the Excel sheet in Chapter 5. The latter is used to examine the investment uncertainty in which the mining firm uses this analysis for their investment decisions making.

To increase the accuracy of the investment project without uncertainty, mining firms should consider the highly uncertain variables, such as mineral prices, that significantly impact the total value of investment and then a discrete chance node is applied. This chance node has two or more outcomes, which occur with specified probabilities to enable mining firms to decide the best outcome of the project investment by calculating the expected value of the decision model when rolling back to the decision tree.

By applying a chance node in the model, a mining company is able to capture the price uncertainties by deciding whether or not the project is achieving the best possible NPV. Decisions that are made also enable a mining company to decide the timing of investment and strategy to be applied in their investment project. If the current project has possibilities to achieve better value, then the investment should wait rather than invest now.

The following analysis involves applying gold and coal prices to determine a decision of mining project investment based on NPV value. An American style call option is applied to simulate gold and coal prices. The purpose of using the American style call option is because the American style options enable mining investors to exercise the option before the expiration date. This is unlike the European options, for which mining investors can choose to exercise their options only at the expiration date. Mining investors have an option to decide their investment decision based on the variation of mineral prices in each period by applying an American style option in this study.

Figure 6.11 Gold price simulations using the European call options

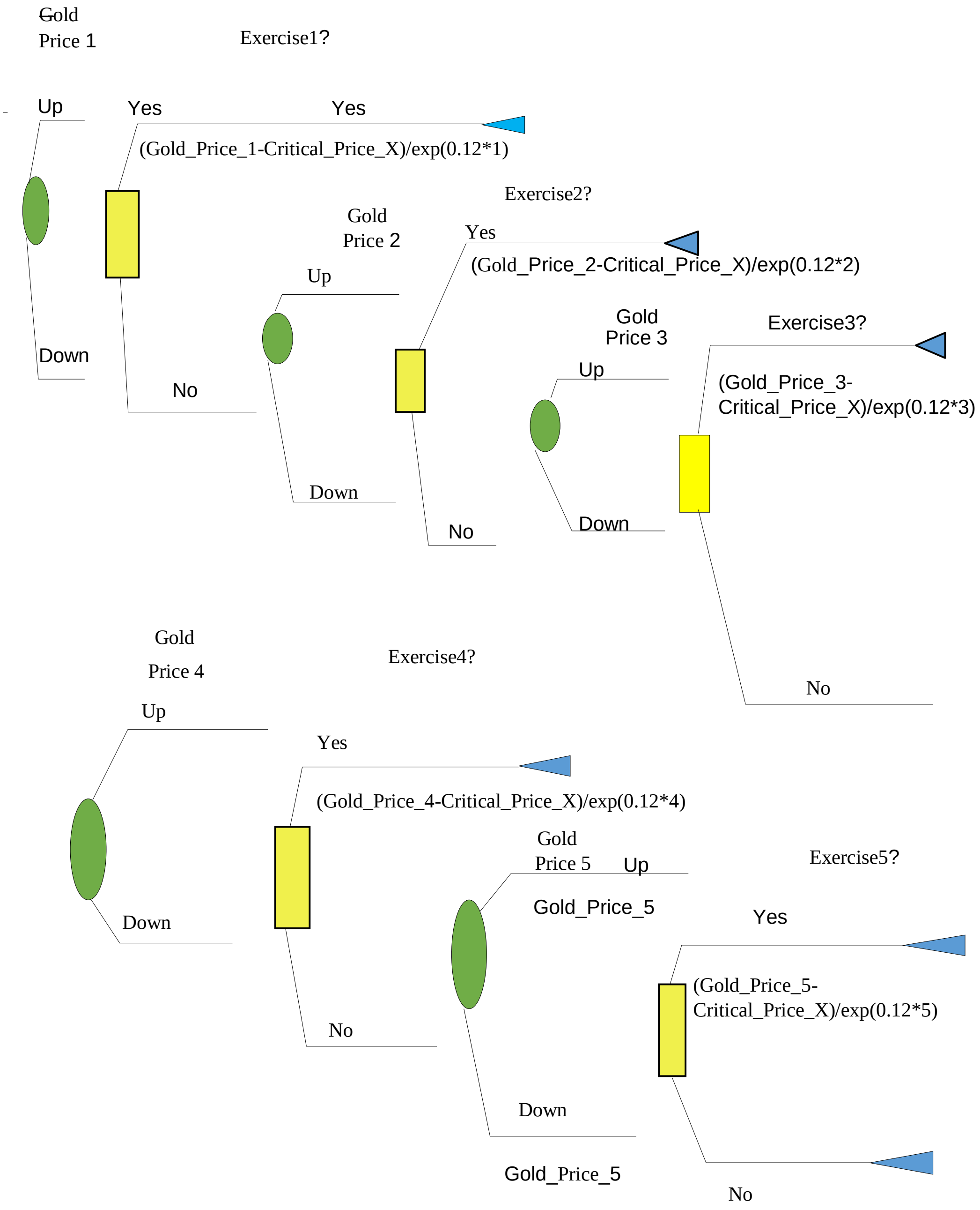


A lognormal discrete form of binomial tree analysis is applied in this study. Five year periods over the total life of the mining project are examined. The project's life is usually longer than five year periods. For instance, the project life of Daunia Mine BHP Billiton Mitsubishi Alliance -Project and Wafi-Golpu Gold Mine project in PNG operated for over 20 years.

These projects are the critical point to solve optimisation investment problems in mining investment decisions. Optimisation issues arising in mining investment can be numerically complicated and capital intensive. In this study, the researcher uses five year periods to conduct a simple example of mine operation under price uncertainty. In such as case, this study is able to identify volatility of mineral prices, which is one of the most significant variables impacting the entire project's NPV.

Initially, using either the European or American options, the outcome should be the same. For illustration purposes, Figures 6.11-6.12 show the model set up using both European and American call options to simulate price uncertainties.

Figure 6.12 Gold price simulations using the American call options



As stated many times in this thesis, timing is crucial for mining investors. Appropriate timing can lead mining firms to choose the best decisions for their investment by waiting for better future information. Obtaining this new information, can completely change the mining firm's investment expenditure, also, this information can accelerate or decelerate their investment decision making.

In most cases, mining investors can simply withdraw the project investment in midstream if uncertainties occur. Applying the above model by making a decision in each period, which is shown in yellow square boxes, mining investors can use a strategic analysis based on timing options to decide whether or not the project should be invested in or not.

A binomial model is adopted in this study in order to estimate flexibilities of mining investment. The binomial model has become one of the easy-to-use approaches to evaluate real options. One advantage of this model is using risk-neutral probabilities to find the expectation option payoff values (Copeland & Antikarov, 2001). In this case, the mining investor is indifferent to risk and the option value of the project grows on average at the risk-free rate.

Using DPL 8, the study follows the steps applied by Tan *et.al.*, (2009) to evaluate a mining project using the binomial model.[72] The first three steps are exactly the same as the set up applied in the traditional DCF model: 1) identify the decision variables 2) build the deterministic DCF model, and 3) specify the distributions for the uncertain variables using a separate excel sheet. The next five steps are conducted as follows: 4) calculate the expected NPV of the mining project without options valuation as time t=0 using a DCF analysis, 5) obtain the cash flow payout rates for each period in *u* and *d* state using exponential function of the cash flow returns volatility multiplied by the square root of time-steps or stepping time *(δt)*, 6) estimate the volatility *(σ)* of the project returns using the Logarithmic Stock Prices Returns Approach, 7) calculate parameters of the binomial approximation, *u, d*, *p* to the Geometric Brownian Process, 8) set up the binomial lattice using DPL, and 9) solve the option by making decision nodes in the model using the risk free rate.

Figure 6.13 shows the binomial decision tree model for the state variables using the forecasted gold price in the American call option. In the previous section the researcher estimates the (normalised) volatility rate using the historical data and then based on the volatility rate calculates the sizes of up and down moves. The researcher then uses this information to construct the American call option binomial decision tree model.

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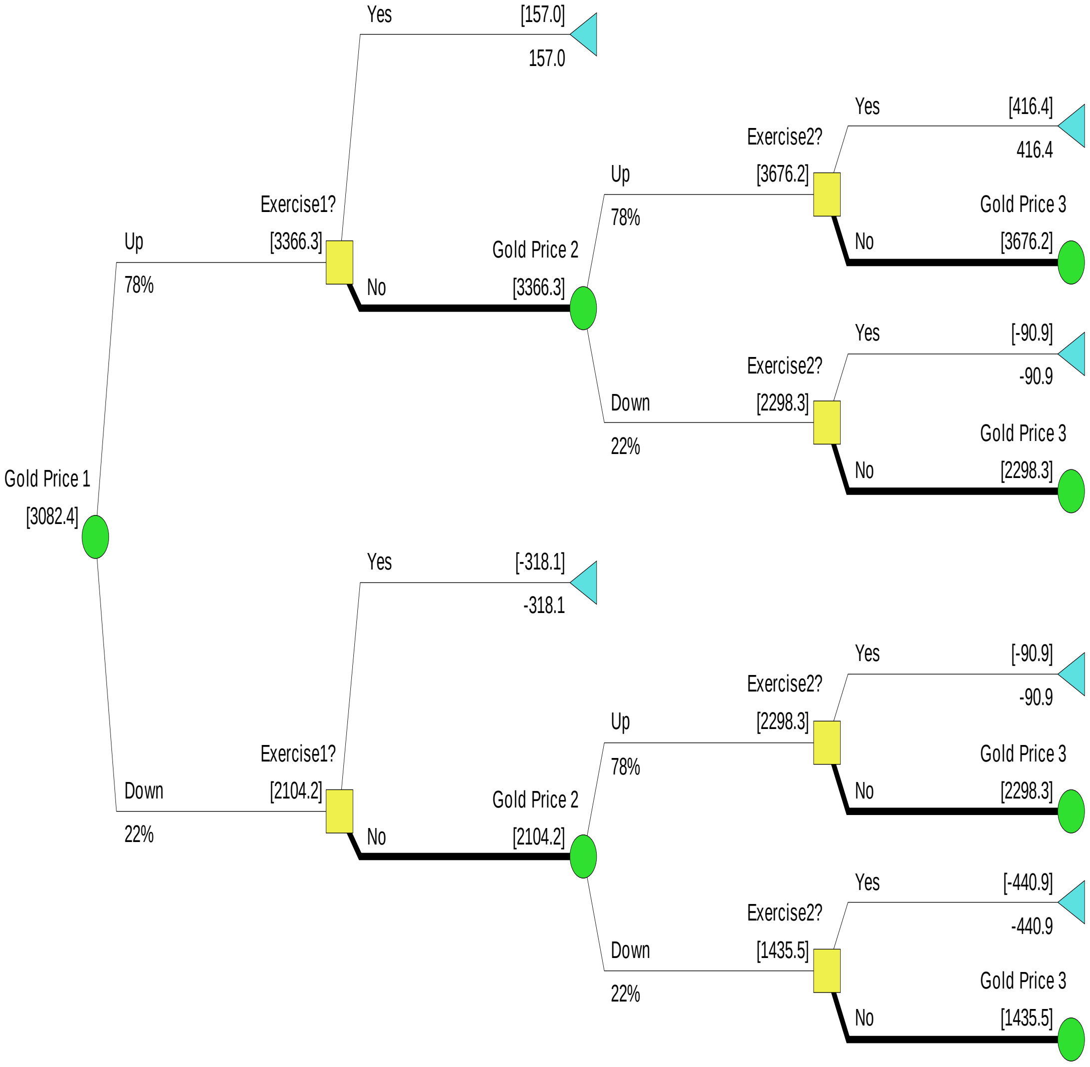
[72] DPL8 is one of the software uses for the system dynamic model to solve the project with uncertainties.

Figure 6.13 Option values of the Mengapur gold mine project in Malaysia using the American Call option[73]



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The model of Figure 6.12 has to be developed prior to conducting an empirical analysis in the Figure 6.13. An advantage of using an American style call option is because this option enables the mining investor to exercise the option prior to expiration date. As a result, the researcher set up a model in which exercising an option can be executed at any time prior to maturity.

Whether to exercise or not to exercise the option, the project's value is dependent on the objective function. In this case, the objective function is *Gold_Price_1-*

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[73] There are 11 levels in the model. The researcher hence has to reduce the model size by showing only 5 levels of this analysis in the thesis.

*Critical_Price_X/exp(0.12*1).*[74] Gold_Price_1 is initially set at USD1434.43 per ounce. As mentioned in the previous section, the researcher constructs investment rule of the project investment based on intrinsic value or so-called critical price. In the objective function, the researcher set the *Critical_Price_X* at USD1550 per ounce. This critical price is the intrinsic value in which the mining firm is able to use this value to make the investment decision. By adopting this investment rule, the mining investor can decide whether or not they should invest, disinvest or hold.

Using the gold price simulation to model the binomial tree American call option, the outcome shows that it is consistent with the application used in the concept of the deferring option. Also, it is not feasible for the mining investor to execute their project investment prior to maturity. A deferring of the project investment by waiting for a better future value is one of the best strategies for mining investors to obtain its project's NPV.

In most feasible cases, the majority of mining investors use the project's NPV to determine if their project is to be invested or disinvested. This methodology has been commonly used in previous literature (e.g., Brennan & Schwartz, 1985); Schwartz (1997); Liao & Ho (2010) and Tan *et.al.,* (2010)). However, a different approach is used in this study in which the researcher applies and determines the project NPV using gold and coal commodity prices.

Figure 6.13 shows that by deferring an investment, the mining investor should wait for the project until its expiration date and then decide whether the project will go ahead or be abandoned. After five periods of waiting, the evidence shows that if the gold price is above USD3000 per ounce, the mining investor should invest immediately at its expiration date; otherwise, the project investment should be rejected if the gold price is below USD1191 per ounce.

On the binomial decision tree model in the coal mine project, Figure 6.14 shows that the coal mining investor should defer their project investment up until the time option value is expired. In the coal project valuation, the outcome shows that if the coal price is above USD400 per metric tonne, the project should invest immediately at the end

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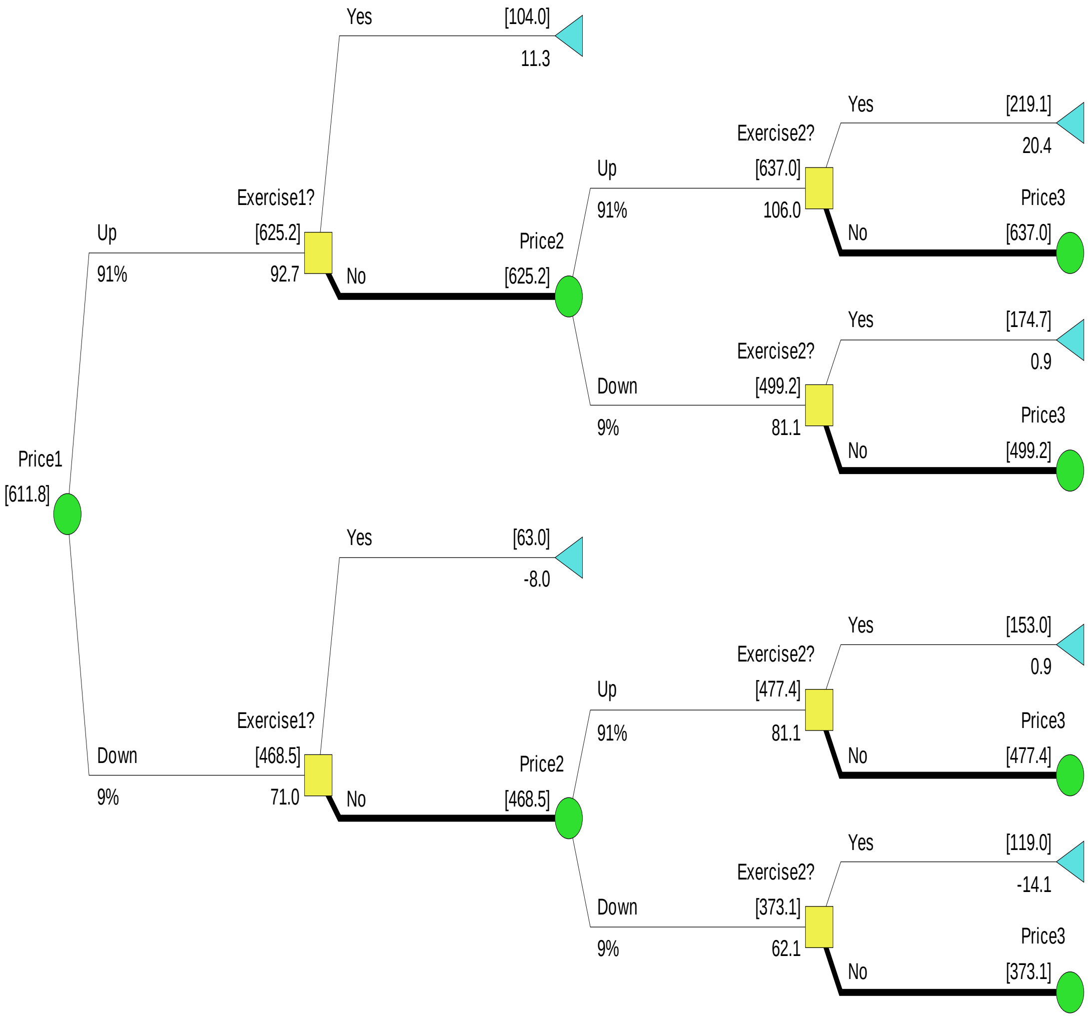
[74] The binomial decision tree model for coal price is not be shown in this section. The coal price model set up is similar to the gold price model shown in Figure 6.12.

of five year periods; otherwise, the project should be completely abandoned if coal price has dropped below USD390 per metric tonne.[75]

The key point to summarise the outcomes replicated in Figures 6.13-6.14 is that from a mining investor's perspective, by accessing timing flexibility, rationality is the key issue in mining investment decision making. By not being entirely rational when conducting a mining investment evaluation, mining firms are most likely miss out on the optimal timing of their investment decisions. The choice of making a decision for a project investment is completely dependent on the mining firm's decision.

Figure 6.14 Option values of the Daunia coal mine project in Australia using the American Call option



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[75] One interesting point of this outcome is that it is better to wait for executing the option value until the time of expiration. From a practical perspective, it is not advisable to exercise an option early. This is because the time value inherent in the option value will be lost if an early exercise of the option is taken.

Understanding timing flexibility is the critical point. The finding of Auger and Guzman (2010) are worth noting. Auger and Guzman state that "there fewer than half of decisions were made at the right time – i.e., low price periods" (p.249). However, capturing the right timing can be a difficult task because of the unpredictable economic climate.

In this section, the researcher conducts an empirical analysis for the optimal timing of mining investment using ROV associated with the determination of the mining project's NPV. As noted above, ROV is the financial technique used to understand the uncertainties in the modern finance literature. In the next section, the researcher conducts an empirical analysis in which policy uncertainties, such as tax policy implications are examined.

6.4.3 An analysis of tax policy implication using binomial decision tree

Real option analysis is the method applied with managerial flexibility, which enables mining investors to determine the timing of the investment. Mining investors should be able to choose options to wait, options to expand, options to contract and many other options to determine investment decisions making that suit their investment needs.

Mining investors are extremely careful in their investment decision making, particularly during policy uncertainty such as tax policy changes. A significant growth in the mineral and energy resource industries globally, such as the resource boom in Australia in recent years, has given much attention to the social impact of policy regimes in the resource sector. The impact of a policy regime is extremely important for mining investors and by giving extra attention to policy issues, investors can reduce the investment risk to the minimum and increase the chance of success rate in their mining investment. This section follows the above method in order to find the optimal policy for mining investors.

Market failure coexists with investment uncertainty and irreversibility is the market factor that induces governments to impose particular policies to ensure the market is efficient. In some contexts, policy implications can also reduce risks as well as offer additional investment incentives for the mining investor. In this section, the researcher extends the previous work by adding tax policy and pursuing this work with further implications.

Policy uncertainty, particularly tax policy changes, have a significant impact on the mining investment decision. The study by Rodrik (1989) shows that even moderate amounts of change in a policy regime can change the mining investor behaviour significantly. As a result, this study involves an analysis in which the mining investor is expected to encounter policy uncertainty. In other words, there will be unexpected tax rate policy changes in their investment decision. In this case, the researcher sets a target in which the tax flow rate is 25 percent, which is a standard corporate tax rate for mining firms and it is expected that the tax flow rate tends to increase or decrease in 5 percentiles.

The researcher then examines the policy uncertainty in the developed and developing nations as discussed in this study. Understanding the impact of an institutional regulatory regime helps to shed light on a new research idea in which mining investors can rely on this information for their investment decisions.

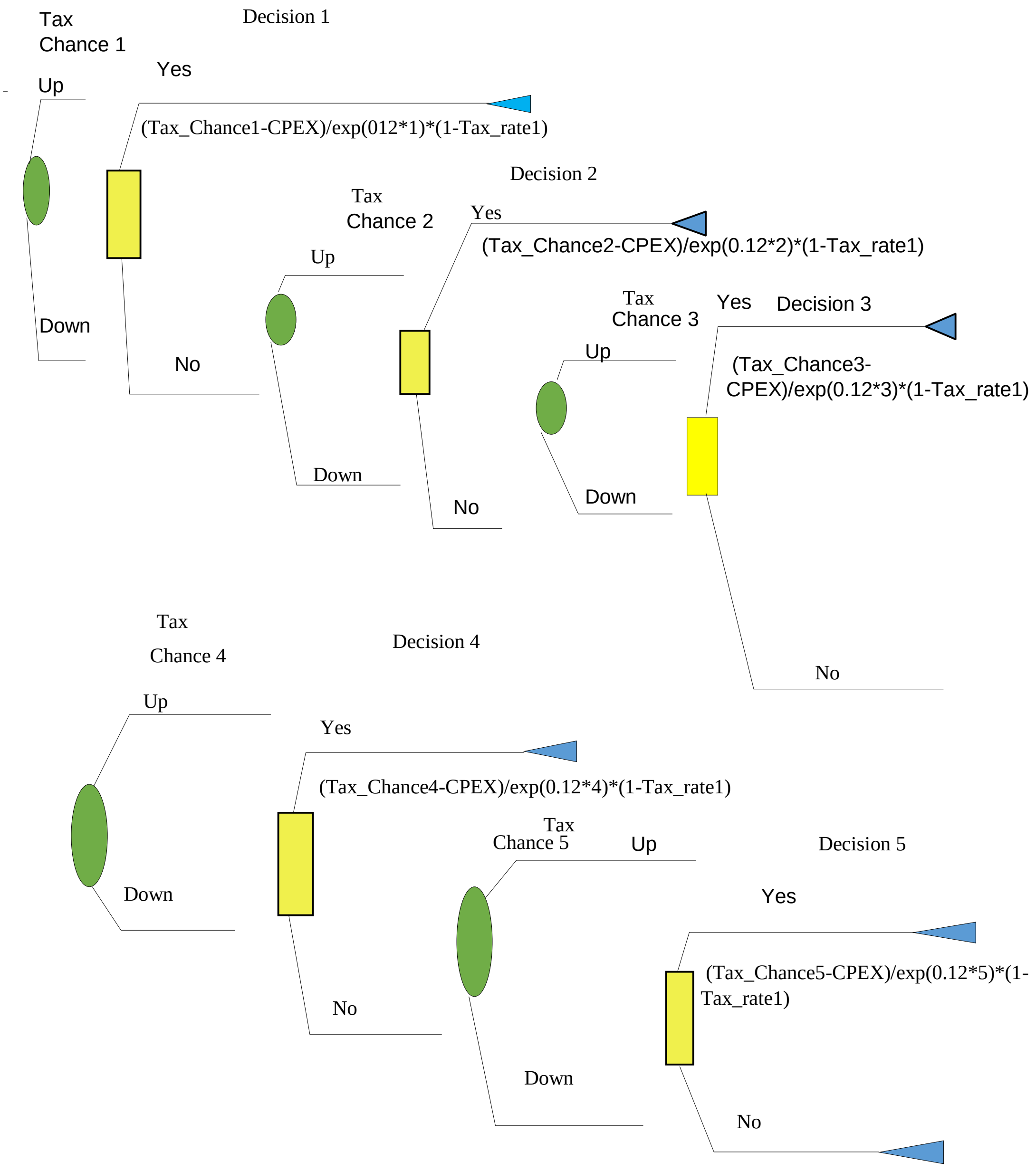
The analysis focuses on coal and gold mining projects in the Asia-Pacific region. Mining investors certainly encounter policy uncertainty in their investment decision making and this analysis can assist in using this information to decide whether their investment should go ahead or whether to defer their investment decision. In previous literature, for instance Lagos (1997), Rodrik (1989), Kumar (1990) and Spiegel (2009) are among the researchers to conduct a study in mining policy analyses in developing nations. Their studies focus on the policy reforms that are needed in the developing nations in order to strengthen the institutional structure and promote mining investor confidence.

The optical timing investment decisions associated with policy uncertainty, in particular the tax policy regime, is emphasised in this study. The mining investor chooses their investment decisions based on the policy decisions implemented by the government.

Deciding on investment in mining projects can take an extremely long time. The costs and time involved to build mining investment projects can be substantial. The project usually does not generate returns until it is entirely completed. For instance, a new underground mine can take five to six years to build provided there are clear constraints on the pattern of expenditures (Majd & Pindyck, 2001). Mining investors need to choose a contingent plan in order to ensure their investment decisions are sequential.

Time to build a mining investment is crucial for mining investors. To some extent, appropriate timing can lead mining firms to choose the best decisions for their investment by waiting for new information. Obtaining new information can change the mining firm's original planned investment expenditure. This information enables mining investors to accelerate or decelerate their investment decision making. In most

Figure 6.15 Policy uncertainties using the American call option binomial decision tree model



cases, mining investors can simply terminate the project in midstream if uncertainties of economic conditions occur. For example: a shaft may be deepened at least 400 feet a year on a working mine, and the provision of equipment needed to eat up the ore-body at this rate of sinking means very early exhaustion indeed. Another example to explain the optimal timing of mining investment would be policy uncertainty.

A case scenario is given in this study in order to examine the mining investor's behaviour on how tax policy implications can possibly impact their investment decisions. There is an assumption that the government amends the tax rate after the commencement of the mining project, which is impacted the project's NPV value.

By adjusting the tax flow, the study shows the responsiveness of profit minded mining investors as to how their investment decisions can change in the project valuation. The decision is whether or not the mine site should remain open or wait for better future information as a result of a change in regulatory framework.

The change of tax flows is not the only issue that mining investors may encounter. Government subsidisation, such as imposing tax credits to encourage mining investment, is another issue that mining firms certainly need to focus on. The government imposes tax credits on investments in order to stimulate investment activities and bolster the economy in a country. However, the change of profits margin as a result of changing tax incentives are one of the optimal investment policies that need to be considered. This is because such changes significantly impact the net present value of mining firms.

In this case, @Risk simulator software is applied in determining the state of uncertainty variables prior to conducting an empirical analysis using the binomial decision tree method. Figure 6.15 shows the model set up with policy uncertainty for the Asia-Pacific countries.[76]

Figure 6.15 shows the simulation of the American call option using the binomial decision tree model with policy uncertainty. A standard tax flow, which is 25 per cent

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[76] Because the model set up for each country conducted in this study is similar, for simplification purposes, only the country of Malaysia has been shown in this section.

is applied, followed by the next model with 30 per cent and 35 per cent tax flow rates respectively.

Using Monte Carlo simulation with the tax flow range between 25 per cent and 35 per cent, the researcher finds that the empirical evidence of a tax policy regime has an impact on mining investment decision making. Among the five selected projects with each country in the Asia-Pacific countries conducted in this study, the empirical evidence shows consistently that the tax rate affects the NPV.

Figures 6.16-6.30 show the Monte Carlo simulation of five selected projects in each Asia-Pacific countries' tax flow using binomial decision tree analysis. The empirical analysis shows that the mining project in countries with an abundance of mineral resources are favoured by the majority of mining investors. Mining projects in Australia, Indonesia and Papua New Guinea are among the countries approval for mining investors to conduct their mining investment activities. Even though policy uncertainties in PNG are one of the factors that can impact the mining project investment decisions, perhaps abundance of mineral deposits and its high quality of ore grades are sufficiently for mining investors willing to take risks to decide their mining investment in this country, particularly junior mining companies. Regardless of the riskiness of their mining investment, the main objective of these junior mining companies is to maximise their return in order to establish a foothold in the industry.

The empirical analysis also shows that mining projects invested in Malaysia and New Zealand are among the two countries that have shown completely different results. The outcomes of investment decisions made in these two projects are mixed. In other words, the strategy of timing plays a crucial role when conducting investment analysis in these two projects in these countries. As shown in Figures 6.22-6.27, the project investment conducts in these countries can be highly volatile. Mining investors should prepare sudden changes, as well as be vigilant in their investment decision-making. Unforeseen events, such as the risk of changing economic conditions and mining policies can indeed increase the risk of their project investment. Understanding timing issues to prevent the sudden change in government policies, again, can become the critical point when capturing the mining investment decisions in these countries. In the binomial decisions tree analysis outcomes indicate that choosing appropriate timing in mining investment helps mining investors reduce such investment risks.

In one of the examples in this study using the application of Malaysia tax policy uncertainty, the empirical evidence shows that if the government imposes a tax flow rate at 25 per cent, the expected outcome of this study shows the NPV of the project is USD2,223,619. If the tax flow rate increases to 30 per cent, the expected NPV of the project is USD2,075,378. If the tax flow rate increases another 5 percentage points to 35 per cent, the expected NPV of the project declines further. The expected NPV at the tax flow rate of 35 per cent is USD1,927,137. In general, the impact of changing tax policy for mining investors is significant. The finding offers similar conclusions in previous empirical studies in which the traditional model of tax policy can certainly slow down mining investment activities (Hassett & Metcalf, 1994).

Applying the expected frequency with which tax policy changes, the finding reveals that mining firms can delay or speed up their investment decisions based on their perception of the tax flow changes. Understanding the effects of uncertain tax policy can completely change the mining investment decisions. The empirical finding in this study follows naturally and directly from previous work (e.g., Pindyck (1988) and Hassett & Metcalf (1994)).

This study also supports the recent empirical work conducted by Stokey (2012). It reveals that policy uncertainty can completely change the profitability of mining investment. Uncertainty about future tax policy can lead to a temporary reduction in investment. In other words, the empirical outcome of this study shows that if the government cannot resolve the uncertainty in the near future, the likelihood of mining firms to delay committing resources to an irreversible project is higher than expected and hence reduces current investment. By contrast, if the government agency can resolve the uncertainty within a short period, the investment in the resource sector certainly can recover and generate a temporary boom. Accordingly, the size of the boom depends on how much percentage of the tax policy is imposed. When there is the possibility of a lower tax flow rate, larger booms in the mining investment can be generated.

Figure 6.16 Australia Daunia coal mine project tax simulations at 25 percentile

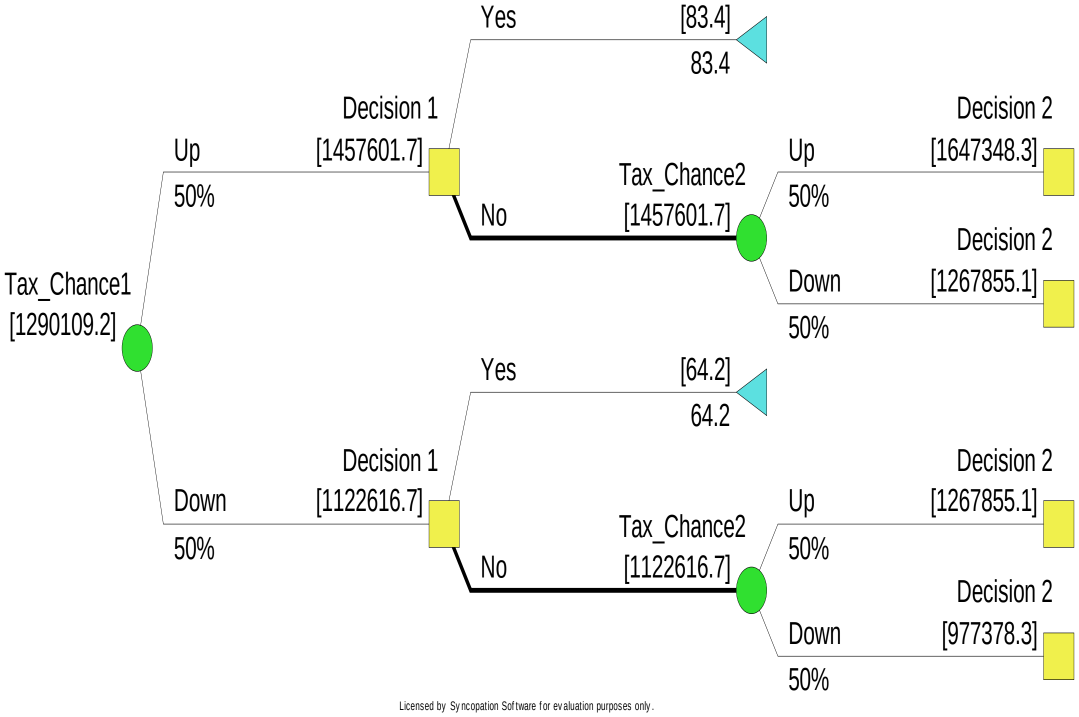

Figure 6.17 Australia Daunia coal mine project tax simulations at 30 percentile

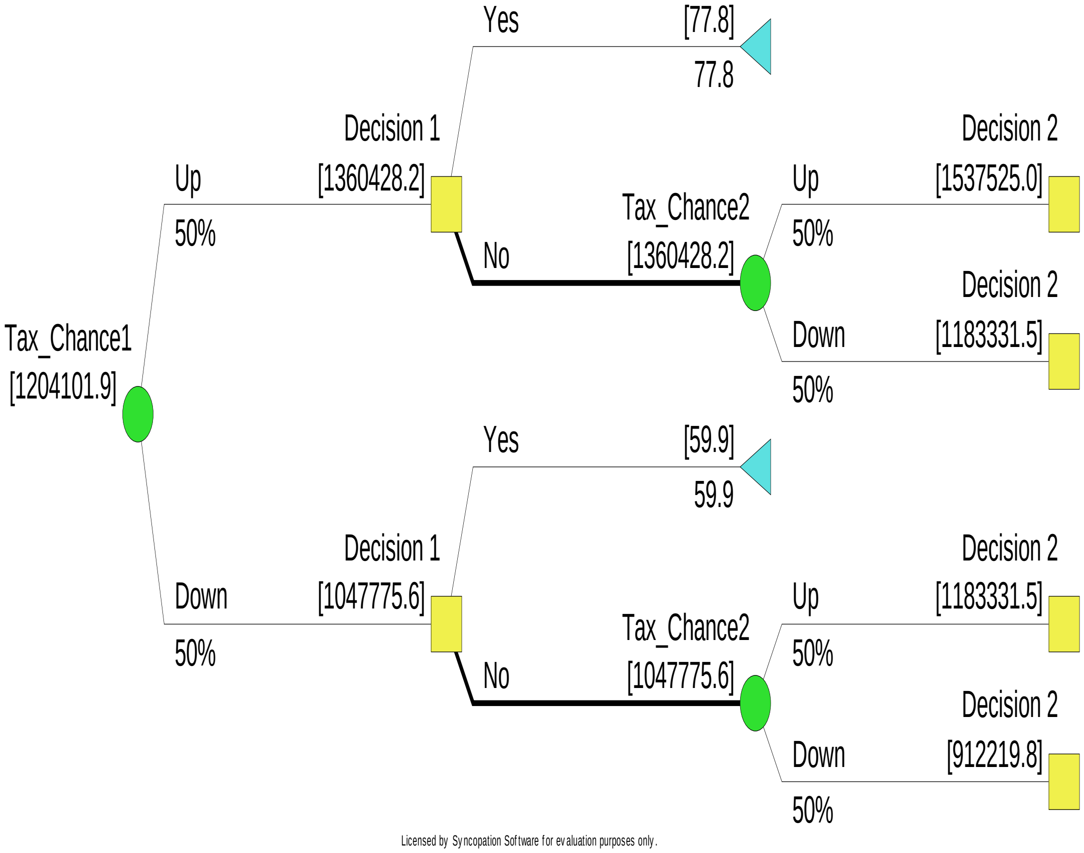

Figure 6.18 Australia Daunia coal mine project tax simulations at 35 percentile

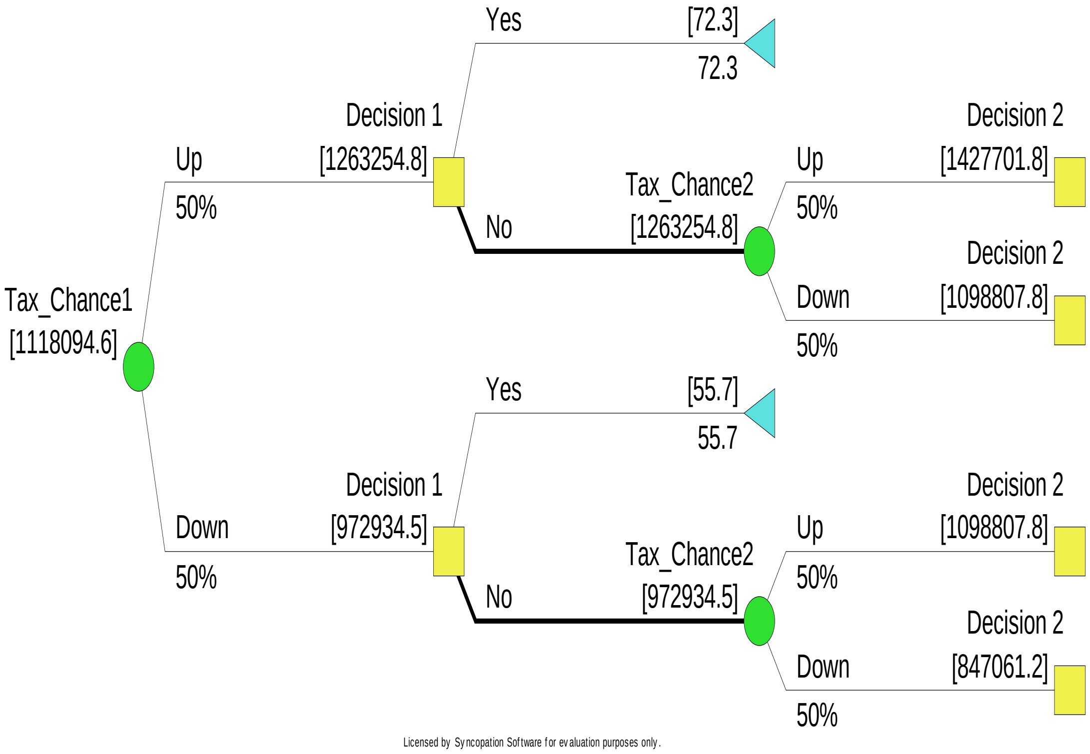

Figure 6.19 Indonesia Tembang gold mine project tax simulations at 25 percentile

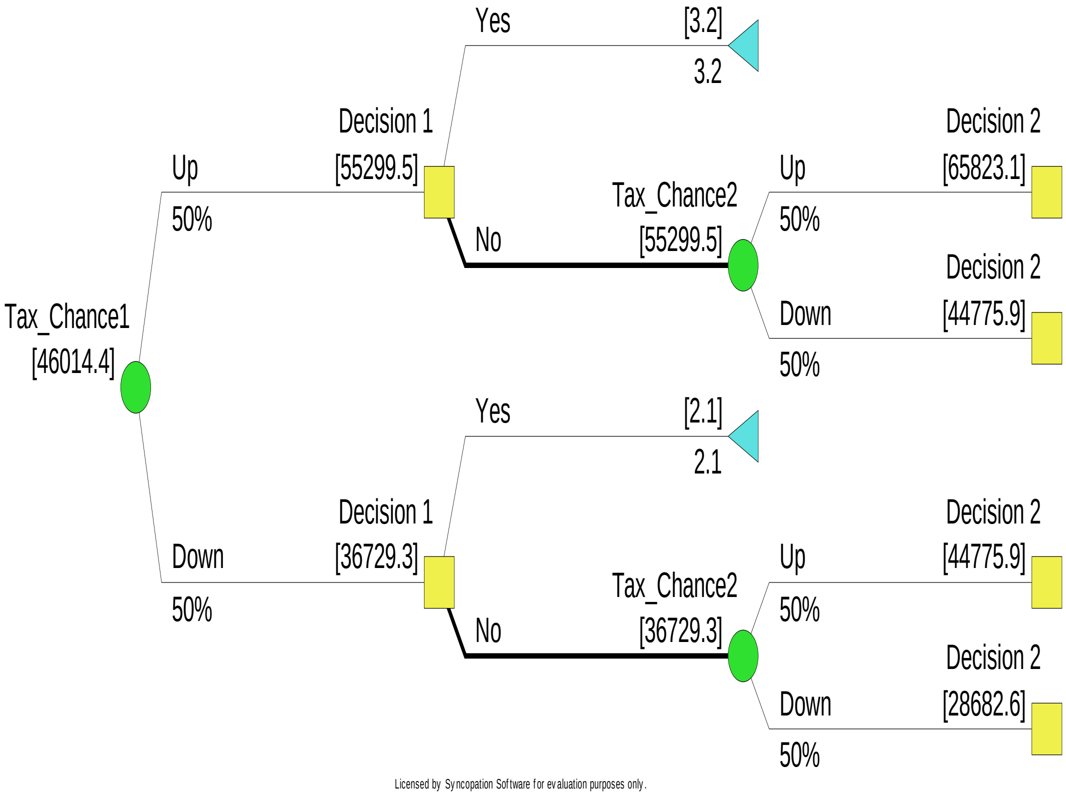

Figure 6.20 Indonesia Tembang gold mine project tax simulations at 30 percentile

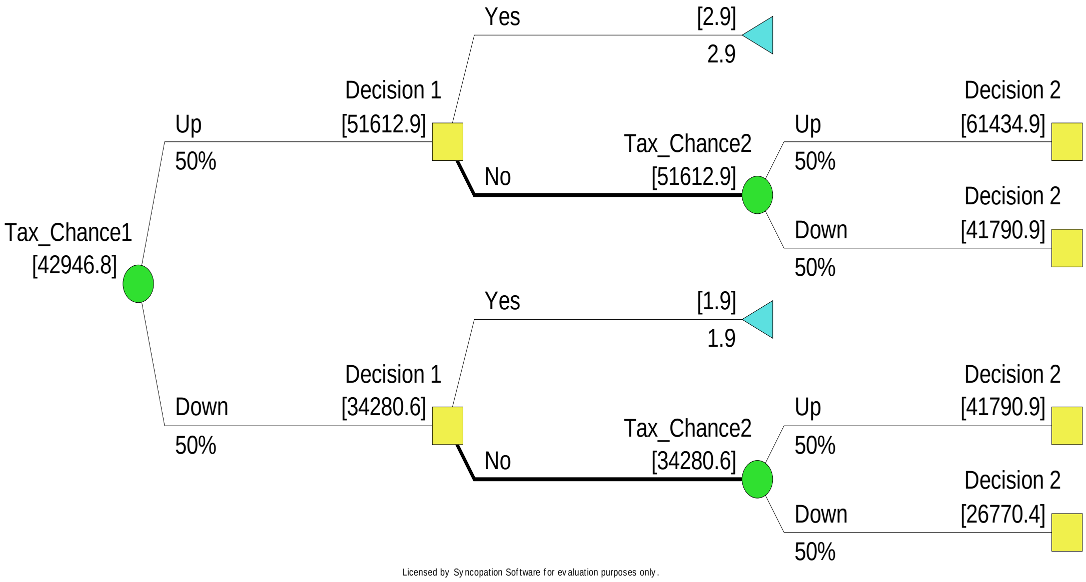

Figure 6.21 Indonesia Tembang gold mine project tax simulations at 35 percentile

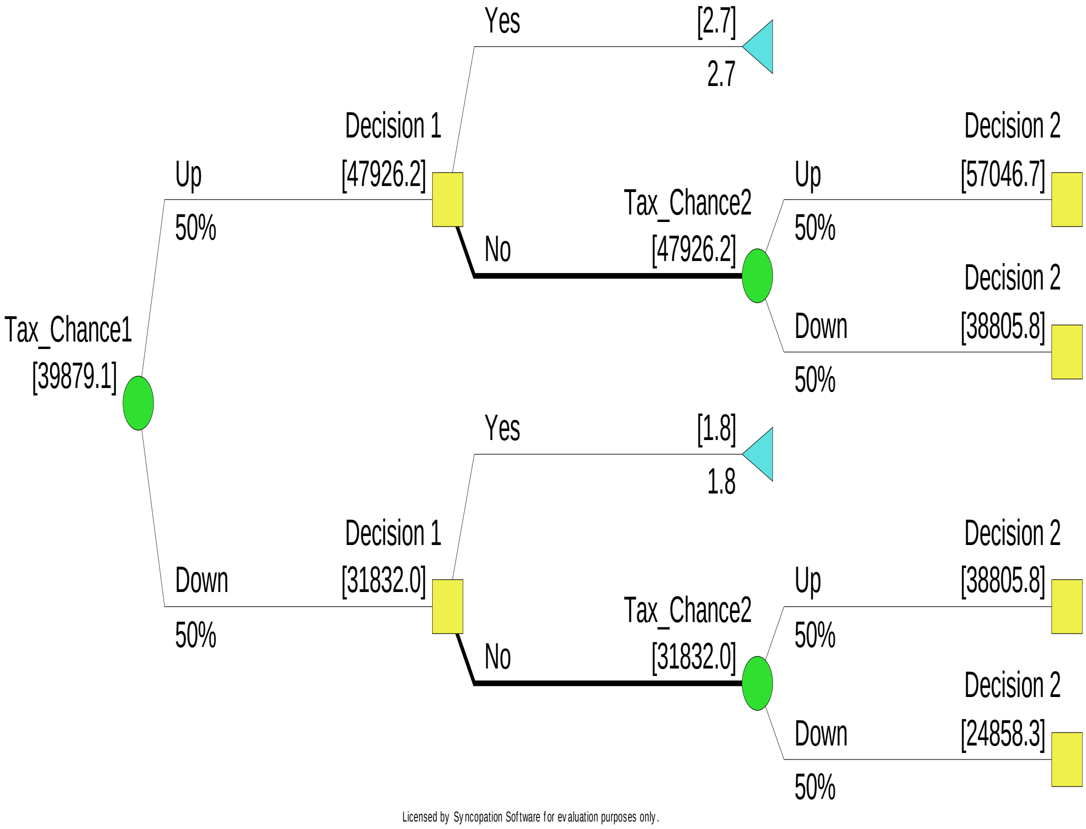

Figure 6.22 Malaysia Mengapur gold mine project tax simulations at 25 percentile

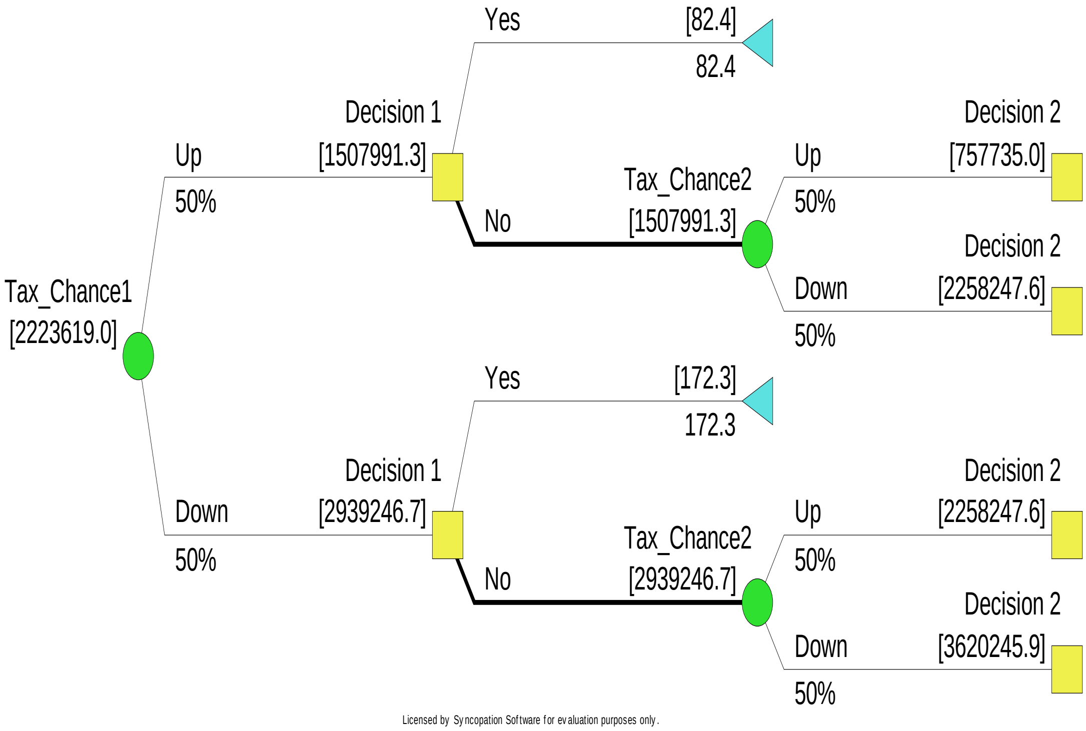

Figure 6.23 Malaysia Mengapur gold mine project tax simulations at 30 percentile

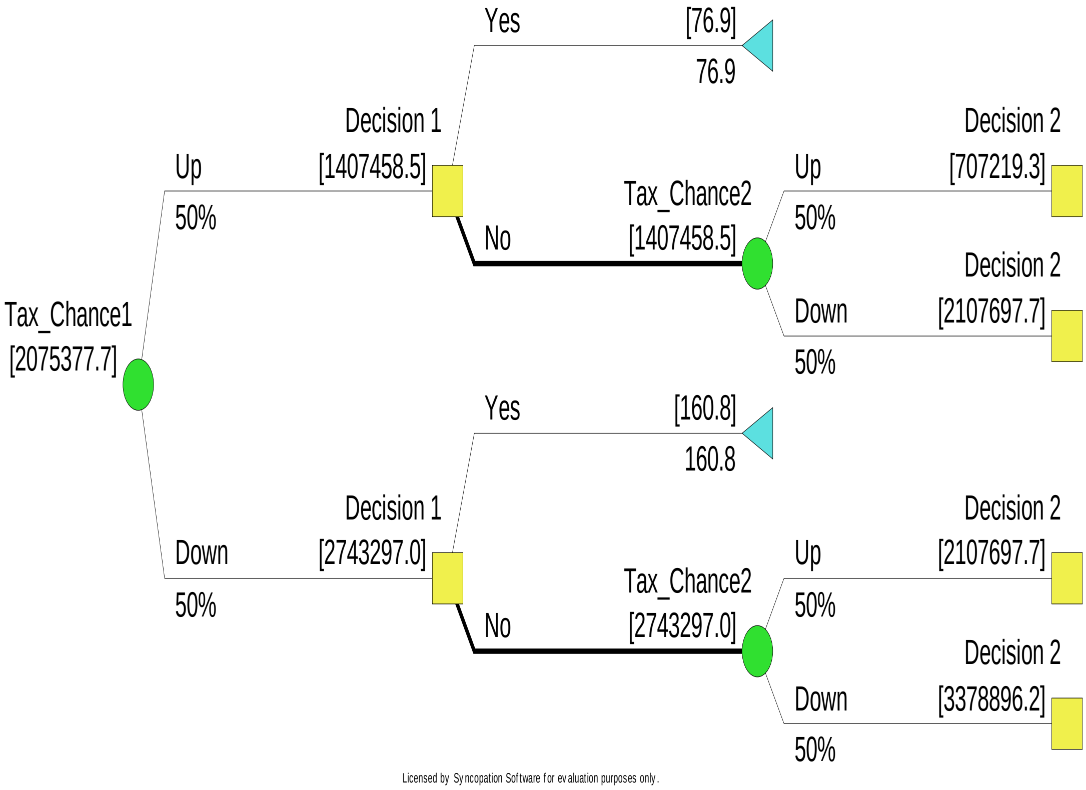

Figure 6.24 Malaysia Mengapur gold mine project tax simulations at 35 percentile

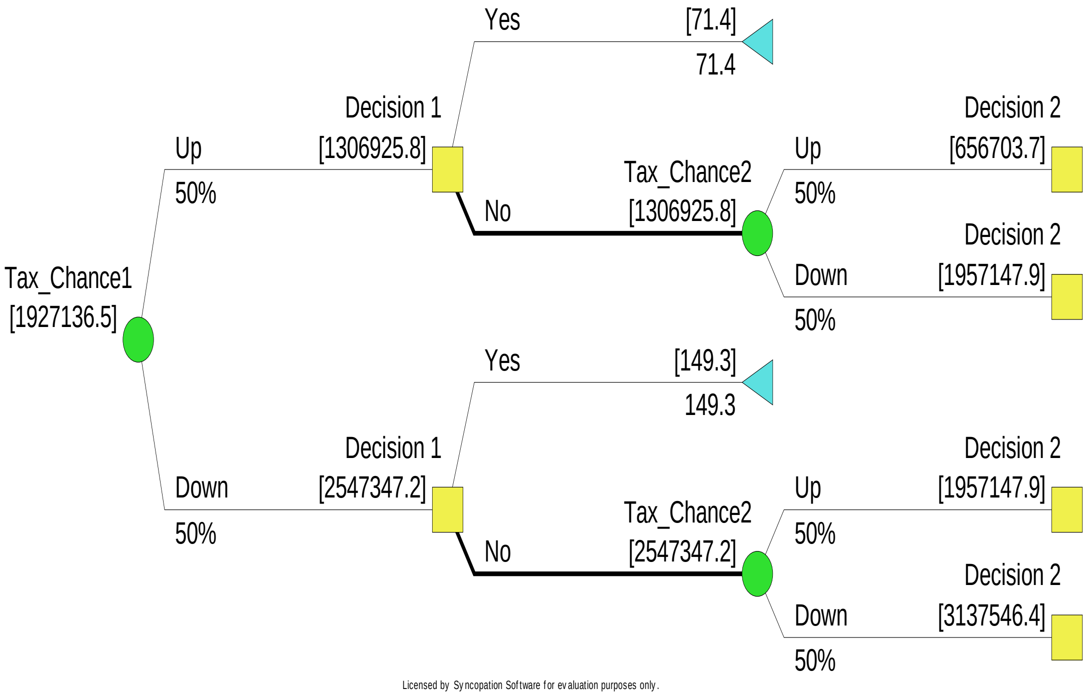

Figure 6.25 New Zealand Buller coal mine project tax simulations at 25 percentile

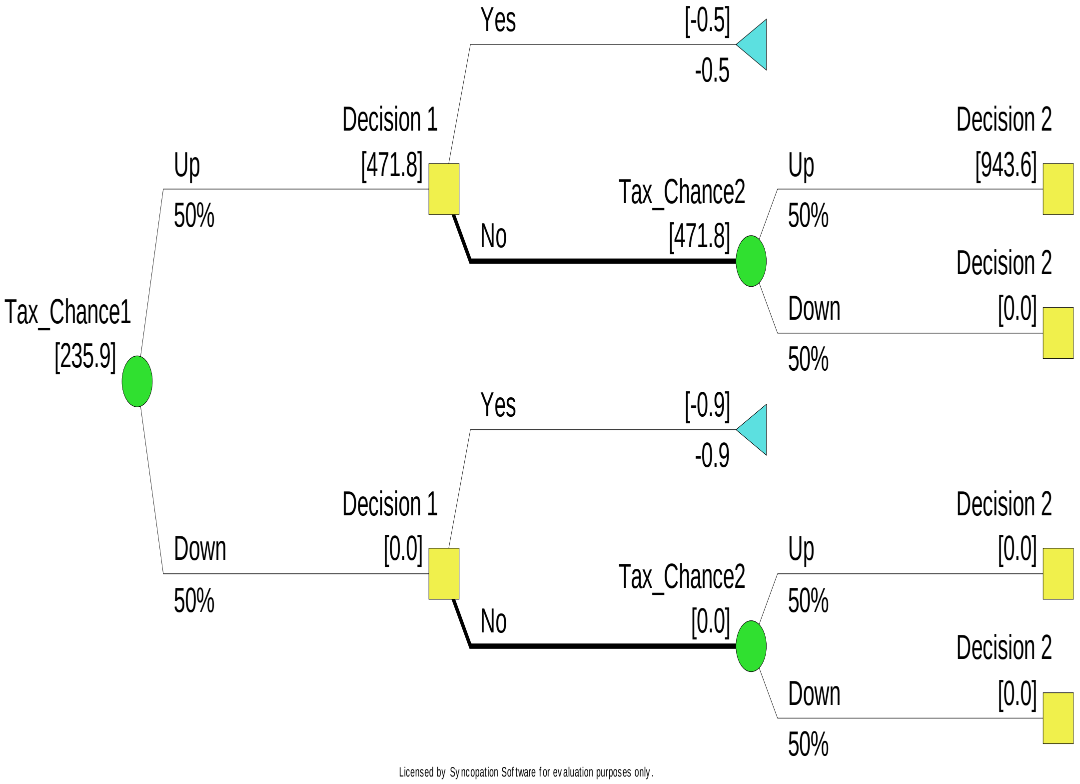

Figure 6.26 New Zealand Buller coal mine project tax simulations at 30 percentile

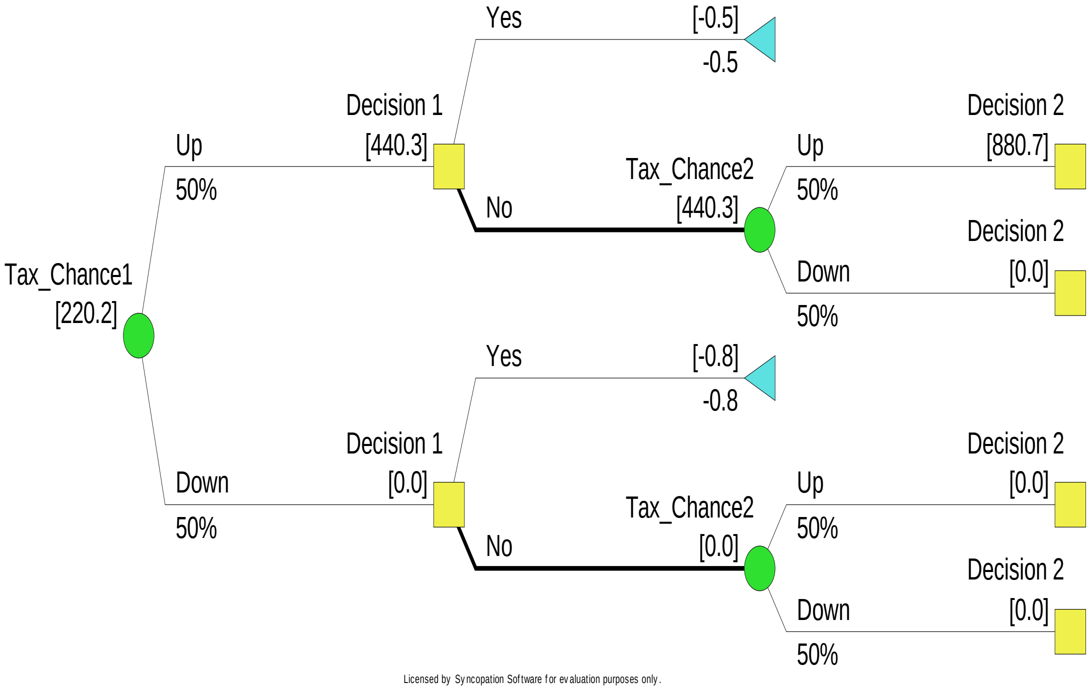

Figure 6.27 New Zealand Buller coal mine project tax simulations at 35 percentile

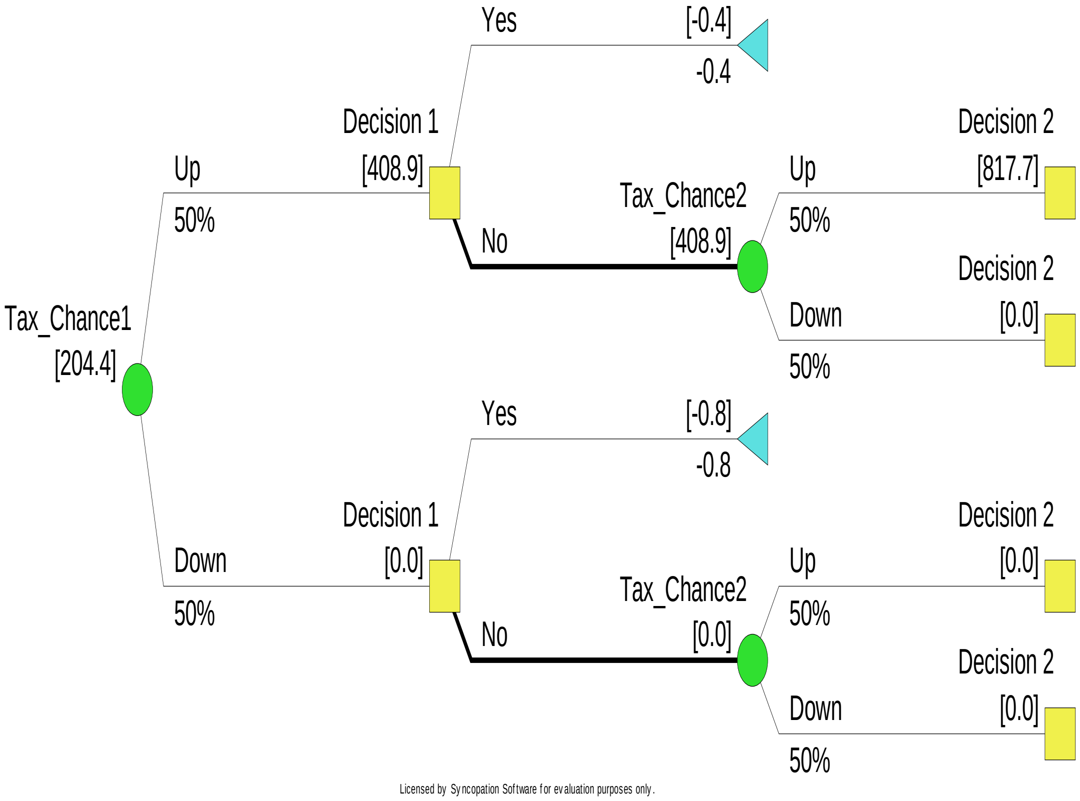

Figure 6.28 Papua New Guinea Wafi-Golpu gold mine project tax simulations at 25 percentile

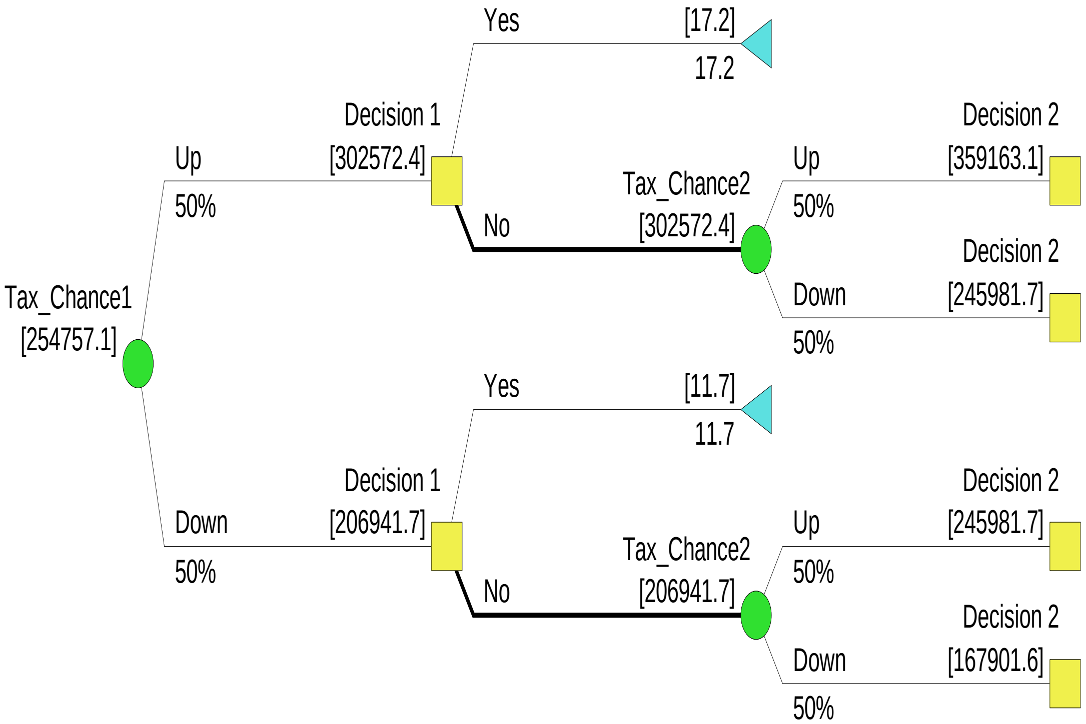

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Figure 6.29 Papua New Guinea Wafi-Golpu gold mine project tax simulations at 30 percentile

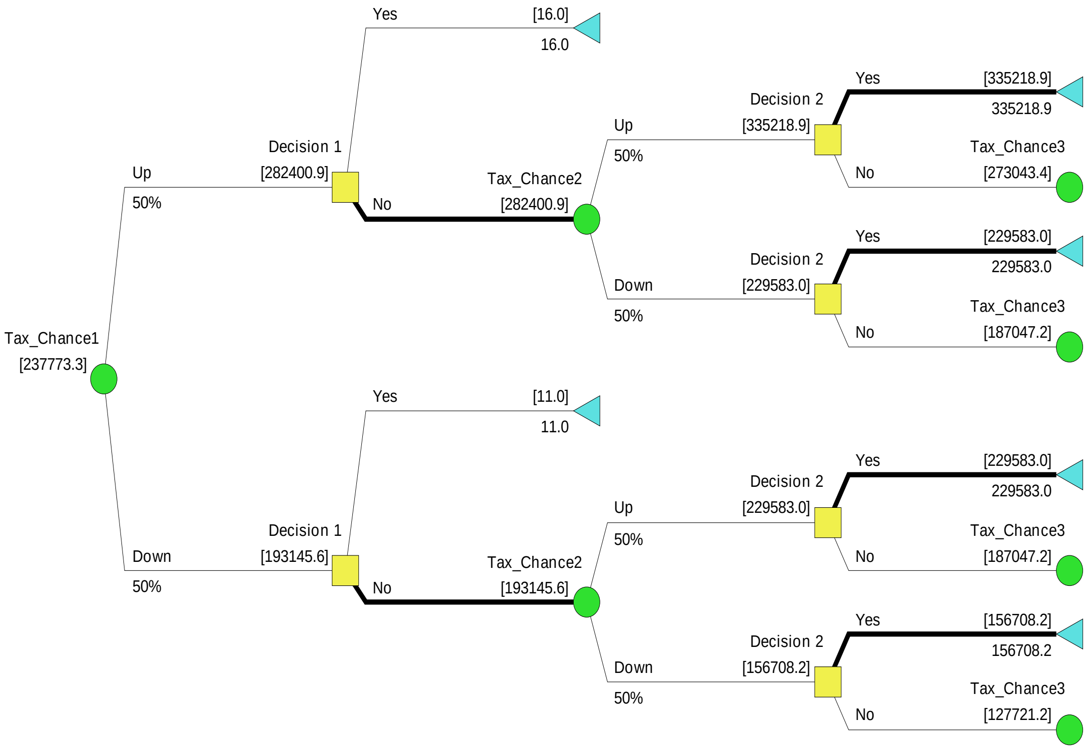

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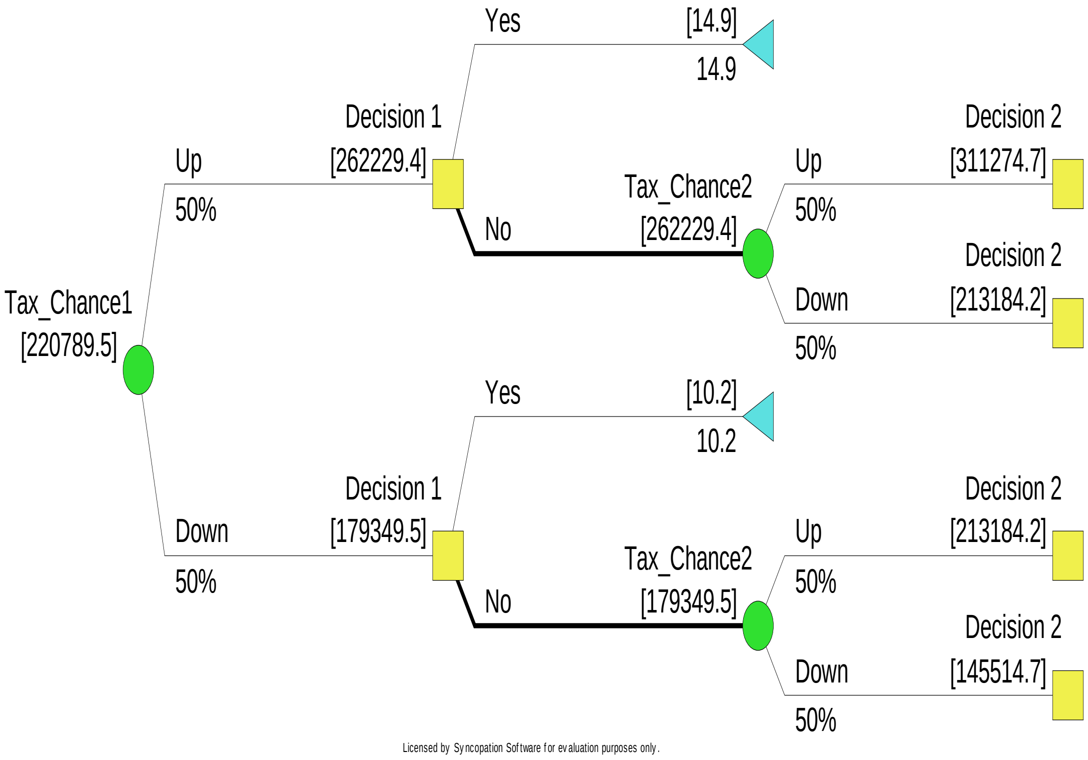
Figure 6.30 Papua New Guinea Wafi-Golpu gold mine project tax simulations at 35 percentile



In general, the findings show a strong support of tax policy implications in which frequently tax reforms and investment tax incentives certainly can affect the mining investors' returns, not only by changing the project's NPV, but also in encouraging or discouraging activities of mining investment in the region.

Among these five mining project invested in Asia-Pacific countries, New Zealand's expected project's NPV is a negative value. To further clarify this outcome, the researcher then applies binomial decision tree model using ROV analysis to reinvestigate this outcome. Even though the analysis has delivered positive NPV for the project investment in New Zealand, the overall revenue for the mining investment in this country is minimal. These revenues are USD236m at a tax flow rate of 25 per cent, USD220m at a tax flow rate of 30 per cent and USD204m at a tax flow rate of 35 per cent. By analysing the investment decisions over five year periods, the empirical outcome shows that the mining investor should favour their projects investment decisions in other Asia-Pacific countries such as Australia, Indonesia, Malaysia and Papua New Guinea rather than New Zealand. Mining projects invested in these countries deliver better NPV in their mining project investment than New Zealand.

For the mining project investment in New Zealand itself, the researcher finds that the mining industry in New Zealand is a new industry and the New Zealand government is concerned about the potential of mineral exports to the country's economy growth. Even though New Zealand's mining industry has been developed since the European settlers arrived in 1840, New Zealand had not fully developed its resource sector until 1999. Since then the resource sector has grown over 40 per cent (TeAra, 2015).

Another reason that may be attributed to the New Zealand's mining revenue is the high mining costs and expenses. Based on the cash flow calculation in Chapter 6, the researcher finds that the mining project set up cost in New Zealand is much higher than the mineral revenue that mining investors have achieved. As well, mineral production in New Zealand also plays a significant role in contributing to the overall mining revenue. As shown in the cash flow calculation, mining project invest in New Zealand produces less than any of the other countries that are part of this analysis, and as a result, mining revenue in New Zealand is not as attractive. Perhaps, the mining revenue in New Zealand can be improved in the future if the resource sector is fully exploited. According to the New Zealand Petroleum and Minerals (2014). New Zealand contains a wide range of minerals, including coal, gold, silver, and iron sand. These minerals have been widely produced and have contributed to several sectors of the economy such as construction, energy, transport, agriculture and manufacturing.

Despite the mining project investment in New Zealand having the least profitable project value, in the most likely case, mining investors should defer or abandon the project investment. Using deferring real options strategy, the mining investor has an option to choose not to exercise the investment project. There is no cost incurred by delaying the investment decisions. Using ROV has an advantage; with little project value, an investor should abandon this project without further consideration.

The empirical analysis also finds that the mining project investment for Australia and Indonesia have the same outcome. Mining investment in these two countries show that deferring investment is the key point to delivering better revenue. The mining firms intending to invest their project in Australia or Indonesia can opt to invest now or defer their investment. According to Business Monitor International mining report (2012), these two countries share some similarities, such as the location. Australia and

Indonesia are both ideally situated in the Asia-Pacific region where major metal consumers, such as Japan, South Korea, Taiwan and China, are located.

The investment project decisions for the mining investor in Malaysia and Papua New Guinea have mixed conditions. Mining investors intending to invest their project in these two countries can opt to invest immediately or defer their investment decisions. The project investment decision is particularly obvious after the third period of the investment. For instance, the mining project decision tree analysis in Malaysia shows (Figures 6.22 – 6.24) that if the mining investor initially has no plan to invest now, they can defer their investment by holding the investment until the third year. This outcome is similar to the investment analysis conducted in PNG. However, by the end of the fifth year, there is an optimisation to invest the project in these two countries and project revenue obtained in these two countries is higher.

This study is adopted two case scenarios using the selected five mining projects operate in the Asia-Pacific regions to examine the behaviour of mining investment activities. The first scenario uses the volatility of commodity prices by assessing the timing flexibility in the mining investment activities. Secondly, the study applies the variation of the tax rate in determining the mining investment decisions.

In the first case scenario, the findings in this study show that the volatility of commodity prices can impact the mining investment decisions. The optimal investment rule that applies in mining investment decisions is undoubtedly influenced by the fluctuation of the world commodity market.

The commodity prices in the binomial decision tree analysis using gold and coal price show that there is likely to be more mining investment if the mineral prices are above the level of mining investor expectations. By contrast, there is less likelihood for mining investment if the mineral prices are below investors’ expectation.

The researcher finds that the timing investment using the binomial decision tree analysis for mining projects based on these two commodities are identical. In this case, mining investment based on timing seems to have a less significant impact on any mining investment activities. However, the volatility of commodity prices are crucial in determining the mining investment decisions making. The finding explicitly shows that investing in mining projects that are ultimately based on the commodity price level is the factor that investors are most concerned about.

In the second scenario, the researcher uses different tax flow rates incorporated with timing flexibility to assess the mining investment decisions in the Asia-Pacific region. The finding shows that tax flow rates can undoubtedly impact mining investors' behaviour. Using five mining projects currently operating in five Asia-Pacific countries, the empirical outcome shows that by changing the tax flow rates, the responsiveness of mining investors in their investment decisions are substantial. Even though the tax flow rates are only adjusted by 5 percent in each case scenario, it is sufficient for mining investors to reconsider their investment activities. The primary factor that causes the change of investment behaviour is the change in project's NPV.

The researcher believes that the variation of tax rate indeed can change the project's NPV. If the NPV changes are minimal, then there is not too much concern by the majority of mining investors who plan to invest in this region. Mining project investment in New Zealand is in a different category because of its negative NPV. In ROV analysis, the negative NPV achieved in New Zealand reflects that mining investors should hold or not exercise the project. However, with the negative NPV shown in the project invested in New Zealand, which comprises several million dollars of losses, the best strategy for mining investors is to abandon the mining. Mining investors can consider other countries, which can generate better profit. Therefore, no timing issue occurs in the mining project investment in New Zealand as a result of negative NPV made in this country.

The empirical analysis in this study also shows that no matter which countries mining investors plan to invest in, the NPV in these countries makes only a small difference. Investment decisions in this region seem not to be occurring even though the variation of tax flows apply. The NPV could be different if mining and royalty taxes were included in the analysis.

In general, the empirical finding in this study suggests that mineral prices uncertainty can indeed impact on the mining investment decisions. That the project proceeds or not depends entirely on the fluctuation of mineral prices, which dominates the whole project value. This scenario certainly can apply in the current resource industry in Western Australia (WA) where some mining projects have been on hold as a result of the record low level of iron ore prices.

The empirical analysis of the variation of tax rates suggests that tax rates can affect the project NPV but it is subtle. The empirical outcome shows that little happen when tax flow rates change among the five countries when considering mining investment decisions, except the mining project in New Zealand. Compared to mineral prices, the tax flow change is not a primary factor that concerns mining investor. Timing flexibility indeed is crucial for mining project investment. However, if timing is incorporated with the variation of tax flow, the outcome in this case, is that it only plays a minor role for the investment decision analysis.

6.5 Concluding remarks

In this chapter, the researcher concludes the empirical analysis of the mining project investment in the Asia-Pacific region with managerial flexibility. The researcher studies the impact of the fiscal policies regime using the ROV to examine the decisions by mining firms to wait, to invest, and/or disinvest in their mining projects. Applying the binomial decision tree analysis to study variations of tax policy in the Asia-Pacific region, the researcher finds that the strategy of the option to delay certainly can apply to mining project investment activities. This option strategy is particularly useful in the current high volatility economic climate, as well as the uncertainty of the current tax reform in the Asia-Pacific region.

Using forecasted commodity prices, an empirical analysis is conducted in order to find the optimisation of investment rule which is crucial for mining investors when making their investment decisions. An application of this investment rule is critical when dealing with investment uncertainty. In the resource industry, any variations of commodity prices can have significant impact on the entire project's NPV. This is critical in current economic conditions in which prices, such as oil and iron ore in the energy and resource industries, has reached new record lows in the world commodity market.

Timing is one of the critical points discussed in this study. The researcher finds that waiting has its value. By deferring the investment option, mining investors can wait for better information for their future investment. By waiting for the future information, the mining investor is able to make a decision in order to deliver better revenue for their project investment.

In relating to institutional policy matters, the study finds that policy uncertainty in developing nations can have significant impact on the mining investor decision making. For example, sudden changes in tax flow rates in the developing countries continue to be one of the risks faced by the mining investor. This is particularly obvious in the analysis in which the mining investor has to wait for certain periods of time, after making the investment decision, before the actual revenue is delivered.

Another issue is the corporate tax flow rates in this region. Corporate tax flow rates have undergone significant reform in Asia-Pacific countries. Governments in these countries often review their fiscal policy to maintain the international competitiveness in relation to mining investment. A reduction of the corporate flow tax rate is the common strategy used by the governments in the region to attract foreign-based mining investors. Despite the highly volatile economic climate, as well as the current tax reforms, the strategy of using the option to defer associated with timing flexibility certainly provides another avenue for mining investors. Indeed, mining companies must be able to use the real options technique to capture the variation of tax policy reforms and boost their investment confidence by accessing managerial flexibility.

Chapter Seven

7 Concluding Remarks

7.1 Overview

The Asia-Pacific region has grown phenomenally in the last two decades. A remarkably high achievement in economic growth in this region has led to the Asia-Pacific region becoming one of the most influential geo-economic spaces in the world. The region covers a wide range of landscapes enriched with mineral resources. The mining industry, therefore, is one of the most significant industries in many Asia-Pacific countries because it has become one of the major contributors to these countries' national economies.

In this thesis the researcher presents the first comprehensive mining investment analysis in the Asia-Pacific region. Specifically, the researcher addresses the timing strategy used in mining investment in this region. Many researchers have examined production capacity, mine closure, and the variability of mineral prices. However, previous research about mining investment analysis in the Asia-Pacific region is vague and incomplete. As a result, a new and extensive study in this research area is essential. This is because many Asia-Pacific countries have been transformed from the poorest to among the most vibrant economies in the last four decades. Notably, it is worthwhile to further investigate the recent development in this region. This thesis is therefore based on ideas developed in previous mining research studies, which are extended and applied to the Asia-Pacific countries' mining investment analysis.

Investment activities conducted in mining project investments are usually extremely risky, capital intensive, environmentally invasive and socially intrusive. Conducting project investment in mining is perhaps the most important and conscious decision making process for many resource firms. Mining project investments also involve long lead times, so timing always plays a crucial role in deciding mining investment decisions, especially when economic conditions have changed.

In this thesis the researcher addresses timing issues that mining investors have encountered. The rigid traditional cash flow analysis shows that mining investors have to rely on available information. The researcher applies a flexibility timing strategy, so that mining investors can abandon, reopen or defer in midstream their mining investment decisions when economic circumstances change.

7.2 Proceedings

This thesis begins in Chapter 1 which reviews the structure of this thesis and discusses some background studies of the Asia-Pacific region. The researcher believes that this background information informs readers about the recent development and significant achievement of the Asia-Pacific economies in the twenty-first century. This chapter focuses on a discussion of the resource industry and the fact that the Asia-Pacific region is enriched with mineral resources. The chapter also emphasises the close relationship between mining investment and the economic growth in this region, as many of the poorest economies have become transformed. Governments in this region have used various policies to encourage mining investment and thereby transform these countries' economies. Enriched with abundant mineral resources and through judicious mining policy, some of these countries have obtained substantial and lucrative mining royalties that have transformed their economies successfully. However, the resource boom has not benefited some of these nations because of their inappropriate governance.

In Chapter Two the researcher conducts a detailed review of the existing literature on the relationship of mineral scarcity and economic growth, which is one of the most contentious issues for mining investment in the Twenty-first Century. The literature review concentrates on the mining investment uncertainty in which mining investors are concerned with how irreversibility of their investment could impact on financial performance. In the national perspective, irreversibility of mining investment can impact the entire nation's economy. The literature review of this thesis draws attention to evaluating mineral resources in general, but where possible the review focuses on studies of resource development in the Asia-Pacific region.

In Chapter Three the researcher reviews various financial techniques used in large scale project investment. The researcher explains some advantages and disadvantages for how each of these financial techniques is being used in the current business investment climate. Choosing an appropriate financial method for mining investment projects is crucial because profit can only be maximised when the appropriate strategies and techniques are applied, particularly in the early stage of the project's investment.

Chapter Four Part A contains the research methodology in which the researcher examines both the traditional static discounted cash flow (DCF) method and the real options approach (ROV). Companies conduct an investment evaluation to ensure that they can generate an investment return at the highest rate possible. In mining project evaluation, mining investors usually carry out their investment analysis using the traditional DCF method. Because of the inflexibility and rigidity of this method, mining investors can miss out on some important opportunities. As a result, an advanced financial technique, the ROV, is applied in this thesis to bridge the gap in the shortfalls of the traditional capital budgeting method. The researcher uses these two models to analyse mining investment projects in this region, particularly investment activities relating to timing flexibility.

In Part B, the researcher conducts a case study of determining the mineral price uncertainty by applying a timing strategy. A mean reversion model is used in the study to forecast the future gold and coal mineral prices. The researcher describes the mining firms' options to invest based on predictions of mineral prices and the degree of uncertainty over the future value of the project.

As mentioned above, dealing with appropriate timing can add value to mining investment decisions that are being considered. Chapters Five and Six reveal the empirical outcome of the mining investment decisions using two methods. In Chapter Five, the empirical analysis is conducted using the traditional DCF method with the absence of flexibility, demonstrating that if the NPV is positive, the investment mining project should go ahead, otherwise, the investment project should be abandoned.

In Chapter Six, the empirical analysis is based on flexibility of timing using the ROV approach. Flexibility in timing allows mining investors to decide when the investments should be made, when they should be deferred and when they should be abandoned. In addition, the advantage of applying flexibility enables mining companies to adapt in that it allows companies to amend mining projects under conditions of economic uncertainty. This includes the volatility of future movements in economic variables. By adopting a flexibility strategy, the researcher develops a mining strategy that is designed for the current Asia-Pacific countries' investment climate.

In these chapters, the researcher conducts mining project investment analysis for selected projects in five countries in the Asia-Pacific region, namely Australia, Indonesia, Malaysia, New Zealand and Papua New Guinea. In the analysis, the researcher focuses on the optimal timing of investment decisions. In determining the optimal timing of mining investment, the researcher follows the investment rule based on forecasted gold and coal prices. After investigating this optimal investment rule, the researcher assesses the highest mineral price at the best timing of the project's NPV.

In developing flexibility of timing investment strategy, the researcher uses both the DCF and ROV approaches to compare the mining investment activities at a glance. The researcher first uses a static strategy in mining investment without attempting flexibility of the timing investment, and then uses a flexible technique in which mining investors are able to defer their investment options. The American style call option based on a binomial decision tree model is used in this thesis. The objective of adopting this particular option method is because mining investors have the right, but no obligation to execute their mining project prior to the expiration date. By having the opportunity to defer their investment activity, mining investors can benefit from the resolution of uncertainty about economic conditions, such as volatility in commodity prices during the investment period.

In these two chapters, the researcher also investigates policy issues in conjunction with the risk that occurs in the mining investment. It is extremely important for mining investors to take extra precaution in high risk mining investment project activities, particularly when the country is in a state of political instability and policy uncertainty.

Policy uncertainty can completely change the direction of an investor's plan. Mining investment activities can be dramatically affected as a result of regulatory uncertainty as investors are extremely sensitive to the regulatory frameworks in the countries they intend to invest in. Policy matters, such as uncertainties in the fiscal regime, corruption, and political instability, are among the top priority investment criteria for mining investors to decide on their project investment. In this study, the researcher considers changes in the fiscal tax flow regime to examine policy issues in the Asia-Pacific region.

7.3 Major findings

As outlined above, the researcher makes an empirical analysis of the mining investment activities in the Asia-Pacific region by assessing the mining investors' use of flexibility timing to respond to changing economic conditions.

Applying the static DCF and ROV methods to conduct an analysis, the researcher's major finding of this thesis identifies that the investment with managerial flexibility is always advantageous to the investor. Accessing flexibility allows mining investors to defer their project investment if current economic conditions are not optimal. Using the options to invest or wait for better information is found to be one of the best techniques, which can be applied in Asia-Pacific countries. The findings also show that this technique is particularly useful when the investment project is conducted in countries with uncertain fiscal policies, which applies in this study.

The empirical studies in this thesis comprises of two components. The first component examines the mining project investment where no uncertainty exists. A static DCF model is calculated using the simple spreadsheet form. The findings of the application of the static NPV rule shows that the illustrative investment projects among the five countries included in this analysis, New Zealand has the only project which achieves a negative NPV. Conducting this traditional static NPV rule is straight-forward. If the project NPV achieves a positive value, the mining project will proceed, if there is a negative NPV for the mining project the investment will be abandoned. Based on this simple NPV rule, the mining investor would abandon the investment project in New Zealand without any further questions. However, the mining investors in other four countries could make their investment decisions based on the project's NPV. In applying this simple NPV rule, mining investors then decide which country they will invest in. Again, this is subject to the variation of the project's NPV.

In the second component of this empirical analysis, the researcher addresses the mining investment problem using the timing strategy through the ROV model. When applying the American style call options with binomial decision tree, in conjunction with the strategic managerial flexibility, the findings show that the illustrative projects for Australia, Indonesia, Papua New Guinea and Malaysia, offer substantial ROV for mining investors. The ROV approach demonstrates sophisticated and advanced financial techniques in which the mining investors can rely on their project investment decision making. The commodity prices and the variation of tax rates are two highly uncertain variables, which are identified in this study. By adopting these two variables into the ROV approach, the study concludes that the ROV method can generate better revenue for the mining investors. Flexibility is one of the greatest advantages of using this model.

The volatility of commodity prices and the variation of tax flow rates are among the highest volatility variables in determining the project investment decision making. The change in these two variables can impact mining revenue significantly. The researcher believes that adopting the option to defer mining investment is one of the best strategies in the current economic climate which is significantly volatile and uncertain. By applying this approach using the ROV method, the study finds that using the option to defer the mining investment can benefit mining investors. The plan to delay the mining project investment offers an avenue for mining investors to take advantage of the resolution of uncertainty about the current low commodity prices.

Rationality is a critical factor for mining investors in determining their investment decisions. Rational mining investors use their resources and information to the fullest extent in order to maximise their project’s value and minimise the project’s risk. This empirical study finds that timing and rationality are interdependent critical factors in the success of mining project investment, a profitable investment project depends on strategically well-timed decisions.

In this thesis, the researcher uses various illustrative projects to conduct an investment analysis in the Asia-Pacific region. Each is a mine project currently operating in one of the five countries as mentioned in this thesis. The empirical evidence shows that by adopting a flexibility ROV approach, the likelihood to defer investment decisions in midstream of the project investment are more likely to occur for the illustrative projects selected in Malaysia and Papua New Guinea than other countries in the region. The nature of the mining project such as cost, production capacity and the mine life can also impact the entire mining investment decisions.

Deferring the investment project can be the best option particularly when there is uncertainty of future conditions. The decision as to whether to invest or not in a mining project is completely dependent on the mining investors themselves. The main idea of this thesis is that the effectiveness of fiscal policies depends on firms’ financial choices. Whether the project should go ahead or wait for better information is entirely up to the mining managers' decisions.

In relation to institutional policy matters, this thesis finds that commodity price instability has significant impact on mining project investment decision making in developing nations. The flexibility of timing of the mining project investment, particularly the extreme volatility factor such as unstable commodity prices is important for the mining investor. The timing issue, on both DCF and ROV in relation to project investments that are affected by the uncertainty of commodity prices, is therefore central to this study. The finding of this thesis reveals that mining investors can use the timing flexibility strategy in the ROV method to make decisions in their investment project. The ROV method enables mining investors to defer their investment in cases where commodity prices are at record low levels.

7.4 Policy implications

As described above, policy matters are one of the key important issues in relation to mining investment decisions analysis. Institutional policies, such as implementing the lower tax rate or higher tax credit are one of the key successes for a nation to attract foreign mining investors. This thesis discusses some key issues of mining investment policy in the context of the Asia-Pacific region.

The mining policies adopted in the Asia-Pacific can ensure prosperity and stability in this region. In this thesis, the researcher suggests some policy implications for governments, as well as strategies for mining investors.

In this thesis, the researcher finds that commodity price uncertainty is a factor that impacts on entire investment decisions making. Tax flow rates also affect mining firms' valuation of investments and their investment decisions. Simulations in this thesis show how different tax flow rates impact both NPV and ROV of the project under consideration. Governments can use option valuation to examine the impact of various tax rates on the investment decisions, including timing, of mining companies.

Mining commodity prices have always showed greater impact and volatility in the NPV of the project investment compared to commodities in any other industries. A change in these prices is also considered to be a reflection of resource availability. Using the optimal investment rule in commodity prices to determine the best timing of the investment is crucial. The optimal investment rule assessing timing flexibility of the project investment is a useful policy which can assist government agencies and mining investors challenge the instability of commodity prices.

The ability to delay an irreversible investment or policy can profoundly affect the decision of government agencies. They can use the technique of assessing timing flexibility to stimulate the nation's mining investment when commodity prices are at record low levels and create stability and credibility of the country's economy by attracting foreign mining investors.

In the wake of commodity price declines with the continued flow of capital and labour necessary for the mining sector in today's global economic trend, government agencies can offer tax holidays for mining investors or introduce incentives to encourage greater mining investment in the country. By providing tax incentive or subsidisation schemes, mining investors certainly can remain their investment in the country by not shifting capital to other countries and subsequently reduce the number of unemployed workers in the resource industry.

The uncertainty of tax flow policy is another critical factor that also can profoundly impact the aggregate mining investment behaviour. Government agencies need to take extra precaution when the variation of tax flow rates decisions is made. Using both the NPV and ROV methods to examine policy matters, the researcher firmly believes that social optimality has an effect on mining investment decisions as a result of the variation in tax flow rates.

The empirical study in this thesis shows that the change in tax flow rates can impact the mining investment decisions in both NPV and ROV methods. By changing tax flow policies at 25 percent, 30 percent and 35 percent, governments should be aware that the higher tax flow rate can discourage foreign mining investors to invest in the country. Policy uncertainty indeed plays a significant role in the current sluggish economic climate.

There are indeed some advantages and disadvantages for mining investors. For instance, lowering the corporate tax flow rate in Malaysia certainly can attract offshore mining investment to invest in the country. However, the decision to reduce nominal corporate income tax rates may penalise the existing investors if the effective tax rate increases. The reason is that foreign mining investors may have tax plans included in their feasibility study that hinge on steady effective tax flow rates, such as methods involving depreciable assets, machinery and deductibility of financing costs. Unpredictable changes in the fiscal system can disrupt these plans and discourage the existing mining investors to replan their current structures (KPMG, 2011).

The result of a steep decline in the current global mining commodity prices, together with significant high national debts and a low climb out of recession in most economies, has elicited a strong reaction from governments in the Asia-Pacific region. Governments in this region have proposed to shift towards indirect taxes and fees to guarantee revenues, striking a balance between a sustainable return on mineral resources and a reasonable profit for mining investors.

In some countries in the Asia-Pacific region, government intervention appears to be riding a wave of mounting hostility toward the resource industry. To ensure a coherent and cohesive tax and royalty policies of the concerned governments in the Asia-Pacific region, government stakeholders can discuss their policy agenda with the mining companies and report through organisations such as the Extractive Industries Transparency Initiative (EITI) and engaging with the supra-national organisation like the World Bank to ensure the policy is in fairness and meet the standard for extractive industry.

In today’s mining investment environment, governments interested in attracting mining investment must take steps to foster greater regulatory stability. To avoid chasing out mining companies out of their regions, governments must become more sophisticated in the application of the country’s fiscal rule. Otherwise, the backfiring government action can only cause the mining investors pull out their investment in the region or leave the investment project on hold. This action will leave governments without access to the revenue they seek.

The burden of proving that mining firms are paying the right amount of tax no longer rests solely with the taxation office or internal revenue. In many countries, the tax reform may soon force the mining companies to disclose fully all revenues and taxes generated globally, on a country by country basis (KPMG, 2015) . Adopting the best strategy to guarantee the profits of mining companies is essential, and this is all about in this study. The researcher also believes that timing flexibility by ability to delay the investment project can capture the variation of tax policy under the current volatility investment climate.

7.5 Limitations and future recommendations

The researcher uses data on a selected mining projects operating in five countries: Australia, Indonesia, Malaysia, New Zealand and Papua New Guinea for illustrative purposes. The individual mining projects operate under different tax rates, exchange rates, costs, and production capacities. These differences affect the project's NPV and ROV. Also, the assumptions that are made about the nature of the mining project, such as the life of the project and the method used to estimate profit and loss, are somewhat subjective, which affects the outcomes of the calculations.

Also, the five year period and study of only five countries in the Asia-Pacific region makes it difficult to generalise about the strategy of flexibility in timing for mining investments. As well, the researcher excludes other countries in the region endowed with minerals resources. Countries such as Vietnam and the Philippines should not be neglected with their future economic potential in the resource industry, which this thesis leaves for future research. In addition, accessing only short periods for mining investment decisions also prevents the researcher from replicating the empirical outcomes more convincingly.

The researcher also suggests that future research can be extended to focus more on the timing flexibility using commodity prices in conjunction with the agricultural investment activities in the regional economies both in Australia and other Asia-Pacific countries. In relation to the changes in tax rates, the research can be extended somewhat further in relation to wages in the mining industry, as well as the number of workers employed in this industry.

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