Graduate School of Business
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Techniques for Analysing and Reconciling the Progressive Mineral Taxation Regime of Papua New Guinea

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Declaration

To the best of my knowledge and belief that this thesis contains no material previously published by any other person except where due acknowledgment has been made. To demonstrate the research integrity, the final thesis document was put through Turnitin™, submission ID Number 896322574. This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from Curtin University Human Research Ethics Committee (EC00262), Approval Number 10-13.

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Abstract

The thesis investigates how governments could use a progressive tax system to raise more revenues from the mining industry. Making mineral taxes more progressive can raise high magnitude of revenues, reduce time-dependent inequality, resolve fiscal instability and restore confidence in tax planning to execute social development goals. However, no study has been conducted to investigate how progressivity distributes burdens and the degree to which revenues are collected and redistributed to a society. Given the gap, this study investigates the revenue collecting potentials of Papua New Guinea's (PNG) progressive mineral taxation regime.

The study methodology differs from stylized models used for building of taxation theory and descriptive analysis of policy issues. The study uses the Lorenz curve, which structurally measures the tax burden distribution and the time-dependent behaviour of tax instruments through computing progression coefficients using the Stroup index model. These techniques use time series financial and tax revenue data to measure the theoretical and actual performance of individual tax instruments. Further, to enhance the reliability of the results, uncertainty of input variables such as price and costs are reduced using real option (RO) solution techniques. The estimated and historical data are then used to compute tax progressivity index (TPI), marginal effective tax rate (METR), net effective tax rate (NETR) and other variables to assess the performance of royalty, basic tax instruments and hybrid resource rent tax. The combination of TPI, METR, NETR and wealth transfer rates and the Lorenz curve make the study a more comprehensive analysis of PNG's mineral taxation regime.

Corporate income tax (CIT), dividend withholding tax (DWT) and ad valorem royalty stand out as the mainstays of PNG's mineral taxation regime compared with equity participation and additional profit tax (APT). The equity participation and the APT generate small amount of revenues and increase the social cost of rent-seeking. Further, indirect and non-tax benefits when added to the direct taxes transfer substantial share of the mineral wealth to PNG. This thesis finds that PNG's progressive mineral taxation framework has the ability to capture high magnitude of revenues from the resources sector. However, there are requirements for calibrating the policy tools such as depreciation techniques, loss carry forward provision, thin capitalisation rules and others to protect the tax base to make the tax instruments more progressive.

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Dedication

This PhD dissertation is dedicated in memory to some important people who raised me in poverty, yet have not lived long enough to see this rewarding lifetime achievement. First, my late mother Nakau Yango Waeya, in a traditional village setting and with no formal income source went far and near selling aprons (*munim - a grass apron used as skirt by women*,*a type of traditional dressing in PNG*) to raise money for my school fees. I may not pay her back in full. However, the pain and the effort would not be in vain as she imparted her life to me to be a blessing to others.

Second, my late father Mulau Pamen taught me the principles of life, especially the way of living by working hard and perseverance have motivated me to accomplish the study successfully. Third, late Ail Tsan supported my childhood and early school days, and his name being my surname, honours him more than my biological parents. Fourth, late Marki Minok and Nyee Londakai are recognised for providing leadership to Tangaip and Lyugin-Aiman tribes. Finally, I dedicate this thesis to God: the source of unlimited knowledge; wisdom; and understanding.

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Glossary of acronyms

ADB – Accelerated Declining Balance

AETR – Average effective tax rate

AMC – Australian Mineral Council

APT – Additional profit tax

BCL – Bougainville copper limited

BDTA – Binomial decision tree analysis

BHP – Broken Hill Propriety

BL – Binomial lattice

BS - Black Scholes

BM – Brown motion

CCA – Contingent claims analysis

CF – Cash flow

CFT – Cash flow tax

CIT – Corporate income tax

CPI – Consumer Price Index

DCF – Discounted cash flow

DTA – Decision Tree Analysis

ADB – Accelerated declining balance

DMPGM–Department of mineral policy and geohazard management

EDR – Effective distortion rate

EIT – Investor wealth transfer

EITI – Extractive Industries Transparency Initiative

EPG – Enga Provincial Government

EPT – Employee payroll tax

ETR – Effective tax rate

EWT – Effective wealth transfer

IMF – International Monetary Fund

IM4D – International Mining for Development

IRC – Internal Revenue Commission

IRR – Internal rate of return

FCE – Free caried equity

FPE – Fully paid equity

FPPE – Fully paid production equity

GBM – Geometric Brown motion

GoPNG – Government of Papua New Guinea

LCF – Loss carried forward

LME – London metal exchange

MAP – Modern Asset Pricing

MCS – Monte Carlo simulation

METR – Marginal effective tax rate

MRA – Mineral Resources Authority

MRDC – Mineral Resources Dev. Company

MRRT – Mineral resource rent tax

NEC – National exective council

NETR – Net effective tax rate

NPV – Net present value

NSR – Net smelter return

OTML – Ok Tedi mining limited

PBR – Profit based royalty

PNG – Papua New Guinea

PNGK – Papua New Guinea Kina

PV – present value

RADR – Risk adjusted discount rate

RO – Real Option

ROR – Rate of return

RRT – Resource rent tax

RSPT – Resource supper profit tax

SLD – Straight line depreciation

SML – Special mining lease

SOE – State owned Enterprises

SSG – Special Support Grant

TCS – Tax credit scheme

TDI – Tax distortion index

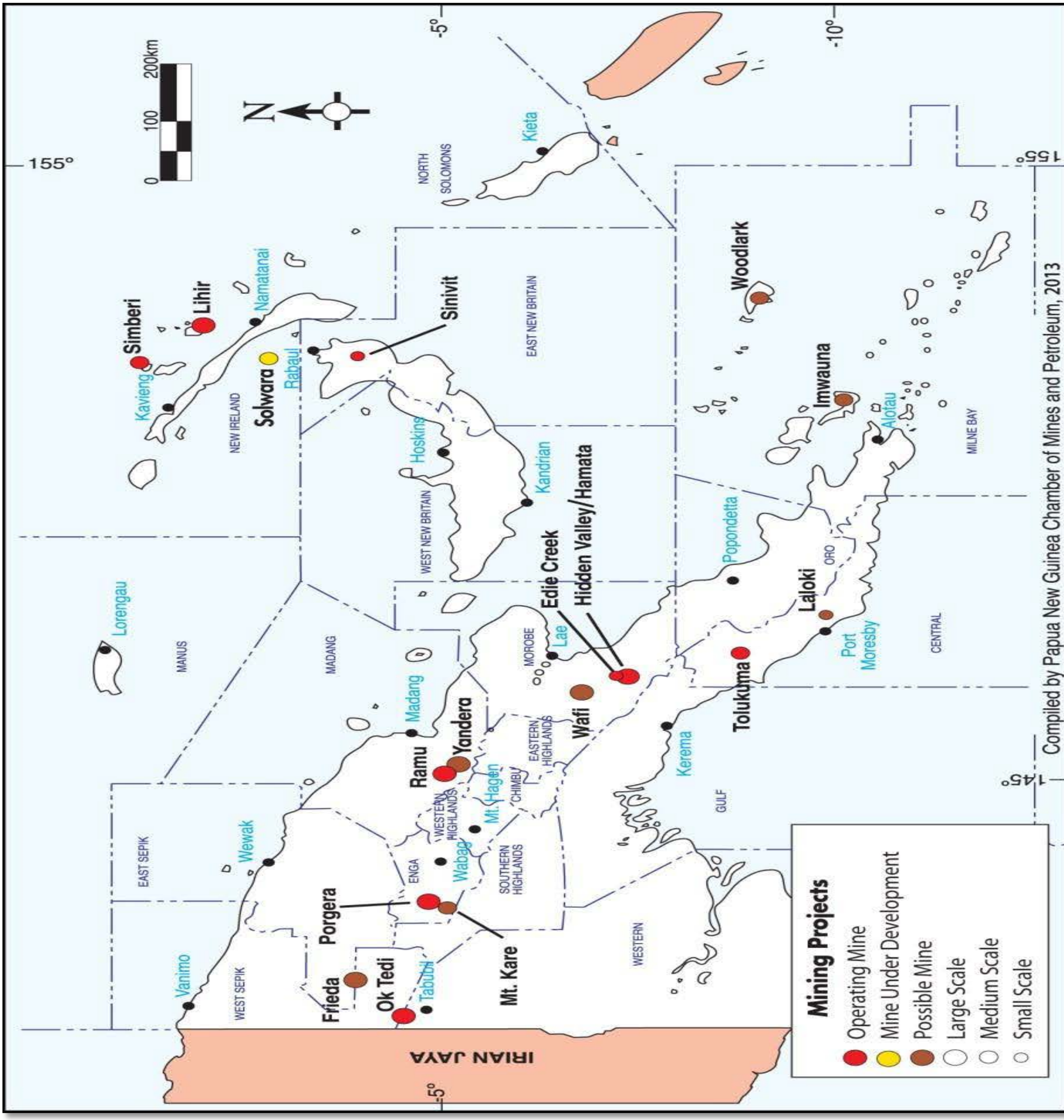
TPI – Tax progressivity index

US – United States

WPG – Western Provincial Government

VAT – Value added tax

Geographical Map of PNG



Chapter 1 : Introduction

Raising revenues from the mining industry is one of the main objectives for devising policies that encourage extraction of mineral resources found within a mineral endowed nation. Recent research indicates that mineral taxation has become more topical in relation to governments seeking innovative ways to capture a high magnitude of tax revenues from mining activities. The objective is achieved through designing suitable tax instruments, including royalties and hybrid rent levies imposed at different taxing points (pre-tax and post-tax bases) so that total revenue collection can be maximised (Conrad 2014). However, designing a balanced tax system that fits into the complex technical, economic and financial structure of the mining industry is a major challenge facing mineral taxation policies. The aim of this study is to analyse how a progressive tax schedule could balance the profit maximisation and revenue raising objectives of the stakeholders.

Recent studies such as Clausing and Durst (2015) and Laporte and Quatrebarbes (2015) suggest that mineral taxation is a primary tool used for raising revenues to meet social development goals. Since governments often play leading roles in minerals supply, tax designates a political risk, which affects both industry returns and social welfare. As a result, mining companies perceive that taxes eliminate rents and thus, they could collude to reduce tax liabilities. On the other hand, governments respond to the perceived revenue losses by adopting corrective strategies to capture more of the resource revenues to support development budgets (Daley and Wood 2016). However, theory states that social return rate cannot rise further than the required return on a mining project that compensates investors for risk-taking investments (Garnaut and Clunnies Ross 1983). These diverging objectives complicate designing a balanced taxation policy.

This dissertation examines the taxation regime of PNG, using it as a case study to investigate the revenue generating capacity of progressive tax instruments, and how they affect investment decision-making. The chapter is organised as follows. Sections 1.1 and 1.2 briefly discuss the background and the research problem. Sections 1.3 and 1.4 discuss the research design and purpose of the study. Sections 1.5 and 1.6 present the significance and scope of the study. Sections 1.7, 1.8 and 1.9 briefly mention ethical considerations, types of rents and provide a summary.

1.1 Study background

Mineral taxation studies are theory-orientated and focus more on optimal tax design structures for broadening the tax base (enlarging the industry through tax competitiveness) and rectifying other policy issues (Boadway and Keen 2014). However, past studies do not cogently explain the distributional characteristics of a neutral tax system and merely use it as a criterion for attaining extraction optimality (Smith and GL 2007). The neutrality principle facilitates the distributions of rents pertaining to risks faced by capital and input factor providers that in turn ensures taxing the resource rents do not distort investment decision-making processes (Daniel, Keen and McPherson 2010). It protects the capital allocation from being distorted by allowing a mining project to attain a normal rate of return (ROR) over a shortest period of time before a government can have access to tax revenues (Hogan 2012).

In order for a neutral tax system to function efficiently, investors expect tax designs that engage governments in sharing risks such as loss carry forward provision and crediting royalty payments against the taxable income (Boadway and Keen 2010). The early work of Brown (1948), which was revised by Garnaut and Clunies-Ross (1979) became the foundation for cash flow tax systems that are commonly employed in most mining jurisdictions (McLaren 2012). The difference between the two cash flow taxes is that the Brownian tax attains neutrality by fully engaging a government into sharing the risks such as market price, exchange rate, operating and capital costs.

Concerning the Brownian tax, subsidising a mining project's cash flow losses using development funds delays a government having access to revenues. On the other hand, the Garnaut and Clunies-Ross tax system creates flexibility for a mining project to offset cash flow losses through the loss carry forward (LCF) provision (McLaren 2012). The LCF provision ensures the opportunity cost of irreversible capital invested must be recouped before taxes can be imposed (Mitchell 2009). This mechanism is facilitated by allowing a mining project itself to offset the losses, which takes the burden away from nations that have limited public finance for achieving social development goals.

The common hybrid taxes devised to capture excess rents are: Resource Rent Tax (RRT), Resource Supper Profit Tax (RSPT) and Mineral Resources Rent Tax (MRRT) (Murray 2015). Recent evidence suggests that none of these hybrid systems have fulfilled Australian federal government's revenue raising projections (Valle de Souza, Dollery and Kortt 2016). The same scenario has been revealed for PNG from which the RRT originated. Furthermore, allowance for corporate capital (ACC) technique and a modified Boadway-Bruce tax system (Boadway and Bruce 1984) are also hybrid systems that are not practically applied at the policy level. Contrastingly, most mining jurisdictions rely more on royalties and basic taxes such as CIT than the hybrid tax systems.

The basic tax instruments are CIT, dividend withholding tax (DWT) and royalties that generate stable and consistent revenues from the mining sector. Protecting the tax base of a cash flow tax system at the policy level is a major challenge because CIT generates greater revenues than the hybrid systems. Further, many countries are adopting the ad valorem royalty because it is a value-based levy, which responds to changes in the market price, deposit quality and production rate (Otto et al. 2006). This has encouraged the resilience of value-based royalties globally despite their distorting behaviours. A recent study by Ergas, Harris and Pincus (2014) shows that royalties can fulfil a government's revenue raising objective with minimum distortion (e.g., Freebairn 2015) compared to the RRT and state equity participation.

Equity participation is a quasi-tax policy in which host governments own interests in mining operations and other extraction activities (oil and gas projects) (McPherson 2010). Equity participation strengthens a partnership between an investor and a government, and is driven by the optimism for financial asset accumulation and skill transfers to the community. However, heavy political involvement complicates measuring its performance, especially the social cost of equity participation that could exceed the expected dividend gains (Mendes 2015). Compared with equity participation and RRT, a few progressive basic taxes, including the ad valorem royalty can raise significant revenues.

Progressivity has a strong connection with rent-based taxes, yet remains largely unstudied, although few scholars do mention it half-heartedly (Kamin 2008a). This could be due to the fear that more progressive taxes increase the marginal tax rate, thereby exposing investors to a high tax burden. Since marginal tax rate measures the burdens placed on values added to capital invested (Chen and Mintz 2013), it eliminates tax competitiveness and discourages risk-taking investment behaviour (Conrad and Hool 1984). However, the incremental tax rate on every dollar increase in net value could be a reflexive behaviour that responds to an increase in the tax base, and therefore, progressivity may not increase the tax burden. Land (2008, 4) contends that an "adaptable and progressive" system is equitable and collects more tax revenues from profitable mines than do fixed systems (also Daniel and Sunley 2008; Duncan and Peter 2016).

The underlying principle of progressivity is that an increase in the marginal effective tax rate (METR) is a response to increases in the incremental rents generated by a profitable mining project (Gatzia and Woods 2014). This behaviour encourages tax instruments to respond positively to changes in the pre-tax base. This being the case, strongly progressive taxes capture the marginal incremental rents thereby transferring substantial mineral wealth to the society (Rousseau 2014). Moreover, progressivity reduces the time-consistency problem by enhancing flexibility that in turn maintains an equilibrium position during both high and low rent periods (Land 2008). This could be the main reason why governments are encouraged to adopt progressive rent-based taxes compared to regressive levies and royalties (Clausing and Durst 2015a).

Regressive levies not only generate lower revenues, but also distort capital allocation and production efficiencies. Hogan (2012) finds that relying on regressive taxes has resulted in losses of resource revenues in Australia. She affirms the findings of earlier studies (Freebairn and Quiggin 2010; Mayo 1979) to argue that profit-based royalties provide a safe option for governments to meet their revenue collection objectives. Additionally, consistent flows of revenues depend on the profit generating ability of the mining industry in the long run. Thus, securing the long-term sustainability of the industry requires a stable and competitive taxation regime. Although these ideas have been widely accepted (Hogan and Goldsworthy 2010), no performance-based studies have been conducted to investigate the revenue collecting capacity of profit-based tax instruments.

1.2 Research problem

With easy access to information, communities in mineral producing countries have become more proactive in determining the benefits they expect to receive from mining activities through more direct involvement in the investment decision-making processes

(Solomon 2012; Ulriksen 2017). The mining boom that was observed from 2003 to 2008 has spurred what appears to be global mining tax inquisitions into the dissipation of tax revenues (Conde 2017). Governments' perception of fiscal imbalance has triggered widespread corrective tax policies that resulted in breaching of existing stability agreements. Additionally, there has been increasing tax rates, partial nationalisation and expropriation occurred in the period from 2009 to 2014 (Heidrich and Loaiza 2016). These trends could arise from governments reacting to the perception that tax instruments are not performing as expected and communities opposing mining activities in view of protecting traditional endowments and physical environment (Williams 2016).

Australia has tested various hybrid RRT models in an attempt to maximise revenues by taxing rents from the mining sector (Daley and Wood 2016). Recently, Western Australia and Victoria drafted proposals to increase the unit-based royalty rates on iron ore and coal respectively (Bowie and Ellison 2016). In other regions, PNG proposes to increase equity participation by 30 to 50 percent, royalty to 4 percent; and reintroduce the APT, which was abolished in 2002 (DMPGM 2014). Further, CIT rates in South American countries have increased by 20 percent between 2009 and 2014. For instance, the Dominican Republic increased the CIT rate from 12 to 36 percent with a prolonged capital recovery period of 15 years (Heidrich and Loaiza 2016). These trends suggest that mining companies who balance economic and social objectives may overcome the protectionist policies (barrier to entry), especially in resource-rich developing countries.

Although the market may play a part in causing the fiscal instability, the first place to search for evidence is in the prevailing tax system and tax instruments, as well as the methodology used for measuring their performances. First, the taxation literature is congested with propositions on how taxes affect extraction decisions using optimal tax models (Smith 2013). The optimal models focus mainly on investigating different risk levels that affect the underlying economic variables required for assessing competitiveness and resolving policy issues. However, those decisions are often biased from the perspective that an investor's risk premium exceeds the social discount rate (Mankiw, Weinzierl and Yagan 2009). This ignores the fact that an investor's risk premium is facilitated in the tax designs where governments are willing to delay their revenue collections until investors realise their RORs on the invested capital. Hence, extreme forms of both complicated and hybrid tax systems that attempt to attain pure neutrality (tax optimality) can cause issues for tax authorities who may not have the skills required for auditing tax compliance.

Second, the main purpose of advocating tax optimality is to reduce the tax burden. This has diverted the attention away from analysis of the revenue collecting potential of various tax instruments, with more efforts placed on diagnosing inefficiencies in the design criteria. Additionally, emphasising the extraction optimality causes an oversight of the social needs when tax revenues are eroded, which partly increases fiscal inequality (Mankiw, Weinzierl and Yagan 2009). This could be the main reason for governments changing their behaviours when the industry enters a boom period or when a quality deposit is found. The fear that an existing tax system may not sufficiently capture the profits encourages corrective tax policies (Guj et al. 2017). Therefore, studying the risk and rent distributions, and revenue raising potential of the tax instruments could explain why there has been an increase in protectionist policies (Humphreys 2013).

Given the problem statement, a suitable method is required to establish a cogent understanding of the distributions of risks, rents and tax transfers to the society. The nature of the problem requires time series data and techniques that deal with uncertainty so that design factors that influence tax performance can be correctly distinguished and quantified.

1.3 Research design

A suitable technique is required for analysing the progressive taxation regime of PNG, especially deriving variables that measure the tax burden distribution and mineral wealth transfer to a society. The Stroup index model (Stroup and Hubbard 2013) is identified to be a suitable technique. It derives the progression coefficients of tax instruments that can be used along with the marginal effective tax rates (METR) and other variables for measuring the overall distribution of tax burdens, rents and revenues (Kamin 2008b). Further, the Lorenz concentration curve (Lorenz 1905) is identified as a suitable technique to structurally measure the degree of progressivity. The progressivity curves plotted against the Lorenz concentration curve will assist in distinguishing the behaviour of tax instruments in terms of burden distribution and the degree of resource revenue transfers to society. The revenue generating potential of various tax instruments are measured by positioning the respective progressivity curves against the Lorenz curve (Stroup 2005).

The quantitative study involves performing a theoretical and a historical tax analysis using time series financial and tax revenue data to compute the functional (decision) variables. Data required are collected from the undeveloped Frieda deposit, the now closed Bougainville mine, and the existing Ok Tedi copper and Porgera gold mines in PNG. These data will be used to statistically generalise mining industry’s tax performance between 1972 and 2013. The theoretical data comprise of prices, costs and production estimates that are highly uncertain. Since the conceptual data are imperfect, some real option (RO) solution techniques are used to reduce the time-dependent data uncertainty. The variations in price and costs are adjusted to make cash flows more stochastic to improve the validity of the findings (Samis, Davis and Laughton 2007). Integrating the theoretical and historical results will broaden the knowledge on the distribution of tax burden, rents and wealth transfers, as well as provide a more balanced analysis.

1.4 Purpose of the study

The purpose of this thesis is to identify whether a progressive tax system, when applied to the mining industry, collects revenue in a manner that does not distort investment decision making (Sunley and Baunsgaard 2001). It is hypothesised that governments can collect more tax revenues through devising a more progressive tax system that includes indirect taxes and non-tax benefits.

The following issues collectively guide the main research question, which is: What mining taxation system is suitable to fulfil the tax revenue collecting objective of the government without conflicting with the established principles of tax design such as neutrality, equity and stability?

Research issues:

(1) Can the progressive tax system augment the capacities of individual tax instruments to capture a higher magnitude of tax revenues for the government?

(2) What are the theoretical and practical aspects of the progressive tax schedule that makes it a suitable tax system for balancing the fiscal needs of investors and governments?

(3) How do the methodology and techniques impact upon the reliability of the results of the thesis?

1.5 Significance

This study will demonstrate how risks and rents are distributed within a taxation framework, which allows a government to accept some forms of risk-sharing and revenue trade-offs arising from uncertain prices, costs and mine operational circumstances. Further, disagreements between investors and governments over tax compliance do arise and can turn into costly litigations (Davidson 2012). Such issues can be resolved by reliably measuring how tax instruments perform when responding to changes under cyclic market and other risk conditions. It will also encourage the GoPNG to have faith in the ability of the existing progressive tax system to fulfil its revenue-collecting objective. The findings of this study, along with the methods used in the analyses will benefit investors, government and communities in different ways.

This study uses techniques for analysing the progressive cash flow tax system, which can be simple to adopt, especially the cash flow tax models. The numerical-based decision variables like the METR and progression indices can clearly explain the tax burden and rent distributions. This study approach can assist the GoPNG to distinguish high performing tax instruments from those that are inefficient. The findings of the study will help the GoPNG to rationalise its policy by retaining and strengthening the progressive tax instruments that will ensure efficient tax planning (Wilson 2016). Additionally, the study may help reduce the tendency of governments to change tax policies during periods of high profits, which often lead to fiscal instability, erosion of investor confidence and derailment of long-term existence of the mining industry (Robson 2015).

The use of a progressive tax system could benefit investors in two areas. First, a progressive tax system is a concession where it's flexibly responds to low and high rent periods, possibly reducing fiscal instability. During periods of high profits, a tax system is in equilibrium position, the marginal tax rate increases slowly relative to increase in profits. Alternatively, the accumulation of tax credits through a full loss-offset provision benefits the investors during periods of low profits. This in turn causes the marginal tax rate to decrease in response to a declining trend in profits accessed. Second, a progressive tax system can discourage the use of equity participation and RRT as they are responsible for causing deadweight losses and wasteful extraction of mineral resources (Mankiw, Weinzierl and Yagan 2009).

1.6 Scope of study

This study is an analysis of tax instruments applied to the mining sector in PNG. It does not include other tax instruments that could be used as alternatives for broadening a tax policy. For example, a sliding scale royalty could provide an alternative to the ad valorem royalty currently in use in PNG. This study does not fully investigate alternative royalty types and hybrid instruments such as the RSPT and profit-to-cost types that are not commonly applied (Otto 2017). It only focuses on the internal rate of return (IRR) to threshold rate type of the RRT and ignores other systems that may be suitable for PNG.

This study is confined to mining taxes, although the taxation policy applied to the mining industry overlaps with the petroleum and gas sectors. For example, equity participation policy is extended to the oil and gas sectors in PNG (Blake and Roberts 2006). Hence, modeling equity participation in the entire extractive industry could broaden the knowledge on implications of community owning equity interests. Additionally, since PNG's petroleum and gas sectors have a higher CIT rate, comparing them with that of the mining industry could provide some important insights into how CIT performs under different fiscal conditions in terms of burden distributions. However, such a comparative analysis could not be completed due to cost and time constraints of the study.

1.7 Ethical considerations

This research follows the ethical guidelines provided by Curtin University and the National Health and Medical Council (NHMRC). The guidelines were observed at all stages of the research process including fieldwork, data aggregation and analysis of results. This study deals with three significant stakeholder groups: the industry; the GoPNG; and the community. Hence, the data dispersion, processing and analysis have been conducted in a manner that avoids biased views of stakeholders, community and the researcher.

1.8 Definitions of rents

The taxation framework in some ways attains neutrality to protect different types of rents and allocates those rents to respective stakeholders. A tax design must allow capital (e.g., equity and debt capital) owners and input factor providers to receive different types of rents before governments can have access to tax revenues (Passant 2012). Further, the existence of rents is one of the main reasons for providing special tax treatment to the minerals sector (Dasgupta, Heal and Stiglitz 1980). Because of these significances, different types of rents identified below will be used in this study.

Rent:

- Rent is defined as "excess payment above that required for keeping a factor in production" (Wessel 1967, 1223). Rent is a neoclassical concept with reference to payments made to landholders for possessing collateral rights to agricultural lands, which include mineral property rights. However, classical economists argue that in-situ mineral has no value without a sacrifice (Tilton 2004).

Ricardian rent:

- These rents are available to different mining operations and mineral types as a result of differences in costs, prices and deposit qualities (Tilton 2004). A government setting different tax rules for different types of mineral extraction may target the Ricardian rents. For instance, Guj (2012) finds that the Australian government devised the RSPT for capturing the Ricardian rents from iron ore (high profit). However, it caused fiscal imbalance amongst the marginal and low profit coal mines.

User cost:

- User cost is a type of rent payment made to a resource owner by the user (miner) for depleting the in situ reserve and transferring the cost to future users. Royalty is recognised as a user cost or explicit tax because extracting today deprives future a generation's opportunity to benefit from the same mineral deposit (Boadway and Keen 2010; Minnitt 2007).

Paretian rent:

- Paretian rent is defined as "excess payment above that required to keep a factor in production" (Worcester 1946, 258). The tax literature integrates Paretian rent with the definition of economic rent, which is derived from the difference between cash inflows (revenue) and outflows (costs) (Hogan and Goldsworthy 2010). It exists within a single mining operation and is determined by prices and costs of the factors employed in production. Profit-based tax instruments can be imposed on the Paretian rent similar to economic rent.

Economic rent:

- Economic rent is defined as “the excess of the return to a factor of production above the amount that is required to sustain the current use of the factor (or to entice the use of the factor” (Ergas, Harrison and Pincus 2010, 171). The tax literature often uses economic rent interchangeably with pure profit, pure rent or excess profit. Identifying the existence of economic rents in mining projects is significant for correctly assessing profit-based taxes such as the RRT, which is based on rents above those considered to be normal (Garnaut 2010b).

Normal rent:

- Normal rent is defined as the “minimum rate of return required to hold capital for the activity” (Hogan and Goldsworthy 2010, 135). The return on the pre-tax cash flow is measured by investor’s discount rate, while the excess rent is measured by internal rate of return (IRR) based on the post-tax cash flow (Torries 1998). The main principle in mineral taxation is that the normal and quasi-rents should not be taxed.

Quasi-rents:

- These are sunk costs incurred over prolonged periods of exploration, as well as capital and operating costs that should be considered before taxes can be imposed (Boadway and Keen 2014). Garnaut and Clunies Ross (1983, 35-6) caution that quasi-rents are not a market-driven values and are often treated as marginal costs on a producer's supply curve. Therefore, quasi-rents should not be taxed, which is why the LCF provision is required when designing a mineral taxation framework.

1.9 Summary

This chapter has introduced the focus of this thesis, which is to investigate the progressive taxation regime applied to the mining sector in PNG. Understanding and measuring the tax performance is significant for supporting economic and social development goals. The research interest is inspired by the increasing tendency of governments to devise tax systems that capture a maximum share of resource revenues from mineral extraction, especially in developing countries.

The thesis is structured in the following order. Chapter 2 reviews the relevant literature to synthesize the complex interface between taxation theory and tax systems that link the objectives of investors and the government. It presents the theoretical perspectives on the principles of progressivity and functional variables for measuring the performance of various tax instruments. The chapter briefly presents the techniques commonly used for taxation studies, as well as techniques required for correcting imperfect data before providing a summary. Chapter 3 explains the research methodology. It presents a conceptual outline of the procedures used for collecting data and identifying the decision variables. It also provides a discussion of the limitations of the analyses undertaken in this thesis.

Chapters 4 and 5 present the results of the theoretical and historical tax analysis respectively, by tabulating the progression coefficients and graphically represent the performance of the tax instruments against the Lorenz concentration curve. Chapter 6 aligns the theoretical and historical results and reconciles the findings to make some policy recommendations for PNG’s mineral taxation regime. The conclusions of the thesis are presented in Chapter 7.

Chapter 2 : Literature Review

Tax policies have become more significant in recent years as communities and host governments broadly expect to retain an equitable share of the minerals extracted. Likewise, investors anticipate fair returns for sacrificing capital, resources and time in risk-taking exploration and mine development. In an attempt to balance these fiscal expectations, the taxation theory developed between 1940 and 1990 has been broadly revised and extended into devising various hybrid systems to provide economically and socially equitable tax systems. This chapter reviews some of these theoretical developments along with the tax instruments, analytical techniques and models, and variables that will be used in this study.

Section 2.1 explains how the theoretical framework tries to balance the extraction efficiency based on time-dependent distributions of risk, while Section 2.1.1 briefly examines some policy issues affecting mineral taxation. Section 2.2 discusses the principles of progressivity from a new perspective, while Section 2.3 presents the functional variables that will be used to measure the performance of various tax instruments. Section 2.4 examines the individual tax instruments and Section 2.5 discusses indirect and non-tax benefits. Section 2.6 examines the techniques used for tax modelling and Section 2.7 examines the techniques used for forecasting the input variables. Section 2.8 provides a summary of the chapter.

2.1 Theoretical Framework

Balancing mineral extraction efficiency with the social dimension of taxation is a major challenge due to recognition that minerals found within a jurisdiction are exhaustible and owned by the state and the community as a whole (Laporte and De Quatrebarbes 2015).

Furthermore, tax policies regulate mining activities so that they occur orderly in accordance with national development goals. Many commentators perceive that resource taxes exist as an exchange for ownership transfers to private owners, depletion of reserves and environmental protection (Ramatji 2013). Given these objectives, some tax policy design criteria such as neutrality, equity and stability are argued as prerequisites for a balanced tax system (Baunsgaard 2001). Amongst those tax design criteria, neutrality principle is a significant one because it regulates the effects of imposing tax on economic, financial and technical aspects of a mining operation. The principle of neutrality states that investment decisions would be unaffected if taxes are not imposed on the quasi-rents by adopting some optimal tax systems (Fane 1987).

Optimal tax theory recognises lump sum and Brownian taxes meet the neutral conditions as they allow the capital allocation process to occur unabated (Fane 1987). In relation to that, investors argue that some forms of neutrality must be maintained to recover the irreversible capital committed towards exploration and mine development before paying taxes. However, conforming to an absolute neutral policy is socially suboptimal as these tax systems may not raise sufficient revenues to compensate the community (Alvarez and Koskela 2007). Sorensen (2007, 383) argues that "optimal tax theory has produced very few robust results that can serve as the basis for useful, concrete policy advice". Placing more emphasis on the effects of taxes on extraction path tends to ignore the redistributive abilities of the tax instruments. Further, a principle underlying the balanced tax system is one that sustains the sources (mines) from which rents and tax revenues are derived to meet the investor and government's objectives.

The Brownian system, or R-based system (Brown 1948) invites a government to directly share the risks of a mining project by subsidising losses so that revenues become accessible when the tax base turns positive (Guj 2011; Hogan 2012). In reality, governments seldom subsidise corporate losses to induce the capital reallocation processes to occur rapidly (Boadway and Keen 2014). A government could be reluctant to subsidise the corporate losses because there is uncertainty surrounding when a tax base would turn positive so that the cost of loss subsidy can be recovered. Moreover, the Allowance for Corporate Equity (ACE) is a modified version of the Brownian tax that permits thin capitalisation and allows a government to refund unallocated capital at the risk-free interest rate (Boadway and Keen 2014). However, the ACE is complex, which makes it unsuitable for immature jurisdictions that have low financial and tax administration capacities.

Designing a pure neutral tax system is politically difficult at the policy level (Garnaut 2010a). A government may not recover the risk payments (using public funds) made to an investor if the subsidy, including interests exceed the future tax revenues. Since mine operators control costs and make decisions (Fessehaie and Morris 2013), they could influence the occurrence of losses so that a loss subsidy can be claimed from a government. This behaviour of investors under a Brownian tax system could be socially unappealing. A government committing scarce development funds towards offsetting corporate losses could reduce social welfare, which is critical for developing countries. Hence, the Brownian tax and its hybird types could exert fiscal burdens on a low-income mineral endowed country (Garnaut 2010a).

Nevertheless, during low mineral prices, the application of Brownian tax system can be useful for subsidising exploration activities to sustain the mining industry. For instance, a government can recapture the cost of subsidy through amortising past exploration expenditures against positive cash flows from a successful mining project (Garnaut 2010a). However, this is also risky because the success rate for a mineral property to advance from exploration to extraction phase is highly uncertain. This could be the reason why Canada has abandoned the exploration subsidy policy (Mintz and Chen 2012a).

In observing these problems, Garnaut and Clunies-Ross (1979) develop the second-best neutral system, which allows a mining project to carry forward its cash flow losses. The losses are uplifted at a risk-free interest rate and the cumulative amount is offset against positive cash flows rather than a government immediately subsidising them. This shifts the financial risks to the mining project, which relieves a low-income developing nation from bearing the financial burden of subsidising corporate losses under the Brownian tax system (Passant 2014). This is the main advantage of the second-best neutral system, which creates flexibility for a mining project to recover its capital cost by delaying the payment of tax revenues. It restricts attaining pure neutrality and is a risk sharing system that is suitable meeting the welfare needs of non-diversified developing countries (Garnaut 2010b).

In summary, the second-best neutrality operates to distribute the quasi-rents according to the risks faced by capital and input factor providers. This manner of risk sharing permits an investor to recover the capital costs rapidly before a government accesses revenues at latter stages of a mine life (Mintz and Chen 2012b). Both the investor and the government capture Ricardian rents on the pre-tax base arising from the interface amongst market price, extraction costs and deposit quality. However, the second-best neutrality is not as well understood as a tax system that can distribute different types of rents to capital owners, input factor providers and investors. Hence, understanding how neutrality works is significant for designing a balanced mineral taxation policy.

2.1.1 Some issues facing taxation policy

According to Otto (2017), a balanced mineral taxation policy is one that facilitates investors' quests for earning excess rents above the normal profit without compromising the opportunities for communities to retain an equitable share of the mineral wealth. This can be done by sustaining the tax base through continued exploration and mine developments in the long-run (Kogel 2015). However, this policy statement is complex and thus difficult to achieve due to the diverging economic and socio-political objectives of investors and governments respectively. A balanced tax policy can be achieved by integrating financial, economic and technical aspects of a mining operation into the theoretical framework, which does not compromise the social needs of host communities (Magno 2015). Aside from these aspects, a tax base is influenced by some uncertainties (risks).

Uncertainties associated with exploration, mine development and extraction activities influence taxation policies (Boadway and Flatters 1993). Since price is a driving force behind mineral exploration, the probability of finding an economic ore body is highly uncertain. Further, costs and deposit quality are also uncetain at the extraction stage. These risks make the opportunity costs of both irreversible capital invested and tax base more uncertain (Evatt et al. 2014). Furthermore, the uncertainty associated with a government's behaviour during profitable periods has historically been responsible for causing fiscal instability (Humphreys 2013).

Investors prefer fiscal stability over neutrality and equity when committing capital for exploration and mine development, which in turn determines the long-term stability of tax policies (Daniel and Sunley 2010). Stability agreement clauses are often devised to provide a guarantee that a government will not change existing tax laws and rates spanning different price cycles and political regimes (Sunley and Baunsgaard 2001). Fiscal stability clauses can be exemplified in bilateral and mine development agreements (MDA) for specific mining projects (Daniel and Sunley 2010). Further, attaining long-term stability can encourage investors to adapt to a nation's tax system, which makes it more 'predictable' in the long run. Amongst these issues, inconsistency in tax revenue collection gives a wrong perception that a tax system is inefficient. This often leads to unpredictable and lengthy reforms, which is a major cause of fiscal instability amongst most mineral endowed nations (Mendes 2015; Sunley et al. 2012).

Taxation policy discourses placed more emphasis on international competitiveness between 1980 and 2000 (Otto 2000). Tax reforms often follow low commodity prices as jurisdictions try to be competitive with other mineral endowed nations, as the mean profitability is higher for low-cost firms in low-tax jurisdictions (Tomasic 2015). This is because attracting foreign direct investment enhances dynamic and static gains: skill replication and physical capital accumulation, as well as non-tax benefits such as inflows of technology. Many countries have experienced positive growths as a result of policy reforms such as the ease of entry of foreign investors leading to increased investments (Sunley et al. 2012). Moreover, taxation regimes are often deregulated to attract the flows of foreign investment capital to low-tax destinations. However, the reforms can also introduce problems during non-boom periods can cause fiscal imbalance during boom periods (Chen and Mintz 2013).

Between 2003 and 2014, the supply cycle inconsistency problem enticed governments to behave indifferently towards the industry making profits, resulting in widespread fiscal instability (Solomon 2012). For instance, South Africa’s move towards resource nationalisation based on black economic empowerment is most surprising for a country that was once known for being one of the highly competitive fiscal regimes in the world (Cawood and Oshokoya 2013). The fiscal disparity gap between investors (high profits) and governments (low tax revenues) could be due to the absence of suitable tax systems that respond to changes in the tax base.

In summary, the debate has reached a consensus that an equitable tax system is one that reduces the average burden, is administratively simple, has less use of regressive levies and more use of progressive rent-based taxes (Heidrich 2013, 6). Progressive taxes are flexible and respond to market and production uncertainties (Baunsgaard 2001; Land 2009). However, little research has been done to encourage a policy-push in this direction. A tax policy shift towards adopting a self-adjusting progressive tax system could resolve the cyclic issues, which could enhance an equitable distribution of risks, rents and revenues.

2.2 Tax Progressivity

The self-adjusting ability of a progressive tax system could resolve the inflexibility associated with a non-progressive tax system, which does not respond to boom and bust cycles (Land 2010). Unfortunately, limited studies have been done to analyse the progressivity of individual tax instruments. Kamin (2008, 241) argues that "policy makers and analysts often rely on progressivity as a guidepost in constructing and analysing tax policy, but do little to justify the progressivity method they employ". Only few scholars such as Keen et al. (2014) use some progressivity curves from the Internatonal Monetray Fund (IMF) to demonstrate how different combinations of progressive royalty (e,g., deductible and creditible royalty) that can be considered as upfront payments of rent taxes. However, they do not fully explain the tax burden and rent distributions, although a creditable royalty could capture a high magnitude of revenues.

Boadway and Keen (2010, 14) define progressivity as "an average tax rate that rises with the realised profitability of the underlying project". However, this definition is shallow because the terms 'average' and 'marginal' have discretely different meanings. Average tax rate is the actual tax revenues paid divided by the corresponding tax base, which is a static measurement of tax liability. Contrastingly, the marginal tax rate is a continuous measurement of tax liability placed on an incremental income, which fits well with the progressivity concept. Progressivity measures the changes in marginal tax rate in response to values added to an invested capital (Stroup and Hubbard 2013). To author's knowledge, there has been no study undertaken to investigate the distributive capacity of cyclical progressivity under certain conditions such as price and tax rate increases. The non-mineral taxation literature suggests that increasing profitability may not induce the marginal tax rate to rise (Kremer and Stähler 2016).

Non-mining taxation uses progressivity to assess the distribution of tax burdens that affect skill development and redistribution of gains in social welfare. A major fear is that strong progressivity causes the marginal tax rate to increase (Conrad and Hool 1984), which distorts labour productivity through discouraging skills development and innovation, and can impede national productivity (Holter, Krueger and Stepanchuk 2014). As a result, less progressive and flat tax systems are favoured over more progressive systems (Guner, Lopez-Daneri and Ventura 2016). Less progressive tax systems such as payroll taxes maintain labour productivity through horizontal distributions of tax burdens.

The horizontal distribution system having the same rate is a flat system, but face different tax liabilities according to skill levels (Mirrlees 1971). Most labour incomes are taxed at a fixed rate, but experience horizontal distributions of burdens due to different income distributions that correspond to skill levels. On the other hand, Mirrlees' (1971) identifies a vertical equity system that differentiates labour income levels and investors' ability to pay (Guj 2012; Kiprotich 2016). The inequality between a tax payer and a recipient of tax revenues is reduced when the tax concentration is closer to a linearly progressive curve.

In support of Mirrlees' findings, Daniel, Keen and McPherson (2010, 215) note that "[a] more progressive regime gives some relief to investors for projects with low ROR while allowing the government to increase its share of the revenue when an investment is highly profitable". In other words, progressivity equalises the distribution of tax burdens under these dynamic conditions (Duncan and Sabirianova Peter 2008), and resolves the time inconsistency problem and increases fairness (Daniel and Sunley 2010). Progressive taxes can transfer a greater magnitude of wealth to the community if price and deposit quality are high, and the mine operating costs are low (Fraser 1993; Tilton 2004). However, the literature on mineral taxation has not kept up with research to conceptualise these relationships despite a considerable number of studies reluctantly mention progressivity as an ideal tax system (Daniel and Sunley 2010; Land 2008, 2010). Others argue that more progressive taxes discourage risk-taking behaviour of investors (Conrad and Hool 1984). This has slowed the conceptual development of progressivity as demonstrated in Figure 2.1.

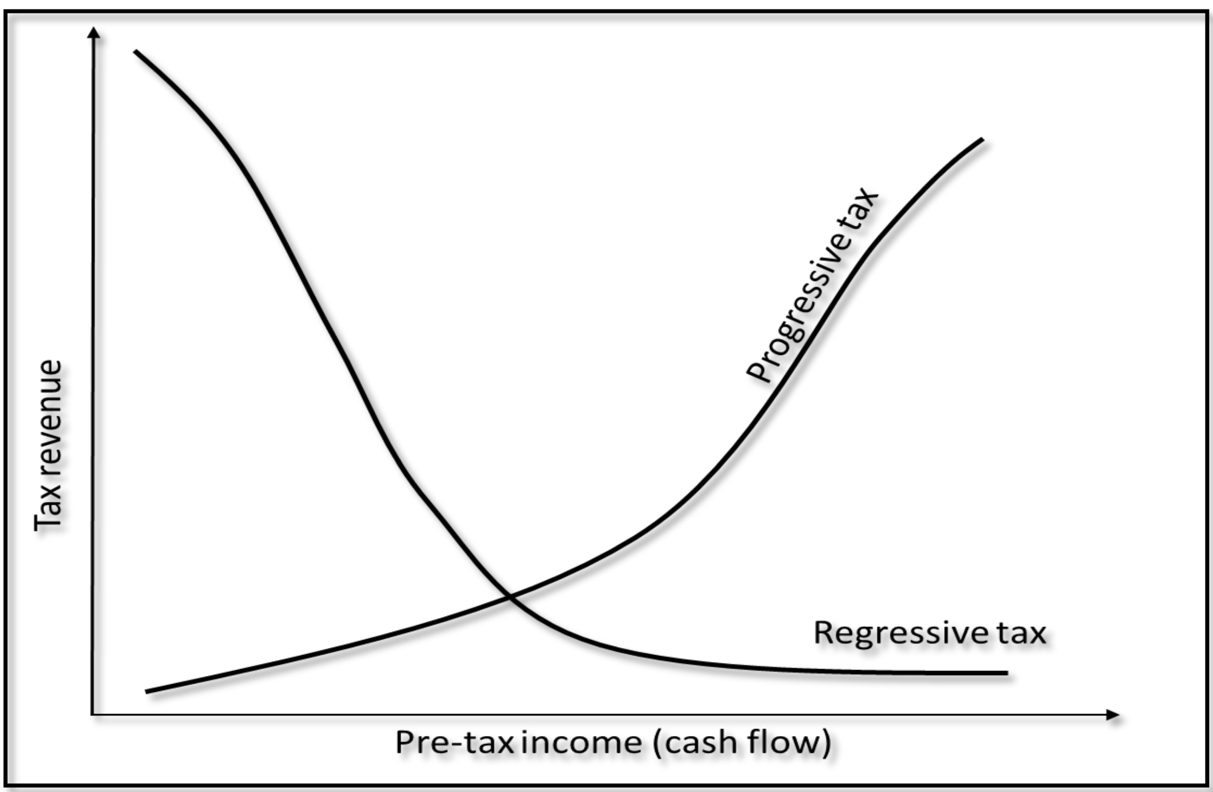


Figure 2.1: Tax curves often used to define progressive taxes and regressive royalties

Figure 2.1 is a graphical representation that is often used to show how progressivity increases as the tax base increases, with the opposite holding for regressive levies. However, Figure 2.1 does not structurally show the effects of cyclical progressivity and regressivity during periods of low and high rent. Regressivity favours investors during high price periods by relaxing the tax liability and favours governments during low price periods. This could cause inequality in terms of governments collecting less revenues from unit-based levies when compared to the value-based levies (Clausing and Durst 2015b). An extreme regressivity with a substantially high level of royalty rates, or with no royalty credits tend to prolong the time for realising a pre-tax rate of return (ROR) (Dowell 1979). These features can be cogently traced within a structural progressivity model featured by the Lorenz concentration curve (Fig. 2.2).

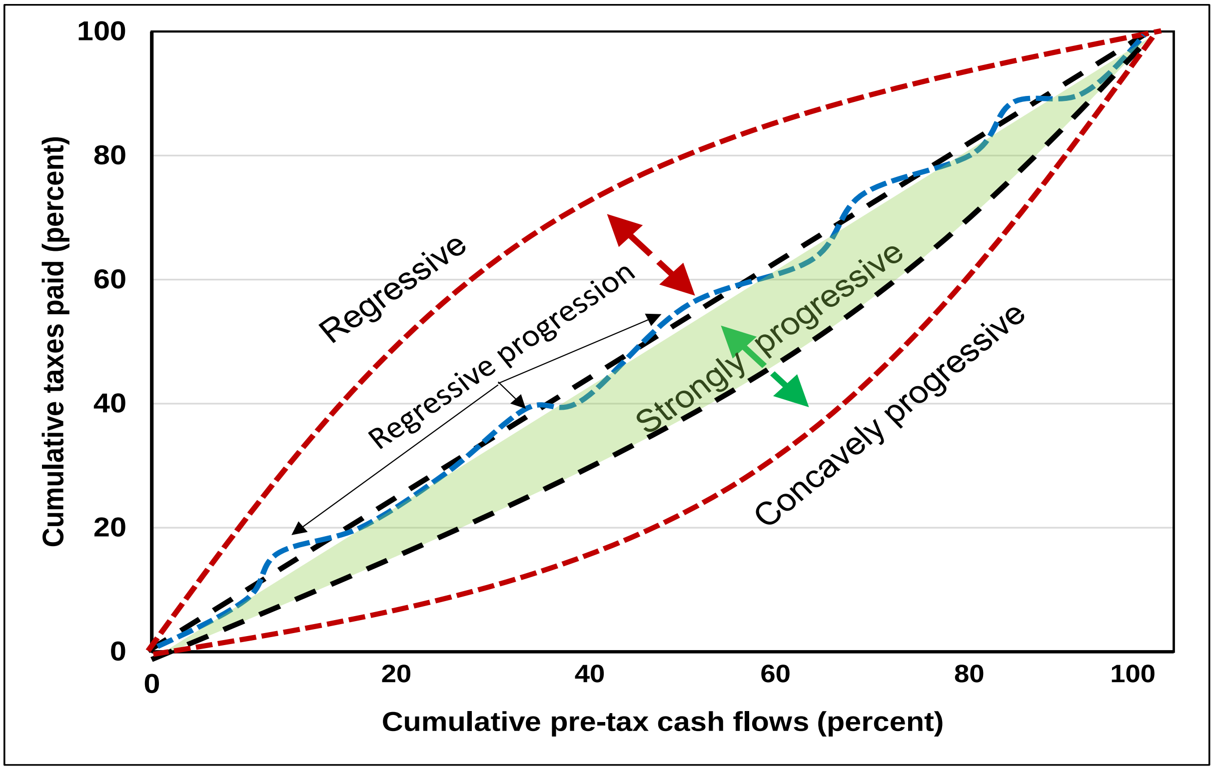


Figure 2.2: Conceptual progressivity chart based on the Lorenz concentration curve (Govori 2015; Roach 2010a)

Figure 2.2 is a Lorenz concentration curve that plots the cumulative taxes paid on the y-axis and cumulative pre-tax cash flows along the x-axis (Lorenz 1905). Lorenz developed the 45-degree concentration curve, which is a linear line that reflects a perfect equilibrium (Roach 2010b) and tracks the performance of individual tax instruments over time. Unfortunately, the taxation literature does not distinguish various progressivity types and simply categorises progressive taxes as those that capture revenues proportional to increases in profits (incomes), which is not correct. The cyclical progressivity being subject to tax design factors, market conditions and operational parameters can cause variations in the abilities of profit-based taxes to capture the incremental rents. Varing degrees of progressivity/regressivity (broken red lines) are represented on the Lorenz curve as shown in Figure 2.2 (Roach 2003). Those that lie below the Lorenz curve are progressive and those that are above it are regresssive.

In Figure 2.2, tax curves closer to the Lorenz curve within the light green coloured boundary are known as strongly progressive because those taxes have stronger aptitudes to capture more of the incremental rents compared to those that are below the boundary. Duncan and Sabirianova Peter (2008) find that inequality is reduced as tax instruments approach linearity (Lorenz curve). Likewise, tax instruments lose their strength in capturing the marginal increases in profits as demonstrated by the concave (weak) progressivity curve in Figure 2.2. Tax instruments collect few revenues as progressivity curves bow downwards away from the Lorenz curve (Heathcote, Storesletten and Violante 2014). These behaviours of tax instruments could be due to factors such as the nature of tax designs, mine operational risks, over-investment or profit and cost shifting.

Similarly, regressive levies, excises and duties lie above the Lorenz curve in Figure 2.2. As mentioned earlier, inequality caused by regressive royalties and levies affects both investors and government. Although some royalties may be progressive, Boadway and

Keen (2014) find that royalties cause time inconsistency problems as they do not respond to changes in the tax base. Further, regressive royalties and levies raise small amount of revenues as income increases. Some tax curves that skip above and below the Lorenz curve are identified by Govori (2015) as having regressive progression behviour under certain conditions (see Section 6.1). Such a manner of defining the domains of tax performance using the Lorenz concentration curve is referred to as structural progressivity analysis (Roach 2010a), and can also be assessed using progression coefficients (indices) (Stroup and Hubbard 2013).

The Kakwani index is a progression coefficient derived by measuring the area under the Lorenz curve against the size of the area defined by a tax curve (Kakwani 1977). It measures the degree of concavity from the Lorenz concentration curve for various tax instruments. Further, the Suits index model (Suits 1977) follows the Kakwani index model. However, it is slightly different as identified by Stroup and Hubbard (2013, 20). They identify the difference as "whereas the Kakwani index sums the difference in convexity between these two curves equally across the entire tax base, the Suits index weights the difference in the upper-income end of the spectrum more heavily than the lower income end". Likewise, the Stroup index, named after Michael D. Stroup (2005), is computed by dividing the ratio of cumulative tax (tax curve area) by the total area below or above the Lorenz curve (or cumulative pre-tax cash flow). The equation for computing the tax progressivity index (TPI) using the Stroup index model is as follows:

$$TPI_t = (1 - (CTR_t / CTB_t)) \tag{2.1}$$

Where TPI_t = tax progressivity index (or progression coefficient) at time t
CTR_t = cumulative percentage change in tax revenues at time t
CTB_t = cumulative percentage change in the tax base at time t

In summary, the progressivity technique using the Stroup model can reliably measure the burden distribution and performance of tax instruments by a means of observing the changes in the progression coefficients over time (Stroup and Hubbard 2013). The claim in literature that progressive taxes increase the tax burden ignores the decline in the real marginal effective tax rate because investors do not precisely pay taxes at the theoretical effective tax rate (Keightley and Sherlock 2014). Further, progressive tax systems not only collect higher tax revenues, but also harmonise a neutral tax system to function efficiently through a fair distribution of risks and rents amongst the participating stakeholders. Moreover, progressivity resolves the problem of cyclicality by regulating tax burden distribution during periods of low and high rents so that the balance can be maintained.

2.3 Functional variables for measuring tax performance

The economic and tax analysis require reliable functional variables because these have to be interpreted into policy information. Functional variables such as net present value (NPV), internal rate of return (IRR), payback period, average effective tax rate (AETR) and marginal effective tax rate (METR) are derived from techno-economic models (Hogan and Goldsworthy 2010). The NPV, IRR and payback period are often used for assessing the economic effects of tax systems on economics of mining projects (Otto 2009). However, these variables are biased towards optimising the extraction efficiency and do not measure the investor and government's behavioural responses with regard to redistributive capacity of a tax system. The financial variables can be effectively integrated with the METR, AETR and other decision-making variables for a balanced tax analysis. Equation (2.2) is often used to derive the AETR:

$$AETR_t \quad = T_\tau / CF_{pre-tax\ base} \tag{2.2}$$

Where $AETR_t$ = average effective tax rate at time *t*
T_τ = actual taxes paid (undiscounted)
$CF_{pre-tax\ base}$ = pre-tax cash flow or the tax base at time *t*

Given the fact that most tax rates are constant, changes in pre-tax cash flows against post-tax cash flows can cause the AETR to vary. In other words, time-lag effects can cause the AETR to increase (or decrease). This could erroneously reflect a tax regime to be unattractive or vice versa (Gordon, Kalambokidis and Slemrod 2003, 4). The authors argue that the AETR is ineffective in measuring the distribution of tax burdens, especially the neutrality aspects of taxation before and after a tax reform. This is because the AETR has no economic merits when compared to the marginal effective tax rate (METR) (Daniel, Keen and McPherson 2010). According to Fullerton (1999), the METR measures changes in the pre-tax IRR against the post-tax IRR as given in equation (2.3).

$$METR_t \quad = (IRR_{pre-tax\ base} - IRR_{post-tax\ base})/(IRR_{pre-tax\ base}) \tag{2.3}$$

Where $METR_t$ = marginal effective tax rate at time *t*
$IRR_{pre-tax\ base}$ = cumulative percentage change in the tax revenues at time *t*
$IRR_{post-tax\ base}$ = cumulative percentage change in the tax base at time *t*

METR measures the effect of an entire tax system on productive capacity of the capital employed (Gillen and Gados 2007), and is widely used for measuring the performance of taxes in the mining industry (Boadway 1987; Chen and Mintz 2015b). A concise definition of METR is given in Fullerton (1999, 270). It measures the effects of taxes on capital invested and is derived by dividing the post-tax IRR by the pre-tax IRR given in equation (2.3). Chen and Perry (2015) analyse the efficiencies of royalty and CIT in Columbia using the METR as a performance measurement criteria. They found that royalty reduces the productive capacity of the capital invested more than that of the CIT because royalties ignore the neutrality requirement for capital allocation. For example, a zero METR reflects a neutral system in which there is no distortion (McKenzie, Mansour and Brûlé 1998).

The METR can be identical to a distortion rate although the techniques used to compute these variables are entirely different. Blake and Robert (2006) use the NPV approach to calculate the distortion index for some mineral and petroleum fiscal regimes, including that of PNG. They show that distortion and METR rates for individual taxes and royalties can be easily computed and tracked over time. With contrast, the AETR provides a static reflection of the overall tax liability without defining the tax burden distributions relative to the capital invested and value of the firm (Kanniainen and Panteghini 2013). Moreover, Chen and Perry (2015) show that a distortion rate can be derived as a ratio of post-tax NPV to pre-tax NPV. Further, aside from the commonly used functional variables, additional variables are required to adequately measure the aggregate wealth transfer to a host nation.

First, the theoretical measurement of the METR may correctly show the effects of taxes on the incremental value in capital employed (Gillen and Gados 2007). However, overinvestment and profit shifting could influence the actual pre-tax IRR (or NPV) and the post-tax IRR (NPV) to change. As a result, the METR may not clearly capture the actual tax revenue flows over time (Keightley and Sherlock 2014). Further, disagreements over actual taxes being paid by mining industry do arise frequently due to misapplications of the functional variables (Marsh, Lewis and Chesters 2014; McPhail 2017). The disagreements could be attributed to tax scholars using different models and techniques resulting in variations in the effective tax rates (Davidson 2012; Swan 2012). Therefore, a risk-weighted net effective tax rate (NETR) can be derived by combining the TPI and METR to account for resource revenue leakages (Guj et al. 2017), (see Section 3.5).

Second, a major limitation of the METR, TPI and AETR is that these variables are only compatible for assessing the distributive capacities of direct and indirect tax instruments. These variables exclude the non-tax benefits such as human and physical capitals (e.g., transport, education, health and social infrastructures) that add to the aggregate wealth transfers to the community (Jackson 2015). The mainstream theoretical models often do not capture the provisons of goods and services, including technical assistances offered voluntarily that are beyond the regulatory requirements. The non-tax benefits are not only for social licence to operate (Owen 2016), but also improve the living standards of the community (Loayza and Rigolini 2016). Because of these significances, a variable is required to designate the proportional distributions of rents and aggregate tax and non-tax benefit transfers associated with a mining operation (see Section 3.5).

In summary, the interpretation of analytical results can be weak unless a suitable combination of decision variables is used. Combining the economic variables (NPV, IRR and payback period) with the TPI and the METR will strengthen the interpretation of tax performance.

2.4 Direct taxes

2.4.1 Royalties

Boadway and Keen (2014) find royalties to be distortionary and time-inconsistent as they do not respond to changes in the tax base. This argument relates to the notion that royalties generally reduce mineral reserves by raising the cutoff grade that in turn reduce the known resource and shorten a mine life (Hogan 2012). Additionally, royalties do not give credence to time preferences for capital and input factors employed for production due to levies on gross revenues occur before distributions of the quasi-rents (Freebairn and Quiggin 2010). However, there are disagreements on the practical aspects of the distortion concept due to royalties being recognised as a user fee or explicit tax (Boadway and Keen 2010; Minnitt 2007). It symbolises a form of rent payment for collateral ownership of land where minerals are found (Duncan and Duncan 1997).

According to Minnitt (2007), royalties are payments for transferring the ownership of exhaustible minerals, since extracting them now diminishes the returns that could be enjoyed by a future user. The existence of royalties originated from Hoteling's (1931) scarcity rent concept, where a rent is paid for exploiting a non-renewable resource in the present time. Community has to be compensated for having the collateral rights to mineral deposits and exhaustion of the finite minerals (Minnitt 2007, 542). However, economic sacrifices such as the commitment of captial and factors of production do require tax policies to rationalise the balance between economic and social dimensions of extracting the minerals.

The literature perceives royalties as regressive and have distortionary effects on the cutoff grade (Freebairn and Quiggin 2010; Helliwell 1978). However, royalties are not the only variables in Lane's (1988) minimum cutoff grade model that is often used in mine design and extraction planning. The interface amongst mining, milling and selling costs, and market price and mill recovery rate determine the minimum cutoff grade (Asad and Topal 2011). Further, Ergas and Pincus (2014) find that royalties do not cause a major distortion that could lead to a mine closure. Additionally, Conrad, Hool and Nekipelov (2015) find that the effects of distortion are minimum. Helliwell (1978, 44) notes that " if there is little scope for cutting costs by raising the cut-off grade, the distorting effects of the gross royalty will be even less". These studies indicate that the argument regarding distortion is less critical for low cost and quality deposits because a positive tax base could enhance the timely allocation of the invested capital (Fraser 1993).

Distortion could remain a conceptual argument in the taxation literature because the measurement of distortion on capital allocation and extraction efficiency is practically complex due to information asymmetry. Further, cost-cutting strategies such as reduction in labour costs through mechanised operations (Fessehaie and Morris 2013), reduced energy costs through a switch to hydro or hydrothermal energy (Patsa et al. 2015), and a fly-in fly-out mode of mine operation (Storey 2010) can offset the effects of distortion. However, time inconsistency problem associated with royalty proceeds being paid before reaching a payback period is the major concern. Aside from these conceptual issues, different royalty types could suit different types of minerals (i.e. base, precious and industrial minerals) attributed to some advantages and disadvantages at the policy level.

Value-based royalties are applied to high value minerals in most jurisdictions (Keen et al. 2014; Western Australian Government 2015). The main reason is that the ability of an ad valorem royalty to respond to changes in the gross revenue is more attractive to governments than regressive royalties. Other factors that favour the value-based royalties are: require low skill levels for auditing purposes; limit the chance of evading payments; and captures the values of by-products (Collier 2010; Guj 2012). On the other hand, unit-based and value-based royalties can have detrimental effects on the profitability of a high-cost mine as they reduce the post-tax profits (Lund 2009). Unit-based royalties are less useful for high value minerals and are more suitable for bulk commodities such as iron ore and bauxite (Bowie and Ellison 2016).

A unit-based, or specific royalty applied at a fixed rate is levied on a physical unit of output, either in dollars per tonne or volume. In most cases, unit-based royalties are suitable for bulky commodities due to their high extraction and transportation costs (Otto 2006, 268). A weight-based charge on a low-value commodity is more favourable than a volume-based charge as it eliminates impurities and captures the values of by-product minerals. However, unit-based royalties are not receptive to market dynamics and only respond to changes in production rate, which can be manipulated to reduce its liability (Guj 2012). This can result in governments receiving less royalty revenues than expected when compared to the value-based royalties. Alternatively, high-cost and high-risk mines favour profit-based royalty arrangements as they provide incentives for attracting investors (Osmundsen 1998).

Behaviour of firms and magnitude of revenues collected from royalties could explain why royalties are resiliently applied (Kemp 2009). Firms tend to respond more aggressively towards profit-based taxes as these may reduce economic rents compared to the effects of royalties. For instance, Australia's mineral resource rent tax (MRRT) attracted ferocious political and academic debates that influenced the introduction of the RSPT (Passant 2014). Mining firms could react more aggressively to the introduction of rent-based taxes that tend to reduce the value of the firm more than the royalties.

In summary, there is consensus among investors acknowledging the societal rationales for applying royalties. Investors are well aware that translating capital losses into welfare gains is socially more important than defending their extraction optimality. This is because the social and economic obligations often fall on a mine operator if fiscal redistributions are inefficiently executed, as often is the case in PNG (Hilson and Garforth 2013). In reality, community protests can temporarily or permanently shut down a mine, whereas royalty charges often do not have this ability (Kirsch 2014; Regan 2014). Recent studies argue that value-based royalties can collect significant revenues when compared to those collected through the RRT and its hybrid types of rent taxes (Freebairn 2015, 2; Ergas and Pincus 2014).

2.4.2 Resource rent tax (RRT)

Garnaut (2010) explains the significance of neutrality, stability and raising revenues using a RRT at the exploration, mine construction and extraction stages. He explains that an exploration subsidy could eliminate the need for rapid amortisation, which would shorten the time for attaining a normal ROR on capital invested. He also argue the there is a high potential for economic gains from resource taxation using a RRT where revenues would become accessible at the early production stage (Garnaut 2010b). However, collecting revenues using a RRT is uncertain due to the risk variables such as price, deposit quality and costs (Smith 1999).

The ability of a RRT to raise revenues from excess profits depend on the profitability of a mine and a threshold rate set by a government. Smith (1999), and Ergas, Harrison and Pincus (2010) argue that uncertainty associated with price and deposit quality controls the time for IRR to reach the threshold rate, which signals a mine has generated the excess profits. Depending on the IRR and the threshold rate settings, a RRT may capture the excess profits during boom periods only (Fraser 1993), and may not perform well for low quality and high cost deposits during non-boom periods. Moreover, a mine operator reluctant to reveal private information concerning the size and deposit quality, costs and financial data could complicate measuring when a threshold rate could be triggered.

Garnaut (2010) argues that an investor’s discount rate is the ideal threshold rate under the second-best neutral tax system. A mine is said to generate excess profits above the expected normal ROR when the IRR exceeds investor’s discount rate. However, setting the ideal threshold rate is complex due to asymmetry of information associated with deposit quality, price and cost uncertainties. Setting a threshold rate below investor’s risk premium causes a distortion since the RRT could tax the quasi-rents (Ergas, Harrison and

Pincus 2010). To avoid distortion, the full loss-offset policy is required to ensure profit tax instruments do not fall on capital and factor allocations (quasi-rents).

Lund (2011) explains that RSPT has features of the threshold rate and IRR-based RRT as well as the Brownian tax. The RSPT was designed to follow the second-best neutrality principle for successful mines. However, a government would make a settling payment equivalent to the unused deductions that are carried forward. This procedure resembles a Brownian tax if a mine ceases production (Land 2010). In that respect, the RSPT is unsuitable for financially constrained developing countries like PNG although the RSPT is neutral and encourages investment decision-making. Further, Australian government replaced the RSPT with the MRRT, which is determined by a profitability ceiling (Passant 2014). Hence, a shift from the RSPT to the MRRT in Australia is an indication of the complexity that could be encountered in maintaining neutrality while at the same time expecting to generate revenues.

In summary, the overwhelming perception that a RRT promises to generate more revenues from profitable mines compared to royalties could have misled tax policies. The APT failed to capture tax revenues from excess profits from mines that existed between 1972 and 2002 in PNG (McLaren 2012). The APT remained a lay-by tax awaiting the existing mines in PNG to generate the excess profits, which never eventuated. Recent evidence from studies of McLaren and Passant (2015) and Murray (2015) strongly suggest that both developed and immature nations may not successfully use either a RRT or its hybrid types to collect revenues from excess profits. The complexity associated with measuring the timing when a threshold rate is triggered under information asymmetry makes the RRT or APT less attractive to developing countries compared to basic taxes such as the CIT.

2.4.3 Corporate income tax

CIT is the most stable, neutral and non-distorting tax instrument since quasi-rents are allocated before imposing it (Sarma and Naresh 2001). As well, CIT generates considerable revenues when compared to royalties, levies and the hybrid RRTs due to its high rate relative to rates of other tax instruments (Thomason 2011). Additionally, CIT becomes payable immediately when a tax base becomes positive, but delays in accessing the CIT revenues can be expected due to unfavourable market prices, low deposit quality and high operating costs. Further, CIT liability is measured as a function of gross revenues minus expenses (royalties, operating costs, depreciation allowances, interest deductions, tax credits) multiplied by the CIT rate (Keightley and Sherlock 2014).

Setting an ideal CIT rate is a significant aspect of its design because higher CIT rates can distort the value of the underlying asset more than all other tax instruments, including royalties. CIT rates for the mining sector are often set at around 30 percent, which the industry accepts as reasonable (Kumar 1991). An increase in the CIT rate can reduce investment competitiveness, as well as the value of a firm operating within a jurisdiction (Lund 2014a). Therefore, keeping the CIT rate constant throughout a mine's life is significant for maintaining its neutrality status (Atkinson and Sandmo 1980, 174). That being said, the real marginal CIT rate can be lower than the statutory rate due to some factors within and external to the tax system affecting the CIT base. A CIT base refers to the pre-tax cash flows derived after expensing depreciation, amortisation, interest and operating costs against the gross revenues (Wilson 2016).

The main factors affecting the CIT base within the tax system are tax depreciation, amortisation and thin capitalisation rules, and investors manipulating it through overcapitalisation and overinvestment (Kawano and Slemrod 2012). First, depreciation techniques such as accelerated declining balance (ADB) and straight-line are components of a fiscal policy and the choice of these techniques is important. The ADB technique shortens the timing for attaining the required ROR on the invested capital (Kulp and Hartman 2011). Although the ADB technique reduces the CIT revenues in the early stages of a mine life, it increases revenue collections by reducing the depreciation deductions at the mature stages of a mine life (Hlouskova and Tsigaris 2012). With contrast, a straight-line depreciation technique prolongs the timing for attaining a normal ROR. However, it improves the post-tax value of the firm due to constant whole of mine life tax deductions and accumulate tax credits under unlimited LCF provision and reduces CIT revenues at the mature production stages (Dwenger and Walch 2011).

Second, thin capitalisation rules can affect the CIT base as well as an investor's decision for financing of a mining project (Auerbach et al. 2017). Thin capitalisation rules limit an investor's ability to make a decision on debt and equity capital financing strategies. On the other hand, it ensures the magnitude of allowable interest deductions do not excessively reduce the CIT base through restricting firms from highly leveraging the capital costs (Christian and Henry 2015). A highly leveraged or thinly capitalised firm gets high interest deductions and reduces the tax base that in turn erodes the CIT revenues. The PNG Taxation Review Committee has recommended reducing the thin capitalisation ceiling to 2:1 from the present ceiling of 3:1 to reduce the existence of tax shields (Mullins and Burns 2016). This ceiling represents a 50 percent debt-equity ratio, which is beneficial for companies in the extraction phase. Hence, excessive regulation of debt financing may erode the CIT base through an increase in interest deductions (Boadway and Tremblay 2016).

Third, overinvestment refers to overstating fixed and operating costs that erodes the CIT base (Kanniainen and Panteghini 2013, 12). Tax evasion tactics such as operating a low IRR mine with inflated costs and over-reporting of non-tax benefits to the advantage of receiving tax credits could write-off CIT revenues (Auerbach 2007, 167). Essentially, CIT is often subject to intense avoidance efforts since its liability is higher than the other tax instruments (Richardson 2015). As result, a major challenge is that tracing tax avoidance is a complex task in jurisdictions that have poor domestic financial institutions, high corruption rankings, and weak tax administration (Devos 2014; Tanzi 2017). Additionally, shifting of costs and profits between mines and exploration properties could duplicate those transactions thereby significantly reducing the CIT base (Guj et al. 2017).

Fourth, CIT concessions are commonly used as incentives for attracting foreign direct investments since mining is characterised as high-risk and capital-intensive (Mansour and Keen 2009). The concessions provide tax relief to exploration activities and mines that are considered high risk (Bhatt 2013, 252). The concessions constitute a tax write-off over a period covering the early part of a mine life, which allow investors to recover their investment capital (Davies et al. 1978; Emerson 1982). For example, a negotiated CIT holiday granted on ad hoc basis in PNG is biased towards risk-taking firms that face the same systematic risks (Filer 2012). However, a prolonged CIT holiday introduced during a non-boom period is likely to cause fiscal imbalance as the industry enters a boom period. For a ten year tax holiday, an investor may attain the ROR on the quasi-rent in year five, and enjoy a tax-free production for the next five years (James 2013; Sheikh-Ahmad 1997). This could result in wasteful extraction, increase inequality and create a negative perception of a tax system being too lenient (Bhatt 2013).

In summary, after attaining a normal ROR on investment, the CIT causes low distortionary effects on the capital invested (Gordon 1985). However, a high CIT rate could raise the liability, which reduces the value of a firm. Because of this, a firm’s attitude towards reducing the CIT liability using overcapitalisation as well as cost and profit shifting is a major challenge facing most jurisdictions (Rao and Sengupta 2014). Further, maintaining the CIT rate at around 30 percent and protecting the tax base from fiscal leakages with a well-resourced tax administration can ensure sufficient flows of

CIT revenues to a government. Aside from the four factors discussed, a combination of market price and deposit quality determine the magnitude of CIT revenues a government may plan to receive (Baffes et al. 2015). The CIT and dividend withholding tax (DWT) and other rent-based taxes are also influenced by these factors influencing the tax base.

2.4.4 Dividend withholding tax (DWT)

DWT is an *in personam* tax that is used to regulate the repatriation of dividends to both non-resident and resident equity investors (Kumar 1991; Otto 2001). The objective of DWT is to encourage reinvestment within a jurisdiction by restricting dividend payments to equity investors. For instance, the DWT may induce an investor to reinvest in energy saving, tailing reclamation and production expansions in the present investment. However, the restriction on corporate decisions with regard to dividend repatriation is a disincentive to attracting equity investors in mineral exploration and development (Sarma and Naresh 2001). Unlike other tax instruments, the DWT reduces a company’s value since it is applied to post-tax cash flows (Kanniainen and Panteghini 2013).

Auerbach (1986) points out that the DWT is a ‘second layer tax’ on the capital gains, which reduces the dividend payments to common shareholders. In that context, the use of DWT to encourage reinvestment in downstream processing is a weak argument. This is because geological attractiveness and favourable market conditions often encourage profits to be reinvested within a jurisdiction (Poterba and Summers 1984). Further, a high DWT rate could affect raising equity capital at the stock market earmarked for exploration, which can affect the chances of delineating a new mine (Forster and Bills 2013). Hence, DWT’s purpose seems to be ineffective in some cases where a policy allows for mineral producers to keep profits abroad, especially for nations that export raw minerals without downstream processing.

2.4.5 State equity participation

Policy on equity participation is common in developing countries as they aim to generate dividends through direct involvement in extraction activities (McPherson 2010; Padmore 1992; Sims 1985). Foreign firms dominating the mining industry create an impression that state and community are spectators, especially in developing countries (Conde 2017). This perception has encouraged PNG to directly participate through stake ownership at both exploration and extraction stages since their land is traditionally-owned, while the GoPNG owns the minerals (Macdonald 2016). However, the economic viability and costs of stake ownerships in mining operations are arguably unclear.

The main focus of equity participation is to earn dividends and accumulate assets (McPherson 2010). However, uncertainty of when equity dividends would become accessible makes equity interest ownership as a form of ‘symbolic’ shareholding (Hancock 2002). The symbolic nature of equity participation could be culturally acceptable as it provides a sense of local control and ownership against foreign firms entirely controlling the industry. On the other hand, investors often secure political tolerance and strengthen their social license to operate by permitting some community involvements (Pike 2012). Additionally, equity interests could compromise environmental standards and allow an investor to use antagonistic tactics to suppress genuine community concerns that could arise relating to incidence of fiscal depravity (Campbell 2013, 216). For instance, the GoPNG being a partner in a mining project allows investors to use disciplinary forces (police and defence forces) to suppress community concerns (Jackson 2015).

Three most common equity interest ownership types are: *free-carried interest* (FCE), *fully paid equity* (FPE) and *fully paid production equity* (FPPE). The FCE allows investors to deduct positive cash flows against equity capital costs until they are fully offset (McPherson 2010). As a result, the term '*free-carried*' is not exactly free. The investor has to recoup its equivalent cost of equity plus interests prior to a community accessing the dividends (Muganyizi 2012). Further, the FCE gives rise to a free-rider problem since an investor has to commit the upfront equity capital costs on behalf of the community (Kim and Walker 1984), which exposes the firm to financial risks.

The FPE involves a market-based financial arrangement where the state has to meet the upfront cost of equity participation at the mine development stage (McPherson 2010). FPE resembles a Brownian tax if the equity capital costs are settled annually over a debt period. On the other hand, the FCE resembles a RRT if state's upfront capital cost contribution is expensed against future cash flows by carrying forward the unrecouped cost of equity at the market interest rate (Kumar and Radetzki 1987; Sarma and Naresh 2001). Both FCE and FPE participation allow the state to access equity dividends on the corporate profits after fully expensing the cost of equity against future equity cash flows. Further, the state acts as an ordinary shareholder to receive dividends from corporate profits when the FCE and the FPE are managed by investors. In this arrangement, the state places less influence on corporate decisions compared to the FPPE (Lundstøl, Raballand and Nyirongo 2013).

The FPPE is a partial nationalisation type of equity interest ownership where the government and the community place direct claims on portions of the physical minerals produced (Mendes 2015). It significantly reduces the deposit reserves when compared to royalties, which means that the state has the discretion to dispose-of the equity interests at a market value. Further, FPPE's financial arrangement is similar to that of FPE, which resembles a production sharing type of direct participation compared to the FPE (McPherson 2010). The production sharing resembles a hybrid Brownian tax, such as the RSPT where the state refunds pre-tax expenses (operating costs, royalties, depreciation and interest) using its share of equity cash flows. The FPPE dividends become accessible after fully refunding the extraction costs and repaying the cost of acquiring the equity interests. Compared with the FCE and FPE, the FPPE has more negative effects than positive ones (Barton 2016).

To facilitate the equity participation policy in mining and oil and gas developments, the GoPNG established separate management companies known as state owned enterprises (SOE) (Fallon 2015; Jackson 2015; Stuva, Iida and Okazoe 2013). As often the case in PNG, delaying of the expected equity dividends places an obligation on the state to subsidise the operational costs of the SOEs that manage the equity interests. These additional financial commitments expose the local stakeholders to financial risks (McPherson 2010). Hence, the cost of rent-seeking could increase state's credit rating and divert funds away from meeting the social development needs of PNG (Hancock 2009; Sunley and Baunsgaard 2001).

In summary, governments perceive that direct equity participation could assure investors of long term fiscal stability, sharing risks in terms of providing development capital, and offer socio-political security required for a smooth operation of a mining project (Filer 2008). On the other hand, a community could be willing to accept the risks of owning equity interests, such as sacrificing resources in the early years of production with the expectation of receiving dividends in later years (Kadenic 2015). However, the increasing trend towards equity participation and nationalisation raises the question of why governments insist on maintaining the equity participation policies (e.g., Lund 2014b). The claim that equity participation encourages skill development and technology transfers and creates employment through establishment of the SOE is not clearly evident in PNG. Also, the financial risks and social costs are not studied in the literature. This thesis will investigate the risks of owning the equity interests in a mining operation and how a government can fulfill the revenue collection objective.

2.5 Indirect taxes

2.5.1 Import (duty) tax

Import duties are an indirect *in rem* levy, a type of royalty on the importation of physical capital. Import taxes increase the fixed costs of imported equipment (Campbell 2003; Otto 2006). They behave similar to the regressive royalties and the effects are similar to an interest withholding tax. Import taxes increase the capital cost while a withholding tax on interest payments increases the cost of sourcing debt capital. By increasing the capital cost of equipment, an import tax prolongs the time until which a ROR on quasi-rents is realised. It also affects the tax base and delays the expected time for realising the revenues.

Industrialised nations use import duties as a way of encouraging domestic production (Chandrasekhar 1987). In the mining industry, developing countries cannot provide substitutes for importation of capital and technology, which are significant inputs to production. In recognition of this disadvantage, concessions on import duties are often granted for the importation of capital and specific goods that a nation does not produce (Singh and Ghosh 1988; Warhurst and Isnor 1996). A government could be tempted to impose import duties as a way of raising taxes in the early stages of a mine operation. However, they increase the cost of capital and equipment importation (e.g., Campbell 2004). In recognition of these implications, governments tend to offer preferential treatment by exempting capital equipment used for exploration and mine development from paying these duties. This concession enhances fast-tracking of a mining project and reduce the cost of importing capital and technology.

2.5.2 Export taxes

According to Otto (2006), most jurisdictions apply export tax on raw minerals as an indirect (*in rem*) levy. It has the same distortionary effects as those of regressive royalties since the levy is imposed when goods or commodities reach an importer's territory (Fliess and Mård 2012). Export tax can be set either on a "*per unit* basis or an *ad valorem* (value) basis" (Otto 2006, 23). The levy restricts exports of raw commodities and encourages value-adding downstream processing within the country that is exporting the minerals. However, export tax on a mineral commodity can affect the expansion of the extractive sector and affect the macroeconomic growth within a jurisdiction, as well as cause supply shortages that can lead to price increases (Korinek 2013). Commodity price cycles can also complicate the ability of investors to invest in downstream processing, which can reduce exploration and mine development in the long run (Otto and Cordes 2002).

Fliess and Mard (2012) collected data on mineral export restrictions globally and found that China and Russia have imposed legislations to restrict mineral exports. Export restrictions, especially by industrialised countries attempt to protect domestic mineral endowments so that internal industrialisation needs can be met. Some countries such as Fiji, Namibia, Sierra Leone and South Africa, impose restrictions on gold and diamond to regulate illegal exports (Fliess and Mård 2012). They find that export taxes are a disincentive to investment and may cause distortions in production efficiency similar to those caused by royalties.

Export tax cannot be an effective tool to encourage downstream processing unless developing countries have the processing technology that can add value to the mineral being produced. For instance, Indonesia recently enacted a legislation to ban the export of unprocessed ore concentrates (Topstad and Karlsen 2015). They note that the legislation has not been practically applied despite undergoing numerous reviews due to lack of constructing downstream processing facilities. Further, export tax could affect exploration and mine development in cases where a nation does not have the required processing technology and a market destination for the final products (Fliess and Mård 2012).

2.5.3 Employee payroll tax (EPT)

Employee payroll tax (EPT) is the largest revenue collector next to CIT from employees in the mining industry in PNG. The EPT behaves progressively during boom periods due to increased workforce, while it behaves regressively during non-boom periods due to declining local labour engaged in the industry. The progressivity of EPT is often weak due to salary range changes depending on the distributions of skill levels and promotions achieved by employees (Motuma and Bekana 2015). These also include Consumer Price Index (CPI) adjustments and negotiated payroll, including motivational incentives such as production bonuses, which may increase the distribution of incomes (Imbun 2002).

However, EPT is normally regressive since salary rates are fixed and distributed across skill levels and promotional awards are often limited (Imbun 1997) and does not respond to mineral price cycles. As a result, the magnitude of EPT revenues depends on the skill distributions and the size of the workforce. For instance, during PNG's liquefied natural gas (LNG) project construction phase between 2010 and 2014, the total direct tax revenues increased (Avalos et al. 2015, 24) due to an increase in local workforce and importation of skills and labour from abroad. Additionally, contractor payroll taxes, and goods and services taxes on disposable incomes contribute significantly to the total tax revenues from mining activities (Devos 2014).

To maintain regressivity and increase productivity, investors often keep the EPT rates constant by increasing the number of low-skilled workers they employ (Checchi and García-Peñalosa 2008). During periods of low commodity prices, a mine operator may lay-off workers to reduce their labour costs. Since the EPT is regressive, its rate does not respond to mineral price increases because the marginal tax rate remains constant and therefore the cost of labour declines. This triggers a demand for labour that in turn causes the EPT to temporarily behave progressively, which increases revenues.

2.6 Techniques for analysing taxes

There is no unified method for assessing specific issues associated with mineral taxation. The contradictions amongst theoretical constructs and diversity of actual policies suggest that tax appraisals are fragmented (Lund 2009). A classic example is found in Ergas and Fincus (2014) who are skeptical of KPMG Econtech, a consultant firm that used a computable general equilibrium (CGE) model in the Henry Tax Review. The authors of that study recommended replacing royalty with a RRT. However, Ergas and Fincus (2014) use a partial equilibrium model to argue that royalties can generate substantial revenues for Australia. Further, Smith (2013) makes a critical overview of the models used for analysing different aspects of tax policies. He found inconsistencies in researchers' choice of methods such as using a single decision variable or in some cases ignore the interface amongst multiple risk variables. Additionally, conceptual analysis of the taxation theory using stylist resource models and descriptive case studies are common in the mineral taxation literature.

Descriptive case studies are useful for expanding the theoretical knowledge and practical policy applications (Garnaut and Clunies-Ross 1983). However, descriptive studies do not efficiently measure the real time behaviours of investors and governments for two reasons. First, actual sacrifices involving market price, capital and extraction costs are subject to technological and competitive forces (Cuddington and Nülle 2014). These behaviours could be effectively captured by a multiple period quantitative model compared to a single-phased qualitative study. Second, since governments have turned to evidence-based policies, quantitive assessments of the actual tax burden and rent distributions are required. Although studies such as Boadway and Keen (2014, 2010) lay the foundation for building theory and resolve specific issues, optimal models are socially biased (Sørensen 2007). This is because stylist resource models investigate how taxes affect the optimal extraction of mineral deposits using value optimization models (Land 2009) that do not measure the magnitudes of the actual tax revenues that could be transferred to the society in real time.

A basic tax model must have variables representing the tax deductibility of upfront capital investments, tax credits, debt interest deductibility, and LCF provisions, which are the main features underlying a neutral tax system. Smith (2013) emphasises that a reliable tax model must build in neutrality function as it is the basic ingredient for measuring a firm’s behaviour associated with a tax policy. Further, a reliable quantitative tax model should address the uncertainty of input variables for cash flow tax systems. It is significant in establishing a stochastic tax base (continuous and random over time) of a conceptual model (Lund 2009). Samis, Davis, and Laughton (2007) advocate the concept of adjusting these uncertain variables separately from their sources, showing that the use of RO method is significant for neutralising these uncertainties.

Blake and Roberts (2006), and Samis, Davis and Laughton (2007) use various types of RO methods to study contingent taxes, although some of those studies were not intended for a comprehensive analysis of resource tax systems. The main contribution made by these studies is that using the RO methods reduces the uncertainty associated with cash flow volatility. This is significant for predicting the probability distributions of the tax base compared to non-stochastic cash flows derived using the discounted cash flow

(DCF) method (Samis et al. 2005). The RO method corrects some weaknesses of the DCF method, which assumes the tax base is linear, thereby introducing errors in forecasting the tax revenues (Samis, Davis and Laughton 2007).

The RO method, including the Monte Carlo simulation (MCS) technique make the tax base stochastic that in turn sample the distribution of burden and revenue forecasts for long life mining projects. The multiple period projection of unit or value-based royalties are linear when using the DCF method. It is against the Jensen's inequality, which states that a mean of a non-linearity is not same as a deterministic price (MacKie-Mason 1990). In this context, the probability distributions of gross revenues correctly estimate the royalty performance compared to the linear DCF method. Moreover, Samis, Davis and Laughton (2007) demonstrate that variance (uncertainty) of the RRT is reduced when using the RO and the MCS technique. Regardless of the tax expenses and deductions, reducing an uncertainty maximises the tax revenue projection more than the DCF method (Samis, Davis and Laughton 2007), although in reality it may not be the case.

In summary, there is a lack of a unified method for tax policy analysis. To rectify this condition, deriving a stochastically distributed tax base through reducing the uncertainty of input variables can lead to develop real option based models. Samis et al. (2005, 286) note that "in the absence of flexibility, the only difference between the two approaches is the manner of accounting for the effects of cash flow uncertainty on the asset value". There are no differences in the cash flow equation structures that facilitate depreciation, interest expenses, loss offset, and configure multiple taxes for a long life mine (Guj and Garzon 2007). Since the RO method being an extended development from the DCF method, a cash flow tax model can easily adopt the structure of these methods (Samis et al. 2005).

2.7 Techniques for forecasting uncertainty variables

To perform a credible mineral evaluation and tax analysis, the first step involves forecasting the cash flows that are the basis for evaluation models commonly applied to the mining industry (McLaren 2012). Cash flows involve transactions of a firm's earnings against operating costs and non-cash charges (depreciation and debt interest deductibles) that define the tax base (McLure, Mintz and Zodrow 2015). Therefore, determining the reliability of price and operating cost forecasts affects the tax base, which is significant for performing a credible tax analysis. Market-based prices can be used either directly for asset valuation, or to determine the parameters as inputs for numerous other forecasting techniques that can be used (Guj and Garzon 2007).

RO solution techniques such as the Black-Scholes (BS) model (Brennan and Schwartz 1985; Merton 1976), the geometric Brown motion (GBM), and the binomial decision tree analysis (BDTA) are considered advanced forecasting techniques (Haque, Topal and Lilford 2014). The BDTA technique was first constructed by Cox, Ross and Rubinstein (1979). It has the flexibility to numerically configure prices for long life mines when compared to the BS model. The latter is a closed form solution technique (Haque, Topal and Lilford 2014). On the other hand, the BS model is an options pricing technique that has attracted wide application for valuing assets. The BS model assumes that risk-free interest rates and volatility are constant for pricing financial stocks that may not work well for mining projects. Further, despite the BS model being a closed form solution, it values mine closure and re-opening options by approximating the actual values (Davis 1995; Benninga 2000).

Various forms of the RO techniques have been used to evaluate the timing preference for investment decision-making such as abandon, start constructing a mine now or delay (shut-down) until market price improves (Kelly 1998). She used a binomial option pricing technique to determine whether to develop the Lihir gold project (not developed at that time) and concluded that price, costs and deposit quality would determine excising those options (Hall and Nicholls 2007). Real options require techniques that are flexible for decision-making compared to now or never decision-making based on the DCF method. Their studies demonstrate that the binomial lattice technique can concurrently forecast long-term price trends, costs and cash flow distributions to determine the values (NPV) of mining projects (Dehghani and Ataee-pour 2013).

2.7.1 Binomial lattice technique

The binomial decision tree analysis (BDTA) is an extension of decision tree analysis (DTA) technique. It is useful because it provides an open form framework from which the price paths can be configured from a network of branches (Page 1998). Flexibility in the DTA technique enables analysing optional decisions by using time-dependent volatility and risk probabilities within a network of branches (Brandao and Dyer 2005). The BDTA systematically extends the branches (nodes) from which stochastic distributions of prices can be computed for long life mining projects (Hall and Nicholls 2007). Within the DTA structure, the BDTA transforms the decision tree into a network of interlinked nodes that are useful for forecasting non-reverting prices such as that of gold (Cox, Ross and Rubinstein 1979).

Since gold price follows a random walk process, the GBM technique cannot be applied as it deviates from the actual price by large margins (Reddy and Clinton 2016). Gold price behaves like a financial stock market that follows random and unpredictable price paths, which increases over time. Unlike other commodity prices that are generally mean reverting (Andersson 2007), physical gold is a derivative of the exchange rate as it is traded as a financial stock because the gold price follows a random walk process (Smith

2002). He found that daily closing prices that are often used as time series data in resource valuation models indeed follow the random walk process. Because of this behaviour, the binomial lattice technique can be useful in forecasting gold prices than copper prices. Hence, integrating the discrete prices derived using the BDTA with Monte Carlo simulation could generate more reliable outcomes.

Development of software such as the LatticeMaker™ eliminates the complexity associated with computing variables within the binomial lattice. The BDTA can compute the price paths and a secondary lattiice can be construted to configure the cash flows from which the value of a real option (a mining project) can be computed (Tan et al. 2009). As a result, up and down movements are mutually exclusive (Orosi 2015). Both cannot occur at the same time because volatility and node price changes are subject to new information in the stock market (Cox, Ross and Rubinstein 1979).

Unlike valuing an underlying asset (NPV) along with the options within the binomial lattice matrix (e.g., Hall and Nicholls 2007), this thesis only seeks to adjust the uncertainty associated with the input variables, mainly the mineral prices and the operating costs. Mineral prices are determined by supply and demand forces, with some experiencing reversion to long term median (e.g., copper) while others (e.g., gold) are non-reverting. The reverting and non-reverting nature of mineral prices make financial stocks follow stochastic processes that affect the value of a mineral project and also the tax revenue forecasts (Miranda and Brandão 2013). The price forecast can be carried out by modular structure of the binomial lattice as given in Figure 2.3.

Figure 2.3 shows the procedures involved in calculating the node values (state prices) in each period represented by symbol S_u (price going up); and S_d (price going down). The value of each node in the lattice is derived by working backwards from values calculated at the end of each branch (Dehghani and Ataee-pour 2013, 2012; Hall and Nicholls

2007). The notation σ represents the volatility of the historical prices, which is calculated as the standard deviation of the changes daily prices.

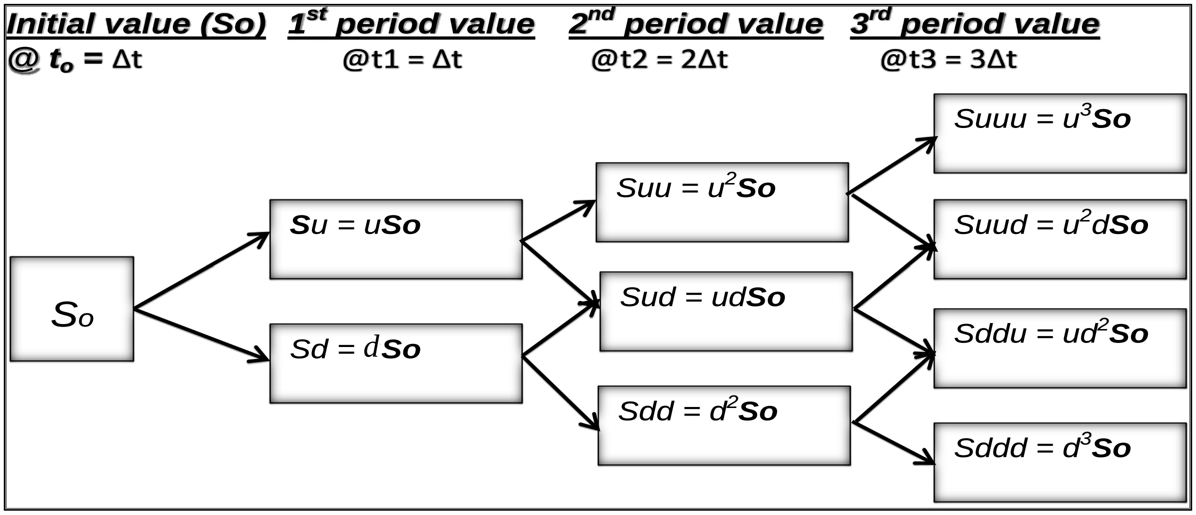


Figure 2.3: Procedures for computing node prices at each node over a three-year period

The equations in Table 2.1 will be used to derive the input variables to generate the binomial lattice. To simulate the behaviour of prices over the life of a mining project using the BDTA, parameters such as spot price (S_o), price volatility (σ) and risk-free interest rate (*Rf*) are required to derive the risk-neutral probability (*p*), and upward (*u*)and doward probabilities (*d*).

As shown in Table 2.1, the discrete time steps are given by Δt (*T/n*) (Mun 2002). For $u>1$, at $t=0+1$, the variable (e.g., price or operating cost) can move up from its current level (S_0) with probability (p_u) (node value). Similarly, for $d<1$, at $t=0+1$, the variable can move down to a new level (node value) with a probability of p_d or 1-p_u. The notations *u* and *d*, are factors designating the probability of state prices increasing and decreasing within the lattice matrix (Miranda and Brandão 2013).

Table 2.1: Equations for computing the node prices as shown in Figure 2.3

Parameter description	Equation/Symbol	
Initial gold price or operating costs:	S_o = Spot price	
Compute node price going up in the lattice:	$S_u = S_o * u$	(2.4)
Compute node price going down in the lattice	$S_d = S_o * d$	(2.5)
As node value goes up risk decreases over time:	$u = e^{\sigma\sqrt{\Delta t}}$	(2.6)
Probability of uncertainty increases over time, t.:	$d = e^{-\sigma\sqrt{\Delta t}} = 1/u$	(2.7)
Risk-neutral probability of node value going up:	$p_{u=}(e^{-Rf*\Delta t} - d)/(u-d)$	(2.8)
Risk-neutral probability of value going down:	$p_d = (u\text{-}e^{-Rf*\Delta t})/(u-d) = 1\text{-}p_u$	(2.9)
Discrete time step sequence	$\Delta t = (T/n)^a$	(2.10)
Volatility obtained from historical price data:	σ	

[a]*T* is the total time for an option to expire, and *n* is the time steps

2.7.2 Geometric Brown Motion (GBM) technique

GBM technique originated from the Brown motion (BM) model, which was developed by Robert Brown (Ermogenous 2006). According to Reddy and Clinton (2016), Robert Brown in 1827 discovered particles displaying jittery motions, which became a basis for tracing stochastic stock price paths. However, the BM model facilitates negative values for market prices that do not represent their behaviours. As a result, it was restructured by Weiner (Wiener and Teichmann 1959) by integrating the geometric motion component into the BM model. This correction ensures a future price path is independent of the past and reverts to a long term mean. In other words, past information (events) do not influence the future prices and the reversion is reflected by a stable and stochastic price growth over time (Pindyck 1999).

Pindyck (1999) identifies the suitability of using the GBM technique is due to hydrocarbon prices (crude oil, gas and coal) trends are mean reverting, where the prices fluctuate over time. Prices react to short-term information which is volatile, but become stable in the long-run as new information erases the effects of older information. He finds that hydrocarbon prices revert to a mean at a slow phase over time. Given such behaviour, the GBM is a suitable technique for forecasting the forward prices of a mineral only if the long term volatility is constant. With contrast, financial options follow the random walk process, whose price paths cannot be reliably predicted (Reddy and Clinton 2016). The authors found that financial stock price paths forecasted using the GBM technique deviated from the actual stock prices by 50 percent because the long term volatility of financial stocks are unstable. As for real assets (mining projects), the GBM technique can reliably forecast the copper price because its long-term price volatility is fairly constant and randomly distributed (Wets and Rios 2015).

The GBM technique has seen broad application in RO-based studies following the initial works of Merton (1976), and Dixit and Pindyck (2001; 1995). Guj and Garzon (2007) provide a revised version of the model based on the work of Blais, Poulin and Samis (2005) to explain the parameters used in the GBM technique, which follows the Ornstein-Uhlenbeck process (McNichols and Rizzo 2012). The GBM technique was first adopted in the Black-Scholes model to forecast stock prices, but it lacked the drift component because the BS model has the assumption of no-arbitrage (Brewer, Feng and Kwan 2012, cited in Reddy and Clinton 2016). The return (profit) condition for real assets such mining projects have the common notion of ‘high-risk, high-gain’. It is opposite to the no-arbitrage principle, which asserts ‘low-risk, high gain’ without a sacrifice such as buying low and selling high (riskless gain) in financial option trading (Fernández 2001). However, as for the mining industry, there is no gain (profit) without an initial investment where the sacrifice is reflected in a discount rate higher than the risk-free interest rate.

Therefore, a risk adjusted discount rate (RADR) could correctly reflect the risk conditions of the mining industry.

In order to slow down the speed of reversion, the mineral price risk and reversion factors are combined to derive the risk discount factor. The risk discount factor is incorporated into the GBM model to moderate the diverging effects on short-term forward prices (Guj and Garzon 2007). Following the Ornstein-Uhlenbeck process, the stochastic price is recursively dragged towards a long-term equilibrium price within an expected timing as measured by the half-life (Dixit and Pindyck 1994). Half-life is the time for the expected price to reach a mid-point (halfway) between the spot price (*So*) and the long term mean (Zhang, Nieto and Kleit 2015b). Stochastic forward prices (*dS*) are forecasted through the following GBM equation:

$$dS = \left[\alpha + \frac{1}{2}\sigma^2 - \gamma ln\left(\frac{S_o}{S_m}\right)\right] So * dt + \sigma Sodz \qquad (2.11)$$

Where: *dS* = continuous spot price change

dz = Weiner process (random variable over time interval *dt*)

dt = continuously measures the drift of the spot price (S_o)

S_o = spot price (at time of evaluation)

S_m = long-term price median (at time of evaluation)

σ = short-term price volatility (standard deviation)

γ = ln (2)/half-life (reversion factor)

α = short-term growth rate of the price median

The Weiner process is defined as: *dz* = Normal. Inv (RAND, 0, 1)* $\sqrt{dt}$ (2.12)

Where: *Normal. Inv (RAND, 0, 1)* = standard normal random variables where the mean variation is between 0 and 1 over a square root of time interval (dt)

Equation (2.11) shows the short-term growth rate of the price median (α), is added to half of the squared standard deviation ($\frac{1}{2}\sigma^2$), which is also the variance. A product of the log normally distributed average spot price ($ln\left(\frac{S_o}{S_m}\right)$) and the reversion factor (γ), is then subtracted from the sum. The result is multiplied by the product of the continuous short-term drift (dt) and the spot price (So). The drift in the short-term price can be either positive or negative. Its magnitude depends on the degree of price volatility: the higher the price drift, the higher the resultant price projection (Sauvageau and Kumral 2017). This effect is moderated by the stochastic component (uncertain random shock ($\sigma Sodz$)) in equation (2.11). It makes the price forecast contingent on a positive (or a negative) shock while keeping the drift constant (Reddy and Clinton 2016). The uncertain random price shock is derived from the product of mineral price volatility (σ), spot price (So), and normal distribution of mean variations in the price movements (or Weiner process) over a time interval (dz).

Historical price data is required for deriving the parameters needed for the GBM model in equation (2.11) because mineral prices behave as stocks that follow the Markov process in which the present price paths are predictors of the future trends (Abidin and Jaffar 2014). Also, mineral prices are lognormally distributed and natural logarithms of historical prices are used to compute the daily volatility, which is then used to derive the annualised volatility (Guj and Garzon 2007). These authors modified the GBM model by discounting the forward prices using the mineral price-risk factor, which restricts GBM technique’s ability to over-estimate short-term price paths if there are positive and large drifts (Dmouj 2006). The mineral price-risk is a product of the market price-risk and correlation factor derived from the natural logarithm of the Standard and Poor (S&P 500) data.

As a synopsis, the GBM and Monte Carlo simulation techniques can resolve the uncertainty associated with future price volatility (Swei, Gregory and Kirchain 2016). Guj and Garzon (2007) use the GBM model to forecast nickel prices for use in a modern asset pricing (MAP) model and compare the results with those of a static DCF model. They noticed that NPV derived using the DCF method was higher than that derived from the MAP model. The differences were due to directional risk-neutral and risk-averse biases associated with the methods used. Further, the binomial lattice and the GBM techniques are identified as suitable techniques for reducing the uncertainties of gold and copper prices respectively. As argued by Samis, Davis and Laughton (2007), separately adjusting the uncertainties of input variables is significant for constructing a financial model that establishes a stochastic tax base that is reliable for resource valuation and tax analysis.

2.8 Summary

This chapter has reviewed the taxation literature in relation to distribution of tax burdens, sharing of risks and the policies associated with design of tax systems. The taxation framework protects and regulates the distribution of quasi and economic rents that could exist in a perfectly competitive market before taxes can be imposed (Boadway 1987). However, the Brownian tax and other hybrid systems devised to attain absolute neutrality tend to place more emphasis on extraction optimality and give little preference to social welfare. This could have affected the efforts made to design a balanced tax system resulting in defensive behaviours of the stakeholders. That is, investors protect the rent maximising objective while governments respond with corrective policies in their quests to capture a greater share of the mineral wealth extracted (Pedro 2016).

In relation to the problem, devising a balanced mineral taxation that meets the fiscal needs of investors and governments is complex (Laporte and De Quatrebarbes 2015). Most jurisdictions deviate from the neutrality principle and continue using royalties and inefficient rent-taxes that affect the extraction efficiency and reduce revenues (Boadway and Keen 2014, 39). The main reasons are: royalties raise more revenues than profit-based royalties; distortion argument is less varifiable in relation to reduction in mineral reserves and complexity associated with administrating the hybrid RRT systems. Given this scenario, measuring the equilibrium condition in which revenues should not exceed the return in access of the capital employed, which is the main argument that should be addressed for devising a balanced mineral tax system. Therefore, measuring the proportional distributions of burden and tax revenues amongst the stakeholders is necessary to understand the behaviours of investors and governments associated with a mineral taxation policy.

The major gap identified relates to the capabilities of governments to raise a high magnitude of revenues from the mining industry by making taxes more progressive. The literature on tax instruments and systems reviewed in Section 2.4 is silent on the theoretical and practical aspects of progressivity. Kamin (2008, 241) identifies this gap and enquires why progressivity has not been developed despite the mineral taxation literature encouraging mineral endowed nations to devise progressive tax systems (Land 2010). A progressive cash flow tax system can fulfil the revenue maximising objective, thereby resolving the behavioural problems of a government (Venables 2016). Australia, Canada and PNG have adopted progressive systems for the respective mining industries but their performances have not been studied.

A subset of the main gaps mentioned above is that there is a need for devising suitable methods to reliably measure the performances of tax instruments for long life mining projects. A major concern in cash flow tax modeling is the need for reducing uncertainty of input variables to ensure tax instruments behave non-linearly in real time when they respond to market conditions. Hence, reducing the uncertainties separately using suitable RO solution techniques can establish a reliable tax base. Chapter 3 presents the methodology of this study.

Chapter 3 : Methodology

Chapter 2 examined the existing literature on mineral taxation and identified the gaps that require further investigation with respect to the objectives of this thesis. This chapter explains the methodology that will be used for data collection and techniques to reduce the uncertainty of input variables for conceptual tax modelling. The evidence-based study also integrates historical data, which includes non-tax benefits to analyse the overall wealth transfers to PNG from the mining sector.

This chapter is organised as follows. Section 3.1 describes the conceptual outline of the research based on the gaps identified in Chapter 2. Section 3.2 explains the procedures for dealing with uncertainty surrounding the input variables. Section 3.3 explains the cash flow models that are used to generate financial and tax data for the theoretical analysis. Section 3.4 discusses the procedures for collecting historical data. Section 3.5 presents the functional variables, followed by limitations in Section 3.6, and a summary of the chapter in Section 3.7.

3.1 Conceptualisation of the research method

Devising tax systems aimed at reducing the average tax burden could lessen the preference for community's fiscal needs. This relates to devising optimal tax systems such as non-distorting lumpsum, Brownian and less progressive taxes that tend to reduce the marginal tax rate. However, these tax systems tend to ignore the social needs of resource owners and may not close the fiscal disparity gaps identified in Chapter 1 (Mankiw, Weinzierl and Yagan 2009). This complicates the objective of achieving a balanced tax system, especially governments having less confidence in their tax systems' ability to collect a high level of revenues. Furthermore, negotiated tax concessions and favourable fiscal terms offered in response to risk situations and the desire to create competitive environment, which tend to erode tax revenues (Conde 2017).

The progressive taxation is ignored despite being identified as possessing some positive attributes required for designing a balanced tax system. Perhaps a major contributing factor for its neglect is the perception that progressivity increases the marginal tax rate, and therefore, exposes an investor to a high tax burden (Conrad and Hool 1984). However, the relationship between neutrality and progressivity under price, cost and tax rate conditions has not been clearly explained. According to Lund (2010), cyclical progressivity enhances capital and factor allocations that occur following the extraction path, which ensures that taxes are levied on the marginal increases in the tax base. As discussed in Section 2.6, the main reason is the lack of using suitable techniques to assess progressive tax system's ability to expose an investor to tax burden while raising revenues. There were two issues identified within this gap.

First, structural progressivity is identified to be a suitable technique for analysing the revenue collecting potential of the progressive tax instruments in PNG. As mentioned in Section 2.6, most descriptive case studies and stylist models establish the economic and financial principles of tax designs (Boadway and Keen 2014). However, the lack of a suitable technique that processes the time-series numerical data makes these study techniques ineffective in capturing the actual tax burdens faced by the mining industry and how different tax instruments perform in terms of collecting revenues. For example, visualising the difference between RRT and royalties has been confusing because governments tend to use value-based royalties more than the RRT (Freebairn 2015). Hence, the structural progressivity could be a suitable technique for processing time-series data to identify which taxes collect much of the revenues.

Second, there is a lack of establishing a stochastic tax base that ensures the functional variables (TPI, METR and others) are reliable for measuring the performance of various tax instruments. As discussed in Chapter 2, reducing the uncertainty of input variables makes forecasting the theoretical tax base (pre-tax cash flow) more predictable than if used deterministically (Kucharska-Stasiak 2013). The use of RO solution techniques such as the GBM, binomial lattice and MCS techniques rectify this setback. The risk-adjusted input variables make cash flow tax models more dynamic than the DCF model (Maybee, Lowen and Dunn 2010). Hence, reducing the uncertainty ensures the tax revenue forecasts are accurate to some extent. The overall conceptualisation of the research method is outlined in Figure 3.1.

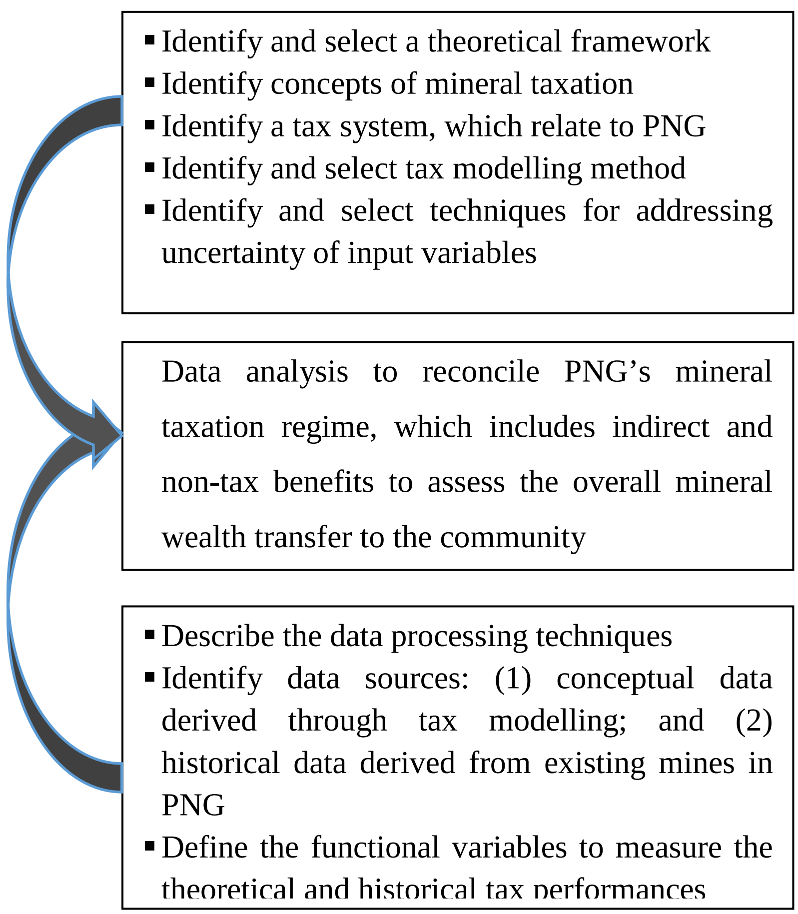


Figure 3.1: Conceptual framework

Figure 3.1 shows that the study connects the theoretical framework with the principles of progressivity that could define how tax instruments behave within a neutral tax design setting. The progressive tax system can generate revenues without distorting the capital and factor allocations. Further, as highlighted in Figure 3.1, much of this chapter entails data selection and identifying the techniques required for correcting the imperfect data. In that case, identifying suitable techniques to forecast financial and tax data is significant for performing a quantitative analysis (Smith 2013). This thesis integrates the theoretical and historical analysis of tax performance using different datasets in order to broaden the understanding of how tax instruments behave in real time.

This study approach contributes to two outcomes. First, the paired analysis has some advantages as the theory-based tax projections alone may not capture the real tax performance, nor correctly predict the behaviour of governments. Most corrective tax policies such as changes in tax rules come about as a result of governments measuring the actual revenues against profits generated by respective mining industries (Ayisi 2015). This difference makes the nature of data and the choice of reliable measurement techniques significant. Further, the paired analysis ensures that the theoretical results are used as benchmarks against the historical results, which provides a deeper understanding of how tax instruments perform under risk factors such as fiscal, cost and market conditions.

Second, a qualitative approach to analysing a tax policy through a bottom-up collection of opinions from the wider community could introduce emotions compared to an empirically-driven policy analysis. The Fraser Institute finds that increased political interventions and community involvement in policy development tend to raise risk ratings (Jackson and Green 2016). Hence, the use of numerical data reduces the bias that could arise from using qualitative data, which makes this study a balanced analysis of PNG’s mineral taxation regime.

Figure 3.2 is an extension of the conceptual framework showing the steps that will be followed in the study. The left-hand side of Figure 3.2 shows the procedures involving numerical data that will be used for the theoretical tax analysis (Chapter 4). The right-hand side of Figure 3.2 shows how the historical financial and tax data will be used to compute the functional variables (Chapter 5). It follows that the conceptual and historical results will be integrated to reconcile the mineral taxation regime in PNG (Chapter 6).

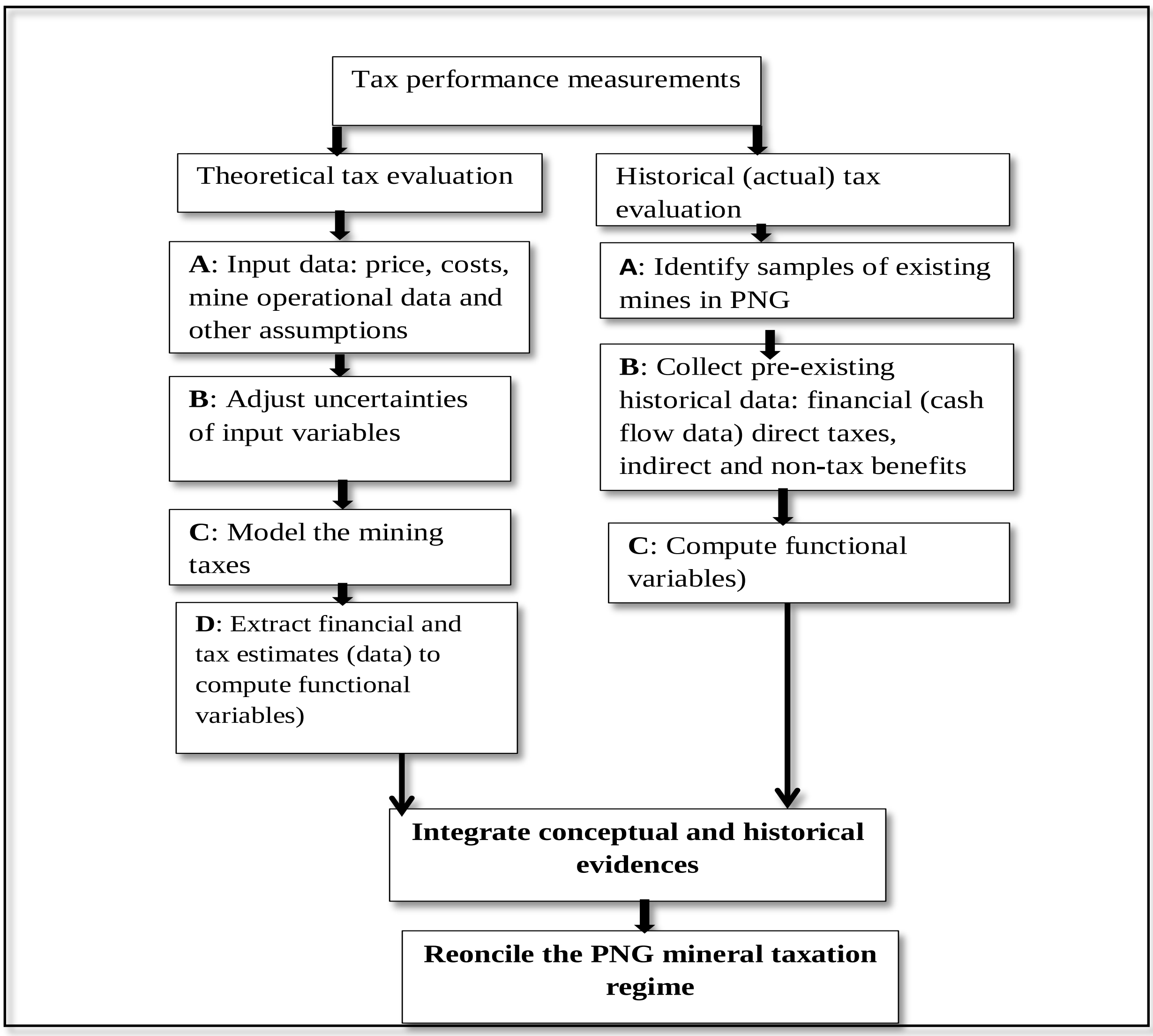


Figure 3.2: Outline of the study procedures

3.2 Procedures for theoretical tax evaluation

3.2.1 Data collection

Since prices of minerals and costs are the major determinants in a mine valuation (Kucharska-Stasiak 2013), forecasting the paths of these risk variables are significant for long life mines. The sampling techniques used in this thesis were non-experimental and based on the theoretically estimated and pre-existing real data. The market and private data for the conceptual tax analysis are given below.

- Historical market data comprising of gold and copper prices from the London Metal Exchange (LME) were downloaded into Microsoft Excel™ spreadsheets from the internet. As for the copper price, the daily spot prices from January 1978 to December 2014 were used to compute the parameters for the GBM model. On the other hand, the spot gold prices from January 1998 to January 2015 were used to forecast the gold price using a binomial lattice method. The prices for copper and gold are presented in *Appendix A* (Table A-1).

  This chapter focuses on copper and gold prices only because PNG's mining industry comprises of these minerals with silver as a by-product. Silver productions are reported in historical production data. However, its quantity in copper and gold deposits are never reported separately at the feasibility stage, which makes calculating the value additivity difficult. Hence, conceptual models tend to ignore the values added by the by-products. Additionally, forecasting the prices of by-products is not required because PNG's symmetrical progressive fiscal regime captures the total export values regardless of producing different minerals and by-products. Moreover, the LME historical prices are applied because they are often used as benchmarks for setting long-term supply contracts. The copper and gold are sold at competitive market prices and producers are price takers.

- Private data from the undeveloped Frieda deposit was obtained from a 2010 pre-feasibility report prepared by the former property owner, Xstrata. The data includes resource reserve, production rate and other private data for the Frieda deposit (Table 3.1). Additionally, the operating and capital costs were obtained from Frieda deposit's pre-feasibility study.

Table 3.1: Frieda deposit data

Parameters	**Symbol**	**Data Estimates as of 2010**	
Diluted reserve (M)		2.8 billion tonnes (untreated rock	
***Head Grades ($\bar{G}$)*:**	Copper:	0.46 percent per tonne of rock mined	
	Gold:	0.22 grams per tonne of rock mined	
Mill Recovery (R^{m})	*Copper:*	85 percent copper recovery rate (LOM)	
	Gold:	72 percent gold recovery (first 8 years & LOM is 71%)	
Contained metal (K)			
	Copper:	12.9 million tonnes copper metal (refinery output)	
	Gold:	20.4 million tonnes gold metal (refinery output)	
***Mining Rate*:**		***First 8 years***	***Life of mine (LOM)***
Throughput		60 million tpa	50 million tpa
Concentrate output		930,000 tpa	716,000 tpa
Metal output (H):	*Copper:*	246,000 tpa copper	190,000 tpa copper
	Gold:	379,000 ounces per year	284,000 ounces per year
Cost estimation		***Xstrata 2010 values***	
Capital cost	*Capex:*	US$5.3 billion	
Operation cost	*Opex:*	US$8.36 tpa*	
***Cut-off grade*:**	*Copper:*	0.2 % equivalent	0.20 % equivalent
	Gold:	0.22 g/t Au	NA
Mine Life (T)		+ 20 years	

*TPA denotes tonnes per year.

Source: Xtrata Pre-feasibility Report (2010) publicly available from the website: http://*www.highlandspacific.com*

3.2.2 Forecasting copper price

This section applies the GBM model described in Chapter 2 (Section 2.7) to forecast the copper price due to its mean-reverting tendency (Dixit and Pindyck 2001, 1995). Daily historical copper prices obtained from the LME were used to derive the parameters required for the GBM model (Blais, Poulin and Samis 2005). The daily copper prices and Standard and Poor 500 (SP500) indices for the period from 2010 to December 2014 were used to calculate the correlation factor between market and daily prices (ρ_{mkt}) (Figure 3.3).

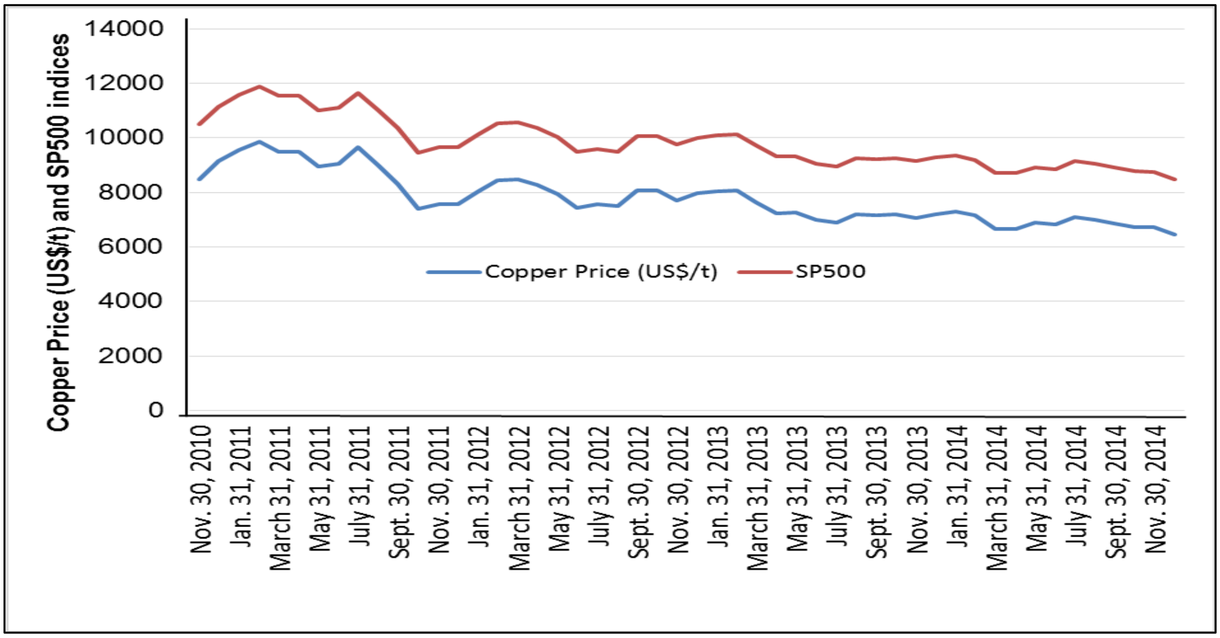


Figure 3.3: Monthly copper price path correlating with the SP500.

The daily volatility in price returns are higher than those of monthly and yearly spot prices due to market's reaction to events (information) and supply-demand cycles (Boehmer and Wu 2013). On the other hand, yearly price returns do not accurately forecast the price paths because long-run price volatilities decrease in response to receding historical information (Redlinger and Eggert 2016). Short-term (daily) historical spot prices tend to give a better measure of volatility since market responses to information are spontaneous. The volatility derived using these daily spot prices accurately reflects the future price paths (Abidin and Jaffar 2014).

Table 3.2: Equations used for estimating parameters based on LME copper prices

Variable		Equation	
Long term (over 5 years)			
Spot price (US$/t)	S_o =	LME spot price as of 31/01/2015	-
Ln (Spot price) average	Φ =	Average of [Ln(t+1)-Ln(t)]	(3.1)
Standard deviation (%)	β =	Stdev (price range)	(3.2)
Mean of price (US$)	μ =	$Exp\ (\Phi + 0.5*\beta^2)$	(3.3)
Long term price median (US$)	S_l =	$((Exp((2*\Phi) + 2*\beta^2)) - Exp(2*\Phi + \beta^2))^{0.5}$	(3.4)
Price volatility (%)	σ =	S_l / μ	(3.5
Price median (US$)	S_m =	$\mu * Exp\ (-0.5*\sigma^2)$	(3.6)
Median price 1 year ago	S_y=	$\mu * Exp\ (-0.5*\sigma^2)$ (Different price range)	(3.7)
Recent 6 months volatility (%)	σ_m =	Stdev (price range)	(3.8)
Short-term price volatility (%)	σ_s =	$\sigma_m/((1/þ)^{0.5}$ where þ = 320 days	(3.9)
Mineral price risk (%)	R_m =	$F_c * P_{mr}$ [*see Appendix A*]	(3.10)
Short-term (6 months)			
LN (Spot price) average	Φ =	Average of [Ln(t+1)-Ln(t)]	(SAA)
Standard deviation (%)	β =	Stdev(price range)	(SAA)
Mean	μ =	$Exp(\Phi + 0.5*\beta^2)$	(SAA)
Short-term median	S_s =	$((Exp((2*\Phi) + 2*\beta^2)) - Exp(2*\Phi + \beta^2))^{0.5}$	(SAA)
Price volatility (%)	σ =	S_s / μ	(SAA)
Price median (US$)	S_m =	$\mu * Exp(-0.5*\sigma^2)$	(SAA)
Short-term growth rate (%)	α =	(S_m / S_s) -1	(3.11)
Reversion half-life (years)		(a number which fits)	-
Reversion factor	ɣ =	Ln (2)/half life	(3.12)

Note: F_c = price correlation factor; P_{mr} = price market risk. *SAA* denotes '*same as above*'.

Table 3.2 presents the formulas used to compute the main parameters required in the GBM model for forecasting the forward copper prices. The LME spot price of copper (S_o) on the 31st January 2015 was used. The other parameters are the price median (S_m); mineral price risk (R_m); short-term growth rate of the price median (α); and reversion half-life. Zhang, Nieto and Kleit (2014, 4) define half-life as "the time for the expected value to real half way price between the current value (S_o) and the long term equilibrium". The half-life was assumed to be 2.5 years required for the expected forward price to reach the half way between spot price and the mean price (μ).

As given in equation (3.5), the long-term price median (S_m) was divided by the mean copper price (μ) to derive the short-term price volatility (σ), based on 320 trading days. Further, equation (3.3) was used to derive the mean price based on the average natural logarithm of daily copper prices. Likewise, equation (3.4) was used to derive the long term price median (S_l) based on the natural log and standard deviation of the historical prices.

The mineral price risk for copper (R_m) was derived by multiplying the daily market price correlation factor (F_c) by the market price risk (P_{mr}) using equation (3.10). The S&P 500 copper price indices between 2010 and 2014 were correlated using Correlation function in Microsoft Excel™ to derive the correlation factor (F_c). Next, the market price risk (P_{mr}) was derived by dividing the mineral risk premium (assumed to be 6 percent) by the annualised volatility of the daily copper prices (Guj and Garzon 2007). This led to compute the mineral price risks as a product of the F_c, and the P_{mr} (equation (3.10)). Further, the short-term growth rate (α) was computed using equation (3.11), which divided the price median by the long-term median of natural logarithm of the daily spot prices from January 1998 to January 2015.

The simulations of the parameters in the GBM model were performed using the Microsoft Excel™. Starting with the spot price of copper, the prices were simulated for a 20-year life of the Frieda copper-gold deposit. In Table 3.3, the variance was recursively simulated following the Weiner process given in equation (2.12). The equations (3.13) to (3.16) were successively used to simulate the expected copper prices presented in Table 3.3. The expected spot prices were then multiplied by risk discount factors to derive the forward prices using equation (3.17). Moreover, lower and upper price confidence intervals were assumed to be $\pm$10 percent and calculated using equations (3.18 and 3.19) (Table 3.3).

Table 3.3: Stochastic copper prices using LME spot price and variables in Table 3.2

Variable	Symbol	Parameter
Spot price (US$/t)	S_o	6,472
Price median (US$)	S_m	7124.4
Short-term price volatility (%)	σ_s	14.25
Mineral price risk (%)	R_m	11.89
Short-term growth rate (%)	α	-0.72
Reversion half-life (years)	-	2.5
Reversion factor	ɣ	0.28
Upper and lower confidence interval	-	$\pm$10%

Time (years)	Variance (%)2	Median price ($/unit)	Expected price ($/unit)	Risk discount Factor	Forward price ($/unit)	Lower 10% Confidence	Upper 10% Confidence
2016	0.0156	6,592.40	6,643.98	0.9853	6,546.38	5,617.62	7,736.32
2017	0.0245	6,699.10	6,781.81	0.9743	6,607.66	5,480.54	8,188.59
2018	0.0297	6,789.02	6,890.53	0.9661	6,656.76	5,443.94	8,466.43
2019	0.0326	6,862.56	6,975.47	0.9599	6,695.55	5,444.21	8,650.42
2020	0.0343	6,921.48	7,041.33	0.9552	6,725.85	5,458.43	8,776.67
2021	0.0353	6,968.01	7,092.12	0.9517	6,749.34	5,476.77	8,865.28
2022	0.0359	7,004.37	7,131.12	0.9490	6,767.46	5,494.89	8,928.50
2023	0.0362	7,032.56	7,160.97	0.9470	6,781.36	5,511.03	8,974.17
2024	0.0364	7,054.30	7,183.77	0.9455	6,792.01	5,524.63	9,007.50
2025	0.0365	7,070.99	7,201.15	0.9443	6,800.13	5,535.73	9,032.02
2026	0.0365	7,083.76	7,214.37	0.9434	6,806.32	5,544.60	9,050.18
2027	0.0366	7,093.51	7,224.43	0.9428	6,811.03	5,551.58	9,063.70
2028	0.0366	7,100.94	7,232.07	0.9423	6,814.61	5,557.02	9,073.81
2029	0.0366	7,106.59	7,237.87	0.9419	6,817.34	5,561.23	9,081.38
2030	0.0366	7,110.89	7,242.27	0.9416	6,819.40	5,564.47	9,087.08
2031	0.0366	7,114.16	7,245.61	0.9414	6,820.97	5,566.96	9,091.37
2032	0.0366	7,116.64	7,248.15	0.9412	6,822.16	5,568.86	9,094.61
2033	0.0366	7,118.52	7,250.07	0.9411	6,823.06	5,570.30	9,097.05
2034	0.0366	7,119.95	7,251.53	0.9410	6,823.75	5,571.41	9,098.90
2035	0.0366	7,121.03	7,252.63	0.9409	6,824.26	5,572.25	9,100.29

Equations used

Variance (A) =	$((\sigma_s)^2 * ɣ)) * (1\text{-exp}(-2 * ɣ * T))$ where T = time (years)	(3.13)
Median price (B) =	$S_m*(((S_o/S_m) * \exp((\alpha/ɣ)* (1-\exp(-ɣ*T))))^{\exp(-ɣT))}$	(3.14)
Expected spot price (C) =	B*exp(0.5 *B)	(3.15)
Risk discount factor (D) =	$\text{Exp}(-((R_m * \sigma_s)/ ɣ)* (1-\exp(-ɣ*T)))$	(3.16)
Forward copper price (E) =	$C * D$	(3.17)
L/C interval (F) =	B * exp(NORMSINV (0.1)*$(A)^{0.5}$)	(3.18)
U/C interval (G) =	C * exp(NORMSINV (0.9)*$(A)^{0.5}$)	(3.19)

Note: Normsinv is a Microsoft Excel™ function that computes the lognormal distribution of price

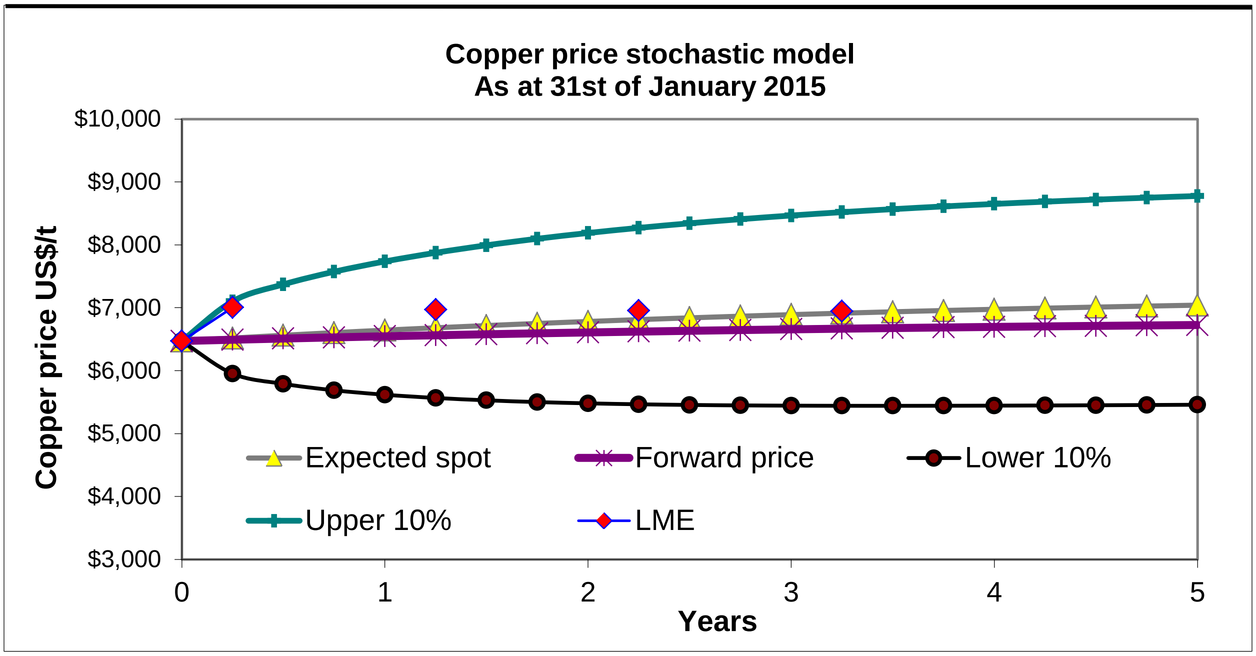


Figure 3.4: Stochastic copper price reverting to a long-term mean.

An important feature of the reverting price process shown in Figure 3.4 is that it follows the future copper price path quoted on the LME that are bounded by ±10 percent upper and lower confidence intervals. It shows that a high price risk discount rate could drag the stochastic copper price towards the lower interval boundary, which could be bias to the real time price (Azimi, Osanloo and Esfahanipour 2013). In other words, the expected copper prices could be over or underestimated within the confidence boundaries. Further, Guj and Garzon (2007) performed a 5-year nickel price forecast commencing 2008. Their nickel price forecast followed the LME path although there were some variations in the initial years due to a high spot price was used at the time of modeling. Hence, the GBM model can provide acceptable price approximations as shown by the similarity between the real LME price and the calculated forward price paths.

3.2.3 Forecasting gold price

The binomial lattice technique described in Chapter 2 (Section 2.7) was used to forecast the gold price over a 20-year period following some steps. The first step was to estimate the parameters required for the binomial lattice technique. The initial gold price, S_o, and volatility, σ, were estimated directly from the LME (daily) prices over the period from January 1998 to January 2015. Since prices are lognormally distributed, the same procedure applied in computing the copper price volatility was used to compute the gold price volatility. The spot price as of January 2015 was US$1253/Oz. The annualised volatility of 22.24 percent was computed using the short-term price volatility equation (3.9). The result was consistent with Hague, Topal and Lilford (2014, 120) who estimate the gold volatility to be around 22.27 percent.

The risk free interest rate (*rf*), price volatility (σ) and time steps (Δt) are the key parameters that were applied in the formula described below.

Probability of node value going up: $u = e^{\sigma\sqrt{\Delta t}}$ (same as 2.7)

Probability of node value going down: $d = d = e^{-\sigma\sqrt{\Delta t}} = 1/u$ (same as 2.8)

Risk-neutral probability of node value going up: $p_u = (e^{-Rf*\Delta t} - d)/(u - d)$ (2.9)

Risk-neutral probability of value going down: $p_d = (u\text{-}e^{-Rf*\Delta t})/(u - d) = 1\text{-}p_u$ (2.10)

Risk discount factor: $R_f = (e^{(r*t/n)})$ (3.20)

Table 3.4: Parameter estimations using equations (2.7) to (2.10)

Spot gold price (S_o) US$/Oz	**Risk free interest rate (*rf*) (%)**	**Gold price volality (σ) (%)**	**Time to maturity (*n*)**	**Number of Steps**
1253	4	22.2[a]	20	40

Calculations

Up movement (*u*)	Down movement (*d*)	Upward probability (*Pu*)	Downward probability (*Pd*)	Discount Factor
1.04	0.97	0.50	0.50	0.999

Note: [a]Equation (3.9) was used

The second step involved the construction of the lattice using the LatticeMaker software add-in for Microsoft Excel™. Discrete node values in the primary lattice structure were simulated using the procedures described in Figure 2.3 (see Chapter 2). For example, in 2016, the upper node value was calculated as follows: $S_o{*}u$ = 1253*1.04 = 1298 and the lower node was $S_o\ {*}d$ = 1253 *0.97 = 1210 (Fig. 3.5).

Time	**0**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
Step	**0**	**80640**	**80680**	**80720**	**80760**	**80800**	**80840**	**80880**	**80920**	**80960**	**81000**
	1253	1298	1344	1392	1442	1494	1547	1603	1660	1719	1781
		1210	1253	1298	1344	1392	1442	1494	1547	1603	1660
			1168	1210	1253	1298	1344	1392	1442	1494	1547
				1128	1168	1210	1253	1298	1344	1392	1442
					1089	1128	1168	1210	1253	1298	1344
						1051	1089	1128	1168	1210	1253
							1015	1051	1089	1128	1168
								980	1015	1051	1089
									946	980	1015
										913	946
											882
Expected gold price	**1253**	**1254**	**1255**	**1257**	**1259**	**1262**	**1265**	**1269**	**1274**	**1279**	**1284**
Risk-discount factor		0.998	0.996	0.994	0.992	0.990	0.988	0.986	0.984	0.982	0.980
Risk-adjusted forward price		1251	1250	1249	1249	1249	1250	1252	1254	1256	1259
MCS -Stochastic Price	**1253**	**1233**	**1111**	**1224**	**1384**	**1320**	**1495**	**1347**	**1404**	**1170**	**1188**

Figure 3.5: Gold prices project over a 20-year life

The third step was to find the average of the continuous up and down values for each period to obtain the annual prices to be used over the 20 year period. The averaging was possible because the upward and downward probabilities were symmetrical (50 percent) and the discrete values were used as unit prices (Orosi 2015). Further, the growth rate with time was reduced since fine granularity of the discrete time step sequence had a similar effect to discounting using the mineral price risk. The fine granularity of time steps (Δt) reduce the upward and downward probability movements in each step, leading to more accurate results that converge with those of the Black-Scholes model (Mun 2002). The price forecast for 10 years is shown in Figure 3.5, with the full 20-year lattice shown in Figure A-1 (*Appendix A*).

This thesis identified a disadvantage associated with directly using the discrete prices. The discrete prices tend to grow at a constant rate identical to inflating the price, gross revenues and operating costs using an escalation rate in a DCF model. According to Mun (2002, 152), the binomial approach is a "discrete simulation process", while the GBM model is a 'continuous stochastic simulation process". This makes the price forecast detached from being continuous and stochastic behaviour as expected. For example, Dehghani and Ataee-pour (2010) use the binomial lattice technique to forecast a 10-year copper price path (2010 to 2020). However, compared with the real LME spot price between 2011 and 2016, their price forecasts using the binomial lattice technique were overly pessimestic, which led to overestimations.

In another example, Hall and Nicholls (2007) use the binomial lattice technique to estimate price and generate cash flows for a coal mine. However, their forecast was not consistent with the real LME coal prices between 2008 and 2017. These examples suggest that forecasting the forward prices is a complex task since prices are susceptible to volatility in the financial market. Having identified these problems, the discrete gold prices in Figure 3.5 were discounted using a risk discount factor (equation (3.20)) (Samis et al. 2005). The decomposed discrete gold prices using the risk discount factor were similar to those calculated using the mineral risk discount factor (equation (3.16)). However, the discrete forward prices were not stochastically distributed.

To resolve these setbacks, the discrete prices were converted into stochastic variables using the MCS technique by setting a minimum and a maximum through a triangular probability distribution (Kucharska-Stasiak 2013). The triangulation process was such that the probability range was configured using RiskSim software add-in for Microsoft Excel^{TM} and simulated for 10,000 trials. Integrating the MCS technique into the binomial process ensured the gold prices were randomly distributed over the 20 years mine life. This same technique was applied to forecasting the operating costs in the proceeding section.

3.2.4 Forecasting operating costs

Since a government is not directly involved in decision-making associated with a mining operation, establishing a reliable operating cost forecast is significant for tax modeling. The unit operating costs (including labour costs) are the largest cost components in mining and investors could increase costs to avoid exposure to high tax liability. For example, low cost mine operations can lower output rates and extend a mine life (Campbell and Wrean 1984). This could be done by offseting the distortion effects of royalty on the cut-off grade (Asad and Topal 2011). However, forecasting the unit costs are significant part of the evaluation process as they determine the size of profits and tax revenues (Zhang, Nieto and Kleit 2015a).

Historical costs are often used for modeling purposes because bottom-up estimation of operating costs are tedious and extracting cost data is expensive (Shafiee, Topal and Nehring 2009). Hence, most evaluation studies use historical costs derived from existing mine operations, which may vary depending on specific locations. This thesis used Xstrata's 2010 operating cost estimation for the Frieda deposit (Table 3.1) in PNG. It was converted to 2014 nominal cost using the United States (US) Consumer Price Index

(CPI). To convert the historical operating and capital costs, the following equations were used:

$$\text{Nominal inflation rate in year: } \tau = \frac{\text{CPI (x)}}{\text{CPI (y)}} - 1 \qquad (3.21)$$

Where year x = present year
y = past year in which historical cost is determined

Average inflation between year x and y:

$$\text{Average inflation: } \upsilon = \left(\frac{\text{CPI (x)}}{\text{CPI (y)}}\right)^{1/n} - 1 \qquad (3.22)$$

Where n = number of year

$$\text{Nominal annual escalation: } \ddot{\upsilon} = (1+\tau) * (1+\mathcal{E})^{n} - 1 \qquad (3.24)$$

Where $\mathcal{E}$ = real escalation rate between year x and y

$$\text{Nominal cost in year x} = \text{cost [year (y)]} * (1 + \ddot{\upsilon}) \qquad (3.25)$$

Xstrata's operating cost estimate for the undeveloped Frieda deposit was US$8.36 per tonne (2010 value) (Table 3.1). The US CPI and a 3 percent real escalation rate were used to convert the 2010 historical costs to 2014 nominal operating costs. The reason for using the US CPI was that the cost estimations were given in US Dollar although the actual operation will be affected by PNG's CPI and exchange rate. As shown in Table 3.5, the real unit opeating cost of US$8.36 per tonne was converted to US$10.12 per tonne (December Quarter 2014) to align with the period for which the tax modeling was undertaken.

Determining the volatility of operating costs of copper mines was a complex task due to the absence of time series data. If the time series operating cost data were available, equation (3.9) would have been used to derive the short term volatility. This study used a volatility of 21 percent, as applied by Dehghani and Ataee-pour (2012) to forecast the operating costs for a copper mine in their study.

Table 3.5: Converting historical to nominal costs at the time of tax modeling

Parameters	**Values**	**Parameters**	**Values**
US CPI (Dec 2010): [y]	219.179	US CPI (Dec 2010): [y]	219.179
US CPI (Dec 2014): [x]	234.812	US CPI (Dec 2014): [x]	234.812
$\tau =$	7.13 (%)	$\tau =$	7.13 (%)
$\upsilon =$	1.74 (%)	$\upsilon =$	1.74 (%)
$\ddot{\upsilon} =$	21 (%)	$\ddot{\upsilon} =$	21 (%)
Real Opex* (2010) =	US$8.36/t	Capex* (2010) =	US$5.3 M
Nominal Opex (2014)	US$10.12/ t	Capex (2014) =	US$6.4 M

*Refers to operating cost and capex refers to capital costs

The MCS technique used in Section 3.2.2 was also applied to the discrete operating cost projections to make them more stochastic. Further, Xstrata's initial capital cost estimate of US$5.3 billion (2010 value) was converted to a December 2014 value of US$6.48 billion using equations (3.21) to (3.25). The results of the binomial lattice simulations are presented in Figure 3.6 and the entire simulated results are presented in *Appendix A*, (Figure A-2). The adjusted operating and capital costs for the Frieda copper deposit were then used for modelling the mining tax instruments and adjust the production data for Frieda deposit in Section 3.2.5.

Time		0	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Step		0	40320	40340	40360	40380	40400	40420	40440	40460	40480	40500
	10.12	10.12	10.58	11.07	11.57	12.10	12.65	13.23	13.84	14.47	15.13	15.82
			9.68	10.12	10.58	11.07	11.57	12.10	12.65	13.23	13.84	14.47
				9.25	9.68	10.12	10.58	11.07	11.57	12.10	12.65	13.23
					8.85	9.25	9.68	10.12	10.58	11.07	11.57	12.10
						8.46	8.85	9.25	9.68	10.12	10.58	11.07
							8.09	8.46	8.85	9.25	9.68	10.12
								7.74	8.09	8.46	8.85	9.25
									7.40	7.74	8.09	8.46
										7.08	7.40	7.74
											6.77	7.08
												6.47
Cost Forecast (US$/t)		**10.12**	**10.13**	**10.15**	**10.17**	**10.20**	**10.24**	**10.28**	**10.33**	**10.39**	**10.46**	**10.53**
Risk Discount Factor		0.00	0.998	0.996	0.994	0.992	0.990	0.988	0.986	0.984	0.982	0.980
Risk adjusted forward opex		10.12	10.11	10.11	10.11	10.12	10.14	10.16	10.19	10.23	10.27	10.32
MCS - (US$/t Cu)		**10.00**	**9.97**	**11.13**	**11.69**	**10.53**	**9.65**	**9.80**	**10.25**	**10.94**	**11.48**	**10.04**

Figure 3.6: Operating costs projected over a 20-year life

3.2.5 Adjusting production estimates from Frieda

Copper and gold prices, along with the operating costs influence the cut-off grade, which in turn will change the initial metal contents (Boadway and Keen 2010). The cutoff grade is the main variable used as a benchmark to achieve optimal productivity under cost and price constraints (Asad and Topal 2011; Bootsma 2013). The prices and costs were integrated into Lane's cutoff grade model (Lane 1988) to adjust Frieda deposit's cutoff grade and mineral reserve given in Table 3.1. Lane's (1988) minimum cutoff grade ($\bar{g}$) model given in equation (3.26) was used.

$$(\bar{g}) = \frac{Mining\ cost\ (M^c) + Processing\ cost\ (P^c)}{(Price\ (P) - Sale\ cost(S^c)) * Recovery\ (R^{m\jmath})} \quad (3.26)$$

$$= (M^c + P^c)/((P - S^c) * R^{m\jmath})$$

Where $\bar{g}$ = cutoff grade at time t
M^c = mining cost
P^c = Processing cost
P = Selling price
S^c = Selling Cost
$R^{m\jmath}$ = mill recovery rate

The contained mineral was derived by multiplying the ore quantity above the cutoff grade by the average grade, $\bar{G}$ (Minnitt 2004). The $\bar{G}$ was calculated by dividing the total metal content by the total tonnes processed. The quantity above the cutoff grade after adjustment (ΔQM), or the proportion of the mined quantity that goes to the mill was calculated using equations (3.27), (3.28) and (3.29):

$$\Delta Q^M = Q_o - Q_o * \bar{g}_a \ \text{ if } \bar{g}_a > \bar{g} \quad (3.27)$$

$$\Delta Q^M = Q_o + Q_o * \bar{g}_a \ \text{ if } \bar{g}_a < \bar{g} \quad (3.28)$$

Where ΔQ^M = adjusted quantity above cutoff grade and $\bar{g}_a$ = adjusted cutoff grade

$$\text{Metal content} = Q^M = \bar{G} * (\Delta Q^M) * R^{m\jmath} \quad (3.29)$$

The summary of the prices, costs and primary (deterministic) data for the Frieda copper-gold deposit are presented in Table 3.6.

Table 3.6: Summary of stochastic prices and costs, and Frieda deposit data

Yr	Prod. Rate (Q^M)	Copper output	Au output	Av. Grade	Av. grade*	Cu Price	Au Price	Opex
	(Rock t)	(tonnes)	(Oz)	Cu (%)	Au (g/t)	(US$/t)	(US$/Oz)	(US$/t)
1	60000000	246000	379000	0.46	0.22	6546	1233	9.97
2	60000000	246000	379000	0.46	0.22	6608	1111	11.13
3	60000000	246000	379000	0.46	0.22	6657	1224	11.69
4	60000000	246000	379000	0.46	0.22	6696	1384	10.53
5	60000000	246000	379000	0.46	0.22	6726	1320	9.65
6	60000000	246000	379000	0.46	0.22	6749	1495	9.80
7	60000000	246000	379000	0.46	0.22	6767	1347	10.25
8	60000000	246000	379000	0.46	0.22	6781	1404	10.94
9	50000000	190000	379000	0.46	0.22	6792	1170	11.48
10	50000000	190000	284000	0.46	0.22	6800	1188	10.04
11	50000000	190000	284000	0.46	0.22	6806	1298	10.47
12	50000000	190000	284000	0.46	0.22	6811	1299	9.89
13	50000000	190000	284000	0.46	0.22	6815	1114	11.32
14	50000000	190000	284000	0.46	0.22	6817	1204	13.54
15	50000000	190000	284000	0.46	0.22	6819	1252	10.53
16	50000000	190000	284000	0.46	0.22	6821	1256	11.36
17	50000000	190000	284000	0.46	0.22	6822	1237	11.62
18	50000000	190000	284000	0.46	0.22	6823	1307	9.73
19	50000000	190000	284000	0.46	0.22	6824	1373	9.92
20	50000000	190000	284000	0.46	0.22	6824	1136	15.29

Source: Xtrata Pre-feasibility Report (2010)

Table 3.7 shows that the quantities of copper and gold above the cutoff grade slightly increased as a result of continuous changes in the cutoff grade due to variability in the forecasted prices and operating costs. The average grades ($\bar{G}$) for gold and copper remained constant because changes in metal contents were small relative to the large mineable reserve. The distribution of prices and operating costs influenced the variations in the cut-off grade, which in turn caused the metal output to vary from the initial data given in Table 3.1. For instance, a fall in the gold price in year 9 naturally caused the cutoff grade to increase, which in turn reduced the gold output to 274,399 ounces per year from the initial output estimate of 379,000 ounces per year (Tables 3.1 and 3.7).

Table 3.7: Adjusted production estimates for the Frieda copper deposit

	$M^c + P^c$	S^c	$\bar{g}a$, Cu	ΔQM	$\bar{G}$, Cu	$\bar{G}$, Au	Q^M, Cu	Q^M, Au
Year		**(5.2%)**	**(% Cu)**	**Tm**	**(%)**	**(g/t)**	**Cu (t)**	**Oz Au**
1	7.78	0.52	0.158	67,130,245	0.38	0.45	254,605	301,394
2	8.68	0.58	0.175	67,886,868	0.38	0.45	257,475	304,791
3	9.12	0.61	0.183	68,217,326	0.38	0.45	258,728	306,275
4	8.21	0.55	0.164	67,360,140	0.38	0.45	255,477	302,426
5	7.53	0.50	0.149	66,717,465	0.38	0.45	253,039	299,541
6	7.64	0.51	0.151	66,795,132	0.38	0.45	253,334	299,889
7	7.99	0.53	0.157	67,086,509	0.38	0.45	254,439	301,198
8	8.53	0.57	0.168	67,548,475	0.38	0.45	256,191	303,272
9	8.95	0.60	0.176	67,908,447	0.38	0.40	257,556	274,399
10	7.83	0.52	0.154	66,907,740	0.38	0.40	253,761	270,356
11	8.17	0.54	0.160	67,202,120	0.38	0.40	254,877	271,545
12	7.71	0.51	0.151	66,793,153	0.38	0.40	253,326	269,892
13	8.83	0.59	0.173	67,771,774	0.38	0.40	257,038	273,847
14	10.56	0.70	0.207	50,704,841	0.38	0.40	192,308	204,884
15	8.21	0.55	0.161	67,224,783	0.38	0.40	254,963	271,637
16	8.86	0.59	0.173	67,797,607	0.38	0.40	257,136	273,951
17	9.06	0.60	0.177	67,969,301	0.38	0.40	257,787	274,645
18	7.59	0.51	0.148	66,677,240	0.38	0.40	252,887	269,424
19	7.74	0.52	0.151	66,803,592	0.38	0.40	253,366	269,935
20	11.93	0.80	0.233	49,512,985	0.38	0.40	187,788	200,068

Note: The cost of mineral sales (**S^c**), estimated as 5.2% of the operating costs. A 95% net smelter return (NSR) rate was used to calculate the cutoff grade.

3.3 Cash flow tax model

Different types of cash flow tax (CFT) systems were briefly discussed in Section 2.1 (Chapter 2). As mentioned in Chapter 2, the R+F-based CFT is defined as taxing the positive tax base after accounting for capital cost allocations, amortisation, operating costs, debt interest deductions and royalty (Auerbach et al. 2017). It also mimicks the S-based CFT because the GoPNG imposes dividend and interest withholding taxes (Walpole 2012). The Brownian and Garnaut-Clunies Ross versions of the CFT are the combinations of the CFT systems that recognise the real increases (decreases) in the tax base.

The CFT has some advantages. It attains some neutrality without severely eroding the tax base so that governments can have access to revenues after a mine realises its normal ROR (Boadway and Keen 2014; Sandmo 1979). Most tax systems are designed to avoid distorting the investment decisions so that investors continue to generate profits from which governments can have access to revenues in the long run. Further, the CFT can control a firm's debt and equity financing options through thin capitalisation rule to ensure interest deductibility does not reduce the tax base (Auerbach et al. 2017). Moreover, CFTs facilitate easy calculations of the tax liability and limit cost and profit shifting between mining projects. Equation (3.30) is a basic cash flow model as provided below.

$$NPV = -I_0 + \sum_{t=1}^{n} PV \ = -I_0 + \{ \sum_{t=1}^{n} [(Gr_t - C_o - D_t) - T]\} * (1+i)^{-n} \qquad (3.30)$$

Where NPV = sum of present values

PV = CF x discount factor $(1+i)^n$, where i is the discount rate

n = number of years (mine life)

I_o = initial capital costs, including past exploration expenditures

Gr_t = gross revenue

T =Tax (represent all tax inputs)

C_o = operating cost

D_t = annual tax depreciation deductions

Equation 3.30 is the standard DCF valuation method used to derive NPV for making after-tax investment decisions (Schreiber 2013). It uses deterministic input variables and a constant discount rate that assumes risk is fixed throughout a mine's life. Within the DCF method, gross revenues and operating costs are usually escalated at a nominal growth rate to cater for future volatility and escalation to cater for improvement in technology and innovation. However, this procedure ignores the stochastic distributions of the tax base (Shafiee, Topal and Nehring 2009). In the absence of management flexibility, incorporating a stochastic cash flow and MCS technique can make the CFT model more dynamic (Samis and Davis 2014).

Following the guidance provided by Samis et al. (2005), a dynamic DCF method (RO CFT model) was developed by taking uncertainty into account when the stochastic price and operating costs were incorporated into the DCF method. Additionally, within the RO CFT model, the MCS technique was further imposed to ensure the financial and tax data were stochastically distributed (Shafiee, Topal and Nehring 2009). It was referred to as a RO MC-CFT model. Further, since PNG's taxation regime has been a progressive one (McLaren and Passant 2015), equation (3.30) was applied to the second-best CFT system as described in Chapter 2 (Section 2.1). The mineral taxation policy of PNG allows investors to fully expense the capital costs and carry forward cash flow losses that are compounded at the risk-free interest rate.

The RO and RO MC-CFT models were used to model PNG's mineral taxation regime that became effective after the 2000 Tax Review (Table 3.8). The direct tax instruments comprise of CIT, DWT, royalty, equity participation and an APT, which was a version of a RRT. PNG applies an ad valorem royalty across the industry, which includes a special support grant (SSG) and Mineral Resources Authority (MRA) levy. PNG also offers a 0.75 percent tax credit scheme (TCS) as an incentive for mining companies to directly apply a portion of the CIT revenue for infrastructure developments within a host mining region.

Table 3.8: Details of PNG mineral taxation regime (Revised 2000-2015)

Basic mining taxes		***Tax Rates***
Corporate Income Tax (CIT)	***Acronym***	**(%)**
• Large Scale Mine Income Tax	SML	30
• Medium Scale Mine Income Tax	ML	25
• Tax credit scheme[1]	TCS	0.75
Royalties[2]		
• Ad valorem royalty		2
• Profit-based royalty	PBR	2
• Mineral Resources Authority levy	MRA	0.25
• Special support grant	SSG	0.75
• Production levy	PL	Ceased in 2006
Quasi-taxes		
• Additional Profit Tax [3]	APT	20 @ 10% threshold rate[a]
Equity Holding[4]		
• Fully paid production equity	FPPE	22.5 – 30 (18)
• Fully paid Equity	FPE	22.5 – 30 (18)
• Free carried equity	FCE	22.5 – 30 (18)
• Value Added Tax (import tax)	VAT	Zero Rating[5]
• Dividend withholding tax	DWT	10
Capitalisation methods		
Accelerated-declining balance	ADB	150 DDB method
Amortization	Exploration (AEE)	Pool depreciation
Amortisation	Feasibility/dev.	Same applies

[1] TCS rate reduces the CIT rate as it is an incentive for development purposes in the host region
[2] NSR ad valorem royalty as well as profit-based royalty applied at the Ramu Nickel mine
[3] Possible reintroduction after 2012 – 2015 Taxation Review recommendations
[4] State and community equity participation varies (case by case basis)
[5] Equipment for exploration, mining and petroleum/gas are exempted from import duty

The CFT model in equation (3.30) was expanded by combining the R+F-based and S-based CFT to insert the tax instruments as given in equation (3.31).

$$NPV^T = -I_0 + \sum_{t=1}^{n} PV^T \tag{3.31}$$

$$= -I_0 + \sum_{t=1}^{n} \{[(Gr_t - L_R) + (L_{MRA} + L_{SSG}) - C_o - (D_t + A_d) - T_{PBR} - T_{FPPE}] - T_{APT} - (T_{CIT} - TCS) - T_{FCE/FPE} - T_{DWT}\} * (1+i)^{-n}$$

Where NPV^T = Sum of present values after tax deductions,

PV^T = Annual present values after tax deductions

Gr_t = Gross revenue

i = Risk adjusted discount rate (RADR) applied to the methods

$D_t + A_d$ = Depreciation and amortisation in time, t

L_R = NSR ad valorem royalty as a levy (outflow)

L_{MRA} = Mineral Resources Authority levy

L_{SSG} = Special support grant (levy)

T_{PBR} = Profit based royalties

T_{APT} = Additional profit tax

T_{CIT} = Corporate income tax

T_{FPPE} = Equity dividend from fully paid production equity (FPPE)

$T_{FCE/FPE}$ = Free carried equity and fully-paid equity

T_{DWT} = Dividend withholding tax (DWT)

TCS = Tax credit scheme that reduces the T_{CIT}

Further clarifications on some aspects of equation (3.31) are presented below:

- The ad valorem royalty (L_R) calculation was based on the Net Smelter Return (NSR) explained by Otto et al. (2006). The NSR accounts for freight, handling costs to the point of export and refining costs in the computation of the ad valorem royalty payable.

- Other levies, such as Mineral Resources Authority levy (L_{MRA}), and a special support grant (L_{SSG}), were expensed against the gross revenue. A MRA levy of 0.25 percent was calculated similar to the NSR royalty. Also, the SSG was computed similar to the NSR royalty and charged at a rate of 0.75 percent.

- PNG offered a profit-based royalty (T_{PBR}) to the Ramu Nickel mine, which was outside of the taxation framework. To assess its effects, the PBR was inserted into the CFT model as a second-tier to the CIT. The ad valorem royalty was excluded before applying the PBR in order to avoid double deductions.

- The CIT (T_{CIT}) was accessible when the pre-tax base became positive. As shown in equation (3.31), a TCS rate of 0.75 percent reduced the CIT rate to an effective CIT rate of 29.25 percent. This was because mining companies are allowed to directly use the TCS funds for infrastructure development purposes in host mining regions in PNG. The DWT (T_{DWT}) was imposed on the post-CIT base (before adding back depreciation, salvage value, and debt capital inflows). The CIT rate was reduced from 35 percent to 30 percent and the DWT was reduced from 15 percent to 10 percent in the PNG 2000 Tax Review (Hogan and Goldsworthy 2010).

- As can be seen in equation (3.31), the three types of equity participations (T_{FPPE}, T_{FCE} and $_{FPE}$) were inserted into the model according to the different financing arrangements discussed in Chapter 2 (Section 2.4.5).

(1) Since FPPE is a production sharing, it appears on the pre-tax base in equation (3.31). This is because the government refunds an investor the cost of sales, royalty and other levies, operating costs, and depreciation and interest deductions. Since the GoPNG does not separately sell its share of minerals produced, mining companies export the minerals and directly deduct the sales expenses. After the deductions, a balance of the equity cash flows is transferred to the state owned enterprises (SOEs) that manage the equity interests on behalf of the state and community. If the pre-tax base is negative, it may turn out to be a Brownian tax as it requires the GoPNG to subsidise the financial costs of equity capital and the administration expenses of the SOEs.

(2) To assess the risk distributions, the FCE and FPE were modeled on the post-tax CF base the dividends were assumed to be paid out of corporate profits. As for the FCE, the GoPNG and the community have access to dividends after fully offsetting the equivalent cost of equity from positive post-tax CFs. Likewise, under the FPE, if investors are allowed to manage the equity interests on behalf of the state and community, positive dividends can be accessed on the corporate profits if the equity capital plus interests are fully expensed against post-tax cash flows as shown in equation (3.31).

- As for the additional profit tax (APT), a rate of 20 percent was applied to the pre-tax base (after applying the FPPE). The Taxation Review Committee has recommended the GoPNG to re-introduce the APT (Emerson and Kraal 2014). The PNG version of the pure RRT with full loss-offset was such that the APT becomes accessible on the pre-tax base by setting the cumulative present values (discounted at the threshold rate) equal zero. In the past, a 15 percent threshold rate was enforced, but it never generated any APT revenues (DMPGM 2014).

Therefore, this thesis used a 10 percent threshold rate. The main reason was that a lowered threshold rate would demonstrate the ability of the APT to collect revenues from porphyry copper-gold deposits in PNG whose average IRRs are mostly around 11 percent (Otto and Cordes 2002).

- The capital cost was depreciated using an accelerated declining balance (ADB) depreciation technique with a premium of 150 percent. Also, a 15 percent of the pre-development and feasibility study costs were amortised over a shorter period (four years) compared to the whole of life depreciation expenditures because the Frieda deposit has been a Greenfield project.

- Equation (3.31) does not have a variable representing the allowances for interest tax deductibility since the model was assumed to be a 100 percent equity-financed mining project (Torries 1998). This was because most evaluations are often carried out with the 100 percent equity assumption because an investment decision is influenced by uncertain input variables, including project and tax risks. However, the effects of different thin capitalisation rules will be investigated in Section 4.2 (Chapter 4).

- A risk adjusted discount rate (RADR) of 5 percent was used to account for operational and tax risks, as well as other uncertain variables not directly considered in the tax models (Guj and Garzon 2007). The RADR is considered a suitable discount rate because risk-averse investors prefer a medium level discount rate (Park and Matunhire 2011) rather than the risk-free interest rate despite using the RO CFT models.

In summary, although cash flows of mineral projects may not be predicted precisely due to market dynamics and uncertainties associated with production, neutralising the sources of volatility was a significant step in the evaulation process. This section has developed the RO CFT and the RO MC-CFT methods that were used to model PNG's mining tax instruments. The financial and tax estimates derived using these theoretical models were then used to compute the functional variables (*Appendix B*).

3.4 Procedures for historical tax analysis

The historical tax analysis used data collected from the closed Bougainville copper mine and two existing mines and these were: Ok Tedi copper-gold, and Porgera gold mines. The mines were selected based on their consistent production histories over prolonged periods. The data represented periods that covered changes in the tax regime and mineral supply cycles from 1972 to 2013. Historical data from the Ok Tedi mine was from 1984 to 2013. As a result, GoPNG's expropriation of the Ok Tedi mine in 2014 and its temporary shutdown in 2015 did not affect the data.

Considering the sample size, the three real mine samples, along with the undeveloped Frieda copper-gold deposit were considered to be an adequate representation of PNG's mining industry, which produces copper, gold, silver as a byproduct and recently nickel from the Ramu Nickel mine.

Pre-existing data collected from the three mines sampled were as follows:

- The Bougainville copper mine data was sourced from the Bougainville Copper Limited Annual Report. The required financial and tax data are presented in *Appendix C* (Tables C-1 and C-2).

- Data for the Porgera mine were obtained from the Annual PJV Statistical Report (2013). *Appendix C* (Tables C-3 to C-6) presents the historical financial and tax revenues from the Porgera gold mine.

- Ok Tedi Mining Limited's (OTML) financial and taxation database for the 1982-2013 periods were accessed through the PNG Chamber of Mines and Petroleum. The Ok Tedi mine compiles annual statistical information specifically at the request of the PNG Chamber of Mines and Petroleum. *Appendix C* (Tables C-7 to C-12) presents the historical financial and tax revenues from the Ok Tedi mine.

- Details of PNG's mining taxation regime were retrieved from the Department of Mineral Policy and Geohazard Management (DMPGM) **(**Table 3.8).

The actual financial and tax data and conceptual data derived using the theoretical models described in Section 3.4 were converted into functional variables that measured the tax performance.

3.5 Defining the functional variables

This section describes the functional variables indexed to measure the theoretical and historical performance of tax instruments as presented in Chapters 4 and 5. These variables were described in Section 2.3 (Chapter 2).

a) ***Tax Progressivity Index (TPI)*****:** Dependent ratio variable. The TPI is a tool used to assess the performance of tax instruments using interval data (Roach 2003). A tax instrument is said to be progressive if the marginal tax rate increases relative to an increment in the tax base. Likewise, a tax instrument is said to be regressive if the marginal tax rate decreases or remains unchanged as the tax base increases (e.g. constant statutory tax rates) (Boadway and Keen 2010). Further, a subset of the regressive category is ‘regressive progression’, which describes a progressive tax that behaves regressively under certain conditions (Govori 2015). Given these definitions, TPIs were computed using the Stroup Index (Stroup 2005) (equation (2.1)). The following criteria were applied to interpret the degree of tax progressivity (regressivity) as depicted in Figure 3.7:

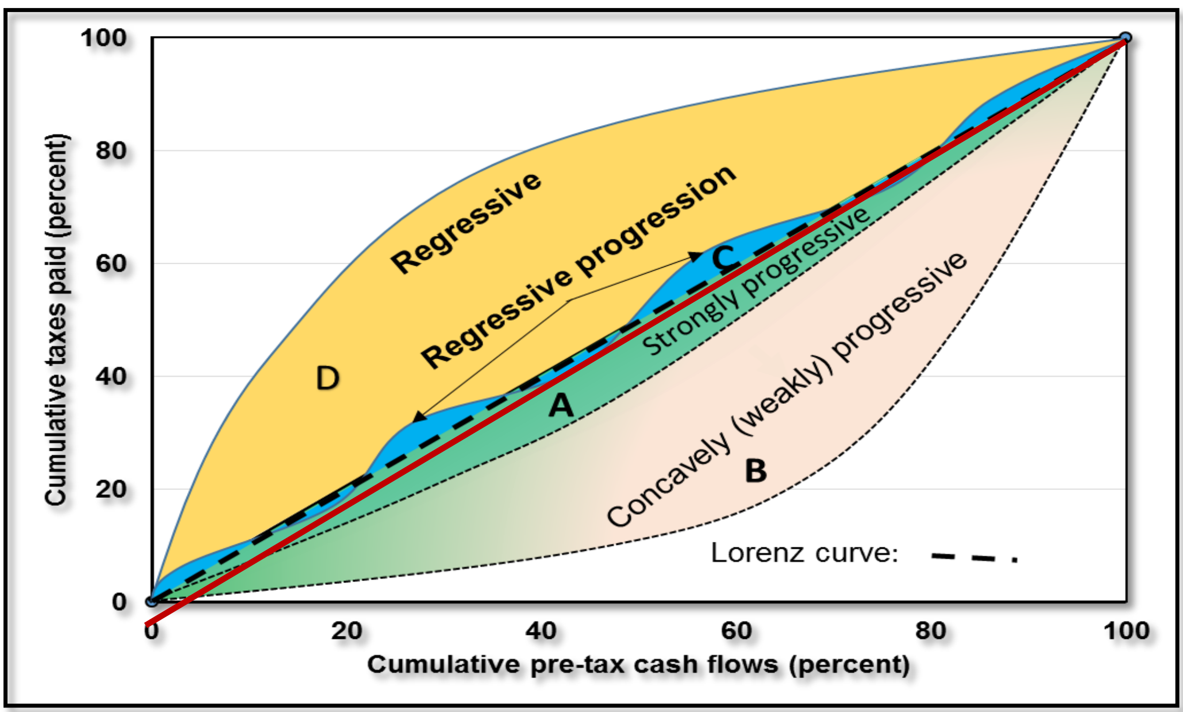


Figure 3.7: Lorenz curve showing the degrees of progressivity.

(i) Perfect linear progression (proportional progression): TPI = 0;

Condition: *equilibrium*

- If the TPI = 0, the tax progressivity is said to attain perfect equilibrium. In this condition, tax burden and government’s share of tax revenues are proportional to the profit-making ability of a mining project. It is represented by the red curve running parallel to the Lorenz curve (broken line in Figure 3.7). With reference to equation (2.1), the TPI = 0, which is given by (1-(CTR_t/CTB_t)) = (1-1) = 0, when CTR_t = CTB_t

This condition is known as perfectly linear progression where a tax curve runs parallel with the Lorenz concentration curve.

(ii) Degrees of progressivity when TPI>0;

***Condition**: linear degree of progressivity*

- Under the condition in which the TPI > 0, a decreasing area under the Lorenz curve reflects a tax instrument that is strongly progressive and has reached linear progressivity (see Zone *A* in Fig. 3.7). Tax curves within zone *A* are strongly progressive where the METR and progression coefficients remain relatively stable irrespective of the changes in the tax base (Kremer and Stähler 2016). Tax instruments within the optimal progressivity area (boundary) capture a high magnitude of tax revenues (Fig. 3.7).

***Condition**: weak degree of progressivity*

- Under the condition in which the TPI > 0, the area between the tax curve increases and the tax curves shift downward (concave) from the Lorenz curve. This condition is said to be weakly or concavely progressive when the tax curves fall within zone *B* (see Fig 3.7). The term non-linear is used to mean that a tax curve bends downwards further away from the Lorenz curve (Mankiw, Weinzierl and Yagan 2009).

(iii) Regressive progression: $\pm$TPI;

***Condition:** low degree of regressive progression*

- If the TPIs are postive and eventually become negative ($\pm$TPI) over time, the tax curve will be slightly above or below the Lorenz curve. A tax instrument under this condition is said to behave regressively progressive (notation *C* in Figure 3.7). This condition could reflect an overpayment situation since profit-based progressive tax instruments do not normally behave regressively. Additionally, this condition could be due to a time lag effect arising from mismatched tax-base with delayed tax payments.

(iv) Regressive: -TPI

- If the TPIs are less than zero (TPI < 0), the tax curves lie above the Lorenz curve. This condition is regressive and represented by the notation *D* in Figure 3.7. This is a common behaviour for levies, excise and duties.

(v) Absolute progression: TPI =1

- If the TPI = 1, a tax instrument is at an absolute neutrality stage. This situation arises when the post-tax base is zero leading to the TPI = 1, (i.e., 1-($CTR_t/CTB_t = 0$)). This is a neutrality condition, which is rare and, is similar to the condition where the METR equals zero (the absence of tax instruments) as explained below.

b) ***Marginal Effective Tax Rate (METR)***: Dependent ratio variable. The METR is an economic variable used to assess the cumulative distortion of an entire tax system (Chen 2000). It measures distortion to the ability of the capital invested to add economic value by producing the last unit of output (Gillen and Gados 2007). A zero METR reflects the situation where a tax instrument does not distort the invested capital. If the pre-tax IRR equals the post-tax IRR, the tax system is said to be purely neutral. That is, when the $IRR_{pre-tax\ base}[a]$ = $IRR_{post-tax\ base}[b]$, the METR = 0 in equation (2.3) (e.g., [a-b]/a =0). This reflects a pure neutral condition in which tax instruments are absent.

However, in the presence of taxes, the METR must be greater than zero (METR > 0). If the reduction in the post-tax IRR is small compared to the pre-tax IRR, the METR will be lower than the statutory rates (Fullerton 1983). Given such scenarios, the tax instruments are said to underperform in their attempts to capture the incremental rents. On the other hand, if the reduction in the post-tax IRR is higher than the pre-tax IRR, the METR will be high. This may reflect that a government is over-taxing the industry (Gillen and Gados 2007). This study will identify the ideal METR for the mining industry by measuring the net effective tax rate.

c) ***Net Effective Tax Rate* (*NETR*)**: Dependent ratio variable. The NETR is a residual tax rate after accounting for tax adjustments. It measures the net tax burden faced by an investor and the exact amount of revenues that would be collected after accounting for possible fiscal leakages and trade-offs. Musgrave (1959) identifies *1-TPI* as a measure of residual progression. In relation to this, the NETR is computed as a product of the METR, residual progression (*1-TPI*), and the proportion of actual tax revenues paid (T_{PATP}/T_{TTP}).

$$NETR = \text{METR x } (1 - \text{TPI}) x\ T_{PATP}/T_{TTP} \qquad (3.32)$$

Where NETR = net effective tax rate
METR = marginal effective tax rate (METR)
$1 - \text{TPI}$ = residual progression coefficient
$\text{T}_{\text{PATP}}/\text{T}_{\text{TTP}}$ = proportion of revenues collected from an individual tax revenues paid divided by total tax revenues paid

Tax revenues are paid to the government after accounting for revenue leakages through sources such as tax holiday, profit and asset transfers, over-capitalisation and weak tax administration (Guj et al. 2013). Hence, factoring the actual tax revenues paid by the residual progression coefficient and METR gives a true measure of the effective tax rate. The factoring process makes the theoretical NETR to be slightly lower than the METR. An advantage of the NETR is that it can measure the effective tax rate for individual tax instruments, while the METR measures the overall tax burden. Note that the METRs of individual tax instruments can be measured as demonstrated by Chen and Mintz (2015*b*).

A validity test was required to assess the usefulness of the NETR that can be reliably used for tax policy analysis purposes. To illustrate how the NETR was computed, the financial and tax estimates and the functional variables were computed using the conceptual data derived using the RO CFT model as shown in Table 3.9. Also, historical data from the former Bougainville and the existing Ok Tedi copper and the Porgera gold mines were used to compute the variables required for equation (3.32) to derive the real NETR.

Table 3.9: Illustrative computations of the NETR for CIT using equation (3.32)

Variable	Theoretical*	Historical	Remarks
METR*	0.45	0.34	PNG's mining industry average METRs
TPI	0.0485	0.33	PNG's mining industry average TPI for CIT
T_{PATP}/T_{TTP}	70	70	CIT is about 70 percent of the total direct taxes (Chen and Mintz 2013)

Theoretical NETR for CIT:

$NETR =$ METR x $(1 - TPI) x\ T_{PATP}/T_{TTP}$ = 0.45 x (1-0.0485) x 70% = 30% = CIT rate

Historical NETR for CIT:

$NETR =$ METR x $(1 -$ TPI$) x\ T_{PATP}/T_{TTP}$ = 0.34 x (1-0.33) x 70% = 16% ≠ CIT rate

Source*: see* Tables 4.3 and 5.9 (Chapters 4 and 5) and *1-TPI* is the progression coefficient (Musgrave 1959). *METR is used as percentage point in order to derive the NETR

Table 3.9 presents the illustrative computations of the NETR using the variables derived from the theoretical model and historical data for the samples of mines in PNG. A proof of the NETR being a reliable variable is that it must be equal to the statutory CIT rate. In this case, the theoretical NETR is equal to the statutory CIT rate of 30 percent, which proves that the residual effective tax rate is reliable. This result suggests that under risk-neutral conditions (no fiscal leakages), a government can collect revenues at the conceptual NETR equal to a statutory rate. Alternatively, the real NETR for the CIT is lower than the statutory rate, which reflects that the CIT does not always capture 100 percent of the taxable incomes.

As the TPI moves closer to linearity (TPI = 0), the NETR approaches the statutory tax rate (e.g., NETR for the CIT= 30 percent). If the TPI is large (> 0.2), the METR declines and the NETR would correspondingly fall below the statutory rate. On the other hand, the METR and TPI will be zero only if the government does not tax the mining industry. The following criteria are used:

- *NETR* = statutory tax rate: reflects the tax system (or tax instrument) has the capacity to collect 100 percent of the taxable revenues.

- *NETR* < statutory tax rate: reflects the tax instrument (or system) is weak in collecting 100 percent of the taxable income. This condition will be featured by high progressivity indices (TPI), concaved progressivity curves against the Lorenz curve and a low METR (less tax revenues collected).

- *NETR* > statutory tax rate: reflects the industry is being over-taxed, beyond the ability to pay.

d) ***Average Effective Tax Rate (AETR*)**: Dependent ratio variable. This variable measures the tax burden placed on the mining industry (Otto 2000). However, it is not an effective measure of tax burden faced by investors. Since most tax rates are constant, changes in the tax base can cause the AETR to increase (decrease) and may not clearly show whether a tax system is attractive or not (Gordon, Kalambokidis and Slemrod 2003). Further, the AETR does not measure the burden associated with the marginal increases in the tax rate. Some important aspects of the AETR were explained in Section 2.3 (see equation 2.2).

e) *Measuring investor returns and wealth transfer rates*

(i) Effective Wealth Transfer (EWT) *rate*: Ratio variable. This variable measures the rate at which a portion of the gross revenue is captured by the tax system, including the non-tax benefits. The EWT rate is significant for two reasons. First, the EWT rate measures the cumulative cash transfers including transport, economic and social capitals that are not captured by the direct tax instruments. The TPI, METR and NETR omit these wealth transfers in the evaluation processes (Loayza and Rigolini 2016). Confining a study to direct tax instruments only undervalues the aggregate wealth transfers to the community (O'Faircheallaigh 2012), which is biased towards investors who make commitments in meeting the social needs of local communities (Yakovleva 2017).

Second, policy decisions are often influenced by the actual minerals produced, price, costs and actual revenue flows to the government. Hence, the EWT rate captures the actual aggregate wealth transfers relative to the gross outputs and measure the entire benefit distributions amongst investors, capital and factor providers and governments.

(ii) Effective investor transfer (EIT) rate: Ratio variable. This variable is a ratio of post-tax CFs to the gross revenues, which is a measure of profit transfers to an investor after the risk allocations. The EIT rate distinguishes the manner in which the second-best neutrality distributes different types of rents to the stakeholders. That is, quasi-rents flow to capital and input factor providers, profits flow to investors, and tax and other benefits flow to a nation as a whole. It is computed by dividing the post-tax cash flows by the gross revenues to grasp a clear picture of how much gross output flows to the investor.

Although the EWT and EIT rate calculations are simple, these variables answer the question of how much of economic rents flow to the investor and how much of the resource revenues are transferred to the society after considering the distributions of economic rents and quasi-rents to suppliers of inputs to production (Magno 2015). The EWT and EIT rates were used in conjunction with the TPI, METR and NETR for analysing the overall performance of the tax instruments.

3.6 Limitations

The lack of data from government institutions such as the Internal Revenue Commission (IRC), and relying on the data provided by mining companies could weaken the interpretation of the results and policy recommendations. The bottom-up data assimilation employed by the mining companies could introduce concerns around the validity and accuracy of the data. Government tax authorities in PNG do not perform regular tax audits, especially the source-based indirect and non-tax benefit redistribution to host region communities (Banks 2006). However, the database created by the mine operators can be considered reliable because investors attempt to improve social responsibility reporting by making data available to the government authorities (Fernandez-Feijoo, Romero and Ruiz 2014).

Another limitation is that the theoretical and historical data did not represent external factors that could influence the performance of the tax instruments. Complex interactions and competitive behaviours of investors, governments, and community can also affect both rent and tax revenue collection objectives. Additionally, the existence of multiple factors such as the market price and deposit quality (Maybee, Lowen and Dunn 2010) affect the performance of tax instruments.

Generally, the historical data could be affected by information asymmetry, cost and revenue shifting, weak tax administration coupled with tax concessions, reduce tax rates through tax competition, over-investments and tax credits could cause leakages in the aggregate revenues that flow to a government. These factors are complex to capture and quantify in a theoretical model. Moreover, the conceptually estimated and historical data rigidly trace the future and past tax performances only and do not cogently explain the manner in which tax payers adapt and behave towards a tax system (Smith 2013).

3.7 Summary

The theoretical tax model resembles a typical risk-based economic modeling of a mining project at the feasibility stage to derive the financial and tax data required for computing the functional variables. This was achieved by using the GBM technique to forecast the copper prices, and the bionomial lattice technique to forecast the gold prices and operating costs, which led to develop the RO CFT method withn which the tax instruments were inserted. The theoretical tax modeling was necessary to derive a stochastic tax base to ensure the revenue projections were representatively distributed over the life of a mining project. Additionally, the historical financial and tax data extrapolated the performance of the tax instruments between 1972 and 2013. An advantage of the parallel analysis is that a comparative analysis of the performance of tax instruments can be made at different points in time.

As mentioned in Chapters 1 and 2, there is a lack of developing techniques to measure the performance of a progressive tax system. In response to that, this study used the structural progressivity technique to simultaneously track the actual degree of tax burden and benefit distributions in terms of governments capturing revenues over the life of a mining project. Tracking the burden and fiscal benefit distribution patterns using the Lorenz curve and progression coefficients assisted in identifying the effects of supply-cycles, tax reforms and fiscal leakages. The results are presented in the proceeding chapters.

Chapter 4 : Theoretical Tax Analysis

This chapter presents the results of the theoretical tax analysis described in Chapter 3. The financial and tax data presented in *Appendix B* were derived using the RO CFT and MC-CFT methods in Microsoft Excel^{TM} described in Chapter 3. These data were used to compute the theoretical progressivity indices and other functional variables. The progressivity indices for each of the tax instruments were averaged and weighted to obtain the statistical results. The METR, NETR, AETR and wealth transfer rates were computed using the equations given in the previous chapter.

Section 4.1 presents the results of the direct tax analysis. Section 4.2 performs series of simulations to examine the effects of tax adjusting techniques such as tax depreciation, tax holiday, and thin capitalisation polices on tax progressivity. Section 4.3 simulates the price and tax rates using the RO CFT method to test the distribution of tax burdens and identify the ideal level of the functional variables and the CIT rate. Section 4.4 simulates the combinations of basic tax instruments with the quasi-taxes (equity participation, APT and profit-based royalty) to examine what constitutes a suitable combination of the direct tax instruments. Section 4.5 provides a summary of the chapter.

4.1 Performance of direct taxes

Table 4.1 presents the TPIs for the royalty and the levies applicable to the mining sector in PNG. The RO CFT method derived a TPI of 9.90×10^{-6} for the NSR ad valorem royalty. The strong progressivity of the ad valorem royalty demonstrates it has the capacity to respond to marginal increases in the gross revenue. The total average TPIs for royalty including the MRA levy and SSG remained unchanged (9.90×10^{-6}), reflecting their strongly progressivity behaviours. The TPIs for the SSG and MRA levy were similar to TPIs for the ad valorem royalty since the net NSR technique was used.

Table 4.1: TPI for royalty and levies

	RO CFT Method			Total		MC-CFT Method			Total	
Year	Royalty (*a*	MRA Levy	SSG (*c*)	(*a*+*b*+*c*)	FPPE (*d*)	Royalty	Levies	SSG	(*a*+*b*+*c*)	FPPE (*d*
2016										
2017	1.40E-05	1.40E-05	1.40E-05	1.40E-05	na	0.0014	0.0014	0.0014	0.0014	na
2018	1.71E-05	1.71E-05	1.71E-05	1.71E-05	na	-0.0070	-0.0070	-0.0070	-0.0070	na
2019	1.51E-05	1.51E-05	1.51E-05	1.51E-05	na	-0.0022	-0.0022	-0.0022	-0.0022	na
2020	1.89E-05	1.89E-05	1.89E-05	1.89E-05	na	-0.0005	-0.0005	-0.0005	-0.0005	na
2021	2.31E-05	2.31E-05	2.31E-05	2.31E-05	na	0.0023	0.0023	0.0023	0.0023	na
2022	1.72E-05	1.72E-05	1.72E-05	1.72E-05	na	-0.0018	-0.0018	-0.0018	-0.0018	na
2023	1.42E-05	1.42E-05	1.42E-05	1.42E-05	na	-0.0038	-0.0038	-0.0038	-0.0038	na
2024	1.77E-05	1.77E-05	1.77E-05	1.77E-05	na	-0.0044	-0.0044	-0.0044	-0.0044	na
2025	1.38E-05	1.38E-05	1.38E-05	1.38E-05	na	-0.0032	-0.0032	-0.0032	-0.0032	0.8544
2026	1.08E-05	1.08E-05	1.08E-05	1.08E-05	na	-0.0015	-0.0015	-0.0015	-0.0015	0.6712
2027	8.26E-06	8.26E-06	8.26E-06	8.26E-06	0.7957	-0.0033	-0.0033	-0.0033	-0.0033	0.5448
2028	7.13E-06	7.13E-06	7.13E-06	7.13E-06	0.6497	-0.0030	-0.0030	-0.0030	-0.0030	0.4470
2029	5.21E-06	5.21E-06	5.21E-06	5.21E-06	0.5195	-0.0020	-0.0020	-0.0020	-0.0020	0.3414
2030	4.10E-06	4.10E-06	4.10E-06	4.10E-06	0.4146	-0.0014	-0.0014	-0.0014	-0.0014	0.2728
2031	3.12E-06	3.12E-06	3.12E-06	3.12E-06	0.3136	-0.0016	-0.0016	-0.0016	-0.0016	0.2093
2032	3.01E-06	3.01E-06	3.01E-06	3.01E-06	0.2342	-0.0015	-0.0015	-0.0015	-0.0015	0.1532
2033	2.27E-06	2.27E-06	2.27E-06	2.27E-06	0.1649	-0.0016	-0.0016	-0.0016	-0.0016	0.1126
2034	2.21E-06	2.21E-06	2.21E-06	2.21E-06	0.1048	-0.0017	-0.0017	-0.0017	-0.0017	0.0694
2035	8.15E-07	8.15E-07	8.15E-07	8.15E-07	0.0472	-0.0008	-0.0008	-0.0008	-0.0008	0.0327
2036	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Average	9.90E-06	9.90E-06	9.90E-06	9.90E-06	0.3244	-0.0020	-0.0020	-0.0020	-0.0019	0.3372

The average TPI for royalty derived using the MC-CFT model was -0.0020 and the average of the total was -0.0019. The negative indices show that at times the ad valorem royalty and levies became regressively progressive. The variations in the TPIs were due to the recursive and random behaviours of the input variables. The recursive and random behaviours of the MC simulation caused the tax base to return negative and positive values every time a cell within the Microsoft Excel™ was activated. Its activation spontaneously sampled the price and costs that in turn increased the cumulative royalty and levy payments that were slightly over 50 percent relative to the cumulative gross revenues, resulting in the negative TPIs (Figure 4.1).

Unlike the production-based royalties, the TPIs for FPPE (0.3244 and 0.3374) were derived from the respective methods. These TPI values reflect the FPPE progressivity is weak and not capable of capturing the dividends as expected. In this thesis, the FPPE was modeled by allocating 18 percent (the FPPE rate) of the gross revenues that were expensed against the mining company’s pre-tax expenditures (e.g., royalty, depreciation deductions and operating costs). This procedure correctly represented all the costs being refunded to a mine operator before expensing the balance of FPPE cash flows against equivalent cost of acquiring the equity interests. This process delayed accessing the dividends, which resulted in high TPIs (e.g., 0.3244) or weak progressivity as reflected in Figure 4.1.

The tax base did not influence the dividend generating ability of the FPPE. Rather, it relied on the government’s ability to source the capital cost of acquiring the equity interests and prudent management of the equity cash flows. Further, the time series TPIs for the FPPE were excluded from grouping along with that of royalty and levies to avoid weakening the total progressivity of those levies and profit-based taxes as shown in Table 4.2. The exclusion of FPPE was partly reasonable since the GoPNG considers equity participation as a policy and not a tax instrument.

Table 4.2: Tax progressivity indices (TPIs) for profit-based taxes

					RO CFT Method		TOTAL		RO-MC CFT method					TOTAL
Year	**CIT**	**PBR**	**FPE**	**FCE**	**DWT**	**APT**	**D/TAXES**	**CIT**	**PBR**	**FCE**	**FPE**	**DWT**	**APT**	**D/TAXES**
2016														
2017	**0.4043**	na	na	na	0.4043	na	**0.4187**	**0.0330**	na	na	na	0.0330	na	**0.1890**
2018	**0.2215**	0.5152	na	na	0.2215	na	**0.2507**	**0.0330**	0.4847	na	na	0.0330	na	**0.1890**
2019	**0.1549**	0.3385	na	na	0.1549	na	**0.1877**	**0.0330**	0.3353	na	na	0.0330	na	**0.1890**
2020	**0.1175**	0.2404	na	na	0.1175	na	**0.1534**	**0.0330**	0.2871	na	na	0.0330	na	**0.1890**
2021	**0.0950**	0.1813	na	na	0.0950	na	**0.1313**	**0.0330**	0.2320	na	na	0.0330	na	**0.1890**
2022	**0.0781**	0.1381	na	na	0.0781	na	**0.1158**	**0.0330**	0.1652	na	na	0.0330	na	**0.1890**
2023	**0.0662**	0.1078	na	na	0.0662	na	**0.1057**	**0.0330**	0.0972	na	na	0.0330	na	**0.1890**
2024	**0.0581**	0.0871	na	na	0.0581	na	**0.0987**	**0.0330**	0.1053	na	na	0.0330	na	**0.1890**
2025	**0.0521**	0.0716	na	na	0.0521	na	**0.0929**	**0.0330**	0.1317	na	na	0.0330	na	**0.1890**
2026	**0.0471**	0.0588	na	na	0.0471	na	**0.0874**	**0.0330**	0.1179	na	na	0.0330	na	**0.1890**
2027	**0.0423**	0.0476	na	na	0.0423	na	**0.0839**	**0.0330**	0.1340	0.8221	na	0.0330	na	**0.1470**
2028	**0.0389**	0.0392	na	0.8436	0.0389	na	**0.0806**	**0.0330**	0.1292	0.6871	na	0.0330	na	**0.1150**
2029	**0.0359**	0.0319	na	0.6733	0.0359	na	**0.0781**	**0.0330**	0.0808	0.5199	na	0.0330	na	**0.0754**
2030	**0.0335**	0.0261	na	0.5360	0.0335	na	**0.0756**	**0.0330**	0.0659	0.4115	na	0.0330	na	**0.0498**
2031	**0.0312**	0.0208	0.7649	0.4100	0.0312	na	**0.0735**	**0.0330**	0.0564	0.3354	0.7500	0.0330	na	**0.0318**
2032	**0.0294**	0.0096	0.5714	0.3063	0.0294	na	**0.0719**	**0.0330**	0.0721	0.2465	0.5777	0.0330	na	**0.0107**
2033	**0.0278**	0.0067	0.4026	0.2158	0.0278	na	**0.0706**	**0.0330**	0.0709	0.1927	0.4274	0.0330	na	**-0.0020**
2034	**0.0264**	0.0043	0.2559	0.1372	0.0264	na	**0.0691**	**0.0207**	0.0664	0.1267	0.2994	0.0207	0.6253	**0.0002**
2035	**0.0119**	0.0020	0.1154	0.0619	0.0119	0.4509	**0.0564**	**0.0087**	0.0545	0.0664	0.1207	0.0087	0.2633	**0.0032**
2036	**0.0000**	0.0000	0.0000	0.0000	0.0000	0.0000	**0.0000**	**0.0000**	0.0511	0.0000	0.0000	0.0000	0.0000	**0.0000**
Average	**0.0827**	0.1071	0.4220	0.3980	0.0827	0.4509	**0.1212**	**0.0311**	0.1493	0.3787	0.3625	0.0311	0.4443	**0.1222**

Table 4.2 shows the TPIs for FCE were consistently positive, and the indices were high across the calculation methods (0.3980 and 0.3762) and that of the FPE were 0.4220 and

0.3608 respectively. The high TPIs reflect that the FCE and FPE are weakly progressive and demonstrate that they generate small amount of dividends. The performance of the FCE and FPE were identical in some cases where the curves bowed away from the Lorenz curve. The FPPE, FCE and FPE exhibited weak progressivity to demonstrate that they are not efficient in capturing the dividends as expected compared with the other tax instruments, (Figure 4.1).

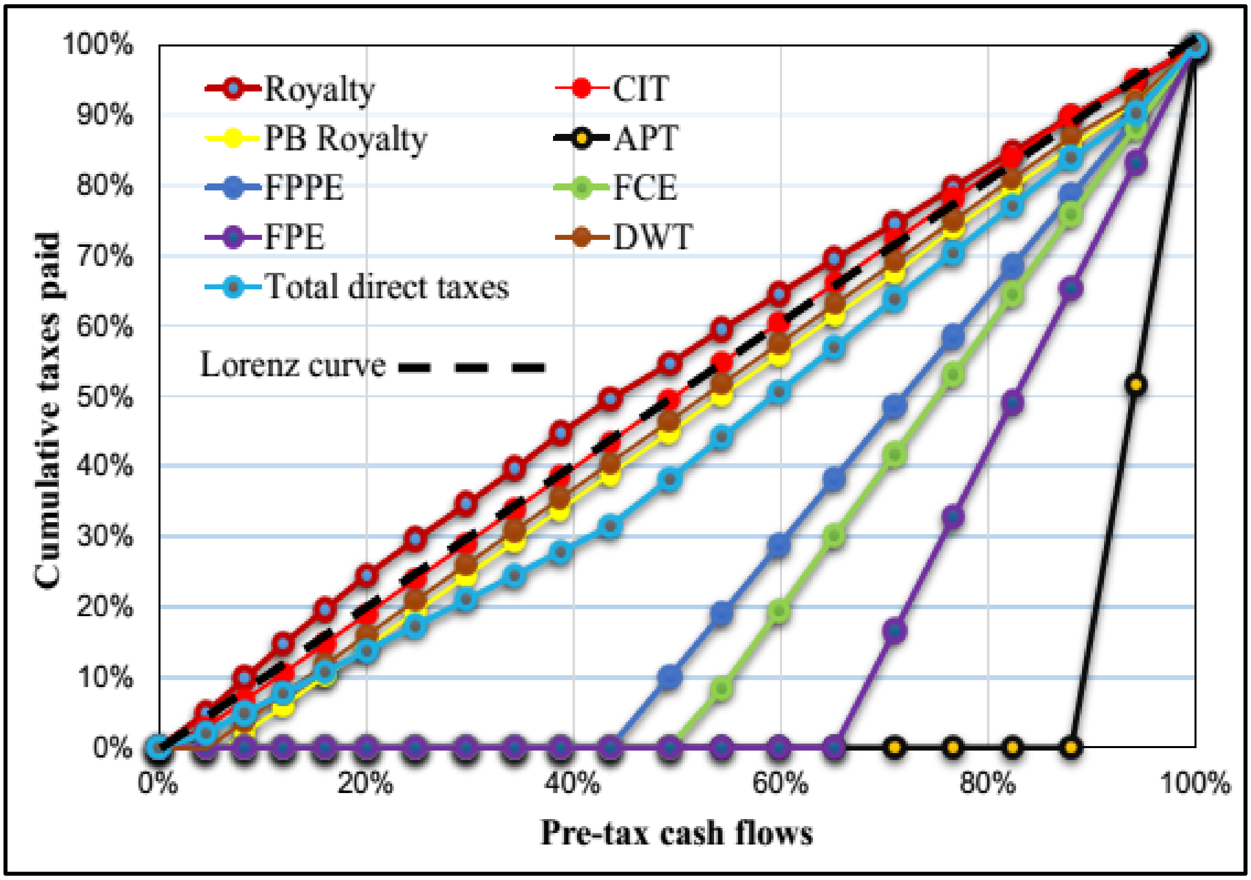


Figure 4.1: Progressivity curves for taxes plotted against the Lorenz curve.

Figure 4.1 is a graphical representation of the TPIs presented in Table 4.2. The x-axis and y-axis are the cumulative pre-tax cash flows and the cumulative taxes paid respectively are plotted against the Lorenz curve. The FCE and FPE curves followed along the x-axis for some time before turning upward from left to right. These curves being parallel with the x-axis before turning away from the Lorenz curve is due to delays in accessing the equity dividends. Further, in Table 4.2, the TPIs for APT were consistently positive and high for both calculation methods (0.4509 and 0.4389). Moreover, a simulation of the threshold rates was required to observe the behaviour of the APT as shown in Figure 4.2.

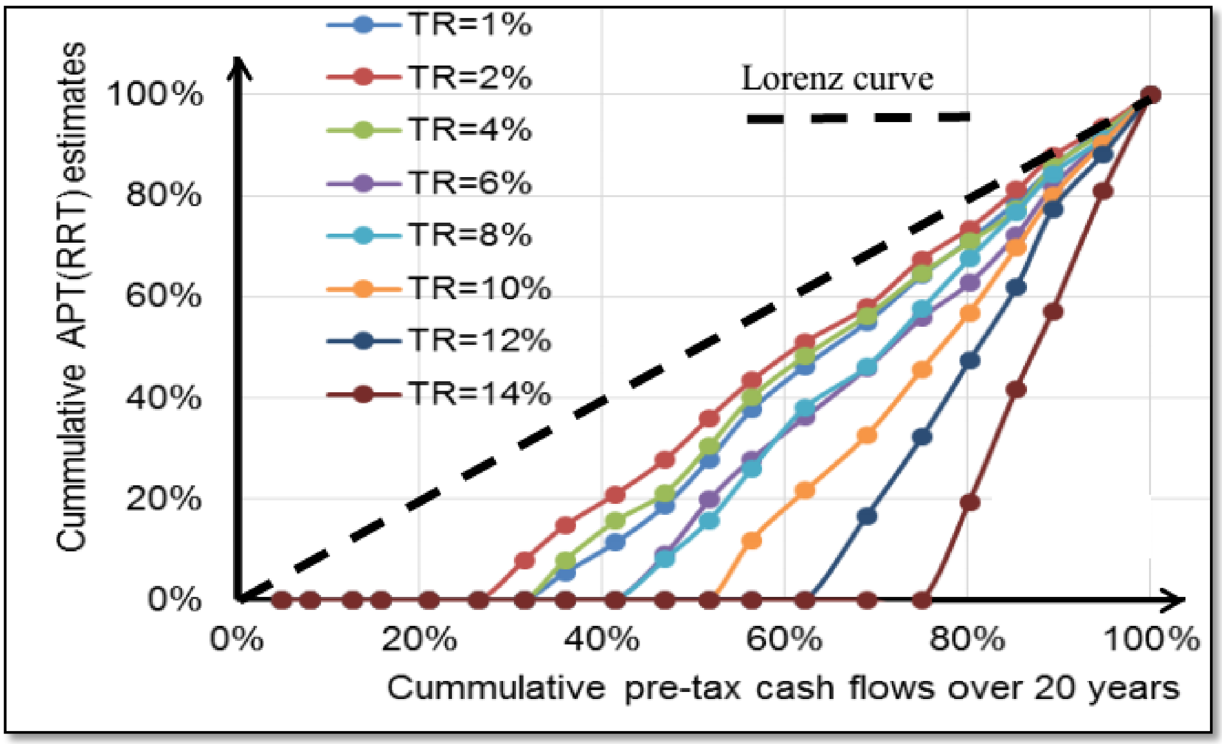


Figure 4.2: Simulations of threshold rates for the APT

In Figure 4.2, the APT progressivity curves were plotted against the cumulative pre-tax cash flows for threshold rates ranging from 1 to 20 percent. This study used the 10 percent threshold rate, which was lower than an 11 percent IRR of the Frieda deposit. Yet, the progressivity of APT was weak. The progressivity curves moved further away from the Lorenz curve as the threshold rates increased up to 14 percent: a point at which the mine was unable to generate the APT revenues as expected. This shows that a threshold rate higher than 14 percent could not capture the desired excess profits. On the other hand, threshold rates between 10 and 13 percent captured a low magnitude of APT revenues as it was the case with the Frieda deposit. Further simulations show the progressivity of APT improves when the FPPE was excluded in the RO CFT model. Similarly, combining the FPPE with the direct taxes weakened the progressivity of CIT and other basic tax instruments.

Table 4.2 shows the TPIs for CIT were consistently positive (0.0827 and 0.0320) and strongly progressive. This result is also reflected in Figure 4.1, where the CIT curve and the Lorenz curve are approximately parallel to each other. Further, the theoretical NETR for CIT is 30 percent [0.45*(1-0.0576)*70], which is equal to the statutory CIT rate. In this calculation, the 45 percent (0.45) is the industry level theoretical METR (see Table 4.3) and 0.0576 is the average TPI for CIT at the industry level. Further, the behaviour of DWT was similar to the CIT with positive indices resulting from both calculation methods (0.0320) (Table 4.2). These results indicate that both CIT and DWT being strongly progressive would generate higher magnitudes of revenues when compared to equity participation and RRT.

The TPIs for profit-based royalty (PBR) were also positive for both calculation methods (0.1071 and 0.1487) (Table 4.2). The progressivity index derived using the RO CFT method was higher (weaker) than that of the MC-CFT method. In both cases, the progressivity curve for the PBR being close to the Lorenz curve (Fig. 4.1) shows that it is capable of generating a substantial amount of revenues. However, the results were slightly biased due to the whole of life tax base of the Frieda deposit modelled being consistently positive, which may not reflect the actual scenarios.

Table 4.3: Theoretical METRs for the RO CFT and MC-CFT methods.

Year	RO-CFT method Free CF ROR (%)	Pre-tax ROR(%)	Post-Tax ROR	Direct Taxes METR	Royalty METR	ETR (%)	MC-CFT method Free CF ROR (%)	Pre-tax ROR (%)	Post-Tax ROR (%)	Direct Taxes METR	Royalty* METR	ETR (%)
2016												
2017	-69	-86	-96	**-11**	-1	78	-68	-86	-93	**-8**	-1	-8
2018	-25	-58	-73	**-26**	-6	32	-26	-56	-70	**-25**	-6	42
2019	-3	-37	-54	**-45**	-58	33	-3	-41	-56	**-36**	-58	23
2020	10	-23	-39	**-72**	14	35	10	-26	-41	**-57**	14	29
2021	18	-14	-29	**-115**	8	36	17	-16	-30	**-92**	8	31
2022	22	-7	-21	**-225**	6	39	22	-9	-23	**-149**	6	31
2023	25	-2	-16	**-873**	5	40	25	-4	-17	**-299**	5	33
2024	27	2	-12	**781**	4	40	27	0	-13	**-5062**	4	36
2025	29	4	-9	**312**	4	41	28	2	-9	**508**	4	36
2026	29	6	-6	**202**	4	42	29	4	-7	**262**	4	56
2027	30	8	-4	**149**	4	75	30	6	-4	**173**	4	69
2028	31	9	-2	**124**	3	75	30	7	-3	**139**	3	68
2029	31	10	-1	**107**	3	77	31	9	-1	**111**	3	75
2030	31	11	0	**96**	3	79	31	10	0	**99**	3	72
2031	31	11	1	**87**	3	80	31	10	1	**88**	3	76
2032	31	12	2	**81**	3	81	31	11	2	**81**	3	76
2033	32	12	3	**76**	3	82	31	11	3	**76**	3	77
2034	32	13	4	**72**	3	83	32	12	3	**71**	3	78
2035	32	13	4	**68**	3	59	32	12	4	**67**	3	54
2036	32	13	5	**65**	3	51	32	12	5	**63**	3	54
Average	32	16	9	**46**	3	58	32	15	9	**44**	3	50

Pre-tax RORs represent the cash flows without taxes (except royalty); (*b*) post-tax RORs affected by taxes; (*c*) METRs for profit based taxes; (d) METRs for royalty and levies; and (*e*) ETRs include the production levies. *Royalty includes MRA levy and SSG.

Table 4.3 shows the METRs derived from the RO CFT and MC-CFT methods were 46 percent and 44 percent respectively. The RO CFT model derived a higher METR than the MC-CFT model because the latter enhanced random distribution of the tax base. The negative METRs were the results of no taxes paid in the early production years and the accelerated deductions using the ADB depreciation technique. The average theoretical METR calculated for PNG's mining industry is 45 percent [(46+44)/2], which is for the direct tax instruments only, including the royalties and the levies. The METR being a measure of the tax burden, PNG's mining industry is expected to perform at around the 45 percent METR benchmark.

The METRs for royalties stabilised around the 3 percent statutory royalty rate (including MRA levy and SSG) after some variations in early production stages (Table 4.3). The METR for royalty was computed by dividing the difference of the IRRs based on the gross revenues and that of the pre-tax base, which correctly reflected the distortion on capital allocation. A further simulation indicated that existing PNG's royalty of 2 percent reduces the NPV by 5 percent. This meant that for every 1 percent increase in the statutory royalty rate, the NPV is distorted (reduced) by a 2.5 percent.

This thesis devised the NETR as a new variable, which proved to be more efficient in capturing the precise tax burden compared to the AETR. Theoretical NETR for PNG was calculated using the variable specifications made in Section 3.5 (Table 3.9). Given the industry level METR of 45 percent and the corresponding average TPI being 0.121, PNG's theoretical NETR is about 40 percent [0.45*(1-0.121)*100], assuming the tax system captures 100 percent of the taxable profits. Moreover, the NETR was lower than the METR because it was based on the residual progression coefficient that accounted for the revenue leakages within the taxation system. Given a correct set of data, the NETR can precisely measure the tax liability and the actual wealth transfers to the society.

Table 4.4: Distributions of wealth transfer and investor return rates (percentages)

Year	RO CFT method				MC-CFT method			
	Investor EIT (*a*)	Direct Taxes EWT (*b*)	Royalties EWT(*c*)	Total EWT (*d*)	Investor EIT (*a*)	Direct Taxes EWT (*b*)	Royalties EWT(*c*)	Total EWT (*d*)
2016								
2017	**14**	11	3	**14**	**26**	15	3	**18**
2018	**19**	14	3	**17**	**21**	12	3	**15**
2019	**19**	14	3	**17**	**20**	12	3	**15**
2020	**21**	15	3	**18**	**19**	11	3	**14**
2021	**21**	15	3	**18**	**21**	12	3	**15**
2022	**23**	17	3	**20**	**24**	14	3	**17**
2023	**25**	17	3	**20**	**23**	13	3	**16**
2024	**24**	17	3	**20**	**26**	15	3	**18**
2025	**22**	16	3	**19**	**27**	25	3	**28**
2026	**25**	17	3	**20**	**26**	25	3	**28**
2027	**29**	30	3	**33**	**30**	28	3	**31**
2028	**26**	27	3	**30**	**24**	22	3	**25**
2029	**28**	29	3	**32**	**24**	22	3	**25**
2030	**27**	28	3	**31**	**33**	31	3	**34**
2031	**29**	30	3	**33**	**35**	32	3	**35**
2032	**28**	29	3	**32**	**28**	26	3	**29**
2033	**28**	29	3	**32**	**31**	28	3	**31**
2034	**29**	30	3	**33**	**33**	31	3	**34**
2035	**31**	32	3	**35**	**24**	22	3	**25**
2036	**29**	30	3	**33**	**32**	29	3	**32**
Average	**25**	22	3	**25**	**26**	**21**	**3**	**24**

Notes: (*a*) effective investor transfer rate; (*b*) effective wealth transfer to the community through direct taxes; (*c*) effective wealth transfer to the community through royalties; (*d*) total effective wealth transfer through the direct taxes.

Table 4.4 presents the EIT and the EWT rates for the RO CFT and MC-CFT methods showing the distribution of the total values of minerals extracted. The EWT rates presented are for the direct taxes, the ad valorem royalty and the levies only. The average

EWT rates for the direct taxes were 22 and 21 percentages for both methods. The slight variation was due to the highly stochastic nature of the MC-CFT method. On the other hand, the industry level average EWT rate for royalty was about 3 percent, which included the levies, SSG and MRA levy. The RO CFT method derived EIT and EWT rates that were equal to each other (25 percent), although there were slight variations using the MC-CFT method. These theoretical results suggest that there is equality in redistribution of the benefits amongst investors, GoPNG and the community. The reduction in inequality is the result of progressive tax system's ability to fairly distribute rents, tax burden and revenues.

As a synopsis, variable specifications of the conceptual methodology limit the use of policy tools that inevitably narrowed the data analysis in this section. Such limitations neglected some basic policy aspects that are often necessary for practically constructing a taxation design such as the LCF provision, tax holiday and thin capitalisation policies. Thus, further simulations were crucial to broaden the understanding of how these policy tools influence the tax base, the degree of progressivity, and the tax burden distribution associated with price and tax rate changes.

4.2 Tests for effects of tax adjusting techniques on progressivity

There are policy choices for applying the accelerated declining balance (ADB) and straight line (SL) depreciation techniques within the LCF policy, and a 10-year tax holiday and thin capitalisation rule as practiced in PNG. These policy tools were simulated using the RO CFT method to observe the changes in the TPI, METR, EIT and EWT rates and NPV by keeping the copper and gold prices and the tax rates constant (Table 4.5).

The TPIs and other variables under the *base case* in Table 4.5 were derived from the RO CFT method based on Frieda deposit's positive tax base (no cash flow losses). Within the no cash flow loss scenario, when a switch was made to apply the SL depreciation technique, the NPV increased to US$4.04 billion compared to US$3.85 billion derived when the ADB technique was applied. Similarly, the TPI for CIT increased to 0.137 compared to the 0.083 TPI derived using the ADB depreciation technique. These results show that the SL depreciation technique improves the whole of mine life NPV compared to the ADB technique. However, it weakens the progressivity where the government gets less tax revenues in the mature production year if only under a no loss condition exists. The whole of life tax deductibility by the depreciation deductions against the positive tax base after attaining the ROR on investment reduces tax revenues.

Table 4.5: Assessing the effects of SLD and ADB techniques and tax holiday policies

Variables	Dep. techniques		LCF with 3 percent uplift rate				10-year Tax Holiday	
	ADB*	SL	Yr-1	Yr-3	Yr-5	Yr-7	With LCF	Without LCF
TPI for CIT	0.0827	0.0957	0.0857	0.0934	0.1244	0.1851	0.2969	0.3343
TPI for direct taxes	0.1212	0.1263	0.1440	0.1953	0.2263	0.2707	0.4927	0.5145
METR	46	49	50	62	78	94	62	31
AETR	58	54	54	48	49	51	43	58
W/transfer rates								
EIT	25	23	22	18	13	9	18	21
EWT	25	24	24	22	21	20	19	24
Economic Variables								
NPV ($ bln) (i = 5%)	3.75	4.04	2.89	1.27	-0.53	-2.03	1.02	5.2

*Used as a *base case* for this analysis

The effects were offset by high tax liability at the mature production stages despite the ADB technique enhanced rapid capital recovery in the early production periods (high NPV). This reduced the NPV (US$3.85 billion). The ADB technique seems to expedite capital recovery in early periods and strengthens progressivity at mature stages of a mine life through offsetting the effects of NPV gains (losses) and revenue gains (losses) to the government. As well, it was difficult to observe changes occurring in the functional variables because the cash flow losses diluted the effects of the depreciation techniques.

The risk-free interest rate of 3 percent was imposed on the cash flow losses to assess how the cumulative tax credits affect the progressivity of the direct tax instruments. The risk-free interest rate represented the opportunity cost of the cash flow losses in the present investment. To represent realistic scenarios, the simulations were performed by inflating the operating costs by 200 percent to induce the losses to occur over a 7-year period, therefore, initiating a limited LCF policy.

Table 4.5 shows the progressivity of CIT gradually weakened from the *base case* TPI (0.0827 to 0.1869) over successive LCF periods. Similarly, aggregate progressivity of the direct tax instruments weakened with the TPIs sliding from 0.1212 to 0.2707 relative to the Lorenz curve. These results reflect that cumulative cash flow losses with compounded interests weakened the progressivity through a delayed accessing of the tax revenues. On the other hand, cash flow losses reduced the NPVs and the EWT rate exceeded the EIT rate. In high risk or low price scenarios, the LCF with compounded interest rate accumulate tax credits for additional years, which is identical to a tax holiday.

To assess how the progressive tax instruments behave under a negotiated tax holiday, the CIT was omitted in the model for over a 10-year period and simulations were performed with and without LCF scenarios. As shown in Table 4.5, the scenario of tax holiday with the tax base loss significantly weakened the CIT progressivity with a TPI of 0.2969 and that of the total direct taxes was 0.4927. Tax holiday being granted without a tax base loss in this analysis was the worst scenario in which the TPIs of CIT and that of total taxes further weakened (0.3343 and 0.5145). These results reflect that tax concessions granted to profitable mines tend to cause fiscal imbalance by substantial margins as shown by the high NPV (US$5.2 billion) and a low METR of 31 percent. These simulations show that the LCF provision is an efficient form of concession policy compared to a negotiated tax holiday because the latter shields tax instruments from responding to changes in the tax base.

Another major policy tool is the thin capitalisation rule, which ensures excessive debt interest deductions do not reduce the tax base. PNG has a 3:1 ceiling on thin capitalisation (75 percent debt to 25 percent equity capital). However, there is a proposed change to a 2:1 ceiling (50 percent debt to 50 percent equity capital). To test these options, some options for thin capitalisation rules were simulated to identify an ideal ceiling range between the two extremes (100 percent equity and 100 percent debt capital) of financing a mining project (Table 4.6). The scenario simulation of 100 percent equity capital (0:1 ratio) generated the TPI for CIT of 0.0827 and a total TPI of 0.1212, which was identified as an ideal *base case* against other financial arrangement scenarios.

For the 4:1 ceiling, Table 4.6 shows that the TPIs of CIT increased from 0.0827 to 0.088 and the aggregate TPIs for the direct tax instruments increased from 0.1212 to 0.1255. The NPV decreased by a small margin ($3.75 billion to $3.68 billion). These results show that a 25 percent debt to 75 percent equity capital financing arrangement tend to weaken the tax progressivity as well as the NPV from the *base case*.

For the 2:1 ceiling, the TPI for CIT and that of the total direct taxes increased significantly from the *base case* TPI (from 0.1212 to 0.1580). Also, the NPV slightly decreased from the previous *case* and EWT rate exceeded the EIT rate (24 percent > 21 percent), although the IRR increased by substantial margins. These results reflect that a 50 percent debt/equity thin capitalisation policy further weakened the tax progressivity from the *base case* due to increase in the interest deductibility against the tax base.

Table 4.6: Effects of thin capitalisation policy on tax base and progressivity

Debt/Equity ratio	Base case	Thin capitalisation ratios			
	100% equity	25% debt/ 75% equity	50% debt/ 50% equity	75% debt/ 25% equity	100% debt
Ceiling	**0:1**	**4:1 (*a*)**	**2:1 (*b*)**	**3:1 (*c*)**	**1:0**
TPIs:					
-CIT	0.0827	0.088	0.1286	0.1909	0.2513
-Direct taxes	0.1212	0.1255	0.1580	0.2069	0.2878
W/transfer rates:					
-EIT rate (%)	25	24	21	20	20
-EWT rate (%)	25	25	24	23	22
Economic Variables					
-NPV ($ bln) (*i* = 5%)	3.75	3.68	3.51	3.34	3.13

(*a*) Ratio refers to a $1 debt for every $4 equity capital; (*b*) $1 debt for every $2 dollar equity capital; and (***c***) $3 debt for every $4 equity capital.

As for the 3:1 ceiling, the TPI for CIT and that of the total direct tax instruments increased substantially (0.1909 and 0.2878 respectively) and the NPV decreased from the previous *case* ($3.34 billion). Similar trends were observed for the scenario with thinly capitalised investment (100 percent debt financing). In this scenario, the TPI for CIT and that of the combined direct taxes further weakened by substantial margins (0.2513 and 0.2878 respectively) from the *base case*. Also, the NPV was reduced to $3.13 billion from the *base case*.

Table 4.6 shows that as the proportion of debt capital increases, the interest deductibility increases against the tax base, which weakened the CIT progressivity and the NPV. Aside from the two extremes (0:1 and 1:0 ratios), the 2:1 ceiling seems to be an ideal thin capitalisation policy because the tax base erosion is moderate compared to the 3:1 ceiling. This finding contributes towards devising a suitable thin capitalisation rule to protect the tax base that could make the tax instruments more progressive, which could suit government's objective of maximising revenues from the mining industry.

4.3 Sensitivity tests for price and tax rates

The behaviour of progressivity indices are influenced by changes in mineral prices that in turn affect the performance of tax instruments in terms of collecting revenues and also the profitability of a mine. As discussed in Chapters 2 and 3, all the profit-based tax instruments, including the value-based royalties respond to changes in price, tax rates, production rates and operating costs. To test these scenarios, series of price simulations were performed to substantiate the main argument that strong progressivity increases the marginal tax rate. To perform these simulations, the copper and the gold prices were successively increased and decreased in steps of ±25 percent to a minimum of -75 percent and likewise the prices were allowed to increase by 100 percent.

As shown in Table 4.7, when the copper and the gold prices were successively increased to 100 percent, the TPIs of CIT were reduced from the *base case* (0.0827 to 0.0178) and gradually moved towards the Lorenz curve. The similar trend was observed for the TPIs of total direct taxes (0.1212 to 0.0354). Concurrently, the METR and NETR increased by 1 percentage point at each step of increasing the prices by 25 percent. These results show that the marginal tax rate does not increase as expected when progressivity increases during periods of high profit.

Table 4.7: Effects of changes in price and tax rates on variables.

	PERCENTAGE CHANGES Base case (*a*)							
MINERAL PRICE CHANGES	**-75**	**-50**	**-25**	**0**	**25**	**50**	**75**	**100**
TPI for Taxes (*b*)								
- CIT	**na**	**na**	**0.1518**	**0.0827**	**0.0380**	**0.0276**	**0.0217**	**0.0178**
- Dividend Withholding Tax	0.89	0.78	0.1518	0.0827	0.0380	0.0276	0.0217	0.0178
- FPPE	na	na	na	0.0361	0.3189	0.2641	0.2371	0.2025
- Royalty (MRA levy & SSG)	4.00E-05	2.00E-04	1.39E-05	1.04E-05	8.34E-06	6.95E-06	0.0000	5.21E-06
- TPIs for Total Direct taxes	**0.8947**	**0.7812**	**0.1977**	**0.1212**	**0.0694**	**0.0526**	**0.0423**	**0.0354**
- METR (%)	na	na	64	44	44	45	46	47
- NETR (*c*) (%)			51	39	41	43	44	45
- AETR (%)	12	14	46	60	69	77	78	82
Fiscal distribution								
- EIT rate (%)	-251	-32	16	25	30	33	36	38
- EWT (Total Direct taxes) (%)	-29	-4	16	25	31	34	37	39
- NPV ($ billion) (*i*=5%)	-1080	-280	0.59	3.85	7.12	10.38	13.66	16.92
TAX RATE CHANGES								
TPI for Taxes								
- CIT	**0.0609**	**0.0609**	**0.0609**	**0.8270**	**0.0609**	**0.0609**	**0.0609**	**0.0609**
- Dividend Withholding Tax	0.0609	0.0609	0.0609	0.8270	0.0609	0.0609	0.0609	0.0609
- FPPE	0.3605	0.3605	0.3605	0.3605	0.3605	0.3605	0.3605	0.3605
- Royalty (MRA levy & SSG)	1.04E-05	1.04E-05	1.04E-05	1.04E-05	1.04E-05	1.04E-05	1.04E-05	1.04E-05
- TPIs for Total Direct taxes	**0.1425**	**0.1326**	**0.1292**	**0.1212**	**0.0966**	**0.0922**	**0.0887**	**0.0860**
- METR (%)	30	36	41	44	53	59	66	74
- NETR (*c*) (%)	26	31	36	39	48	54	60	68
- AETR (%)	32	40	50	60	73.00	88	106	128
Fiscal distribution								
- EIT rate (%)	33	30	27	25	22	20	17	14
- EWT (Total direct taxes) (%)	18	20	23	25	28	31	33	36
- NPV ($ billion) (*i*=5%)	5.82	5.16	4.51	3.85	3.20	2.55	1.89	1.24

(a) Base case refers to initial results obtained from the RO CFT method; (*b*) APT was omitted because it distorted the TPIs of CIT; and (c) *METR**(*1-TPI*).

These results were further affirmed by slow increases in the METR and the NETR that were offset by large increases in the NPV ($3.85 billion to $16.92 billion) when the prices increased by 100 percent. In this setting, the EWT rate exceeded the EIT rate by about 1 percentage point. The simulated results show that a price-induced strong progressivity reduces inequality and does not necessarily increase the marginal tax rate by substantial margins that can cause a distortion.

On the other hand, as the prices were made to decrease towards a negative 75 percent, the TPIs became distorted and all the other functional variables became unstable. In both cases, there were no negative progression coefficients as the prices were made to increase. This reflect that progressive tax instruments cannot become extremely regressive during low profit periods under those conditions but the historical case may be different due to actual time lag effects as observed in Section 4.1. Further, the AETR increased by large margins as the prices were made to increase. Such a behaviour of the AETR did not correlate well with any of the changes in the TPIs and the METR. The high AETR did not indicate that the marginal tax rate has increased pertaining to the price-induced strong progressivity compared to a tax rate-induced progressivity.

Similarly, some allowances for changes in the CIT rate were made to observe the relationship between progressivity and tax burden that exist when tax rates increase. The objective was to identify the ideal rate for the CIT, progression coefficient range, METR and NETR for PNG’s mining industry. The simulations were carried out by iteratively increasing the CIT rates in steps of 25 percent to a maximum of 100 percent and decrease the *base* CIT rate up to 75 percent. The simulations were performed using the RO CFT method by keeping the other input variables constant.

Table 4.7 shows the TPIs of CIT remained relatively constant when the rate was successively made to increase and decrease. The TPIs of total direct taxes decreased at a slower phase when the CIT rate increased by 100 percent. Likewise, the METR increased by larger margins (44 percent to 74 percent) and the NETR increased from 39 percent to 68 percent. The EWT rate exceeded the EIT rate (36 percent > 14 percent). Also, the NPV decreased from the *base case* ($3.85 billion to $1.24 billion). These results indicate that strong progressivity induced by an increase in the CIT rate significantly increases the marginal tax rate and therefore the tax burden.

When the CIT rate of 30 percent was reduced by 75 percent, the TPIs of direct tax instruments weakened (0.1212 to 0.1425), the NPV increased (from $3.85 billion to $5.82 billion), and the EIT rate exceeded the EWT rate (33 percent > 18 percent). The METR and NETR also decreased by substantial margins. These results suggest that decreases in the CIT rate weakens the progressivity leading to erosion of revenues.

The simulated results led to identify an ideal CIT rate for PNG. A 25 percent reduction in the CIT rate slightly weakened the progressivity (0.1292) from the *base case* and the EWT reduced by 2 percent (28 percent to 25 percent). On the other hand, the increase in the CIT rate by 25 percent increased the METR to 53 percent from the *base case*. These results show 30 percent is the ideal CIT rate for PNG. At the 30 percent CIT rate, the theoretical METR and NETR were 44 percent and 39 percent respectivley, and the EIT and EWT rates were equal at 25 percent. These results were consistent with the results obtained in Tables 4.2 and 4.3. The ideal NETR is around 40 percent and the METR falls within a range between 40 to 45 percent. At these levels, the TPI range between 0 and 0.20 was identified as an effective boundary, which exist below and closer to the Lorenz curve. The tax instruments found within the ideal progresivity boundary tend to capture higher magnitude of tax revenues than those that are outside of the boundary.

4.4 Sensitivity tests for optimal combinations of multiple tax instruments

The objective of this section was to simulate the quasi-tax intruments against the basic tax instruments to identify a suitable mix that could complement with the results found in Section 4.1. The basic tax instruments comprised of the ad valorem royalty, CIT and DWT and the quasi-taxes comprised of the equity participation, APT and PBR. Using the RO CFT method, a series of simulations were performed by adding each quasi-tax instrument to the basic tax instruments by simulating one at a time, along with various other combinations. The simulated results are presented in Table 4.8.

Basic taxes (Royalty, CIT and DWT)

The TPI for the basic tax instruments was close to the Lorenz curve (0.0852), and the corresponding METR and AETR were 35 and 48 percent respectively. These results show the tax burden faced by the investors is low without introducing the quasi tax instruments. Similar results were observed where the EIT rate exceeded the EWT rate by 6 percent (30 percent > 24 percent). The TPI, METR, EIT and EWT rates indicate that the basic tax instruments alone could be reasonable under the risk-neutral conditions for adopting a simplified taxation regime to attract foreign direct investments. That said, the low METR also left an opportunity for other quasi-tax combinations to raise it to a reasonable level.

Table 4.8: Results for combinations of multiple taxes.

	Combinations of basic and quasi taxes							
	Basic	***Case 1***	***Case 2***	***Case 3***	***Case 4***	***Case 5***	***Case 6***	***Case 7***
	Taxes	***APT***	***FCE***	***FPE***	***FPPE***	***APT &FPPE***	***PBR***	***APT,FPE &PBR***
TPIs for Quasi Taxes		(0.3980)	(0.3993)	(0.42203)	(0.3605)	(0.4551; 0.3605)	(0.111)	(0.385;0.422 &0.111)
TPIs for Basic Taxes								
- CIT	0.0498	0.0498	0.0498	0.0498	0.0609	0.0609	0.0475	0.1130
- DWT	0.0498	0.1120	0.0498	0.0498	0.0609	0.0280	0.0475	0.1130
- Royalty (MRA levy & SSG)	1.04E-05	1.04E-05	0.0000	1.04E-05	1.04E-05	1.04E-05	1.04E-05	1.04E-05
- Total Direct taxes	0.0852	0.0688	0.0890	0.0864	0.1024	0.2200	0.0826	0.1910
- METR (%)	35	40	46	45	47	48	36	53
- AETR (%)	48	62	62	60	60	65	46	79
Fiscal distribution (%)								
- EIT rate	30	26	25	25	25	24	31	22
- EWT (Direct taxes & royalties)	24	28	26	25	25	26	21	26
- NPV ($ bln) (*i* =5%)	5.25	4.49	3.89	3.89	3.85	3.71	5.42	3.30

Case 1*: *Basic taxes plus additional profit tax (APT)

When the APT was added to the basic instruments, the total TPI slightly rose to 0.0688, which reflected that the APT weakens the total progressivity. However, the TPI for CIT remained steady (0.0498) because the APT was imposed on the net CF after imposing the CIT. Since the TPI for APT was high (0.3980), it was not capable of capturing profits above the required threshold rate and therefore did not capture much revenues from excess profits (if any existed). Also, the METR increased from 35 percent to 40 percent due to collection of some revenues from the existence of additional profits above the normal ROR. The fiscal transfer gap between the EWT and EIT rates slightly increased (28 percent > 26 percent).

The NPV slightly increased, which reflected that APT does not cause an economic incidence. However, a threshold rate below the project IRR could capture the quasi-rents, and therefore cause distortion. As demonstrated in Figure 4.2, a lower threshold rate (e.g., 10 percent used in this thesis) reduced the NPV from the *base case* ($5.25 billion to $4.49 billion). This result was due to the distorting effects of the FPPE being absent in the tax model and carry-over credits, which reduced the progressivity (slightly higher TPIs) and increased the NPV. These simulations show that depending on the threshold rate, the combination of the basic taxes and the APT is slightly unsuitable for high cost/low-rent mines. Also, the APT (RRT) does not cause tax burden unless the threshold rate is below the normal ROR.

Cases 2 and 3*: *Basic taxes plus free carried equity (FCE) and fully paid equity (FPE)

The FCE and FPE were separately simulated using the 3 and 12 percent interest rates alluding to different equity financial arrangements. The respective TPIs were 0.3993 and

0.4220. In both cases, the METR rose to 46 percent, the EIT rate exceeded the EWT rate by 2 percent, and the NPV reduced from the *base case* ($5.25 billion to $3.89). The total TPIs of the basic tax instruments and that of the FCE and FPE remained steady (0.0688 and 0.0864). These results show that the FCE and FPE once combined with the basic taxes collect relatively small amounts of revenues for the community. As shown in Table 4.8, the progressivity of CIT remained relatively unaffected because the FCE and FPE were imposed on the post-CIT cash flows or more specifically on the corporate profits.

Although the NPVs derived from the *cases 2* and *3* were same, inclusion of the FCE weakened the combined progressivity of the basic taxes compared with the FPE. The difference was due to the treatment of the cost of FCE as an internal loan to the investor, which was analogous to the FPE. The basic tax instruments and the FPE was a favourable combination as reflected by the slightly lower METR because it freed the cash flows from the internal debt obligations that would be faced by investors.

Case 4*: *Basic taxes with fully paid production-based equity (FPPE)

The TPI for FPPE was 0.3605 and combining the FPPE with the basic taxes weakened the average TPI for the total direct tax instruments from the *base case* (0.1024). The METR increased from 46 percent to 48 percent from the *base case*. The EIT rate was reduced by 5 percent and the EWT rate slightly increased by 2 percent. These results show that FPPE itself being weakly progressive erode revenues that could have been collected if it was not combined with the basic tax instruments. This was caused by erosion of the tax base arising from deadweight losses through reductions in the total mineral outputs. These results suggest that there is wasteful extraction arising from reduction in the mineral reserve when the FPPE is combined with the basic tax instruments. Further simulations of the FPPE rates were necessary to identify a suitable range of rates for the equity stake ownership in mining projects (Fig 4.3).

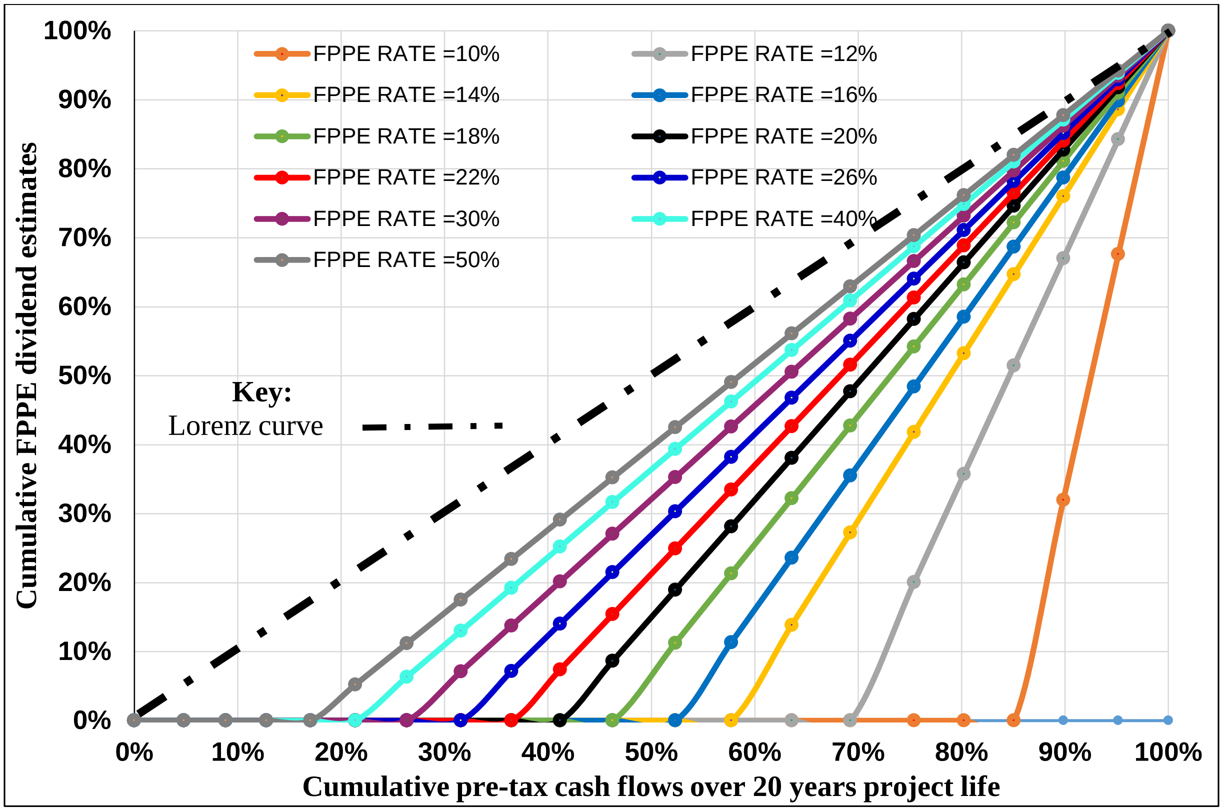


Figure 4.3: Equity interest rates plotted against the Lorenz curve

Figure 4.3 shows the progressivity curves for the FPPE rates ranging from 0 to 50 percent were measured against the pre-tax cash flows over the 20-year life of the project. The curves show that there was no dividend accessible from owning the equity interests at FPPE rates less than 10 percent. The government and community may have access to some equity dividends from FPPE rates above the 10 percent benchmark.

Case 5**:** ***Basic taxes plus APT and FPPE***

This scenario tested the suitability of combining the basic taxes with the FPPE and the APT. This combination of the basic and quasi-tax instruments, which represents the real situation in PNG where a Taxation Review Committee has recommended reintroducing the APT. This combination of tax instruments weakened the total progressivity by significant margins (0.0852 to 0.220) and the METR increased to 48 percent from the *base case*. However, the METR did not change significantly from the *base case* because the APT and FPPE were weakly progressive (0.450 and 0.400) (i.e., small amounts of revenues were collected). When comparing this *case* with *case 1*, the FPPE eroded APT's ability to capture revenues from excess profits due to the wasteful extraction problem mentioned in *case 4*. This finding suggests that APT cannot be expected to raise substantial revenues from taxing excess profits once it is combined with the FPPE and basic tax instruments.

Case 6*: *Basic taxes with the PBR

This scenario was simulated to test the adoption of PBR at the Ramu Nickel mine in PNG. The shift from ad valorem royalty to PBR produced a TPI of 0.111 in combination with the basic taxes. However, the total TPI remained steady (0.034) from the *base case*. The METR slightly increased by 1 percent (36 percent > 35 percent), while the EIT rate exceeded the EWT rate (31 percent > 21 percent). The strong performance was attributed to the PBR being applied as a second-tier tax to the CIT and consistently positive tax base of the Frieda deposit being assessed. Further, delaying the PBR revenues was seen to be a major problem, especially for low quality and high cost mines compared to the ad valorem royalty.

Case 7*: *Basic taxes plus APT, FPPE and PBR

In this scenario, the total TPI increased by a substantial margin (0.1910) from the *base case* (0.0852) when the basic tax instruments were combined with the APT, FPPE and the

PBR. The corresponding METR was 53 percent, the EWT rate exceeded the EIT rate by 4 percent (26 percent > 22 percent) and the NPV decreased from the base case ($5.25 billion to $3.30 billion). These results suggest that the combination of basic tax instruments with the quasi-taxes greatly influenced the combined progressivity to be weak and tends to crowd-out the revenue generating potentials of the strongly progressive tax instruments.

As mentioned in *case 6*, the PBR revenues are accessed at the early stages of a mine life only if the tax base is positive. On the other hand, the FPPE and the APT revenues are delayed mainly because of their weak progressivity alluding to the tax base uncertainty, the costs of acquiring the equity interests and setting a suitable threshold rate. Finally for this section, there are avenues for integrating some quasi-taxes with the basic tax instruments. However, a suitable combination of the multiple tax instruments should not deviate from the theoretical values of the TPI, METR and NETR identified and established in Sections 4.1 and 4.3.

4.5 Summary

This chapter has presented the data analysis using the techniques described in Chapter 3. The case study used data from the undeveloped Frieda copper-gold deposit to model PNG's mining tax instruments. The first part of this chapter used the TPI, METR, NETR, and EIT and EWT rates to measure the ability of individual taxes, royalty and levies to raise tax revenues. The second part of the chapter simulated the tax adjusting techniques that influenced the degree of progressivity for the various tax instruments to support the main results obtained in the first part of the chapter. Remarkably, the tax model results and those derived from the simulations were similar to each other, which suggest the methods and techniques used were reliable.

The results obtained from simulations of depreciation techniques, LCF, tax holiday and thin capitalisation rules generated some significant results that are useful for addressing some specific tax design issues in PNG. These are the major techniques applied for protecting the tax base that in turn will strengthen the progressive tax system. The simulated results are useful for strengthening the progressive mineral taxation regime of PNG through an accelerated depreciation technique. It is supplemented by a time-dependent LCF provision that recognises the riskless capital invested and the operating costs. The LCF provision within the progressive tax system is indeed a concession and therefore, PNG does not need a tax holiday. Moreover, the thin capitalisation rule of 2:1 protects the tax base thereby making the tax instruments more progressive and improves the economics of a mining project compared to the debt to equity ratio of 3:1, which is presently applied in PNG.

The scenario analysis involving copper and gold prices, and tax rate changes cogently explained the degree to which strong progressivity and changing tax rates influence the marginal tax rate to increase. The price simulation results cogently showed that increased progressivity of tax instruments associated with increasing profitability of a mine does not cause the marginal tax rate to increase as often argued in the mainstream taxation literature. The results also showed that as profitability falls, progressivity makes a vertical adjustment so that tax burden is recognised on the ability to pay. This finding is significant for PNG to make policy adjustments to strengthen its progressive mineral taxation regime, while maintaining a competitive level of the statutory tax rates.

The scenario analysis of the combinations of taxes was required to identify some suitable mix of tax instruments that could reduce wasteful extraction and fulfil the revenue maximising objective. The simulation results showed that the basic tax instruments collect much of the revenues for PNG but there are rooms for devising additional tax instruments to bring the net wealth transfer to an acceptable level. However, the results showed that combining APT and FPPE with the basic tax instruments makes PNG's mineral taxation most unattractive in the world. According to these results, PNG can increase the CIT rate to an acceptable level if the FPPE is abolished.

The validity of the theoretical results relied on the techniques used for reducing the uncertainty of input variables, which led to forecasting a more reliable tax base. The findings of the study illustrated that ignoring uncertainty made the results more susceptible, especially if the NPV and the AETR were used for measuring the distribution of tax burden. It was necessary to establish reliable theoretical TPIs, METR, NETR and other findings associated with PNG's mining taxation regime to make a comparative analysis of the historical tax performance in Chapter 5.

Chapter 5 : Historical Tax Performance Analysis

Chapter 4 used the theoretical tax revenues and financial data to measure the performance of direct tax instruments under various price, cost and risk conditions. This chapter computes the progressivity indices, METR, NETR, wealth transfer rates and other variables using the real-time data presented in *Appendix C*. Further, inclusion of non-tax data allowed the computation of aggregate fiscal benefits generated by the sample of mines assessed. This approach goes beyond the limitations of the theoretical tax models in Chapter 4, which did not capture the non-fiscal benefits such as land use compensation and expenditures on infrastructure and human development. The indirect tax instruments and non-tax benefits were included in the total EWT rates for this analysis.

This chapter is organised as follows. Section 5.1 presents the results for direct tax instruments, indirect taxes and non-tax benefits for the Bougainville copper mine between 1972 and 1988. Section 5.2 presents the results for the Ok Tedi copper mine between 1982 and 2013. Section 5.3 presents the results for the Porgera gold mine from 1984 to 2012. Section 5.4 presents a summary of the chapter.

5.1 Bougainville Mine

Table 5.1 presents the TPIs calculated for the direct tax instruments associated with the former Bougainville mine. There was no time series data for the royalty payments, despite some royalty proceeds were paid over the short-lived mine operation. However, the 1.25 percent royalty rate at that time was lower than the present average applied in most mining jurisdictions. As a result, a total royalty payment of about PNGK 74 million represented about 0.1 percent of the gross outputs over the 16 years of the mine operation. Hence, a royalty rate below the present rate of 2 percent is suboptimal.

Table 5.1: TPIs for direct taxes of the Bougainville mine (closed).

Year	FCE	CIT	DWT	APT*	Total DT
1971	0.00	0.00	0.00	0.00	0.00
1972	0.29	na	0.32	na	0.56
1973	0.03	0.99	0.08	na	0.39
1974	0.13	0.55	0.16	na	0.31
1975	0.13	0.51	0.17	na	0.30
1976	0.14	0.44	0.17	na	0.28
1977	0.13	0.40	0.17	na	0.26
1978	0.09	0.34	0.13	na	0.22
1979	0.02	0.23	0.07	na	0.14
1980	-0.01	0.19	0.03	na	0.11
1981	0.00	0.16	0.04	na	0.10
1982	0.01	0.13	0.05	na	0.10
1983	0.03	0.08	0.07	na	0.10
1984	0.03	0.06	0.07	na	0.09
1985	0.03	0.05	0.05	0.67	0.07
1986	0.02	0.03	0.04	0.33	0.04
1987	-0.01	0.01	0.00	0.21	0.01
1988	0.00	0.00	0.00	0.00	0.00
Average	**0.06**	**0.26**	**0.10**	**0.30**	**0.18**

*****APT revenue payments placed together to make the TPI calculation convenient.
Source: Bougainville Copper Limited (BCL) annual report (2013) (*Appendix C*, Tables C-1 and C-2)

Table 5.1 shows that the TPIs for CIT were consistently positive, and the average TPI (0.26) was slightly outside of the ideal degree of progressivity boundary identified in Section 4.3. The TPIs approaching zero (Lorenz curve) represented CIT's potential of collecting a high magnitude of revenues at the mature stages of mine's life. Given the CIT captured about 70 percent of the revenues, Bougainville mine's NETR was 21 percent [0.40* (1-0.26) *70]. It was about 16 percent below the 35 percent statutory CIT rate that existed between 1972 and 1988. It shows that there were some underpayments of the accessible CIT revenues. Further, the average TPI of 0.10 for the DWT was within the effective progressivity boundary, which performed stronger than the CIT and the APT because the DWT was imposed on the post-tax base.

The GoPNG received the APT payments only four times during the period analysed: first in 1974, second in 1979, third in 1980 and fourth in 1988. The irregular payments of the APT revenues and the lack of time series data made computing the TPIs difficult. This setback was resolved by grouping the cumulative APT payments towards the last periods to maintain the continuity of TPI calculations, leading to a well-structured curve that demonstrated the burden distributions (see Fig. 5.1). This approach enabled the progressivity curve to correctly represent the APT performance since matching the APT payments with the cumulative pre-tax base did not affect the results.

The average TPI for APT being 0.30 (Table 5.1) reflects it was unreliable in capturing the excess profits. The APT revenues became accessible due to a high mine profitability impelled by a copper boom in the early 1970s, and low capital and operating costs as the Bougainville mine was located near the coast. Conceptually, the APT revenues would have become payable when the cumulative PVs of the pre-tax CFs were discounted using the threshold rate that equaled to zero. This meant that the threshold rate was triggered when the IRR was equal to 15 percent in 1974. However, the APT payments just three years after the mine was commissioned were inconsistent with theory as it was too early for the mine to trigger the threshold rate prior to attaining the normal ROR in 1979.

Figure 5.1 is a structural representation of the degree of progressivity along the Lorenz curve for the direct tax revenues paid by the Bougainville mine. The TPI curves for profit-based taxes are slightly concaved at the base along the x-axis, which is normal for allowing the investor to attain the pre-tax ROR before government can access the tax revenues. The CIT progressivity is slightly outside of the optimal margin compared to the DWT. Further, the APT curve bowing downwards to show that it was weakly progressive. On the other hand, the progressivity curve for FCE was more closer to the Lorenz curve compared to all the tax instruments. This was because both FCE and DWT were based on the post-tax base and were paid out of the corporate profits.

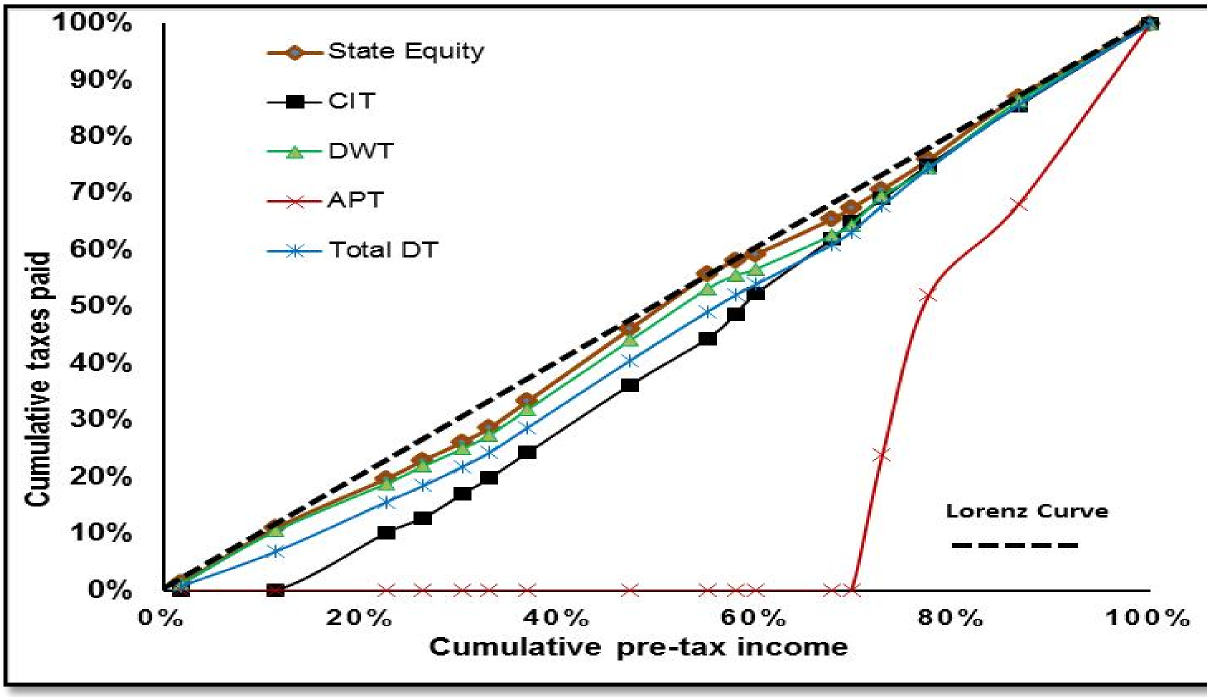


Figure 5.1:TPIs for direct taxes plotted against the Lorenz curve.

The TPI for FCE was 0.06, which shows that there were substantial amounts of equity dividends paid between 1972 and 1988. The early dividend payments arose from positive tax base in the first year of mine operation, which rapidly offset the capital cost of equity participation. Although the company could have recouped its share of equity capital cost plus interests, strong progressivity of the FCE contradicted with that of the theoretical FCE (Table 4.2). As observed in Table 4.7, the strong progressivity of the FCE was equivalent to that of the DWT because these taxes were paid out of corporate profits. As the post-tax base became positive, the FCE and DWT became more progressive than the tax instruments imposed on the pre-tax base.

Table 5.2: METRs and wealth distributions from the Bougainville mine.

Year	Free Cash Flow ROR	Pre-Tax ROR	Post-Tax ROR	METR DT	AETR	EIT	EWT (a)	EWT (b)	EWT (C)	Total EWT
1972										
1973	-82	-95	-95	0	18	29	5	49	4	**58**
1974	-22	-45	-43	0	9	63	5	19	2	**25**
1975	-8	-16	-22	-30	46	39	27	16	1	**44**
1976	18	-10	-16	-50	34	24	10	24	2	**36**
1977	25	-5	-11	-120	45	20	13	23	2	**37**
1978	29	-2	-8	-320	47	14	10	23	2	**35**
1979	32	1	-4	5	51	21	13	21	2	**36**
1980	34	7	1	90	59	24	27	14	1	**42**
1981	36	10	3	70	53	21	19	14	1	**34**
1982	37	10	4	60	63	8	9	16	1	**26**
1983	37	11	4	60	70	4	8	17	1	**26**
1984	38	12	6	60	48	14	14	12	1	**27**
1985	38	13	6	50	70	4	7	15	1	**23**
1986	38	13	6	50	57	9	9	15	1	**25**
1987	39	13	7	50	52	13	11	14	1	**26**
1988	39	14	8	40	48	22	16	11	1	**28**
Total	**39**	**15**	**9**	**40**	**48**	**21**	**13**	**19**	**2**	**33**

Source: Bougainville Copper Limited (BCL) annual report (2013) (*Appendix C*: Tables C-1 and C-2)
*METR for royalty was computed by the IRR for gross revenue minus IRR for gross revenues less royalty divided by the IRR for gross revenue. (*a*) direct tax instruments, (*b*) indirect and non-tax benefits, and (*c*) royalty.

The average TPI for total direct tax instruments was 0.18, which was within the acceptable progressivity boundary (Table 5.1). Further, the actual METR for Bougainville mine was 40 percent (Table 5.2), which was significantly high compared to the theoretical METR of 45 percent. Bougainville mine's high METR was attributed to positive tax base in the early production years, which was similar to that of the Frieda deposit model. Based on the combined TPI and METR, the industry level NETR for the Bougainville mine was 30 percent [0.4*(1-0.26)*100], which was to some respect within the proximity of PNG's theoretical NETR of 40 percent established in Chapter 4. This shows that the Bougainville mine generated substantial revenues for PNG when combined with the indirect and non-tax benefits.

The EIT rate exceeded the EWT rate for the direct taxes (21 percent >13 percent) (Table 5.2). However, the total EWT rate comprising of direct and indirect tax instruments, and non-tax benefits exceeded the EIT rate (33 percent > 21 percent). Also, the EWT rates for indirect and non-tax benefits exceeded that of the direct tax instruments (19 percent >13 percent). This shows that while the direct tax instruments alone were incapable of transferring a satisfactory level of benefits to the community, its combination with the non-tax benefits was able to transfer a substantial amount of resource revenues.

5.2 Ok Tedi Mine

Table 5.3 shows that the average TPI for royalty was strongly progressive (0.07), but slightly weaker than the theoretical case in Section 4.1. The progressivity of ad valorem royalty decreased (negative TPIs) during low mineral prices (1991 to 2000) and became strongly progressive during high prices (2003 to 2012). This shows that progressivity of value-based royalties decrease during period of low prices and increase during high prices. This result was observed to occur in Table 4.1 (Chapter 4) with the MC – CFT model as a result of time-lag effects. Additionally, the TPI for mining levy was weakly progressive (0.21) and the combined TPI was 0.170 when the mining levy was introduced in 1998. When the mining levy was phased out in 2006, the progressivity of ad valorem royalty improved between 2007 and 2013 (Table 5.3).

Table 5.3 shows the CIT progressivity was weak (0.36). The NETR for CIT was 13 percent [0.30*(1-0.36)*70], which was below the statutory CIT rate. This performance was unrelated to the CIT rate, which was reduced from 35 percent to 30 percent in 2000. Rather, the negative TPIs were due to a decline in copper and gold prices during the global recession between 2007 and 2008, whose effect continued to 2012 and onwards. The negative TPIs were caused by time-lag effects where the cumulative CIT revenues exceeded the cumulative pre-tax cash flows by more than 50 percent. This result shows that progressivity of the profit-based taxes increase during periods of high profit and decrease to regressive progression during periods of low profit (Fig. 2.2). Further, the average TPIs for DWT and royalty withholding tax were 0.32 and 0.27 respectively. The actual progressivity of DWT being weak suggest that there were few dividends paid to host communities partly since the Ok Tedi became a 100 percent locally-owned mine in 2002.

Figure 5.2 graphically presents the TPIs in Table 5.3 to show the degree of progressivity of the direct tax instruments, royalties and levies paid by the Ok Tedi mine between 1982 and 2013. Ok Tedi mine paid the DWT taxes in 1998, and the CIT proceeds and equity dividend payments were received after the mine attained its pre-tax ROR in 1991. The cumulative tax payments did not reach 20 percent until 2004, except for the levies (Table 5.4). As a result, the tax curves are concentrated near the origin along the x-axis, which is why weak tax instruments that are expected to form concave curves are not clearly demonstrated in Figure 5.2. This result was due to high costs associated with the geographical location of the Ok Tedi mine.

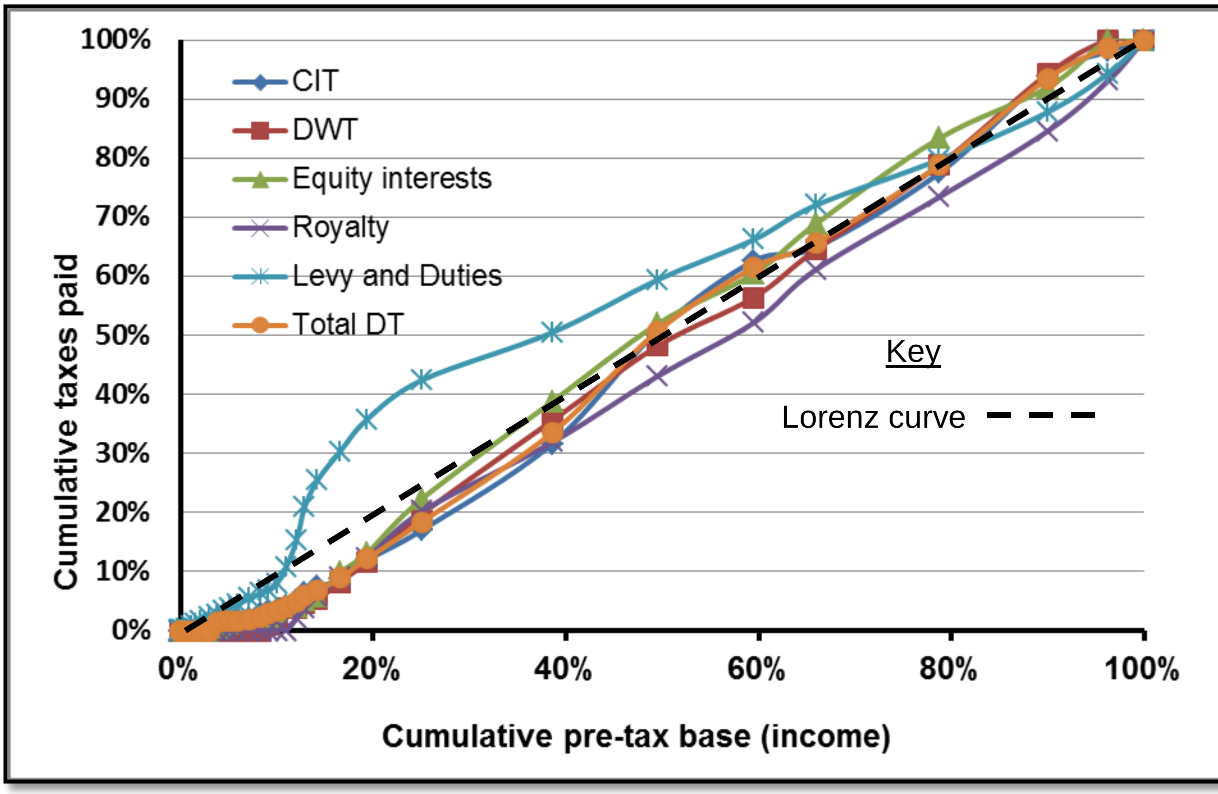


Figure 5.2: TPIs of taxes for the Ok Tedi mine are plotted against Lorenz curve.

Ok Tedi mine's average TPI for the total direct taxes was 0.39, which was outside of the effective progressive range (0>TPI<0.20) identified in Section 4.3. This performance was characterised by a low METR of 30 percent (Table 5.4) and similarly the NETR was 18.3 percent [0.3*(1-0.39)*100]. These results were lower than the theoretical ones because most of the tax revenues became accessible after Ok Tedi mine's 10-year payback period due to cost challenges associated with environment and social impacts. This result shows that low performance of the direct tax instruments is more predictive for porphyry copper deposits that share similar geological and geographical settings to that of the Ok Tedi copper mine.

Table 5.3: TPIs for all types of taxes between 1982 and 2013 for the Ok Tedi mine.

Year	Royalty	Levy	Total R+L	CIT	Equity Div.	DWT	Royalty WHT	Total DT
1982	na	na	**na**	**na**	na	na	na	**na**
1983	na	na	**na**	**na**	na	na	na	**na**
1984	0.74	na	**0.96**	**na**	na	na	na	**na**
1985	0.45	na	**0.97**	**na**	na	na	na	**na**
1986	0.33	na	**0.73**	**na**	na	na	na	**na**
1987	0.32	na	**0.65**	**na**	na	na	na	**na**
1988	0.26	na	**0.61**	**na**	na	na	na	**na**
1989	0.29	na	**0.56**	**na**	na	na	na	**na**
1990	0.00	na	**0.52**	**na**	na	na	na	**na**
1991	-0.07	na	**0.31**	**0.47**	0.91	na	na	**0.61**
1992	-0.04	na	**0.24**	**0.55**	0.82	na	na	**0.65**
1993	-0.02	na	**0.23**	**0.61**	0.75	na	na	**0.68**
1994	0.01	na	**0.22**	**0.67**	0.72	na	na	**0.71**
1995	-0.16	na	**0.22**	**0.71**	0.77	na	na	**0.75**
1996	-0.10	na	**0.02**	**0.66**	0.80	na	na	**0.73**
1997	-0.09	na	**0.07**	**0.63**	0.76	0.90	na	**0.68**
1998	-0.05	0.95	**0.10**	**0.63**	0.69	0.79	na	**0.66**
1999	-0.03	0.89	**0.07**	**0.62**	0.63	0.66	na	**0.63**
2000	-0.01	0.71	**0.03**	**0.57**	0.66	0.69	0.82	**0.60**
2001	0.01	0.45	**-0.06**	**0.50**	0.61	0.64	0.71	**0.54**
2002	0.02	0.16	**-0.19**	**0.48**	0.59	0.62	0.59	**0.52**
2003	0.03	0.05	**-0.29**	**0.47**	0.41	0.50	0.45	**0.46**
2004	0.03	-0.04	**-0.34**	**0.38**	0.32	0.40	0.37	**0.37**
2005	0.04	-0.03	**-0.34**	**0.32**	0.11	0.21	0.19	**0.26**
2006	0.03	0.10	**-0.27**	**0.18**	-0.01	0.08	0.17	**0.13**
2007	0.03	0.03	**-0.07**	**-0.03**	-0.05	0.03	0.13	**-0.02**
2008	0.02	0.00	**-0.05**	**-0.05**	-0.02	0.05	0.12	**-0.03**
2009	0.03	0.00	**-0.02**	**0.02**	-0.04	0.02	0.07	**0.00**
2010	0.03	0.08	**-0.02**	**0.02**	-0.06	0.00	0.07	**0.00**
2011	0.02	0.08	**0.03**	**-0.04**	-0.02	-0.05	0.06	**-0.04**
2012	0.01	0.02	**0.04**	**-0.02**	-0.04	-0.04	0.03	**-0.02**
2013	0.00	0.01	**0.02**	**0.00**	0.00	0.00	0.00	**0.00**
Average	**0.07**	**0.21**	**0.17**	**0.36**	**0.41**	**0.32**	**0.27**	**0.39**

Source: Ok Tedi Mining Limited (OTML) production and financial data (2013) (*Appendix C*: Table C-8)

Table 5.4: METRs for direct taxes and royalty and ETRs for the Ok Tedi mine.

Year	FCF ROR	Pre-tax ROR	Post-tax ROR	Direct taxes METR	Royalty + Levies METR	AETR
1982	na	na	na	**na**	**na**	na
1983	na	-100	na	**na**	**na**	na
1984	-85	-96	na	**na**	**0**	na
1985	-41	-64	na	**na**	**-2**	0
1986	-20	-39	-59	**-52**	**-5**	0
1987	-5	-24	-37	**-56**	**-17**	0
1988	1	-17	-33	**-97**	**82**	0
1989	9	-10	-28	**-2**	**10**	0
1990	14	-3	-19	**-4**	**8**	0
1991	17	0	-14	**39**	**7**	2
1992	19	3	-11	**528**	**6**	14
1993	21	4	-9	**309**	**5**	15
1994	22	6	-6	**190**	**5**	5
1995	24	8	-2	**131**	**4**	3
1996	24	9	-1	**107**	**4**	28
1997	25	10	-1	**107**	**4**	-317
1998	25	10	0	**98**	**4**	46
1999	26	11	1	**91**	**4**	61
2000	26	11	2	**81**	**3**	38
2001	26	12	3	**78**	**3**	132
2002	26	12	3	**73**	**3**	50
2003	27	13	5	**65**	**3**	51
2004	27	13	6	**56**	**3**	52
2005	27	14	8	**46**	**3**	47
2006	27	15	10	**38**	**3**	64
2007	28	16	11	**33**	**3**	67
2008	28	16	11	**31**	**3**	69
2009	28	17	12	**29**	**3**	21
2010	28	17	12	**27**	**3**	51
2011	28	17	13	**27**	**3**	94
2012	28	17	13	**27**	**3**	45
2013	28	17	13	**27**	**3**	58
Total	**28**	**18**	**13**	**30**	**3**	**37**

Source: Ok Tedi Mining Limited (OTML) production and financial data (2013) (*Appendix C*: Table C-7)

Table 5.5: Distributions EIT and EWT rates for Ok Tedi mine.

Year	ERTI	EWT (*a*)	EWT (*b*)	EWT (*c = a+b*)	EWT (*d*)	EWT Total (*c + d*)
1982	0	0	0	0	0	**0**
1983	0	0	0	0	0	**0**
1984	0	0	28	28	7	**35**
1985	-26	9	41	50	2	**52**
1986	20	0	5	5	1	**6**
1987	26	0	8	8	1	**9**
1988	9	0	6	6	14	**20**
1989	6	0	3	3	26	**29**
1990	17	0	2	3	25	**28**
1991	14	21	3	24	30	**54**
1992	10	2	3	4	30	**34**
1993	10	2	2	4	29	**33**
1994	19	1	2	3	23	**26**
1995	16	1	2	2	16	**18**
1996	18	5	3	8	22	**30**
1997	-4	13	6	19	48	**67**
1998	8	5	3	7	23	**30**
1999	9	8	3	11	28	**39**
2000	12	5	3	7	22	**29**
2001	5	8	3	10	25	**35**
2002	9	6	3	9	25	**34**
2003	15	11	2	13	20	**33**
2004	24	15	3	18	27	**45**
2005	32	20	2	21	18	**39**
2006	41	32	1	33	14	**47**
2007	40	32	2	33	13	**46**
2008	32	26	2	29	19	**48**
2009	39	12	2	15	16	**31**
2010	40	27	2	29	16	**45**
2011	27	29	3	32	11	**43**
2012	27	16	4	21	14	**35**
2013	7	4	6	10	19	**29**
Average	16	**10**	**5**	**15**	**18**	**33**

Notes: (*a*) direct tax instruments, (*b*) royalty and levy, and (*c*) *a* + *b*, (*d*) non-tax benefits.
Source: Ok Tedi Mining Limited (OTML) production and financial data (2013) (*Appendix C*: Tables C-8 to C-12)

The EWT rates show that there were substantial amounts of non-tax benefits flowed to local communities surrounding the Ok Tedi mine. Although the average EIT rate exceeded the EWT rate based on the direct tax instruments (16 percent > 10 percent), the addition of non-tax benefits caused the EWT rate to exceed the EIT rate (33 percent > 16 percent). This meant that indirect and non-tax benefits make up for the fiscal disparity gap created by weak progressivity of the direct tax instruments. The total wealth transfer rate constituted a high magnitude of benefits flowed to PNG and host Ok Tedi communities.

Data provided in *Appendix C* show that between 1982 and 2013, about 70 percent of the total tax and non-tax benefits from the Ok Tedi mine flowed to rest of PNG. This comprised of CIT, business development and other indirect taxes. Out of the 30 percent benefit streams that were retained within the host Ok Tedi region, 16 percent flowed to rest of the Western Province and 14 percent was retained by landholder communities. These benefit distributions were in form of royalties, equity dividends, compensation, non-tax benefits, infrastructure created through the TCS and SSG and spin-off business activities. However, the entire social and economic assets created by the Ok Tedi mine could be underestimated due to data limitations and the techniques used in this study, which focused on few variables that were easily accessible.

5.3 Porgera gold mine

Royalty and levies for the Porgera gold mine are presented in Tables 5.6 and 5.7. The ad valorem royalty was strongly progressive throughout the mine life, with an average TPI of 0.022, which was consistent with that of the Ok Tedi mine. The excise and duties and mining levies collected small amounts of revenues as they performed regressively (-0.107).

Table 5.6: TPIs for the Porgera mine (1990-2012).

Year	CIT	Com. & EPG Equity (FPPE)	Exercise & Duties	Royalty	Total DT
1990	**na**	na	na	0.045	**na**
1991	**na**	na	na	0.035	**na**
1992	**na**	na	na	0.015	**na**
1993	**0.533**	na	0.775	0.025	**0.571**
1994	**0.57**	na	0.685	0.029	**0.597**
1995	**0.526**	na	0.384	0.026	**0.535**
1996	**0.518**	na	0.274	0.023	**0.519**
1997	**0.505**	na	0.158	0.020	**0.499**
1998	**0.493**	na	0.054	0.014	**0.48**
1999	**0.487**	na	-0.133	0.098	**0.461**
2000	**0.477**	na	-0.251	0.075	**0.443**
2001	**0.486**	na	-0.379	0.050	**0.441**
2002	**0.475**	na	-0.425	0.044	**0.428**
2003	**0.432**	na	-0.447	0.044	**0.388**
2004	**0.367**	na	-0.437	0.039	**0.313**
2005	**0.305**	0.547	-0.461	0.028	**0.252**
2006	**0.311**	0.449	-0.480	0.023	**0.253**
2007	**0.289**	0.209	-0.473	0.011	**0.225**
2008	**0.242**	0.239	-0.368	-0.001	**0.193**
2009	**0.182**	0.220	-0.293	-0.010	**0.145**
2010	**0.169**	0.126	-0.179	-0.020	**0.14**
2011	**0.01**	0.020	-0.096	-0.045	**0.002**
2012	**-0.05**	-0.050	-0.050	-0.055	**-0.05**
Average	**0.366**	**0.220**	**-0.107**	**0.022**	**0.342**

Source: Porgera Joint Venture information booklet (2013) (*Appendix C*: Tables C-3 & C-4)
Note: (a) CIT was adjusted to isolate mining levy and 4 percent mining levy was estimated.

Historical data presented in *Appendix C* shows the central government (GoPNG) retained about 77 percent of the total royalty proceeds and redistributed 23 percent to the host

Porgera communities. The royalty proceeds distributed were as follows: EPG received 50 percent; SML landholders 15 percent; Porgera Landholder Association has 12 percent; Children's Trust Fund 10 percent; and Young Adults Association 8 percent. Substantial amounts of royalty proceeds were generated from the Porgera mine and distributed to these local stakeholders.

The average TPI for CIT was weakly progressive (0.366), which was outside of the effective progressivity boundary. This implied that Porgera mine paid only 63 percent of its CIT payable. The functional variables detected the problem but did not explain why the Porgera gold mine underpaid the CIT relative to the tax-base. Porgera mine's NETR for CIT was 13.2 percent [0.33*(1-0.366)*63], which was about 16.8 percent lower than the statutory rate of 30 percent. Porgera mine's CIT performance was similar to that of the Ok Tedi mine, but both were lower than that of the Bougainville copper mine.

The progressivity of FPPE was weak as shown by the TPI of 0.240 (Table 5.6). It was due to inconsistent payments of equity dividends between 1990 and 2006. The Porgera community and the EPG initially have a 5 percent FCE interest in the Porgera mine. The FCE type of equity interest was changed to FPPE following an industry protest against the FCE between 1990 and 1994. In Figure 5.3, the FPPE curve moving along the x-axis at early periods reflects that FPPE dividends have been delayed or inconsistent in the most productive stages of the mine life.

In Figure 5.3, strong progressivity of the direct tax instruments in early production years was due to the Porgera mine produced over a 1 million ounce of gold for two successive years (1992 and 1994) (*Appendix C*: Table C-3). As a result, the mine attained its normal ROR in 1994 after commissioning in 1990 (Table 5.7). However, the progressivity curves for CIT and total tax instruments bow downwards away from the Lorenz curve despite the mine having high production rates and low costs, especially at the mature production periods. The low METR of 19 percent reflects that Porgera has been a low-tax paying gold mine in PNG (Table 4.7). The total TPI for direct taxes being 0.342 constitutes a NETR of 13 percent [0.19* (1-0.342)*100], which is significantly lower than the theoretical NETR of 40 percent.

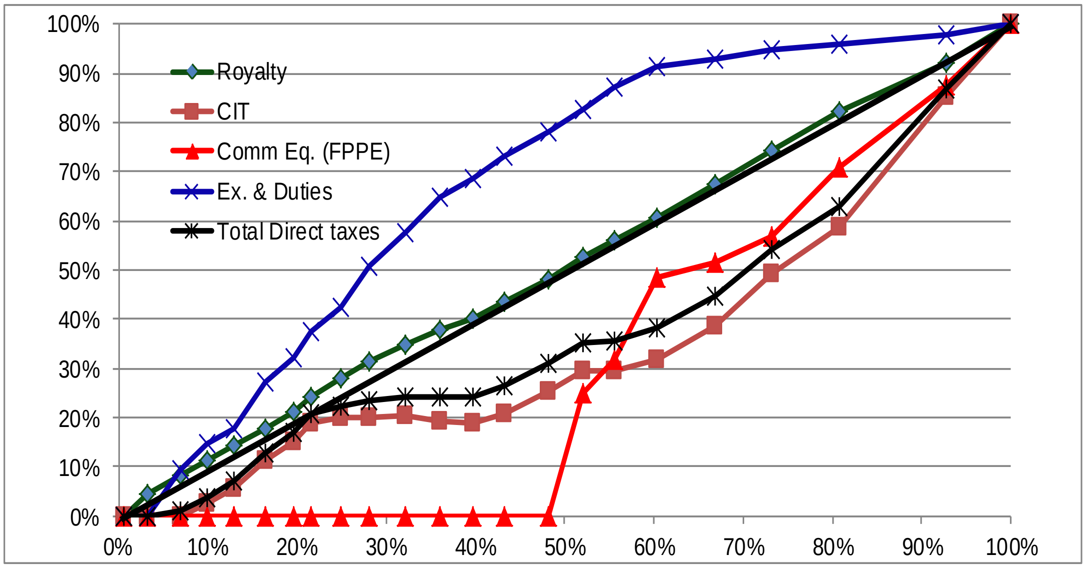


Figure 5.3: Tax progressivity curves the Porgera mine.

Table 5.7 also presents the rates of fiscal distributions among the stakeholders relative to gross values extracted from the Porgera mine. The EIT rate exceeded the EWT rate by 18 percent (28 percent >10 percent) based on the direct tax instruments. The EIT rate exceeded the EWT rate (28 percent >24 percent) when combining human capital, infrastructure (SSG and TCS), compensations, and business development, together with the direct and indirect taxes. This result was inconsistent with the Bougainville and Ok Tedi mines. There were less direct and indirect and non- tax benefit streams flowed to the Porgera region, Enga Province and rest of PNG between 1990 and 2012. This shows that the Porgera being a world class gold mine paid less direct tax revenues and the overall wealth transfer was substantially less than the copper mines.

Table 5.7: METR and ETRs, EIT and EWT rates for the Porgera mine

Year	Marginal Effective tax rate (%)					EWT RATE					Total
	FCF ROR	Pre-tax CF ROR	Post-tax CF ROR	METR DT	METR Royalty	EIT	Royalty EWT	Direct Taxes	Indirect Taxes	Total Non-Tax Benefits	Total EWT
1989											
1990	-86	-97	-97	0	0	21	1	-1	0	61	**60**
1991	-11	-91	-73	-2	-6	10	1	-1	0	13	**12**
1992	21	-31	-33	-4	3	32	1	42	5	12	**59**
1993	33	-9	-13	-57	3	44	1	7	2	14	**23**
1994	40	0	-6	1409	2	26	1	16	3	14	**33**
1995	44	8	-1	111	2	27	1	11	3	14	**28**
1996	46	12	3	78	2	22	1	7	3	13	**23**
1997	47	13	3	75	2	8	1	11	4	17	**32**
1998	48	16	8	52	2	47	1	10	4	13	**27**
1999	49	18	10	44	2	34	1	10	2	11	**23**
2000	49	19	12	37	2	31	1	5	1	8	**14**
2001	50	21	14	33	2	38	1	7	1	8	**16**
2002	50	21	15	30	2	26	1	11	1	7	**19**
2003	50	22	16	29	2	18	1	12	1	6	**19**
2004	50	23	16	27	2	24	1	8	1	5	**14**
2005	50	23	17	27	2	19	1	4	1	5	**10**
2006	51	23	17	26	2	27	1	9	2	7	**18**
2007	51	24	18	25	2	35	1	13	2	6	**21**
2008	51	24	18	23	2	36	1	9	1	4	**14**
2009	51	24	19	23	2	29	1	8	2	4	**14**
2010	51	24	19	23	2	23	1	25	2	4	**31**
2011	51	25	19	22	2	33	1	10	2	3	**15**
2012	51	25	19	22	2	36	1	-1	3	4	**6**
Average	**51**	**26**	**21**	**19**	**2**	28	**1**	**10**	**2**	**11**	**24**

Source: Porgera Joint Venture (PJV) information booklet (2013) (*Appendix C*: Tables C-3 to C-6)

5.4 Summary of historical results

The significance of the ad valorem royalty being strongly progressive (with a TPI of 0.050) was that it timely captured the marginal increase in gross revenues. Concerning the distortion, the average METR for royalty was fixed at the 2 percent statutory rate. When the MRA levy and SSG were added, the METR increased to 3 percent. On the other hand, the levies were regressive with negative TPIs and therefore captured small amount of revenues for the government.

PNG's average TPI for CIT was 0.3287 and given the average METR of 30 percent, the real NETR was about 20 percent [30*(1-0.3287)]. The 20 percent NETR indicates that the CIT performed below the theoretical benchmark. This is acceptable because PNG's mining industry has been immature, which involves high costs and risks, fiscal wastage through inefficient tax instruments (e.g., FPPE) and risks associated with the socio-political environment. However, the actual NETR was above the industry average as expected. Further, the actual NETR for the overall industry was calculated to be 21 percent [(30)*(1-0.30)] assuming the tax system had the ability to capture 100 percent of the tax liability. The industry level NETR for the copper sector was 25 percent compared to the gold mines that were around 13 percent. It reflected that the copper mines transferred a higher proportion of the value of the minerals extracted than the gold mines.

The wealth transfer rates for the three samples of mines examined in this chapter were averaged to compute the industry level rates. The average industry level EIT rate exceeded the average EWT rate of the direct tax instruments by 8 percent (22 >14 percent). This result was anticipated due to the low average METRs and NETRs based on the direct tax instruments. However, the result did not reflect the taxation system being imbalanced just because the EIT rate exceeded the EWT rate. When the indirect and non-tax benefits were included, the EWT rate exceeded the EIT rate by 8 percent (30 percent > 22 percent). These results imply that the TPI, METR and NETR undervalued the actual wealth transfers in form of physical assets, human capital and monetary benefits distributed to PNG and host communities. These outcomes and the differences between the actual and theoretical results generated some significant inferences that will be discussed in Chapter 6.

Chapter 6 : Results Discussion and Recommendations

Chapter 4 used the stochastic cash flows to model the mining taxes and converted the theoretical data into ratio variables. Chapter 5 derived the same variables using the historical data to analyse the actual tax performances. Both cases computed progressive indices, marginal tax rates and wealth transfer rates for a more comprehensive analysis of PNG's mining taxation regime. In light of the findings, this chapter aligns the results of the theoretical and the historical analysis for reconciling the tax instruments.

This chapter is organised as follows. Section 6.1 interprets the performance of the royalty, the levies, the PBR and the APT. These royalties and rent taxes are grouped together because they have some common links in terms of comparing the burden distributions and their abilities to collect revenues. Sections 6.2, 6.3 and 6.4 respectively discuss the CIT, DWT and equity participation results and implications. Section 6.5 examines how the study has fulfilled the hypothesis and Section 6.6 discusses the methodological implications. Section 6.7 presents the study limitations and Section 6.8 highlights the need for future research based on this thesis.

6.1 Ad valorem royalty and levies, PBR and APT

Strong progressivity of the ad valorem royalty makes it a special case amongst the regressive unit-based royalties, excise and duties that do not respond to changes in gross revenues. This result is consistent with Gaudin and Padilla (2014) who found that the value-based royalties capture the marginal increases in the gross revenues, which is significant for communities since minerals extracted are finite (also Conrad, Hool and Nekipelov 2015). Additionally, royalties compensate for the negative social and environmental externalities that host communities could face beyond a mine life. The revenues collected through the ad valorem royalty can make up for suspected revenue leakages from the profit-based tax instruments. Further, the strong progressivity of ad valorem royalty appears to attract a wider audience across South America, Africa and Asia (Western Australian Government 2015) despite its ability to distort the production efficiency.

The ad valorem royalty being strongly progressive did not influence the marginal rate to increase and distortion was found to be modest. This result was consistent with that of Otto et al. (2006) who noted that burden placed by royalties is around 2 to 3 percent. Additionally, Ergas and Pincus (2015) use a partial equilibrium model to argue that distortion caused by royalties is small and can raise substantial revenues for Australia. The notion of the distortion to extraction optimality is complex to practically verify and remains a conceptual argument. Further, the interface amongst the stochastic input variables and deposit reserves added to the initial stock through continuous exploration within an orebody tend to dilute the effects of distortion on production efficiency. Hence, the strong progressivity of ad valorem royalty and its distortion being low suggest that it can raise substantial revenues compared to the APT and the PBR.

The PBR was strongly progressive similar to the CIT mainly because the tax base of Frieda deposit model was consistently positive, which caused the PBR proceeds to become accessible in the first year of production. In reality, high-cost and low-quality mineral deposits and short mine lives can delay community's expectation of receiving the PBR revenues sooner than later. In the recent past, PNG allowed the Ramu nickel mine to apply the PBR as a second-tier tax to the CIT. However, on numerous occasions, there were community protests against the nickel mine operator over delayed remittance of royalty proceeds. Thence, the ad valorem royalty is more suitable given the complex land and mineral ownership system compared to the profit-based royalties.

The theoretical and historical analysis show that the APT had consistently performed poorly across PNG's mining industry before its elimination in 2002. The weak progressivity of the APT was mainly attributed to design factors such as the threshold rate and uncertainty of the tax base. The uncertainty of a mine's profitability regulates the time for a threshold rate to be triggered (Ergas, Harrison and Pincus 2010). In relation to that, different threshold rate scenarios simulated in Figure 4.2 predict that most porphyry copper-gold deposits in PNG conditions have IRRs are around 11 percent (including that of the Frieda deposit). Therefore, the APT has less chances of raising revenues using threshold rates greater than 12 percent from mining porphyry copper and epithermal gold deposits in PNG. This finding opposes a proposed reinstatement of the APT in PNG.

PNG Taxation Review Committee (2015) has recommended the reintroduction of APT. This scenario was simulated in scenario *5* in Table 4.8. Under the proposed structure, the APT rate of 15 percent will be designed with a 15 percent threshold rate to coexist with the basic taxes and FPPE. This combination was assessed *case 5* (Section 4.4) and the results suggest that the APT and FPPE combination could make PNG's mineral taxation regime one of the most unattractive in the world. These results suggest that APT cannot coexist with the FPPE because the latter weakens the progressivity of the former, and thus it will not generate revenues for PNG.

In the past, tax authorities in PNG did not measure the behaviour of APT in terms of taxing the accessible profits. For example, Porgera mine's IRR exceeded the APT threshold rate of 15 percent between 1998 and 2002 (Table 5.7), but PNG's tax administrators did not know that was happening. That being the case, the lack of understanding accounting techniques and information asymmetry, intertwined with poor tax audit systems complicate assessing when an IRR would surpass the threshold rate to trigger the APT payments. Further, recent findings show that Australian government's expenditure planning based on the expectation of receiving the MRRT revenues did not occur (McLaren 2012). These results concur with Ergas et al. (2010). More recently, Valle de Souza et al. (2016) noted that the RRT or its hybrid ones do not generate revenues as expected mainly due to the uncertainty regarding when a mine would trigger a threshold rate.

As a synopsis of this section, the APT is less attractive when compared to the ad valorem royalty. This is because the latter collects higher revenues when compared to the PBR and APT (Freebairn 2015). Early studies argue that the RRT and its hybrid types should completely replace the distorting and regressive royalties (Freebairn and Quiggin 2010; Mayo 1979). However, there has been a slow pace of adopting the profit-based royalties and the ad valorem royalty has become common in the Asia and Pacific regions (Bowie and Ellison 2016). Many nations are adopting the sliding scale ad valorem system. This thesis finds that capital losses due to distortion can be small. The royalty proceeds can be substituted into social welfare gains if the ad valorem royalty proceeds are wisely reinvested into sustainable enterprises rather than redistributing for direct consumption.

6.2 Corporate income tax

The theoretical progressivity of CIT was strong and within the effective progressivity boundary (Table 4.3) and captured about 70 percent of the total direct tax revenues compared to that of other tax instruments assessed. The theoretical NETR for CIT was equal to the statutory tax rate, which strongly suggests that PNG’s existing CIT design and the related rate have augmented its strong progressivity. The profit-based taxes imposed on the post-CIT base (e.g., DWT and FPE) did not affect the CIT progressivity compared to those imposed on the pre-tax base (e.g., APT and FPPE). This shows that the presence of APT and FPPE decreases the CIT progressivity and erodes revenues if they are imposed on the pre-tax base. Further, price and CIT rate simulations in Table 4.7

revealed that CIT progression coefficients consistently fell within the effective progressivity domain because its payment is proportional to changes in the pre-tax base.

From the historical case study, the actual NETR for CIT was 20 percent, which was slightly lower than the statutory CIT rate of 30 percent. In some other studies, the Australian Minerals Council (AMC) argues that the aggregate effective tax rate for Australia has been 40 percent. Although AMC's estimate was consistent with the theoretical NETR derived in this study, the optimal NETR cannot be achieved in real terms unless computations are performed under risk-neutral conditions (Slemrod 1989, 12). According to the actual results, the claim that CIT captures rents closer to the theoretical effective tax rate could be flawed because mining firms do not precisely pay the CIT liability at the theoretical NETR (Keightley and Sherlock 2014). The actual NETR will be invariant to any reforms intended to cause the CIT to perform at the theoretical level if performance measurements are extended under risk-neutral conditions (Mankiw, Weinzierl and Yagan 2009).

The CIT performance was influenced by production and supply cycles, and time-lag effects. Low prices caused the CIT to temporarily behave regressively progressive (negative TPIs) (Table 5.3). It neither increases nor reduces the tax burden because the progressive system carries the tax credits over to be offset by the next lag period through the LCF provision. This observation is significant for social expenditure planning for governments that rely on corporate profits from the extractive sector to respond by making appropriate financial and macroeconomic adjustments. The government could reduce fiscal deficits by prudent management of social and infrastructure expenditures, avoid excessive foreign debts to offset the deficits and use more of resource wealth fund savings.

On the other hand, investors as price takers would extract at a higher rate when prices are high and slow down mining (extraction) rate when prices are low. These strategies adjust the long-run market price and mining cost differentials that in turn readjust the equilibrium position. The effects of market conditions and investors' behaviours influence the performance of CIT as observed from the samples of real mines investigated in this thesis.

The CIT performance based on the Bougainville and Ok Tedi copper mines was much better than that of the Porgera mine. This was possibly due to the Bougainville mine attaining a positive tax base in the first year of production (Fig. 4.1 and 5.1), which was identical to the undeveloped Frieda deposit. By contrast, the Ok Tedi mine was a classic example in which the CIT payments were delayed for 10 years. This performance was predictable since the Ok Tedi mine has been a low-quality porphyry copper deposit and a high-cost operation. The prolonged lag period for accessing the CIT revenues had a differential effect on the progression coefficients, resulting in the weaker CIT progressivity than that of the theoretical progressivity (Figure 5.1). However, the Ok Tedi mine performed strongly when the mineral prices coincidentally improved between 2003 and 2013 (Fig. 5.3), and after BHP Billiton exited the mine in 2002. To date, the Ok Tedi mine has generated greater CIT revenues for PNG over its three decades of operation than the Porgera mine did.

Porgera mine's CIT performance was expected to be strong since it has been a quality deposit with a low-cost operation, especially during periods of high price. However, this was not the case (Fig. 5.3). At the time of writing this thesis, PNG's first Extractive Industry Transparency Initiative (EITI) Report indicated that there were a lot of inconsistencies in tax data provided by the Porgera mine. The data irregularities complicate auditing tax compliance, and the high level of information asymmetry can be a sign of tax evasion (Hines Jr 2014). In another example, the Lihir gold mine (not sampled in this study) has not paid CIT according to the former Mining Secretary and 2013 EITI Report (EITI National Secretariat 2016). There is a serious resource governance issue associated with PNG's gold mining sector (Bauer and Quiroz 2016).

These issues are critical for highly corrupted jurisdictions with poor domestic financial institutions. The tax avoidance exists externally and is complex to trace using the tax policy framework. Since tax avoidance through profit and cost shifting are complex to detect and rectify, the GoPNG can make use of tax adjusting techniques such as depreciation technique, loss carry forward policy, thin capitalisation and tax holiday to protect the CIT base to make it more progressive.

First, the ADB depreciation technique enhances early capital allocation (Adkins and Paxson 2013) in exchange for collecting more CIT revenues at the later stages of a mine life. The ADB technique correctly facilitates risk sharing by deferring the CIT revenues until investors have recovered their invested capital. The World Bank opposes the ADB technique because it delays the government accessing the CIT revenues (Emerson and Kraal 2014). However, the ADB technique regulates the timing for capital allocation and balances the distribution of rents and tax transfers amongst the stakeholders. Further, the ADB technique reduces tax credits to investors at a mature productive stage of a mining project, which in turn strengthens the progressivity of the profit-based tax instruments (Table 4.5). On the other hand, the SL depreciation technique slows down the time for attaining the ROR on the invested capital and at the same time reduces CIT revenues at the mature production stages (Section 4.2).

Second, the 100 percent debt capital weakened the CIT progressivity compared to the 100 percent equity financing of a mining project (Table 4.6). This effect was due to excessive interest deductions against the CIT base before instalment of the debt principal on the post-tax base. Presently, PNG has a 3:1 debt-to-equity ratio, which reduced the CIT progressivity and the NPV (Table 4.6). As a result, the GoPNG proposed to reduce the thin capitalisation ceiling to 2:1 debt-to-equity ratio, which ensures mining companies are eligible for benefit from a 50 percent of their debt interests are tax deductible. In this arrangement, non-resident mining companies pay an interest withholding tax on the balance (if their leverage exceeded the ceiling). Hence, the 2:1 debt-to-equity ratio is an ideal thin capitalisation rule for PNG as it protects the CIT base and improves the progressivity of other profit-based tax instruments.

Third, separating the non-cash depreciation expenditures for tax purposes from the extraction costs was identified to protect the CIT base in situations where an unlimited LCF policy exists (Table 4.5). Risks associated with the initial capital being invested diminish upon reaching the ROR on quasi-rents. Compounding the unused capital costs, including tax deductible interest at a risk-free rate recognises the opportunity cost of the capital being locked in the present investment (Boadway and Keen 2014). In that context, logic suggests that an uplift rate imposed on the cumulative losses after attaining the normal ROR could unfairly inflate the operating costs, causing over-capitalisation and weaken the CIT progressivity. The true neutrality can be attained only if the uplift rate on losses being carried forward relate to the unused depreciation allowances.

Continuous compounding of cumulative losses without separating the unused depreciation allowances and the extraction costs accumulate tax credits to investors that in turn weaken the CIT progressivity as well as other profit-based tax instruments. The unlimited LCF provision recognises the production and tax risks that exist over the entire life of a mine (Hlouskova and Tsigaris 2012, 561). With resepct to that, excising the uplift rate on the entire cumulative losses causes underinvestment and weakens the CIT progressivity and that of other strongly progressive tax instruments. This thesis illustrates that limiting the compounding of unused depreciation allowances to the payback period will improve the CIT progressivity (in Table 4.5). The limited LCF provision with an uplift rate applied to the unused depreciation allowance is identical to a self-adjusting tax concession, which offers sufficient tax credits to high-risk mining projects.

Fourth, the fixed CIT holiday weakened the progressivity with a negative METR, and a high NPV (Table 4.5). A CIT holiday provides an artificial shelter against the second-best neutrality over the concession period. The tax write-off over the concession period allows rapid recovery of the capital invested. However, changes in price, deposit quality and operating costs can allow an investor could make untaxed profits if the pre-tax base turns positive before the tax holiday period lapses. In such circumstances, tax holiday causes wasteful extraction and weakens the progressivity, leading to a reduction in revenues, although it could encourage firms to mobilise capital to high-risk investment destinations.

Without the knowledge of communities, the GoPNG grants tax holiday on ad hoc basis (case by case basis). It is often instrumented under a mine development agreement, which is often drafted by lawyers rather than tax experts. For example, the GoPNG granted a ten-year CIT holiday to the Ramu Nickel mine (Nelson 2010), and a twenty-five year CIT holiday for the PNG liquefied natural gas (LNG) project. Although the tax break is an incentive to reduce initial investment risks, it discriminates against other mining and exploration activities that face the same level of systematic risks. PNG already has a flexible CIT concession system featured by limited LCF provision with an uplift rate, along with the accelerated depreciation on pooled pre-production capital costs, and amortisation of all the exploration costs (Hatcher 2012, 434-435). Since the progressive tax system has the ability to achieve this function, policy makers need to reconsider the use of tax holiday as an incentive to attract foreign direct investment in mineral exploration and mine development.

Summary, the weak progressivity of actual CIT from the three mines sampled suggest that PNG needs to seriously intervene with policy strategies to protect the CIT base from being eroded. Chen and Mintz (2015*b*) find that tax deductibles and other tax evasion tactics are the major causes of reduction in the METR. Furthermore, the 2012-2015 Mineral Taxation Review recommended a reduction of the CIT rate from the present 30 percent to 25 percent. However, Auerbach (2007, 167) is critical of reducing the CIT rate when the actual marginal tax rates have declined, which is consistent with the results of this study. The actual NETR for CIT has declined to 20 percent from the statutory rate. Thus, a further reduction in the CIT rate could cause the real NETR to decline, which could result in substantial losses of CIT revenues. Given these findings, PNG critically needs to patch up the policy loopholes to protect the tax base and strengthen the tax administration to make CIT more progressive.

6.3 Dividend withholding tax

The theoretical progressivity of DWT was similar to that of the CIT, as those taxes have the same attributes (Auerbach 1986). Figure 4.2 showed that the 10 percent DWT rate, being within the optimal progressivity sphere, demonstrated its ability to collect a high magnitude of revenues. The historical progressivity of DWT based on the Bougainville mine was strongly progressive, while that of the Ok Tedi mine was weak. The shift from a 17 to 10 percent DWT rate did not appear to affect the historical progressivity curves for the Ok Tedi and Porgera mines (see Fig. 5.1 and 5.2). The DWT was computed on the assumption that corporate decisions are made to pay dividends on all profits, although in practice mining firms retain much of their earnings.

The distortion index for DWT was high, similar to the CIT, which affects the value of the firm as it was computed on a post-CIT base (Table 5.10). A major effect is that the DWT affects junior firms that rely on equity capital for financing exploration activities. Another effect is that given PNG has a foreign-dominated mining industry, investors could negotiate with tax authorities for favourable incentives that allow them to retain profits offshore and employ complex accounting techniques that are inaccessible by tax authorities. This makes the use of the DWT to restrict profit repatriation ineffective. Moreover, the DWT could encourage a mine operator to reinvest profits in the present mine, especially for highly leveraged investors. Hence, where interest withholding tax distorts sourcing debt capital for a mine development, the DWT affects the equity capital for exploration activities more than operating mines.

The DWT based on the Bougainville and Ok Tedi mines raised exceptionally high revenues since the tax curves were within the optimal progressivity boundary (Fig. 5.2). This reflected that there was a tendency for mining companies to pay dividends to equity holders from which the GoPNG raised significant DWT revenues. The results indicate that CIT and DWT performed within the effective progressivity boundary, thereby raising a higher level of tax revenues for the PNG government (Devos 2014, 8) compared to equity participation.

6.4 State and community equity participation

Previously, PNG had a FCE policy where the GoPNG became an ordinary shareholder in the former Bougainville copper mine and equity dividends were paid out of the corporate profits. This was the main reason why the progressivity of FCE was strong and the curves were parallel to that of the DWT against the Lorenz curve (Figure 5.1). In the early 1990s, PNG made a policy shift to adopt the FPE, which was also imposed on the post-tax base. In that arrangement, the government had to procure the equity interests using externally sourced capital compared to the internally arranged financial transactions associated with the FCE. The results of scenario analysis in Section 4.4 showed that FPE was better than the FCE. The FCE increased the METR to 46 percent. This result shows the FCE is slightly unattractive although other functional variables are identical to that of the FPE (Table 4.8). In both cases, if a mine operator cumulatively offsets the equivalent cost of FCE against positive equity cash flows (internally) and at the same time treats it as a tax deductible item, the progressivity of other tax instruments will be weakened. Further, the theoretical and historical analyses of all the equity types were found to be weakly progressive (Fig. 5.2 and 5.3).

Presently, PNG's taxation regime comprises of the basic tax instruments and the FPPE, which was identified to raise the METR and reduce the NPV (*case 4*, Table 4.8). It causes two problems. First, deadweight losses (economic inefficiency) arise due to the government taking away portions of the mineral outputs before they reach the market. It causes higher distortion to reduce a firm's share of mineral reserves than that of royalty. This being the case, the weak progressivity of FPPE exposes both investor and government to financial risks. Thus, it becomes a wasteful extraction: deadweight loss to the investor and increases social cost to the government. Second, equity participation exposes society to risk since it contributes less revenues towards supporting sectoral development goals such as capital accumulation, income diversification and skills development (Smith and Dorward 2014). Further, due to price uncertainty and equity cash flows locked-in to servicing of equity debts using offshore accounts, macroeconomic effects such as increased foreign debts, current account deficits and depreciation of the currency and foreign exchange shortages have emerged strongly in PNG in the 2012-2016 periods (Gilberthorpe 2016). Therefore, PNG's mineral taxation regime with the inclusion of the FPPE is identified to be unattractive (Table 4.8).

GoPNG has maintained its policy stance by taking up equity interests at the exploration stage in various exploration projects. For instance, the state entered into a 30 percent equity facility with Nautilus (PNG) Pty Ltd to explore for mineral deposits on the ocean floor of Bismarck Sea. Owning equity interests at the exploration stage can raise exploration capital domestically and share the risks with investors. As mentioned in Section 2.1, it resembles a Brownian tax in which the government can subsidise exploration costs so that it can amortise the subsidy costs if the mineral property advances into a mining project. Also, state's direct involvement enhances fast-tracking of the social bargaining processes so that a mine development can occur without delays (e.g., Banks 2003). However, there is uncertainty associated with when the subsidy costs would be recouped. Thus, subsidising exploration costs using public funds in pursuit of future dividends diverts the attention away from meeting the social development needs of the country.

The GoPNG reserves a 5 percent equity interest for host landholder communities to directly participate in mining activities (DMPGM 2014). However, Figure 4.3 showed that an equity interest rate less than 10 percent is not economically viable. It makes host communities to struggle against the financial risks as they quest to earn future dividends. As shown in Section 5.3, the Porgera landowners and the EPG have not benefited much from owning the 5 percent FPPE. The dividends were insufficient to offset the cost of equity (Figure 5.3). When the dividends were delayed, the EPG and the Porgera landowners used public funds and royalty proceeds to repay the cost of equity. They occasionally make funds available from other sources when a cash-call from the Mineral Resources Development Company (MRDC) is made to meet its management costs. Similarly, the Lihir landowners did not realise the dividends expected for owning about 7 percent FPPE since 1997. As a result, they disposed the equity interests in 2012 and entered into spin-off business activities that led to significant capital accumulations. Hence, the empirical results strongly suggest that communities in PNG should not own equity interests in mining and exploration projects.

The GoPNG has pursued an inconsistent and a cyclical policy on equity participation with establishments and demolitions of various SOEs such as the former Oregon Minerals and Petromin. The same entity has been resurrected in a different name (e.g., Kumul Minerals Limited). The frequent changes of the SOEs dilute PNG's long-term ambitions to accumulate assets, transfer knowledge and acquire entrepreneurship skills required for sustaining the growth of the SOEs. State equity participation entices the GoPNG to use social development funds to subsidise start-up and overhead costs of maintaining the SOEs. This thesis predicts that a prolonged recession period can increase the burden of subsidising the SOEs, which could force the GoPNG to disband the Kumul Minerals as it was the case with the former Oregon Minerals. These implications along with distortion to production efficiency and the prolonged lag periods of accessing the dividends suggest that PNG needs to rethink its equity participation policy, although it is politically and socially complex.

As a summary, this thesis makes these recommendations due to two underlying conditions. First, PNG-based investors perceive that equity participation could provide a security against political and social disturbances (Emerson and Kraal 2014). Second, royalty and equity participation are complex to repeal because GoPNG owns the minerals while community have integenerational ownerhip rights to the land (Imbun 2013). Therefore, amongst the options assessed, increasing the CIT rate to 35 percent and a 4 percent increase in the ad valorem royalty rate seems to be a suitable substitute for phasing out the FPPE as it increases the total government revenues by 10 percent. These options could raise more revenues than if the basic tax instruments are combined with the APT and FPPE, which is identified to be most unattractive combination according to this thesis. If the GoPNG chooses to maintain its policy stance on equity participation, a shift to the FPE type can reduce the overhead management costs and achieve a high performance similar to the Bougainville experience.

6.5 Integrating the results with the hypothesis

The research explored how a balanced mineral taxation regime could be devised by adopting a progressive system. The thesis hypothesised that governments can collect a high magnitude of revenues through devising a more progressive tax system that includes indirect tax instruments and non-tax benefits. The hypothesis relates to the most asked question, which is: how much of the private profits could be transferred for public use? Further, the non-tax benefits are not progressive derivatives because they do not respond to market dynamics and changes in the tax base. Because of this complexity and in order to measure the entire wealth transfers, the non-tax benefits were converted into wealth transfer ratios (EIT and EWT rates) relative to the gross outputs (see Section 3.5).

There were no indirect and non-tax benefits in the theoretical analysis and the EIT and EWT rates were based on the combination of strongly and weakly progressive direct tax instruments, which included the ad valorem royalty, the MRA levy and the SSG. The theoretical EIT and EWT rates for the direct tax instruments were equal (25 percent each) when the METR was at 45 percent (Tables 4.3 and 4.4). The other balance (50 percent) comprising of quasi-rents flowed to capital owners and suppliers of inputs to production. This shows that without external influences (e.g., profit and cost shifting), the risk, rent and tax revenue allocations are equitable as long as the procedures are transparently executed (Magno 2015). This suggest that PNG's existing taxation regime is theoretically balanced (that is, without the FPPE).

From the historical perspective, the EWT rates of non-tax benefits when added to that of the direct tax instruments exceeded the EIT rate, which was also indicated by the low METR and NETR (Section 5.4). These results were consistent with Mirrlees' (1971) optimal model, suggesting that the historical METR and NETR were not necessarily required to reach their theoretical thresholds. A main reason is that investors are competitive in protecting their economic rents compared to governments that do not efficiently use their tax systems when it comes to creating a stable mineral taxation policy.

A mining levy introduced in the 1990s and the production-based equity participation, which the former was repealed along with the APT in 2002, greatly reduced the historcial performance. The empirical results suggest the government loses revenues through weakly progressive tax instruments and those that cause distortion (e.g., production levy). Furthermore, Ok Tedi mine's EIT rate exceeded the EWT rate by a 1 percentage point compared to that of the Bougainville mine. The Porgera mine was the worst case. As can been seen, these are evidence of tax evasion amongst the gold mines in PNG when compared with the copper mines, which affected the aggregate industry level transfer rates.

When indirect tax instruments and non-benefits were added to the direct tax instruments, including royalties and levies, the fiscal disparity gap created by the weakly progressive tax instruments was reversed. This was reflected by the aggregate EWT rate exceeded the EIT rate (Section 5.4). These results fulfilled the hypothesis of the thesis where communities can collectively bargain with the government and investors to create incentives for them to capture more of the quasi-rents through spin-off business activities, as well as direct and indirect employment opportunities created by the extraction activities (Filer and Macintyre 2006). In that respect, the GoPNG needs to build capacities like skill development and provide seed capital to encourage the communities to capture more of the quasi-rents instead of making policy provisions that encourage direct participation like stake ownership. However, a point of caution is that non-tax benefits cannot be a substitute for paying lower levels of direct tax revenues than the tax-base requires. This is because the government needs revenues from the direct and indirect tax instruments for a fair redistribution of goods and services at the national level and to diversify the resource revenues into other sectors such as agriculture to maintain economic stability.

The main problems identified in this thesis were: geological prospectivity and the perception of PNG not benefiting from its resource abundance caused socio-political instability and the mineral taxation regime was thought to be less competitive. This has been exacerbated by the lack of recognising progressive tax system's ability to raise revenues by adjusting to supply cycles and reducing inequality, while accepting some trade-offs associated with investors' expectations (Lund 2008). However, the results of this study shows PNG's taxation regime is theoretically a robust system that has not been identified by past studies. As a result, it underwent reforms on several occasions (Daniel et al. 2000; McLaren and Chabal 2011) to improve the tax competitiveness by eliminating production levies and royalties, reduce tax rates and restore fiscal stability. However, the reforms did not focus on performance-based policy reforms aimed at strengthening the revenue collecting potentials of the progressive tax instruments.

This study resolves the knowledge gap on the robustness of PNG's taxation regime and where PNG stands amongst other immature economies concerning the CIT and the overall tax performance. Although competitive ranking using the AETR has creditability issues, a past study by Otto (2009) find that PNG's international ranking improved significantly from having over 70 percent AETR along with Mexico and Indonesia to a 45 percent ranking with Zimbabwe and Navada (USA). According to this thesis, PNG's theoretical METR and NETR of 45 and 40 percentages affirm that the mineral and hydrocarbon Tax Review in 2000 improved PNG's global competitive ranking. The improvement was due to phasing out the 4 percent mining levy and the APT (McLaren and Chabal 2011). This study also found that PNG's historical METR (30 percent) and NETR (20 percent) for the CIT to be lower than the theoretical ones, but are above the global average METR of 17 percent (Chen and Mintz 2015a; Swan 2012). Therefore, the present taxation regime of PNG does not need a major review aside from the inefficient equity participation.

The variations in the real METR and NETR were due to the theoretical data did not take into account all the risk factors such as the time lag delays accessing the revenues, overcapitalisation and existence of other factors caused the fiscal leakages as observed in the historical analysis. The lower averages of the actual TPIs, METRs and NETRs were the result of actions taken by mine operators in their quests to reduce risks and maximise profits. To counterbalance that, the government has not been proactive towards protecting the tax base using the recommended tax adjusting techniques (Section 6.2) to make the tax instruments more progressive to ensure a greater share of resource revenues are transferred to PNG citizens.

6.6 Methodological implications

The lack of a unified methodology for tax analysis has been blamed for contradictory empirical results that lead to divergent policy guidance (Lund 2009). Most optimisation models obtain empirical results in risk neutral settings that do not reflect the actual tax revenues that a mine would generate (Boadway and Keen 2014). This research has integrated two techniques that were unique in measuring the performance of tax instruments. First, neutralising the uncertainty of input variables improved the internal validity of the theoretical results. Second, the structural progressivity analysis enabled identifying the revenue collecting potential of the tax instruments and tax burden placed on investors.

The theoretical tax models using the RO CFT and MC-CFT methods generated financial and tax data that mimicked the future trends. In a perfect setting where the tax base is unaffected by external factors, such as profit and cost shifting, the theoretical and historical results should be similar. The theoretical cash flow forecasts were identical to the former Bougainville and the existing Ok Tedi copper mines, which suggest that the methodology employed was reliable. The establishment of PNG's theoretical METR (45 percent) and NETR (40 percent) is attributed to the reliability of the methodology, and suggests that reducing the uncertainty in a tax policy is significant for correct measurement of burden distribution and tax benefit transfers for a long life mining project.

The deterministic DCF method lacks recognition of the probabilistic movement of input variables. Shortcut procedures such as inflating the prices, gross revenues and operating costs may not produce robust results (Mun 2006). The risk-adjusted cash flow models enhanced deriving reliable METRs and NETRs, as well as other variables that enhanced the reliable measurement of performance of various tax instruments compared to the AETRs. A significant observation was that the historical AETR did not significantly differ from the theoretical one (Tables 4.3 and 5.9). The AETR being approximately the same for the two case studies suggests that it does not cogently measure the distribution of burdens over time when compared to the METR and NETR (Gordon, Kalambokidis and Slemrod 2003). A high AETR on its own (without the METR and NETR) could have erroneously suggested that PNG's taxation regime is unattractive.

The structural progressivity approach improved the measurement of the performance of the tax instruments. The common use of a point-scale matrix for comparing tax systems only provides guidance on determining the structural design of tax systems. The static methods do not assess the distribution of burdens or the ability of a tax instrument to collect revenues. In contrast, the structural progressivity technique enabled clearly tracking of the tax burden distribution over the entire mine life cycle. Further, when compared with the traditional understanding of progressivity (Fig 2.1), the Lorenz curve was a useful tool for identifying which tax instruments collected higher revenues than others. For instance, the study found that not all rent-based taxes collect revenues as expected, and not all royalties are regressive, as often featured in the mineral taxation literature.

In both cases, integrating the theoretical and historical data enabled the parallel measurements of tax performances in real time. A significant implication of this approach was that without the historical results, the theoretical evidence would not have revealed the actual magnitude of tax revenues collected. Further, most stylised and hypothetical models tend to overestimate the tax performance, undervalue social optimality, and may not reflect the actual tax burden and fiscal distributions in real time. This study would have inaccurately indicated that investors pay tax at the theoretical METR and NETR if the actual tax analysis was not done. This implication would suggest that a parallel analysis of the theoretical and historical data generated reliable results, which in turn validated the theory and ensured a more balanced policy analysis in this thesis.

In summary, the improved methodology enhanced the precision with which the functional variables were forecasted to provide a more accurate prediction of the mining taxes in PNG. The deviations between the theoretical and historical results were due to the actual risk conditions, such as mine operational uncertainties, social and political risks that were not represented in the theoretical models. Therefore, the gap between theory and practical aspects of taxation modelling still exists (Mankiw, Weinzierl and Yagan 2009). It means that conceptual studies alone may not clearly reflect the actual tax burden and revenue transfers to society. The validity of the results showed that the methods employed were reliable for establishing the relationship between progressivity and the revenue collecting potentials of tax instruments within the theoretical, analytical and data limitations.

6.7 Limitations

This section explains the theoretical, methodological, sampling, measurement and data analysis limitations encountered in this study. First, the study focused on the hypothesis of how tax instruments would collect revenues and distribute tax burdens and ignored other factors required for structural design of a tax system. Criteria such as equity, stability, ease of tax administration, flexibility, efficiency and neutrality are the basic ingredients for a balanced tax system (Sunley et al. 2012). Although these attributes were not considered in determining the optimal mix of tax instruments for PNG, the progressive system automatically possesses all these attributes as shown by the results of this study (Conesa and Krueger 2006). In other words, a progressive tax system distributes the tax burdens as desired by the second-best neutrality framework and reduces inequality during periods of high rents and likely to reduce instability as it swiftly responses to changes in the tax base.

Second, the lack of data verification weakened the reliability of the results. It was difficult to cross-check and verify the firm-based historical data with the Internal Revenue Commission (IRC). Additionally, IRC's confidentiality clause restricted accessing the historical data for the purpose of verifying data provided by the mining companies. Data anomalies, such as poor reporting, over-payments and mixing of tax payment data could have also affected the results. Further, the theoretical tax models were constructed under the assumption of 100 percent equity financing. This ignored the real situation where most mining companies use a combination of equity and debt capital arrangements to finance a mine development.

Third, identifying and drawing specific inferences on tax evasive behaviour has been complex to capture using the structural progressivity technique. Duncan and Sabirianova

Peter (2012) find that there is no clear relationship between progressivity and tax evasion and suggest that developing countries could reduce tax evasive behaviour by adopting less progressive and flat taxes is against the tax revenue collection objective. However, tax administrators can use the structural progressivity technique to initially detect the existence of tax evasion during periods of high prices to impose a higher degree of tax audits and penalties that will encourage more tax compliance (Sandmo 2005). Tax evasion is becoming extremely complex to track as it involves many countries and is an increasing trend in the mining industry (Gumpert, Hines Jr and Schnitzer 2016). That said, investigating tax evasion is beyond the scope of this study.

In summary, this thesis was confined to direct and indirect tax instruments, and non-tax benefits and ignored the efficiency of redistribution of these benefits. The performance of tax instruments and wealth transfer rates indicate that there are substantial financial benefits and physical and human capital being created at the micro level. As a result, it could be incorrect to make a claim that the fiscal dissipation perception experienced in PNG is a redistribution problem because that issue was not investigated in this study. A parallel case study along with this thesis could clearly identify why communities in PNG perceive that they are not benefiting from the exploitation of its vast mineral resources. However, such a broadened study could not be successfully completed due to the magnitude of workload and time limitations.

6.8 Future research

Further research is required to investigate how revenues collected using direct tax instruments and non-tax benefits are redistributed, as this may be inducing community's perception that they are not benefiting from the mining activities (Avalos et al. 2015). Ulriksen (2014) presents the redistribution dilemmas facing Botswana's mining industry, and it is expected that a similar case could exist for PNG. Given the finding of this study, the perception of fiscal dissipation could be a redistribution problem, but was not investigated in this thesis. A further study is required to investigate the efficiency of PNG's redistribution structures to identify what causes the fiscal dissipation problem. Such an extended study which measures both tax performance and efficiency of the redistribution systems will enhance devising suitable policy measures to ensure PNG citizens benefit from exploitation of its vast mineral endowments.

Chapter 7 : Conclusion

The aim of this research was to investigate PNG's progressive mineral taxation regime in order to draw some policy recommendations that could assist in devising a balanced tax system. The main gap identified in Chapter 2 was the lack of understanding in how progressive tax instruments collect revenues without distorting investment decision making. Within this gap, the three issues identified were: (a) the degree of progressivity of direct tax instruments; (b) how a progressive tax system works to reduce inequality; and (c) identifying a suitable methodology and techniques for enhancing the stochastic distribution of the tax base for deriving reliable results.

The steps taken to investigate these issues within the main research question were guided by the following questions:

- Can the progressive tax system augment the capacities of individual tax instruments to capture a higher magnitude of tax revenues for the government?

- What are the theoretical and practical aspects of the progressive tax schedule that makes it a suitable tax system for balancing the fiscal needs of investors and governments?

- How do the methodology and techniques impact upon the reliability of the results of the thesis?

The overall finding of the study is that existing progressive tax instruments established by the 2000 Mineral and Hydrocarbon Tax Review are suitably positioned to capture a high magnitude of revenues from the resources sector. This funding is supported by identifying the theoretical METR and NETR as globally competitive, which constitute the CIT, DWT and the ad valorem royalty are the main tax instruments that collect much of the resource revenues for PNG. The overall industry level tax performance for PNG (that is, 30 percent METR) was above the global average METR of 17 percent (Chen and Mintz 2015a; Swan 2012). To balance the effects of the tax combinations to a reasonable level, repealing the FPPE policy and compensating this shift by raising the ad valorem royalty rate and/or a shift to the FPE can reduce distortion, wasteful extraction and maximise revenues.

There are policy areas that need improvement for making the tax instruments more progressive by adopting the accelerated depreciation technique, 2:1 thin capitalisation, discourage tax holidays, a suitable LCF policy and strengthening the capacity of tax administration. There is no need for tax holiday because the LCF provision within the progressive tax schedule provides sufficient years of tax relief, which could encourage investments in risky exploration and mine development. It also enhances the tax system to flexibly adjust to periods of low and high rents to make adjustments to risk and rent sharing more efficient. Further, addition of indirect taxes and non-tax benefit streams make up for revenue leakages from the direct tax instruments. Investors and the GoPNG can design incentives for communities to capture more of the quasi-rents from a mining operation.

A key prediction of this thesis was about how a progressive tax system would distribute the tax burden and reduce inequality. This thesis identified an effective progressivity range within the range: 0.0>TPI<0.2. This range is a boundary between the Lorenz curve and the threshold progressivity curves marked with a progressive coefficient less than 0.2, which is identified to be welfare enhancing (Kremer and Stähler 2016, 2). The individual tax instruments that fall within this domain tend to have constant progression coefficients and remain relatively closer to the Lorenz curve as profitability increases (Fig. 4.3). Depending on the cyclical progressivity, this scenario reduces inequality characterised by an effective METR range between 40 percent and 45 percent, and a 40 percent NETR. The theoretical and the historical progression coefficients, METRs and NETRs for PNG can be used as benchmarks for future policy analysis, reforms and research in mineral taxation.

Making tax instruments more progressive enhances governments to have a high degree of confidence in a tax system's ability to respond to high profit situations thereby reducing the inequality and generate greater tax revenues than flat tax systems. On the other hand, progressive tax system equalises the intertemporal burden distributions subject to cyclical progressivity under different risk conditions. A price-induced linear progressivity causes the progression coefficients, METR and NETR of the direct tax instruments to reach steady states as profitability approaches infinity. These attributes suggest that marginal tax rate does not always rise beyond the equilibrium limit or beyond an investor's ability to pay if a mine profitability increases (Kremer and Stähler 2016). During low prices, progressivity of tax instruments within the limited (or unlimited) LCF provision generate tax credits that can be carried over to the next period. This behaviour reduces the tax burden that could be faced under a regressive tax system. According to this thesis, the CIT rate-induced strong progressivity is the only scenario, which influences the METR to increase rapidly that in turn discourages investment decision-making.

The thesis investigated some guidelines for devising a balanced tax policy which allows investors to operate mines profitably so that governments can continue to tax the profits generated from a sustainable mining industry. From a re-distribution perspective, the benefits flowing to investors and governments (profits and tax revenues) depend on the preferential treatments given to allocation of risks and rents within the second-best neutrality design settings. The time-dependent rent distributions within the taxation framework tend to determine how much rent an investor gets for initial risk-taking and the share of revenue flows to a government after factor allocations. This provides a broader view than most analytical results would, suggesting that equity, fairness, stability and other components required for a balanced tax design are the outcomes of an efficient redistributive tax system. The progressive tax schedule fulfills this requirement for a balanced tax design.

The methodology took uncertainty into account when tracing Frieda deposit's value creation that led to correctly predict the magnitude of tax revenues. The GBM and binomial lattice techniques reduced the uncertainty of the whole of life tax base, whose variability was adjusted by the MCS technique. The stochastic tax base accurately follows a time-dependent neutrality path over the mine life compared to the deterministic DCF method. This was revealed by revenues being delayed at the early stages of a mine life. Likewise, a high magnitude of revenues could be collected when risk levels decline at the mature production stages if tax adjusting techniques such as the ADB technique improve the tax base. However, some setbacks were identified when using the RO method.

RO method's application of a constant risk-free interest rate ignored the cyclical progressivity that responded to the dynamic risk conditions at different phases of a mine life (Lima and Suslick 2006). This problem was not recognised by Samis, Davis and Laughton (2007) who concluded that the use of RO methods could maximise tax revenues. Their prediction of RO method's ability to maximise tax revenues was partly due to the constant risk-free interest rate, which assumed a mine was absolutely risk-neutral throughout its life. However, the value creating ability of a mining project and the magnitude of tax revenues depend on uncertainty of commodity prices, costs and deposit quality and not the study methodology itself. These factors suggest that tax planners should cautiously distinguish the differences between theoretical and actual projections of revenues. For example, incorrectly predicting APT's performance can mislead governments into optimistic social expenditure appropriation and planning that could result in budget deficits.

This study is important for some reasons. First, this thesis has applied the structural progressivity as an evidence-based analysis tool to measure the behaviour of progressive cash flow tax instruments, which has not previously been done in mineral taxation studies. The graphical representation of the tax curves against the Lorenz curve and projection of time series progression coefficients make tracking the long-term behaviours in terms of burden distribution and revenue collecting potentials of tax instruments more convenient than the traditional methods. Second, reducing the uncertainty of input variables (price and costs) and incorporating Monte Carlo simulation are significant for establishing a stochastically distributed tax base that in turn correctly predict the time-dependent behaviour of the tax instruments and the functional variables.

Third, a parallel study of theoretical and historical tax performance assists in using the theoretical results as benchmarks against the historical results to identify and resolve policy factors that erode actual tax revenues. Additionally, integrating non-tax benefits with the direct tax instruments, royalties and levies in the historical tax analysis captured most of the wealth transferred compared to single phased tax study. This approach effectively measures and reconciles the redistribution capacity of a tax system.

Finally, the data used in this thesis were compiled by the mining companies. As a result, a lack of verifying the actual tax revenues paid to the GoPNG through the IRC and lack of auditing of non-tax benefits at the micro level could have affected the results and therefore the policy recommendations. The researcher hopes that future studies will improve the methodology explained in Chapter 3 and the underlying limitations of the techniques employed for analysing the performance of a progressive mineral taxation regime in any mineral endowed nation.

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Appendix A: Parameter estimations for price forecasting

Table A-1: Parameter estimations using historical copper prices

Date	ice (US$	LN(Pric	Ln(t+1)-Ln(t)
5/01/1998	1694.50	7.4351	
6/01/1998	1650.50	7.4088	-0.026
7/01/1998	1656.00	7.4122	0.0033
8/01/1998	1667.00	7.4188	0.0066
9/01/1998	1645.00	7.4055	-0.013
12/01/1998	1629.00	7.3957	-0.01
13/01/1998	1642.00	7.4037	0.0079
14/01/1998	1681.00	7.4271	0.0235
15/01/1998	1657.00	7.4128	-0.014
16/01/1998	1709.50	7.444	0.0312
19/01/1998	1683.00	7.4283	-0.016
20/01/1998	1677.00	7.4248	-0.004
21/01/1998	1693.00	7.4343	0.0095
22/01/1998	1689.50	7.4322	-0.002
23/01/1998	1709.00	7.4437	0.0115
26/01/1998	1739.00	7.4611	0.0174

Recent 12 months (Volatility)		ϕ Long	β Long	μ Long	S_l Long	σ Long	Median (Sm) Long	ϕ Short	β Short	μ Short	S_l Short	σ Short	Median (α) short
0.80%	Current	8.8718	0.213	7291.7	1570.9	21.54%	7124.43	8.8786	0.1997	7321.3	1476.6	20.17%	7173.87
Annualise	6 months ago	8.9311	0.125	7623.3	956.79	12.55%	7563.49	8.8824	0.1064	7245.1	773.2	10.67%	7203.94
14.25%	1 Year ago	8.8792	0.2314	7376.2	1729.8	23.45%	7176.10	8.9763	0.0423	7920.3	335.45	4.24%	7913.19

Compound Annual Rate of Growth

-0.72%

1. The symbols and equations are defined in Table 3.1
2. Highlighted parameters are the ones used in Table 3.2
3. Prices are lognormally distributed (LN (price) that is useful for computing the volatility

Price sourced from LME: available www.lme.com

Time	**0**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Step	**0**	**80640**	**80680**	**80720**	**80760**	**80800**	**80840**	**80880**	**80920**	**80960**	**81000**	**81040**	**81080**	**81120**	**81160**	**81200**	**81240**	**81280**	**81320**	**81360**	**81400**
	1253	1298	1344	1392	1442	1494	1547	1603	1660	1719	1781	1845	1911	1979	2050	2123	2199	2278	2360	2444	2532
		1210	1253	1298	1344	1392	1442	1494	1547	1603	1660	1719	1781	1845	1911	1979	2050	2123	2199	2278	2360
			1168	1210	1253	1298	1344	1392	1442	1494	1547	1603	1660	1719	1781	1845	1911	1979	2050	2123	2199
				1128	1168	1210	1253	1298	1344	1392	1442	1494	1547	1603	1660	1719	1781	1845	1911	1979	2050
					1089	1128	1168	1210	1253	1298	1344	1392	1442	1494	1547	1603	1660	1719	1781	1845	1911
						1051	1089	1128	1168	1210	1253	1298	1344	1392	1442	1494	1547	1603	1660	1719	1781
							1015	1051	1089	1128	1168	1210	1253	1298	1344	1392	1442	1494	1547	1603	1660
								980	1015	1051	1089	1128	1168	1210	1253	1298	1344	1392	1442	1494	1547
									946	980	1015	1051	1089	1128	1168	1210	1253	1298	1344	1392	1442
										913	946	980	1015	1051	1089	1128	1168	1210	1253	1298	1344
											882	913	946	980	1015	1051	1089	1128	1168	1210	1253
												851	882	913	946	980	1015	1051	1089	1128	1168
													822	851	882	913	946	980	1015	1051	1089
														793	822	851	882	913	946	980	1015
															766	793	822	851	882	913	946
																739	766	793	822	851	882
																	714	739	766	793	822
																		689	714	739	766
																			665	689	714
																				642	665
																					620
Expected gold price	**1253**	**1254**	**1255**	**1257**	**1259**	**1262**	**1265**	**1269**	**1274**	**1279**	**1284**	**1290**	**1297**	**1304**	**1312**	**1320**	**1329**	**1338**	**1348**	**1359**	**1370**
Risk-discount factor		0.998	0.996	0.994	0.992	0.990	0.988	0.986	0.984	0.982	0.980	0.978	0.976	0.974	0.972	0.970	0.969	0.967	0.965	0.963	0.961
Risk-adjusted forward price		1251	1250	1249	1249	1249	1250	1252	1254	1256	1259	1262	1266	1270	1275	1281	1287	1293	1300	1308	1316
MCS -Stochastic Price	**1253**	**1233**	**1111**	**1224**	**1384**	**1320**	**1495**	**1347**	**1404**	**1170**	**1188**	**1298**	**1299**	**1114**	**1204**	**1252**	**1256**	**1237**	**1307**	**1373**	**1136**

Figure A-1: Gold price forecast using the binomial lattice and MCS techniques

Time		0	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Step		0	40320	40340	40360	40380	40400	40420	40440	40460	40480	40500	40520	40540	40560	40580	40600	40620	40640	40660	40680	40700
	10.12	10.12	10.58	11.07	11.57	12.10	12.65	13.23	13.84	14.47	15.13	15.82	16.55	17.30	18.09	18.92	19.79	20.69	21.64	22.63	23.66	24.74
			9.68	10.12	10.58	11.07	11.57	12.10	12.65	13.23	13.84	14.47	15.13	15.82	16.55	17.30	18.09	18.92	19.79	20.69	21.64	22.63
				9.25	9.68	10.12	10.58	11.07	11.57	12.10	12.65	13.23	13.84	14.47	15.13	15.82	16.55	17.30	18.09	18.92	19.79	20.69
					8.85	9.25	9.68	10.12	10.58	11.07	11.57	12.10	12.65	13.23	13.84	14.47	15.13	15.82	16.55	17.30	18.09	18.92
						8.46	8.85	9.25	9.68	10.12	10.58	11.07	11.57	12.10	12.65	13.23	13.84	14.47	15.13	15.82	16.55	17.30
							8.09	8.46	8.85	9.25	9.68	10.12	10.58	11.07	11.57	12.10	12.65	13.23	13.84	14.47	15.13	15.82
								7.74	8.09	8.46	8.85	9.25	9.68	10.12	10.58	11.07	11.57	12.10	12.65	13.23	13.84	14.47
									7.40	7.74	8.09	8.46	8.85	9.25	9.68	10.12	10.58	11.07	11.57	12.10	12.65	13.23
										7.08	7.40	7.74	8.09	8.46	8.85	9.25	9.68	10.12	10.58	11.07	11.57	12.10
											6.77	7.08	7.40	7.74	8.09	8.46	8.85	9.25	9.68	10.12	10.58	11.07
												6.47	6.77	7.08	7.40	7.74	8.09	8.46	8.85	9.25	9.68	10.12
													6.19	6.47	6.77	7.08	7.40	7.74	8.09	8.46	8.85	9.25
														5.92	6.19	6.47	6.77	7.08	7.40	7.74	8.09	8.46
															5.66	5.92	6.19	6.47	6.77	7.08	7.40	7.74
																5.41	5.66	5.92	6.19	6.47	6.77	7.08
																	5.18	5.41	5.66	5.92	6.19	6.47
																		4.95	5.18	5.41	5.66	5.92
																			4.73	4.95	5.18	5.41
																				4.53	4.73	4.95
																					4.33	4.53
																						4.14
Cost Forecast (US$/t)		**10.12**	**10.13**	**10.15**	**10.17**	**10.20**	**10.24**	**10.28**	**10.33**	**10.39**	**10.46**	**10.53**	**10.61**	**10.70**	**10.79**	**10.89**	**11.00**	**11.12**	**11.24**	**11.38**	**11.52**	**11.67**
Risk Discount Factor		0.00	0.998	0.996	0.994	0.992	0.990	0.988	0.986	0.984	0.982	0.980	0.978	0.976	0.974	0.972	0.970	0.969	0.967	0.965	0.963	0.961
Risk adjusted forward opex		10.12	10.11	10.11	10.11	10.12	10.14	10.16	10.19	10.23	10.27	10.32	10.38	10.44	10.51	10.59	10.68	10.77	10.87	10.98	11.09	11.21
MCS - (US$/t Cu)		**10.00**	**9.97**	**11.13**	**11.69**	**10.53**	**9.65**	**9.80**	**10.25**	**10.94**	**11.48**	**10.04**	**10.47**	**9.89**	**11.32**	**13.54**	**10.53**	**11.36**	**11.62**	**9.73**	**9.92**	**15.29**

Figure A-2: Operating cost forecast using the binomial lattice and MCS techniques

Appendix B: Financial and tax data derived from the theoretical CFT models

Table B-1: Financial data estimates derived from the RO CFT model

Year	Copper (t)	Production Gold (Oz)	Copper Price (US$/t)	Gold Price US$/Oz	Gross Revenue (US$)	Tax-Base (US$)
2016					-6,480,000,000	-6,480,000,000
2017	253,865	300,518	6,546	1,253	2,038,442,637	913,163,777
2018	257,516	304,840	6,608	1,272	2,089,336,759	775,158,857
2019	251,135	297,286	6,657	1,203	2,029,381,487	756,608,663
2020	253,517	300,106	6,696	1,196	2,056,362,994	820,828,312
2021	250,286	296,281	6,726	1,250	2,053,735,037	828,643,195
2022	259,307	306,961	6,749	1,238	2,130,171,960	959,112,817
2023	259,249	306,891	6,767	1,192	2,120,268,479	1,005,832,171
2024	249,943	295,875	6,781	1,269	2,070,417,154	943,380,531
2025	257,409	274,242	6,792	1,321	2,110,597,072	903,590,025
2026	252,805	269,337	6,800	1,311	2,072,205,202	980,011,285
2027	253,903	270,507	6,806	1,380	2,101,447,046	1,166,351,053
2028	254,146	270,765	6,811	1,213	2,059,433,089	1,040,271,139
2029	258,065	274,941	6,815	1,292	2,113,840,904	1,128,087,681
2030	253,392	269,962	6,817	1,259	2,067,340,984	1,091,029,200
2031	257,732	274,586	6,819	1,295	2,113,164,200	1,188,624,481
2032	256,736	273,525	6,821	1,426	2,141,232,508	1,149,833,936
2033	256,236	272,993	6,822	1,383	2,125,632,587	1,163,665,577
2034	252,616	269,135	6,823	1,406	2,102,017,443	1,160,391,709
2035	256,930	273,732	6,824	1,329	2,117,119,461	1,273,468,057
2036	255,733	272,457	6,824	1,386	2,122,814,634	1,188,732,415
Total	**5,100,520**	**5,674,941**			**41,834,961,636**	**20,436,784,881**

Table B-2: Royalty and tax estimates from the RO CF model

Year	Ad Valorem Royal (NSR based)	MRA Levy	SSG	CIT	DWT	S/Equity Free Carried	Royalty & Levies	Total Direct Taxes	Total Gov Income
2016	0	0	0	-1944000000					
2017	40,762,655	5,095,332	15,285,996	178,918,124	34,602,555	-	**61,143,983**	**225,783,955**	**286,927,937**
2018	41,780,130	5,222,516	15,667,549	226,187,479	43,744,392	-	**62,670,196**	**285,435,048**	**348,105,244**
2019	40,581,575	5,072,697	15,218,091	220,774,625	42,697,553	-	**60,872,363**	**278,604,351**	**339,476,714**
2020	41,120,332	5,140,042	15,420,125	239,513,597	46,321,648	-	**61,680,498**	**302,251,812**	**363,932,310**
2021	41,067,407	5,133,426	15,400,278	241,793,941	46,762,664	-	**61,601,111**	**305,129,469**	**366,730,580**
2022	42,598,027	5,324,753	15,974,260	279,864,324	54,125,431	-	**63,897,040**	**353,172,012**	**417,069,052**
2023	42,399,675	5,299,959	15,899,878	293,496,798	56,761,936	-	**63,599,513**	**370,375,378**	**433,974,891**
2024	41,400,852	5,175,106	15,525,319	275,273,722	53,237,614	-	**62,101,278**	**347,378,947**	**409,480,224**
2025	42,206,825	5,275,853	15,827,559	263,663,051	50,992,124	-	**63,310,238**	**332,726,976**	**396,037,214**
2026	41,439,070	5,179,884	15,539,651	285,962,393	55,304,791	-	**62,158,605**	**360,867,409**	**423,026,014**
2027	42,023,850	5,252,981	15,758,944	340,335,406	65,820,467	-	**63,035,775**	**429,482,894**	**492,518,669**
2028	41,183,205	5,147,901	15,443,702	303,545,917	58,705,424	-	**61,774,807**	**383,056,763**	**444,831,570**
2029	42,271,715	5,283,964	15,851,893	396,347,966	76,653,231	-	**63,407,573**	**721,180,487**	**784,588,060**
2030	41,341,548	5,167,694	15,503,081	383,327,654	74,135,118	-	**62,012,322**	**697,489,196**	**759,501,518**
2031	42,257,888	5,282,236	15,846,708	417,617,268	80,766,689	177,292,731	**63,386,832**	**937,174,074**	**1,000,560,906**
2032	42,818,676	5,352,335	16,057,004	403,988,404	78,130,883	171,506,815	**64,228,014**	**906,589,568**	**970,817,582**
2033	42,507,186	5,313,398	15,940,195	408,848,082	79,070,738	173,569,914	**63,760,780**	**917,495,161**	**981,255,941**
2034	42,034,491	5,254,311	15,762,934	407,697,825	78,848,280	173,081,591	**63,051,737**	**914,913,872**	**977,965,608**
2035	42,337,562	5,292,195	15,876,586	447,426,634	86,531,785	189,947,821	**63,506,342**	**1,004,069,213**	**1,067,575,556**
2036	42,451,080	5,306,385	15,919,155	417,655,190	80,774,023	177,308,831	**63,676,620**	**937,259,175**	**1,000,935,796**
Total	**836,583,751**	**104,572,969**	**313,718,906**	**6,432,238,403**	**1,243,987,346**	**1,062,707,703**	**1,254,875,626**	**11,010,435,760**	**12,265,311,386**

Table B-3: Financial data estimates derived from the RO-MCS CFT model

Year	Copper (t)	Gold (Oz)	Free CF (US$)	Tax-Base CF (Pre-tax CF)	Post-Tax CF (US$)
2016			-6,480,000,000	-6,480,000,000	-6,480,000,000
2017	253,865	300,518	2,001,378,145	818,787,914	-3,948,891,475
2018	257,516	304,840	2,107,313,744	854,142,482	655,388,693
2019	251,135	297,286	2,068,711,083	738,541,388	867,122,436
2020	253,517	300,106	2,021,201,204	857,850,525	900,405,204
2021	250,286	296,281	2,100,677,033	825,740,406	858,854,357
2022	259,307	306,961	2,161,692,259	1,004,787,320	926,465,550
2023	259,249	306,891	2,126,378,767	1,091,786,959	949,099,246
2024	249,943	295,875	1,991,190,655	927,421,773	845,706,083
2025	257,409	274,242	2,120,674,626	832,870,621	764,288,513
2026	252,805	269,337	2,086,588,357	849,765,354	770,877,594
2027	253,903	270,507	2,068,501,052	1,354,798,076	914,488,428
2028	254,146	270,765	2,048,950,259	1,101,433,815	885,480,538
2029	258,065	274,941	2,087,962,377	1,133,766,762	891,874,093
2030	253,392	269,962	2,080,839,714	1,049,103,616	817,747,591
2031	257,732	274,586	2,160,099,347	1,219,480,989	920,542,158
2032	256,736	273,525	2,149,412,743	1,348,214,639	988,750,196
2033	256,236	272,993	2,133,276,618	1,173,526,955	872,216,502
2034	252,616	269,135	2,069,111,303	1,060,079,597	793,888,113
2035	256,930	273,732	2,126,494,023	1,321,810,266	945,696,526
2036	255,733	272,457	2,190,521,201	1,212,604,061	896,457,841
Total	**5,100,520**	**5,674,941**	**41,900,974,511**	**20,776,513,518**	**12,516,458,187**

Note: These data will vary from the ones used for computing the progression coefficients and other variables because MCS template is active and values change recursively.

Table B-4: Royalty and tax estimates derived from the RO-MCS CFT model

Year	NSR Royalty	MRA Levy	SSG	CIT	Profit-based Royalty	S/Equity Free Carried	Paid equity Production	DDW	APT	Total Direct Taxes
2016				-1944000000						
2017	40,762,655	5,095,332	15,285,996	238,918,219	16,375,758	0	0	46,206,503	0	301,500,480
2018	41,780,130	5,222,516	15,667,549	249,234,505	17,082,850	0	0	48,201,660	0	314,519,016
2019	40,581,575	5,072,697	15,218,091	215,502,684	14,770,828	0	0	41,677,966	0	271,951,478
2020	41,120,332	5,140,042	15,420,125	250,316,494	17,157,010	0	0	48,410,916	0	315,884,420
2021	41,067,407	5,133,426	15,400,278	240,946,922	16,514,808	0	0	46,598,851	0	304,060,581
2022	42,598,027	5,324,753	15,974,260	293,191,916	20,095,746	0	0	56,702,972	0	369,990,634
2023	42,399,675	5,299,959	15,899,878	318,577,976	21,835,739	0	0	61,612,606	0	402,026,321
2024	41,400,852	5,175,106	15,525,319	270,617,036	18,548,435	0	0	52,337,017	0	341,502,489
2025	42,206,825	5,275,853	15,827,559	243,027,483	16,657,412	0	0	47,001,230	0	306,686,125
2026	41,439,070	5,179,884	15,539,651	247,957,281	16,995,307	0	0	47,954,647	0	312,907,235
2027	42,023,850	5,252,981	15,758,944	395,323,305	27,095,962	0	244,386,636	76,455,062	0	743,260,965
2028	41,183,205	5,147,901	15,443,702	386,983,264	22,028,676	0	198,682,809	74,842,108	220286763	902,823,621
2029	42,271,715	5,283,964	15,851,893	398,343,283	22,675,335	0	244,086,481	77,039,123	226753352	968,897,574
2030	41,341,548	5,167,694	15,503,081	368,597,310	20,982,072	183,655,575	254,631,507	71,286,286	209820723	1,108,973,474
2031	42,257,888	5,282,236	15,846,708	428,458,548	24,389,620	175,282,934	190,969,244	82,863,380	243896198	1,145,859,923
2032	42,818,676	5,352,335	16,057,004	473,688,472	26,964,293	176,655,563	220,168,602	91,610,794	269642928	1,258,730,652
2033	42,507,186	5,313,398	15,940,195	412,312,828	23,470,539	159,049,532	179,066,701	79,740,816	234705391	1,088,345,808
2034	42,034,491	5,254,311	15,762,934	372,453,666	21,201,592	210,228,793	228,560,242	72,032,101	212015919	1,116,492,313
2035	42,337,562	5,292,195	15,876,586	464,411,428	26,436,205	202,991,776	208,041,106	89,816,624	264362053	1,256,059,192
2036	42,451,080	5,306,385	15,919,155	426,042,374	24,252,081	186,656,085	219,882,845	82,396,094	242520812	1,181,750,292
Total	**836,583,751**	**104,572,969**	**313,718,906**	**6,694,904,995**	**415,530,270**	**1,294,520,259**	**2,188,476,173**	**1,294,786,756**	**2,124,004,140**	**14,012,222,592**

Appendix C: Historical financial and tax data derived from samples of mines in PNG

Table C-1: Financial data from the Bougainville mine (Millions PNGK 1972-1988)

Year	Copper (t)	gold (Oz)	Silver (Oz)	Free Cash Flow	Pre-tax CF	Post-Tax CF
1972	95,900	10,702	10,837	-	- 535,714,286	-
1973	189,468	15,256	21,514	95,900,000	28,100,000	27,700,000
1974	201,211	14,417	20,997	252,200,000	145,800,000	158,400,000
1975	185,237	12,260	15,317	292,600,000	171,600,000	114,600,000
1976	186,261	12,276	16,679	193,100,000	56,300,000	46,200,000
1977	209,981	12,070	17,798	208,900,000	60,300,000	41,300,000
1978	251,058	12,701	17,349	205,300,000	42,300,000	28,500,000
1979	211,486	10,336	14,087	225,100,000	59,700,000	48,000,000
1980	192,012	7,546	8,198	343,100,000	158,300,000	83,900,000
1981	216,323	9,448	10,925	338,700,000	120,100,000	71,500,000
1982	249,856	9,043	11,538	296,400,000	42,300,000	22,800,000
1983	303,992	9,417	11,458	283,200,000	31,800,000	11,200,000
1984	252,278	7,321	8,362	392,900,000	117,800,000	54,600,000
1985	291,307	7,854	7,850	310,900,000	29,600,000	11,600,000
1986	280,923	7,919	9,045	317,600,000	48,500,000	28,100,000
1987	282,211	7,716	8,088	342,700,000	71,700,000	45,300,000
1988	26,325	727	727	415,400,000	138,500,000	90,500,000
1989	41,596	3,176	3,608	493,400,000	204,700,000	108,600,000
1990		**-**	**-**	**-**	**-**	**-**
Total	**3,667,426**	**170,183**	**214,375**	**5,007,400,000**	**1,527,400,000**	**992,800,000**

Table C-2: Royalty and tax data from the former Bougainville mine (PNGK)

Year	NSR Royalty*	CIT	DWT	APT	Equity Div	Total GoPNG
1972	3,800,000	-	1,222,222	-	11,000,000	16,022,222
1973	3,800,000	300,000	9,044,444	-	81,400,000	94,544,444
1974	3,800,000	49,100,000	8,166,667	17,400,000	73,500,000	151,966,667
1975	3,800,000	12,400,000	2,966,667	-	26,700,000	45,866,667
1976	3,800,000	20,300,000	2,966,667	-	26,700,000	53,766,667
1977	3,800,000	13,700,000	2,377,778	-	21,400,000	41,277,778
1978	3,800,000	22,000,000	4,455,556	-	40,100,000	70,355,556
1979	3,800,000	57,500,000	11,877,778	20,400,000	106,900,000	200,477,778
1980	3,800,000	39,600,000	8,911,111	11,600,000	80,200,000	144,111,111
1981	3,800,000	20,600,000	2,233,333	-	20,100,000	46,733,333
1982	3,800,000	17,300,000	1,111,111	-	10,000,000	32,211,111
1983	3,800,000	46,900,000	5,788,889	-	52,100,000	108,588,889
1984	3,800,000	15,200,000	1,777,778	-	16,000,000	36,777,778
1985	3,800,000	19,000,000	4,958,824	-	28,100,000	55,858,824
1986	3,800,000	28,700,000	4,900,000	-	44,100,000	81,500,000
1987	3,800,000	50,600,000	11,407,147	-	93,200,000	159,007,147
1988	3,800,000	70,000,000	13,399,067	23,200,000	108,300,000	218,699,067
1989	3,800,000	25,700,000	-	-		29,500,000
1990	-	**6,000,000**	-	-		6,000,000
Total	**68,400,000**	**514,900,000**	**97,565,038**	**72,600,000**	**839,800,000**	1,593,265,038

Table C-3: Financial data for the Porgera gold mine (Millions PNGK 1990 – 2013)

Year	Gold (Oz)	Silver (Oz)	Free Cash Total gross exports	Tax-base Cash Flow	Post-Tax Cash Flow
					- 647,058,823.53
1990	265,890	224,227	91,857,555	20,891,937	19,741,761
1991	1,216,101	593,312	426,893,680	47,716,460	42,117,700
1992	1,485,077	139,619	492,868,936	166,341,152	159,902,774
1993	1,156,670	129,860	411,069,164	245,277,988	181,289,777
1994	1,032,768	133,890	405,765,609	178,724,058	106,700,193
1995	848,870	90,770	417,962,487	226,852,739	114,750,700
1996	854,822	106,535	442,263,452	192,167,699	98,666,926
1997	712,693	100,479	336,637,249	129,372,383	28,290,668
1998	726,806	91,614	449,310,098	266,383,912	212,650,992
1999	754,754	100,694	516,951,181	242,771,210	177,188,929
2000	910,434	110,276	702,753,670	298,904,046	216,713,648
2001	760,622	113,043	701,033,252	339,663,331	264,620,137
2002	641,811	126,772	780,464,416	277,704,753	205,180,955
2003	851,920	164,691	1,086,612,526	324,241,118	200,765,193
2004	1,019,746	185,336	1,296,237,836	487,248,758	316,608,980
2005	867,925	157,740	1,178,606,063	383,302,155	228,228,851
2006	523,358	104,238	915,432,548	336,089,079	248,976,803
2007	513,177	79,561	1,050,619,029	482,275,519	369,224,854
2008	632,603	90,610	1,465,666,202	706,641,743	523,661,298
2009	572,595	94,764	1,510,789,753	674,817,234	438,993,896
2010	527,399	100312	1,317,772,441	515,262,078	299,213,171
2011	519,946	106150	1,817,217,959	1,068,717,739	608,590,931
2012	448,316	91789	1,560,789,567	851,506,360	565,727,136
2013	448,173	92105	1,551,033,510	719789688.7	- 628,335,884
TOTAL	**18,292,476**	**3,328,387**	**20,926,608,183**	**9,182,663,140**	**5,627,806,273**

Table C-4: Tax data for the Porgera mine (Millions PNGK)

Year	NSR Royalty	Income Tax	Customs, Fuel and execrise	Community & EPG Equity	Total Direct taxes	Total Royalty Exc & Duties	Total GoPNG
1990	1,150,176	-	-		-	**1,150,176**	**2,300,352**
1991	5,598,760	-	-		-	**5,598,760**	**11,197,520**
1992	6,438,378	-	-		-	**6,438,378**	**12,876,756**
1993	5,117,283	34,814,623	7,613,538		**42,428,161**	**12,730,821**	**102,704,427**
1994	5,030,785	46,006,979	4,755,477		**50,762,456**	**9,786,262**	**116,341,959**
1995	5,391,524	75,254,720	14,737,296		**89,992,016**	**20,128,820**	**205,504,376**
1996	7,429,566	58,125,949	10,254,719		**68,380,668**	**17,684,285**	**161,875,188**
1997	6,639,116	52,639,133	10,337,976	18,000,000	**80,977,109**	**16,977,092**	**185,570,427**
1998	9,701,000	14,419,914	11,639,602		**26,059,516**	**21,340,602**	**83,160,634**
1999	11,547,250	6,077,953	27,279,031		**33,356,984**	**38,826,281**	**117,087,499**
2000	14,698,079	7,046,897	27,335,275	5,000,000	**39,382,172**	**42,033,354**	**135,495,777**
2001	14,552,212	10,611,330	31,060,982	12,000,000	**32,449,652**	**45,613,194**	**146,287,370**
2002	15,715,840	1,406,577	24,995,958	2,000,000	**25,589,381**	**40,711,798**	**110,419,554**
2003	21,945,267	26,001,444	28,064,713	4,000,000	**58,066,157**	**50,009,980**	**188,087,561**
2004	25,946,925	57,806,487	25,036,853	10,000,000	**92,843,340**	**50,983,778**	**262,617,382**
2005	23,483,964	50,649,757	21,795,340	12,000,000	**84,445,097**	**45,279,304**	**237,653,463**
2006	18,308,651	1,367,713	21,818,610	9,000,000	**32,186,323**	**40,127,261**	**122,808,558**
2007	20,953,462	32,029,181	18,043,261		**50,072,442**	**38,996,723**	**160,095,069**
2008	29,945,588	86,995,283	7,412,926		**94,408,209**	**37,358,514**	**256,120,520**
2009	30,349,259	137,681,216	7,361,273		**145,042,489**	**37,710,532**	**358,144,769**
2010	35,158,736	123,755,529	4,423,744		**128,179,273**	**39,582,480**	**331,099,762**
2011	38,206,906	341,797,868	7,433,316		**349,231,184**	**45,640,222**	**782,309,496**
2012	27,455,324	189,601,732	6,290,585		**195,892,317**	**33,745,909**	**452,985,867**
2013	3,091,466	-				**3,091,466**	**6,182,932**
TOTAL	**383,855,517**	**1,330,054,472**	**317,690,475**	**72,000,000**	**1,719,744,947**	**701,545,992**	**4,524,891,404**

Table C-5: Total benefit redistributions to Enga communities (Millions PNGK)

Year	Royalty (*a*)	Mining Levy (*b*)	Direct Taxes & Equity Div. (c	Special support Grant (*d*)	Total Indirect Taxes (	Compensatio (f)	*Donations* (g)	*Human capital* Dev. (*h*)	Infras Dev. (*i*)	Business Dev. (PNG) (*j*)	TOTAL
1990	1.15		-	0.70	-	-	-		0.64	108.47	111
1991	5.60		-	3.08	-	-	-	2.00	0.64	108.47	120
1992	6.44		-	3.14	-	-	-	2.36	0.64	108.47	121
1993	5.12	-	205	3.54	30	-	-	4.71	0.64	108.47	358
1994	5.03	-	27	3.25	12	11.20	1.92	3.97	0.64	108.47	174
1995	5.39	-	57	1.58	25	5.48	0.59	7.62	0.64	108.47	212
1996	7.43	1.64	39	5.92	23	4.56	0.79	4.78	0.64	108.47	196
1997	6.64	1.25	48	3.50	22	3.31	0.73	5.64	17.30	108.47	217
1998	9.70	1.30	31	3.59	26	2.87	1.69	29.08	18.11	108.47	232
1999	11.55	1.07	26	3.00	47	5.15	1.44	4.95	18.34	108.47	226
2000	14.70	1.41	39	3.00	47	4.15	1.67	4.20	18.56	108.47	242
2001	14.55	0.70	29	1.80	53	7.05	2.84	3.75	16.59	108.47	237
2002	15.72	1.19	30	1.80	50	7.62	2.12	4.48	18.73	108.47	240
2003	21.95	2.78	71	0.95	59	6.16	1.20	5.03	23.54	108.47	299
2004	25.95	4.39	116	3.50	61	3.90	5.77	4.25	23.99	108.47	356
2005	23.48	3.91	106	2.70	63	7.78	5.45	8.48	23.92	108.47	353
2006	18.31	1.52	45	50.80	63	8.34	2.01	8.17	31.33	108.47	337
2007	20.95	2.96	71	6.30	72	6.83	2.77	5.95	32.93	108.47	330
2008	29.95	5.82	140	6.50	52	6.97	1.42	7.53	32.70	108.47	391
2009	30.35	5.51	132	5.50	62	7.24	1.76	8.32	30.27	108.47	392
2010	35.16	4.95	119	0.00	65	6.91	1.70	9.18	27.83	108.47	378
2011	38.21	13.67	328	0.00	78	5.23	1.81	11.40	24.01	108.47	609
2012	27.46	7.58	182	0.00	76	9.19	1.70	6.34	24.82	108.47	444
2013	30.91	-	-	0.00	89	10.40	1.10	7.43	21.55	108.47	269
Total	**412**	**62**	**1,841**	**114**	**1,074**	**130**	**40**	**160**	**409**	**2,603**	**6,845**

Notes:

a) Royalty rate changed from 1.25 percent (1972-1996) to 2 percent NSR (1997-2013). The proceeds are distributed to EPG (50 percent); PDA (5 percent); Special Mining Lease Landholders (15 percent); Children's Trust Fund (10 percent); Porgera Landholder Association (12 percent); and Young Adults (8 percent)

(*b*) CIT data for Porgera was contaminated with the inclusion of the Mining Levy. Based on the assumption of the 4 percent levy component was separated in order to calculate the METR.

(*c*) Direct tax comprises of CIT and equity dividends and there no indications of PJV paid DWT

(*d*) SSG was paid to the EPG, of which 50 percent was distributed to the Porgera Development Authority to improve infrastructure and livelihood in the region. No SSG data available in the 2010-2013 periods.

(*e*) Indirect taxes comprise of payroll salary taxes, dividend withholding taxes; and SSG (but note that SSG is separated)

(*f*) Compensations comprise of occupation fees, riverine tailings are disposed into Porgera and Kaiya rivers; general compensation; community asset and relocation; and occupation fees.

(*g*) Donations upon request to the Porgera Joint Venture (PJV)
(*h*) Human capital comprised of internal skills driven training and general education to PNG, including Programs and Engans
(*i*) Infrastructure comprise of Tax Credit Scheme (0.75 percent of CIT); Infrastructure development program (IDP); and community projects such as schools; social and health services; water supply and feeder roads within Porgera-Paiala
(*j*) Business development comprised of direct contracts awarded to Programs, Engans, and rest of PNG

Table C-6: Non-tax benefit redistributions from Porgera mine (PNGK Millions)

Year	ROYALTY TO HOST COMM & EPG	SSG TO EPG PDA (*a*)	Compensation	Donations	Human Capital Dev. (50% of total) (*b*)	Equity Dividends EPG & Porgeran LO (*c*)	Business Dev. Enga & Porgera (d)	Infras	TOTAL
1990	1.15	1	0	-	0.73	-	54.47	0.70	**58**
1991	5.60	3	0	-	0.80	-	54.47	3.08	**67**
1992	6.44	3	0	-	1.24	-	54.47	3.14	**68**
1993	5.12	4	0	-	1.37	-	54.47	3.54	**68**
1994	5.03	3	11.20	1.92	1.58	-	54.47	3.25	**81**
1995	5.39	2	5.48	0.59	1.15	-	54.47	1.58	**70**
1996	7.43	6	4.56	0.79	1.91	-	54.47	5.92	**81**
1997	6.64	4	3.31	0.73	2.08	18	54.47	20.16	**109**
1998	9.70	4	2.87	1.69	1.78	-	54.47	21.06	**95**
1999	11.55	3	5.15	1.44	1.51	-	54.47	20.70	**98**
2000	14.70	3	4.15	1.67	1.56	5	54.47	20.92	**105**
2001	14.55	2	7.05	2.84	1.93	12	54.47	17.75	**113**
2002	15.72	2	7.62	2.12	2.24	2	54.47	19.89	**106**
2003	21.95	1	6.16	1.20	1.86	4	54.47	23.85	**114**
2004	25.95	4	3.90	5.77	3.65	10	54.47	26.85	**134**
2005	23.48	3	7.78	5.45	3.05	12	54.47	25.99	**135**
2006	18.31	51	8.34	2.01	2.45	9	54.47	81.49	**227**
2007	20.95	6	6.83	2.77	3.24	-	54.47	38.59	**133**
2008	29.95	7	6.97	1.42	3.57	-	54.47	38.57	**141**
2009	30.35	6	7.24	1.76	3.83	-	54.47	35.14	**138**
2010	35.16	0	6.91	1.70	3.67	-	54.47	27.19	**129**
2011	38.21	0	5.23	1.81	2.46	-	54.47	23.37	**126**
2012	27.46	0	9.19	1.70	2.48	-	54.47	24.19	**119**
2013	30.91	0	10.40	1.10	-	-	54.47	20.91	**118**
TOTAL	**412**	**114**	**130**	**40**	**50**	**72**	**1,307**	**508**	**2,634**

Notes:

(*a*) SSG funds are levied on the gross to host provinces. Enga Provincial Government shares the SSG fund with the Porgera Development Authority to deliver infrastructure and social services in Porgera
(*b*) A 50 percent of the total expenditures on skills driven human capital development benefited the Porgera, and Enga Province
(*c*) Enga Provincial Government and Porgera Landowners own 5 percent equity in the Porgera mine. They share the equity, each holding of 2.5 percent
(d) An average value was calculated for the business development data was provided time series data format.

Table C-7: Financial data for the Ok Tedi mine (1982-2013) (Millions PNG K)

Year	Royalty Porgera	SSG TO PDA (50% of total	Donation (50% to Host)	Compensation	Human Capital Dev. (25% of total	Equity Dividends Porgera LO	Business Dev Porgera	InfrasDev. Porgera Region	Total
1990	0.26	0.35	-	-	0.36	-	31.83	0.64	33
1991	1.29	1.54	-	-	0.40	-	31.83	0.64	36
1992	1.48	1.57	-	-	0.62	-	31.83	0.64	36
1993	1.18	1.77	-	-	0.69	-	31.83	0.64	36
1994	1.16	1.63	1.92	11.20	0.79	-	31.83	0.64	49
1995	2.27	0.79	0.59	5.48	0.57	-	31.83	0.64	42
1996	3.72	2.96	0.79	4.56	0.95	-	31.83	0.64	45
1997	3.32	1.75	0.73	3.31	1.04	9.00	31.83	4.61	56
1998	4.85	1.80	1.69	2.87	0.89	-	31.83	5.42	49
1999	5.77	1.50	1.44	5.15	0.76	-	31.83	5.66	52
2000	7.35	1.50	1.67	4.15	0.78	2.40	31.83	5.87	56
2001	7.28	0.90	2.84	7.05	0.97	6.06	31.83	3.90	61
2002	7.86	0.90	2.12	7.62	1.12	0.87	31.83	6.05	58
2003	10.97	0.48	1.20	6.16	0.93	2.00	31.83	10.86	64
2004	12.97	1.75	5.77	3.90	1.83	5.14	31.83	11.30	74
2005	11.74	1.35	5.45	7.78	1.53	6.00	31.83	11.24	77
2006	9.15	25.40	2.01	8.34	1.23	4.45	31.83	18.65	101
2007	10.48	3.15	2.77	6.83	1.62	-	31.83	20.25	77
2008	14.97	3.25	1.42	6.97	1.78	-	31.83	20.02	80
2009	15.17	2.75	1.76	7.24	1.92	-	31.83	17.59	78
2010	17.58	-	1.70	6.91	1.83	-	31.83	15.14	75
2011	19.10	-	1.81	5.23	1.23	-	31.83	11.32	71
2012	13.73	-	1.70	9.19	1.24	-	31.83	12.14	70
2013	15.46	-	1.10	10.40	1.24	-	31.83	8.86	69
TOTAL	**199**	**57**	**40**	**130**	**26**	**36**	**764**	**193**	**1,446**

Note: Royalties represent the amount paid to Porgera entities and communities only.

Table C-8: Total tax and non-tax payments from Ok Tedi mine (Millions PNGK)

Year	Copper (t)	Gold (Oz)	silver (Oz)	Gross Sales	NATP
					0
1982				0	0
1983				0	0
1984		10985	5123	19.6	0
1985		538537	185683	171.9	-45
1986		598790	184638	208.9	42.5
1987	38167	567180	220510	297	77
1988	50910	579319	630951	231.5	20.7
1989	131142	509544	965364	460.4	27.9
1990	153162	414759	792855	538.5	89.6
1991	198325	345716	821579	545.8	74.5
1992	187004	325719	748597	513.4	51.3
1993	202206	387866	865465	518.1	53.4
1994	206639	447470	973684	684.2	126.6
1995	229362	509621	998054	1074.1	166.8
1996	188414	443326	875625	802.6	147.1
1997	86741	187310	389184	391.4	-15.5
1998	187249	501133	974970	1003.3	80.8
1999	182588	388959	1031918	1043	92.5
2000	187952	490555	1347918	1297.2	151.3
2001	211975	480749	1236677	1491.6	69
2002	181146	414808	928668	1532.3	139.9
2003	228997	587139	1213977	2176.8	322.3
2004	166328	491005	1132251	2088.4	493
2005	204840	594402	1415692	3308.3	1047.3
2006	177538	505248	1312842	4643.2	1881.2
2007	186526	523446	1612968	5039.7	2040.5
2008	162722	504123	1380840	3826.6	1226.7
2009	150579	499300	1418617	4002.1	1562.2
2010	158692	482068	1507096	5086.1	2029.3
2011	146336	146336	1189029	4535.9	1239.3
2012	121432	121432	889385	3359.6	913.3
2013	100212	352050	929380	2670.2	181.9
TOTAL	**4427184**	**12948895**	**28179540**	**53561.7**	**14287.4**

Table C-9: Redistributions of direct and non-tax benefits (Millions PNGK)

Year	Royalty(a	Mining Levy	Productio Levy	CIT	DWT	Royalty WHT	Withhold Tax	Customs Duties	Salaries/ Wages Tax	Payee	GST	State Dividends (	Business Dev (c)	Human Capital (d	TOTAL Direct Taxes (	TOTAL Indirect (f)	Non-Tax Benefits (g	TOTAL FISCAL
1982									0.2					0.05	**-**	**0.2**	**0.1**	**0.25**
1983								0.2	1.5					0.05	**-**	**1.7**	**0.1**	**1.75**
1984								0.8	4.7				8.07	0.35	**-**	**5.5**	**8.4**	**13.92**
1985	2						16.1	28.2	42.2				8.07	0.65	**18.1**	**70.4**	**8.7**	**97.22**
1986	2.6						0.1	5.1	5.5				8.07	0.35	**2.7**	**10.6**	**8.4**	**21.72**
1987	3.4						0.5	16.1	7.7				18.97	0.3	**3.9**	**23.8**	**19.3**	**46.97**
1988	3.6						0.3	5.1	8				61.62	0.4	**3.9**	**13.1**	**62.0**	**79.02**
1989	4.7						0.3	6.8	6.9				69.72	0.65	**5.0**	**13.7**	**70.4**	**89.07**
1990	5.5						0.8	5.6	7.5				84.52	0.85	**6.3**	**13.1**	**85.4**	**104.77**
1991				108.9			1	7.2	8			5.8	79.27	1	**115.7**	**15.2**	**80.3**	**211.17**
1992							0.8	6.5	8.1			7.1	78.02	0.65	**7.9**	**14.6**	**78.7**	**101.17**
1993							0.6	5.9	6.5			7.8	80.52	0.6	**8.4**	**12.4**	**81.1**	**101.92**
1994							0.7	5.4	7.2			6.5	81.12	0.6	**7.2**	**12.6**	**81.7**	**101.52**
1995				4.9			0.5	8.7	10.2			0	86.92	1.3	**5.4**	**18.9**	**88.2**	**112.52**
1996				41			0.4	8.6	12.9			0	91.07	1.55	**41.4**	**21.5**	**92.6**	**155.52**
1997				32.2	7.5		0.5	6.3	15.7			9.4	114.67	1.15	**49.6**	**22**	**115.8**	**187.42**
1998				13.6	9.5		3.4	5.3	20.3			14.1	141.57	0.7	**40.6**	**25.6**	**142.3**	**208.47**
1999		19.4		26.9	12.9		8.2	1.3	28			16.6	127.57	1.25	**84.0**	**29.3**	**128.8**	**242.12**
2000		49.2		56.4		0.4	7.3	3.2	29.7			0	130.42	2.4	**113.3**	**32.9**	**132.8**	**279.02**
2001		58.7		70	7	0.3	8.6	2.4	35.2			14.9	160.22	2.8	**159.5**	**37.6**	**163.0**	**360.12**
2002		43.8		50	6.1	0.4	8.6	2.4	41.4			13.7	191.17	2.7	**122.6**	**43.8**	**193.9**	**360.27**
2003		30.9		74.1	22.9	0.6	8.5	1.6	41.1			66.2	242.02	1	**203.2**	**42.7**	**243.0**	**488.92**
2004		41		175.4	27.8	0.6	7.2	1.7	42.2	6.7	1.9	54.8	257.97	1	**306.8**	**52.5**	**259.0**	**618.27**
2005		37.1		277.8	64.7	1.5	6.2	2.7	43.4	6.4	1.7	150.9	289.57	5.345	**538.2**	**54.2**	**294.9**	**887.32**
2006		30.6		797.7	127	2.2	7.8	3.2	44.9	14.2	2	271.2	243.62	6.0275	**1,236.1**	**64.3**	**249.6**	**1,550.05**
2007		31.5		1043	101	2.1	10.5	13.3	48.3	26.6	2.9	216	274.47	6.9265	**1,403.4**	**91.1**	**281.4**	**1,775.90**
2008		2.5	11.4	646.2	65.5	1.7	15.9	9.2	53.1	17.3	3.8	139.1	230.87	7.5715	**882.3**	**83.4**	**238.4**	**1,204.14**
2009			8.4	126.2	65.3	1.7	20.2	3.3	54.5	27.4	3.1	140	309.92	10.723	**361.8**	**88.3**	**320.6**	**770.74**
2010			9.3	685.5	115	2.3	12.3	3.3	69.7	18.8	4	303.9	151.47	13.189	**1,127.8**	**95.8**	**164.7**	**1,388.26**
2011			11.8	896.7	123	2.1	12.2	5.1	78.3	39	4.9	141.6	164.72	13.8025	**1,187.8**	**127.3**	**178.5**	**1,493.62**
2012			10.5	228.6	45.8	1.6	8	33.2	74.5	37.9	4.5	132.3	155.07	13.523	**426.8**	**150.1**	**168.6**	**745.49**
2013			7.7	105	0	1.3	9.2	22.2	82.9	38.4	4.9	0	3715.32	18.919	**123.2**	**148.4**	**3734.2**	**4,005.84**
TOTAL	**22**	**345**	**59**	**5,460**	**800**	**19**	**177**	**230**	**940**	**233**	**34**	**1,712**	**7,657**	**118**	**8,593**	**1,437**	**7,775**	**17,805**

Notes:

(*a*) Royalty collection was centralised, but increasing community demand had shifted in policy where 100 percent royalty paid to community entities and provincial governments as of 1990

(*b*) State disposed of its Preference Certificate to shareholders and earned ordinary share dividends from owning 18.30 percent until the Ok Tedi mine was expropriated in 2014. These data exclude the dividend payments to PNG Sustainable Development Program (PNGSDP).

(*c*) Business development comprised of goods and services procurements and direct contracts (assume 50 percent of total)

(*d*) Human capital assumed 50 percent of the total expenditure on in-house and external training

(*e*) Direct taxes are taxes recognised on the project cash flow

(*f*) Indirect taxes are taxes paid for employment of inputs production (e.g., salary and GST)

(*g*) Non-tax benefits are business development, contracts, and donations.

Table C-10: Benefit redistributions to Ok Tedi region and PNG (Millions PNGK)

Year	Royalty	Mining Levy(*a*)	MRA Levy(*b*)	Direct Taxes(*c*)	Indirect Taxes(*d*)	Equity Dividends(*e*)	Compo(*f*)	MCA (g)	Service Contracts (h)	Goods Proc & Business Dev. (i)	Human (j) Capital	Infras TCS (*k*)	Total
1982	0.2			0	0.2		0.4				0.1		**0.90**
1983	0.2			0	1.7		0.7				0.1		**2.70**
1984	0.1			0	5.5		0.6				0.7		**6.90**
1985	2			16.10	70.4		1.6				1.3		**91.40**
1986	4.5			0.10	10.6	0	0.9				0.7		**16.80**
1987	5.6			0.50	23.8	0	0.9				0.6		**31.40**
1988	5.8			0.30	13.1	0	1		9.47	21.8	0.8		**52.27**
1989	8.2			0.30	13.7	0	1		9.47	107.1	1.3		**141.07**
1990	9.3			0.80	13.1	0	1.6		9.47	123.3	1.7		**159.27**
1991	10.3			109.90	15.2	5.8	1.9		9.47	152.9	2		**307.47**
1992	8.3			0.80	14.6	7.1	2.6		9.47	142.4	1.3		**186.57**
1993	8.2			0.60	12.4	7.8	2		9.47	139.9	1.2		**181.57**
1994	10.6			0.70	12.6	6.5	3.9		9.47	144.9	1.2		**189.87**
1995	17			5.40	18.9	0	17.8		9.47	146.1	2.6		**217.27**
1996	13.8			41.40	21.5	0	7.9		9.47	157.7	3.1		**254.87**
1997	8.4			40.20	22	12.6	9		9.47	166	2.3	1.37	**271.34**
1998	18.7			26.50	25.6	18.7	9.4		9.47	213.2	1.4	2.2	**325.17**
1999	24	19.4		48.00	29.3	33.2	11.6		9.47	267	2.5	2.3	**446.77**
2000	28.5	49.2		64.10	32.9	0	13.3		9.47	239	4.8	14.5	**455.77**
2001	31.1	58.7		85.90	37.6	29.8	54.1	41.76	9.47	244.7	5.6	13.1	**611.83**
2002	32.6	43.8		65.10	43.8	27.4	35.8	18.51	9.47	304.3	5.4	11.6	**597.78**
2003	48.4	30.9		106.10	42.7	132.3	33.5	14.78	9.47	366.2	2	5.11	**791.46**
2004	48.1	41		211.00	52.5	109.5	35.4	16.83	9.47	467.9	2	31.66	**1,025.36**
2005	71.6	37.1		350.20	54.2	301.7	41.4	22.93	9.47	499.8	10.69	5.78	**1,404.87**
2006	101.9	30.6		934.30	64.3	542.4	36.5	19.92	9.47	563	12.055	6.28	**2,320.73**
2007	114.5	31.5		1,155.90	91.1	432	90.4	53.05	9.47	471.1	13.853	8.3	**2,471.18**
2008	97.3	2.50	11.4	729.30	83.4	278.2	81.1	52.75	9.47	532.8	15.143	24.1	**1,917.47**
2009	87.8		8.4	213.40	88.3	279.9	77.1	53.62	9.47	445.6	21.446	40.3	**1,325.34**
2010	116.6		9.3	814.60	95.8	541.6	76.4	53.71	9.47	603.7	26.378	46.8	**2,394.36**
2011	120.3		11.8	1,034.40	127.3	283.2	76.2	53.77	9.47	286.8	27.605	42.5	**2,073.35**
2012	96.8		10.5	284.00	150.1	264.5	75.4	53.91	9.47	313.3	27.046	6.3	**1,291.33**
2013	85		7.7	115.50	148.4		76.2	54.75	9.47	294	37.838	25.6	**854.46**
TOTAL	**1,235.70**	**344.70**	**59.10**	**6,455.40**	**1,436.60**	**3,314.20**	**877.60**	**510.29**	**246.29**	**7,414.50**	**236.75**	**287.80**	**22,418.93**

Notes:

(*a*) Mining levy was introduced in 1996 was eventually abolished in 2008
(*b*) MRA levy of 0.25 percent was introduced in 2008 to enforce policy implementation
(*c*) Direct taxes comprise of CIT, DWT, equity dividend, royalty withholding tax
(*d*) Indirect taxes comprise of employee salary tax, GST, duties and customs, etc.
(*e*) Equity dividend comprises of GoPNG, Western Provincial Government and landholder communities
(*f*) General compensation to mine-affected communities, which includes donations to disasters and sports
(*g*) Funds managed for community projects under the Mine Continuation Agreement as of 2001
(h) Contracts owned by community, and PNG owned firms excludes international service providers
(*i*) Goods and services procure within PNG
(*j*) Human capital comprise of skills driven in-house and external training to PNG and locals
(*k*) TCS was the source of infrastructure development, which also includes a portion of royalty for on-going maintenance of the Kiunga to Tabubil road

Table C-11: Non-tax benefits redistributions to Western Province (Millions PNGK)

Year	Royalty (*a*)	Equity (b) Dividends	Compo (c General	Compo MCA (*d*)	Business Dev (*e*)	Service contracts (*f*	Human Capital (*g*)	Infrast. TCS (*h*)	TOTAL FISCAL
1982	0.2		0.4				0.01		**0.61**
1983	0.2		0.6				0.01		**0.81**
1984	0.1		0.6			0.00	0.09		**0.79**
1985	0		1.6			0.00	0.16		**1.76**
1986	1.9		0.9			0.00	0.09		**2.89**
1987	2.2		0.9			4.74	0.08		**7.91**
1988	2.2		1		5.45	4.74	0.10		**13.49**
1989	3.5		1		26.78	4.74	0.16		**36.17**
1990	3.8		1.4		30.83	4.74	0.21		**40.97**
1991	10.3		1.7		38.23	4.74	0.25		**55.21**
1992	8.3		1.9		35.60	4.74	0.16		**50.70**
1993	8.2		1.9		34.98	4.74	0.15		**49.96**
1994	10.6		3.8		36.23	4.74	0.15		**55.51**
1995	17		17.7		36.53	4.74	0.33		**76.29**
1996	13.8		7.7		39.43	4.74	0.39		**66.05**
1997	8.4	3.2	8.8		41.50	4.74	0.29	1.37	**68.29**
1998	18.7	4.6	9.3		53.30	4.74	0.18	2.2	**93.01**
1999	24	16.6	11.4		66.75	4.74	0.31	2.3	**126.10**
2000	28.5	0	13		59.75	4.74	0.60	14.5	**121.09**
2001	31.1	14.9	53.9	41.76	61.18	4.74	0.70	13.1	**221.37**
2002	32.6	13.7	35.7	18.51	76.08	4.74	0.68	11.6	**193.60**
2003	48.4	66.1	33.5	14.78	91.55	4.74	0.25	5.11	**264.43**
2004	48.1	54.7	35.2	16.83	116.98	4.74	0.25	31.66	**308.45**
2005	71.6	150.8	41	22.93	124.95	4.74	1.34	5.78	**423.13**
2006	101.9	271.2	36.2	19.92	140.75	4.74	1.51	6.28	**582.49**
2007	114.5	216	89.6	53.05	117.78	4.74	1.73	8.3	**605.69**
2008	97.3	139.1	80.6	52.75	133.20	4.74	1.89	24.1	**533.68**
2009	87.8	139.9	76.8	53.62	111.40	4.74	2.68	40.3	**517.24**
2010	116.6	237.7	75.7	53.71	150.93	4.74	3.30	46.8	**689.47**
2011	120.3	141.6	76.1	53.77	71.70	4.74	3.45	42.5	**514.16**
2012	96.8	132.2	74.1	53.91	78.33	4.74	3.38	6.3	**449.75**
2013	85		75	54.75	73.50	123.14	4.73	25.6	**441.72**
TOTAL	**1,214**	**1,602**	**869**	**510**	**1,854**		**30**	**288**	**6,613**

Notes:
(*a*) Total dividends comprise of equity ownerships: Mineral Resources Star Mountain (MRSM) 3.05 percent; Mineral Resources Ok Tedi 3.05 percent; WPG 6.10 percent; and Non-CMCA 6.10 percent
(b) Compensation comprised of payments in the form of cash to affected communities
(c) Compensation paid into funds tied to community projects under the Mine Continuation Agreement
(d) Business development comprised of goods and services, and direct contracts (50 percent of total)
(e) Assume 50 percent of the total expenditure on in-house and external training flowed to the host region
(f) The TCS has financed infrastructure around OK Tedi since its inception in 1997

Table C-12: Non-tax benefits redistributions to WPG (Millions PNGK)

Year	Royalty (a	Equity (b Dividend	Compo (c General	Compo MCA (d)	Business Dev. (e)	Human Capital (f)	Infrast. TCS (g)	TOTAL
1982	0.2		0.4			0.01		**0.61**
1983	0.2		0.7			0.01		**0.91**
1984	0.1		0.6		2.84	0.09		**3.62**
1985	0		1.6		2.84	0.16		**4.60**
1986	0		0.9		2.84	0.09		**3.82**
1987	0.1		0.9		2.84	0.08		**3.91**
1988	0		1		2.84	0.10		**3.94**
1989	0		1		2.84	0.16		**4.00**
1990	0		1.6		2.84	0.21		**4.65**
1991	1.5		1.9		2.84	0.25		**6.49**
1992	1.4		2.6		2.84	0.16		**7.00**
1993	1.3		2		2.84	0.15		**6.29**
1994	1.9		3.9		2.84	0.15		**8.79**
1995	2.5		17.8		2.84	0.33		**23.46**
1996	3.3		7.9		2.84	0.39		**14.42**
1997	1.7	3.2	9		2.84	0.29	0.34	**17.37**
1998	4	4.6	9.4		2.84	0.18	0.55	**21.56**
1999	4.6	16.6	11.6		2.84	0.31	0.58	**36.52**
2000	7.8	0	13.3		2.84	0.60	3.63	**28.16**
2001	6.5	14.9	54.1	41.76	2.84	0.70	3.28	**124.07**
2002	7.1	13.7	35.8	18.51	2.84	0.68	2.90	**81.52**
2003	10.6	66.1	33.5	14.78	2.84	0.25	1.28	**129.34**
2004	10.8	54.7	35.4	16.83	2.84	0.25	7.92	**128.73**
2005	28	150.8	41.4	22.93	2.84	1.34	1.45	**248.75**
2006	43.2	271.2	36.5	19.92	2.84	1.51	1.57	**376.73**
2007	42.7	216	90.4	53.05	2.84	1.73	2.08	**408.79**
2008	35.1	139.1	81.1	52.75	2.84	1.89	6.03	**318.80**
2009	31.8	139.9	77.1	53.62	2.84	2.68	10.08	**318.01**
2010	44.5	237.7	76.4	53.71	2.84	3.30	11.70	**430.14**
2011	40.7	141.6	76.2	53.77	2.84	3.45	10.63	**329.18**
2012	31.1	132.2	75.4	53.91	2.84	3.38	1.58	**300.40**
2013	23.9		76.2	54.75	2.84	4.73	6.40	**168.82**
TOTAL	**387**	**1,602**	**878**	**510**	**85**	**30**	**72**	**3,563**

Notes:
(*a*) Royalty payments to community entities exclude the Western Provincial and Fly River Local Level Governments
(*b*) Dividend payments to community entities only and exclude the lower levels of governments
(*c*) Compensation flows directly to the host communities and excludes donations

(*d*) The Supplementary Ok Tedi Act provides the mine to pay compensation to affected communities under the MCA
(*e*) Business development benefit to the enclave Ok Tedi community comprises local owned contracts and 50 percent of JV with other Papua New Guineans wholly
(*f*) Assume 25 percent of the total expenditure on in-house and external training directly benefited the host community
(*g*) Since TSC is spread wide within the region, about 25 percent of the TCS funds are spent within the host mining area