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An Estimation of the Optimal Royalty Rate for Gold: A Case Study of Zimbabwe

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Abstract

This paper estimates the optimal royalty rate for gold in Zimbabwe from a social planner's revenue maximisation perspective. Frequent reviews of the royalty rates create instability in the royalty regime hence are detrimental to potential investment as well as fiscal revenue. Estimation of an optimal royalty rate thus guides fiscal policy and promotes fiscal stability. This paper applied an Autoregressive Distributed Lag (ARDL) error correction model to estimate the optimal royalty rate. The results show that the optimal royalty rate, other things being equal, is 6.85% which is 1.85% above the current rate. The conclusion is that there is scope for fiscal authorities to increase the royalty rate in order to generate maximum potential revenue.

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This research owes much to many. As the saying goes, “No man’s story is his alone,” I wish to express my gratitude to the institutions and persons without whom this research could not have seen the light of day. Among these include MEFMI and MOFED that provided an opportunity for me to carry out this study.

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Acronyms

AMV	Africa Mining Vision
ARDL	Autoregressive Distributed Lag
AMDC	African Minerals Development Centre
AU	African Union
CERDI	Center for Studies and Research on International Development
DRM	Domestic Resource Mobilization
ECA	Economic Commission for Africa
FAD	Fiscal Affairs Department
GDP	Gross Domestic Product
HAC	Heteroscedasticity and Autocorrelation Consistent
ICTD	International Centre for Tax and Development
NPV	Net Present Value
NRGI	Natural Resources Governance Institute
IMF	International Monetary Fund
MDA	Mining Development Agreement
MEFMI	Macroeconomic and Financial Management Institute of Eastern and Southern Africa
MOFED	Ministry of Finance and Economic Development
RESET	Regression Specification Error Test

1. INTRODUCTION

1.0 Background

Once production begins, mining royalty revenue guarantees government revenue, especially if the royalty regime is based on production or value of mining output. Royalty revenue generated depends to a larger extent on the level of the royalty rate applied. To mobilise fiscal revenues efficiently, the royalty rate for gold should be set at an optimum level that confer maximum fiscal benefits to the government whilst ensuring that a reasonable return on investment accrues to the investor. Daniel *et al*. (2010) pointed out that if the royalty rate applied is too high, investment and the tax base are likely to shrink as investors tend to shift their focus to other alternative forms of investments, and if the rate is too low, governments lose potential revenue through under-taxation, hence a need for an optimal level. However, frequent changes in royalty rates create uncertainty and present a challenge for mining companies in terms of project investment appraisal especially if an initially viable project turns out to be unviable after the policy change. This leaves the investors more vulnerable to policy changes, especially considering the fact that mining projects involve high up-front investment costs and long exploration and development phases lasting up to a decade before any revenue is earned (ICTD, 2016).

In recent decades, countries have lost considerable revenue because of fiscal competition as they attempt to attract more investment, especially foreign investment (Tanzi, 2011). In most cases, fiscal competition has worsened rather than maximised government revenue because tax rates, including royalty rates, have not been set optimally. With increased globalisation of mining operations, it is critical that countries set royalties at optimal levels so as to leverage on both revenue and investment flows.

The exploitation of gold deposits in Zimbabwe offers an opportunity for mobilisation of domestic resources that are required to finance development programmes among other things. Trench *et al*. (2015) postulated that gold mining requires minimal capital relative to other mineral deposits hence presents low hanging fruits for developing countries to generate fiscal revenues and other economic benefits. However, the revenue maximisation objective is often affected by the dire need to attract investment particularly in most developing countries. (Guj *et al.*, 2013, p.4) stated that Arrangements for raising revenue from the mining industry can be effective only if they operate within sound policy and legislative frameworks. It is vital that governments be clear and realistic about their mining revenue objective, and strategies be consistent with that objective. For example, governments often seek to attract new mining investment using favourable fiscal regimes. However, in doing so, they need to appreciate that such incentives may constrain future revenue raising and can be a cause of public concern long after the reasons for conceding the incentives in the first instance have been taken for granted or even forgotten.

The forgoing citation suggests that governments are confronted with contrasting objectives, which sometimes result in suboptimal tax regimes. Due to mineral resource endowments, resources rich countries are expected to grow much faster than resource poor countries. However, empirical evidence from a study by Sachs & Warner (2001) has shown that countries with greater natural resource wealth tend to nevertheless grow more slowly than resource-poor countries, culminating into a resource curse. The Economic Commission for Africa (ECA) argued that resource mobilisation efforts from the mining sector in Africa have been hampered by the choice of fiscal regimes, the design and types of fiscal instruments employed, and their implementation (ECA, 2016). Furthermore, the ECA report indicated that domestic resource mobilisation efforts from natural resources are also hindered by aggressive tax avoidance schemes that manifest through illicit financial flows.

In the face of tax planning initiatives and relatively weak tax administration authorities, an ad valorem royalty seems to be a more plausible fiscal instrument. This is consistent with Hubert (2017) who suggested that mining royalties could provide a reasonable guarantee of revenue to governments. The author stated that “Royalties are now more commonly seen as a political necessity, guaranteeing at least some government revenue in the early years of production before income tax payments begin” (Hubert, 2017, p. 16). Furthermore, Baunsgaard (2001) postulated that mining royalties are the predominant form of mining taxation.

Zimbabwe made several reviews of mining royalty rates over the period 2009 to 2017. These changes in the mining royalty rates indicate that the search for an optimal royalty rate is ongoing. Hubert (2017) pointed out that securing a fair share of government revenue from extractive sector projects is a two-step process of establishing an optimal royalty rate for the project at the outset and protecting the tax base over the project lifespan. Otto *et al.* (2006) suggested that relatively high rates of royalties can negatively affect investment decisions by raising the cut-off grade[1] of the mine. This implies that marginally profitable mines can become commercially unviable. Cawood & Macfarlane (2003) suggested that the royalty rate on gold mining should be levied at rates not exceeding 3% in order to ensure that mining is viable. They argued that rates of royalty above 3% would raise the cut-off grade and reduce mineral reserves. Contrary to this proposition, Grobler (2014) examined the impact of increasing mining royalty rates for gold and concluded that marginal increases in the royalty rate do not distort mining industry operations. However, Hall (2014) maintained that mineral royalties will significantly affect the mine cut-off grade if levied on gross revenue and their effect on cut-off grade could be ignored if levied on net profit.

Conclusions from an empirical study by Gajigo *et al*. (2012) suggest that there is scope for African countries to increase royalty rates for gold to levels above the modal rate of 3% in order to improve governments' share of the resource while still enabling mining firms to realize reasonable returns on their investments. While the case for increasing the royalty rate for gold in Africa is based on empirical evidence, Gajigo *et al*. (2012) did not determine the optimal royalty rate to which countries should graduate. This research, by way of the Zimbabwean case study, thus, estimates the optimal royalty rate and draws lessons for MEFMI member countries. An optimal royalty rate ensures that the country generates the maximum possible mineral revenue without undermining private investment in the mining sector.

1.1 Problem Statement

Sub-optimal and unstable mining royalty regimes are often detrimental to fiscal revenue, mining profitability and investment flows. The Chamber of Mines of Zimbabwe (2015), in its State of the Mining Industry Survey report, indicated that the relatively high royalty rates particulartly for gold (7%), platinum (10%) and diamond (15%) are among the major cost drivers that undermine mining industry viability thereby detering potential investors. The compounding effect of royalty rate and decline in commodity prices resulted in a decline in profitability of the gold sector from US$21 per ounce in 2014 to a loss of US$30 per ounce in 2015 (Chamber of Mines of Zimbabwe, 2015, p. 61). Scurfieild (2018) argued that failure to maximize government revenues may lead to budgetary or political pressures to change the regime in the future, hence setting a low tax burden to attract investment can therefore be

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[1] Cut-off grade measures the richness of the ore body in terms of gold grams per tonne of ore extracted. A higher grade means that the mine is richer in gold. Rich gold mines usually range from 2.5 grams per tonne to 7 grams per tonne.

counterproductive. Land (2009) argued that governments often resort to unilateral actions to redefine the fiscal terms under which investment in the extractive industry takes place and this sometimes creates disputes with mining companies. Furthermore, potential investors tend to be increasingly wary of investing on terms that will probably be too good to last.

Hawkins (2009) pointed out that while mineral endowments provide scope for economic development and poverty reduction, many economies driven by extractive industry activities have failed to leverage this wealth efficiently mainly due to suboptimal fiscal regimes. The author suggests that a mining fiscal regime must therefore take the form of a delicately balanced compromise between the government and the investor, thus prompting the estimation of an optimal royalty rate.

Over the period 2009 to 2016, the royalty rate for gold has been reviewed several times, ranging from a low rate of 3% to a maximum of 7%. The frequent reviews of royalty rates attest to the need for an optimal royalty regime for gold. However, frequent policy reviews within the lifespan of a mine may significantly distort initial project appraisals of the mining industry and create uncertainty for both existing and potential investors. The frequency of royalty rate reviews is itself a second-guessing and trial-and-error process presumably because knowledge of the optimal royal rate is non-existent. The reviews have a long run detrimental effect on mining investment and exports and, as a result, fiscal revenues.

Notwithstanding the fact that international gold prices were increasing, the most significant adverse effects of the reviews were felt in 2013 when the Zimbabwe Federation of Small Scale Miners (ZFSSM) expressed that the reviews were detrimental to the viability and growth of small-scale gold miners (Gutu, 2017). As a result, gold exports declined from an average of 5% of GDP to 4% of GDP[2]. This prompted government to put in place a two-tier royalty regime for small-scale gold miners and large-scale gold miners.

Royalty rates are either charged on gross gold revenue or on net profit. Most African countries, with the exception of South Africa charge royalty rates on gross revenue, in order to capture both the impact of increased output and prices. The rates of royalties charged on gross revenue range from a lower rate of 3% for Namibia to a high of 6% for Tanzania and Mozambique. Other main producers of gold in Africa like Ghana, Mali and Zimbabwe charge royalty rates of 5%, 3.5% and 5% respectively. For South Africa, royalty rates are based on profitability and

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[2] See Figure 3 in Chapter 2

are capped not to exceed 5% for refined mineral resources and 7% for unrefined mineral resources. Key variables that inform the optimal royalty rates are usually the cost of extraction, the quantity extracted, the commodity price and the amount of information available to the government regarding the quality or grade of ore extracted.

In South Africa, the estimation of the optimal royalty rates has ensured that the revenue risk is shared equally between the government and the mining industry (Van Der Zwan and Nel, 2010). With an optimal rate, no party is unfairly exposed to the fiscal risk of royalty rate fluctuations, hence the risk is well balanced between the state and extractors. In this regard, it is expected that the optimal royalty rate will provide certainty and stability of investors’ fiscal obligations as well as ensuring that risk is equally shared between the government and the investor.

1.2 Objective of the Study

The royalty rate for gold in Zimbabwe has been varying over the years. The optimal rate has not yet been estimated and this research attempts to fill this gap. The objective of this study, therefore, is to estimate the optimal royalty rate for gold in Zimbabwe.

1.3 Justification of the Study and Relevance to the MEFMI Region

Gold mining is relatively less capital intensive compared to other minerals hence small-scale investors including artisanal miners can engage in mineral extraction with minimal constraints (Trench, 2015). Where capital investment is substantially large, such as in platinum, copper, gas or crude oil, investors usually engage the host governments and negotiate to include a fiscal stabilisation clause in the Mining Development Agreement (MDA). The stabilisation clause secures government commitment to not arbitrarily change the current fiscal regime over an agreed period, thus insulating the investor from policy changes that may otherwise affect viability of the mine (Revenue Watch, 2014). However, due to relatively low capital requirements, gold mining licences rarely include a fiscal stabilisation clause. As such, gold mining projects are vulnerable to changes in fiscal regimes. Given the possibilities of changes in the fiscal regime and the consequences of such changes on fiscal revenues and on investor appraisals, this paper focuses on estimating the optimal royalty rate for gold in Zimbabwe.

Notwithstanding the fact that the country is endowed with various mineral deposits, the analysis focuses on gold, which has been gaining a bigger share of exports over the past five years[3]. A finite natural resource such as gold presents a single opportunity for the government to balance fiscal terms with industry viability. Minerals Council of Australia (2017) estimated that an average gold mine can have a life of more than 30 years, from exploration, mine development, production, rehabilitation up to mine closure, depending on geological conditions and size of deposit.

In this regard, an optimal royalty regime is important for gold mining in order to create fiscal stability whilst ensuring that a fair share of mineral revenues accrues to the governments. This paper, thus, provides useful insights that can guide tax policy design for the gold sector in Zimbabwe. It provides the basis upon which the government can realign royalty rates for gold, with a view to establish a stable royalty regime that facilitates long term investment planning. The optimal royalty rate provides the certainty that a stabilisation clause provides in other minerals, assuming politicians behave rationally.

The study also provides insights to MEFMI member countries on how they can domesticate the continental vision on mining, that is, the African Mining Vision (AMV). The AMV's thrust is to ensure the transparent, equitable and optimal exploitation of mineral resources to underpin broad-based sustainable growth and socio-economic development (AU, 2009). The continental vision compels governments to design fiscal regimes that capture optimal fiscal revenues. Notwithstanding the variations in geological occurrence of gold ore between Zimbabwe and other MEFMI member countries, this study is a timely first-step towards region-wide royalty policy formulation that fosters certainty and stability for both government and private investors. Such a policy is an important consideration for long term investment, hence maximum revenue generation.

This technical paper, therefore, provides a positive empirical step towards the actualisation of the AMV from which other MEFMI region countries can infer. To accomplish this task, the Laffer Curve model has been extended into a dynamic Laffer Curve model that takes into account the complexities of the relationship, through an Autoregressive Distributed Lag (ARDL) Model. The Autoregressive Distributed Lag (ARDL) Model was constructed to estimate the government revenue function from which the optimal royalty rate was derived.

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[3] A detailed review of trends in mineral exports is contained in Chapter 2

1.4 Organisation of the Paper

Following this introduction is Chapter two, which provides an overview of the gold mining sector in Zimbabwe including trends in the relative share of gold to GDP, exports and mineral revenues. Chapter three reviews theoretical and empirical literature on optimal taxation of minerals with specific focus on gold. Chapter four presents the methodology applied to estimate the optimal royalty rate for gold in Zimbabwe. Data analysis, results and discussion of results are presented in Chapter five while conclusions and recommendations are discussed in Chapter six.

2. RECENT TRENDS IN THE ZIMBABWE GOLD MINING SECTOR

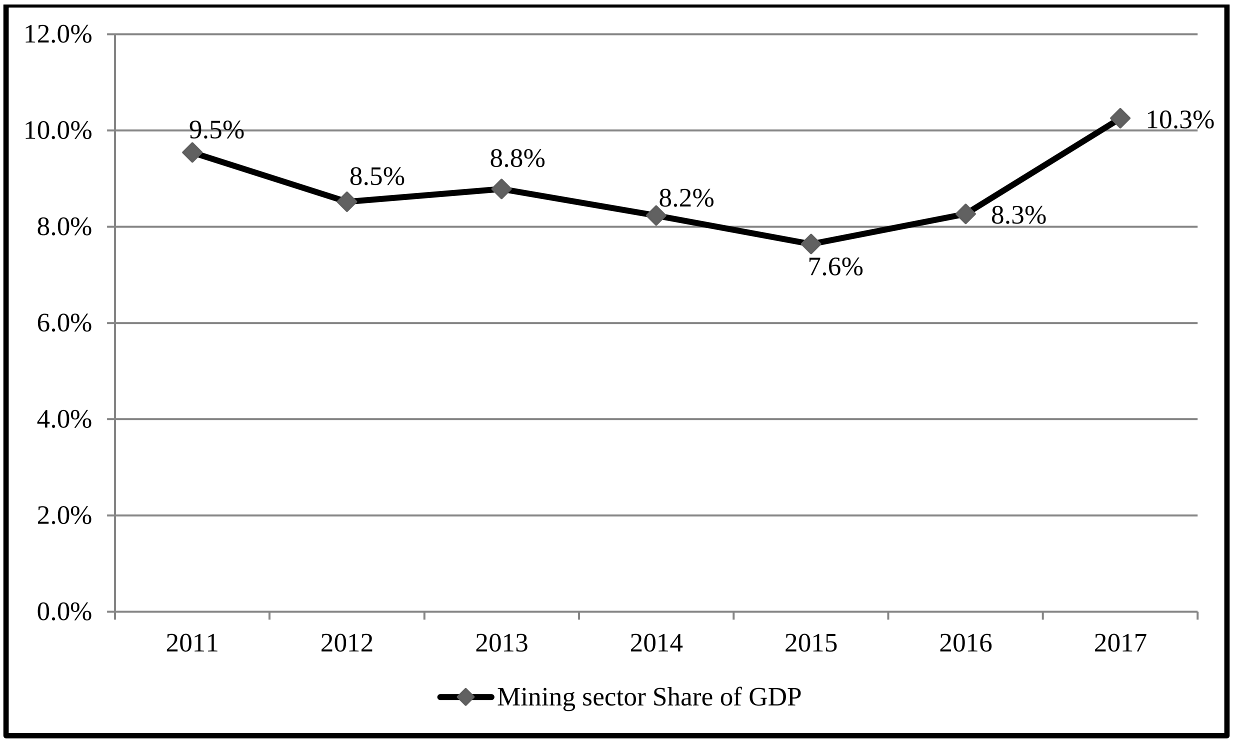
2.0 Introduction

This section reviews trends in the Zimbabwe gold mining sub-sector. The Zimbabwean economy is mainly dominated by primary activities such as agriculture and mining, hence, it is vulnerable to shocks such as drought and global commodity price shocks. The country experienced a slowdown in economic activity during the period 2014 to 2017 mainly due to the combined effect of declining mineral prices and the *el-nino* drought that negatively affected the 2015/2016 farming season (IMF, 2017).

2.1 Mining Sector Contribution to GDP

The Zimbabwe National Statistics Agency (ZIMSTATS) reported that the mining sector contributed an average of 8.5% to GDP between 2011 and 2016 (ZIMSTATS, 2018). The mining sector's contribution to GDP has, however, increased to approximately 10.3% of GDP in 2017. The sector also contributes to economic growth indirectly through forward and backward linkages with other sectors of the economy, such as transport, energy and the financial sector among others. Figure 1 shows the trend of the relative share of the mining sector output to Gross Domestic Product over the period 2011 to 2016.

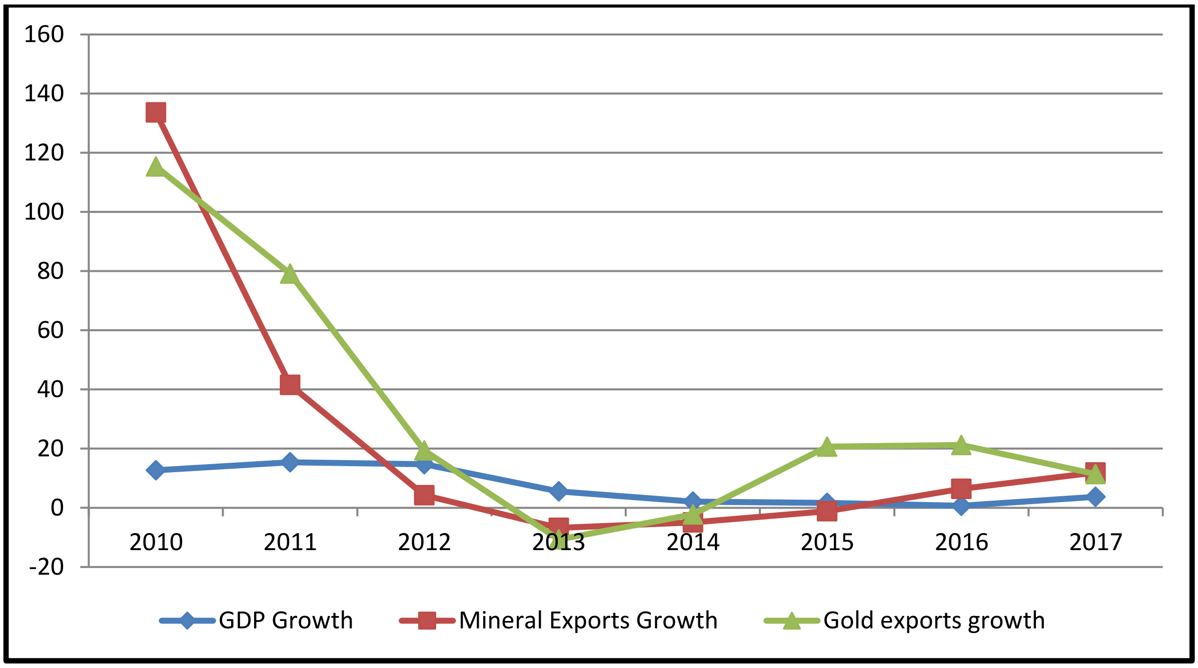
Figure 1: Mining Sector Contribution to GDP



Source: Zimbabwe National Statistics Agency, 2017

There is a fairly stable contribution of the mining sector to GDP in Zimbabwe. The increase in 2016 occurred when prices were below the peak levels of the price boom of 2011, suggesting that it is mainly attributable to increased production. The mining sector is, thus, an important determinant of economic growth in the country.

Figure 2: Real GDP Growth, Mineral Export Growth and Gold Export Growth



Source: Zimbabwe National Statistics Agency

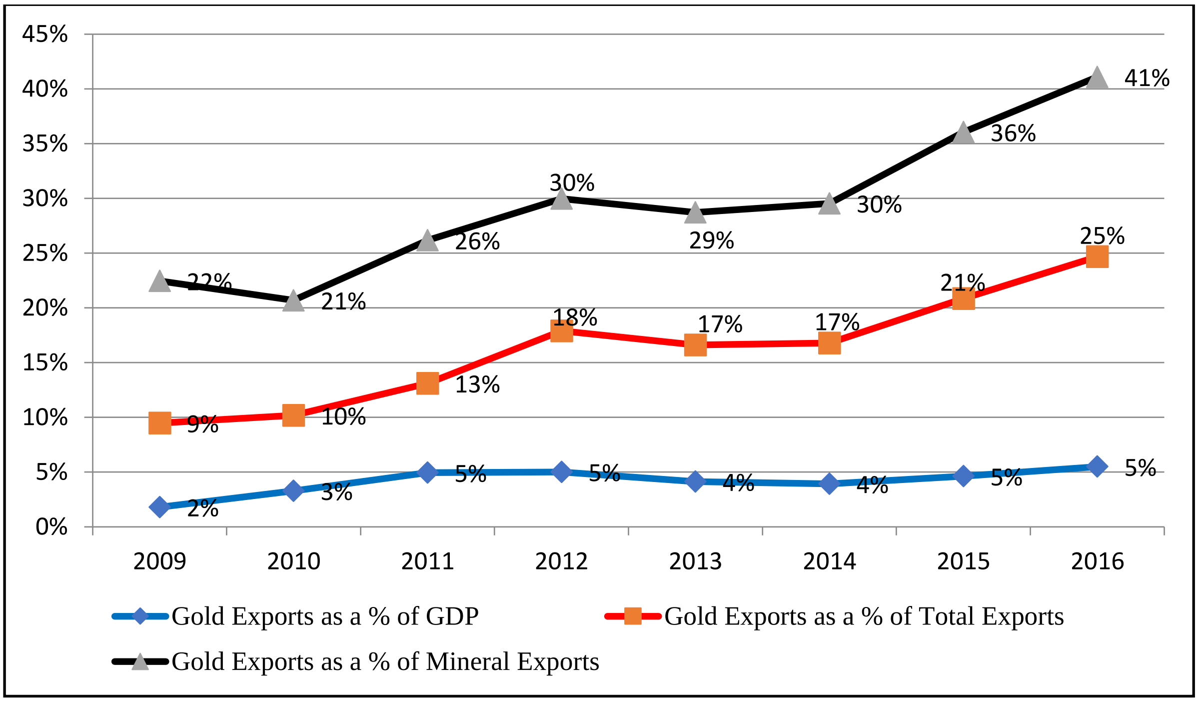
Figure 2 shows trends in GDP growth, mineral export growth and gold export growth from 2010 to 2017. GDP and mining sector growth co-moved, especially when there were no significant shocks on commodity prices or on other sectors of the economy. GDP growth slowed down with the slowdown in mining activity over the period 2012 to 2015. Furthermore, notwithstanding that the correlation between gold exports and GDP growth is positive and moderately strong, there is an observed weak positive association between GDP growth and mining sector export growth as illustrated by the correlation matrix below.

Table 1: Correlation Matrix: GDP Growth, Mineral Exports and Gold Exports

	Gold exports	Mineral Exports	Real GDP Growth
	1		
Mineral Exports	0.716	1	
Real GDP Growth	0.595	0.211	1

The correlation between GDP growth and mining is affected by shocks in other sectors of the economy. A case in point is in 2016 when the economy was shocked by the *el-nino* drought. It is also observed that mineral exports and gold exports grew whilst real GDP growth slowed down. Gold exports and total mineral exports have a strong positive correlation of 0.716. The mining sector in Zimbabwe contributes on average 54% to total exports with gold contributing 30.2% of total exports in 2017 (Reserve Bank of Zimbabwe, 2017). Thus, gold has become the dominant mineral export commodity for Zimbabwe. The relative share of gold exports to GDP depends partly on the gold output and on the price prevailing on the international market.

Figure 3: Trends in Gold Export as a share of GDP, Total Exports and Mineral Exports



Source: Reserve Bank of Zimbabwe; Ministry of Finance & Economic Development

Figure 3 shows trends in gold exports relative to GDP, total exports and mineral exports. As can be observed from Figure 3, the share of gold exports increased from 2% of GDP to 5% and from 9% of total exports to 25% between 2009 and 2016. Notwithstanding the impact of price increases on the value of exports, this performance suggests that the stock of available gold in Zimbabwe is gradually depleting. It is therefore important to ensure that government captures a fair share of the resource and transforms it into other productive assets with a permanent stream of income.

2.2 Review of Gold Royalty Rates

There have been notable reviews of royalty rates in Zimbabwe, over the period of study. Prior to 2009, the remittance of royalties was suspended. However, the government lifted the suspension following recommendation from the Fiscal Affairs Department (FAD) of the

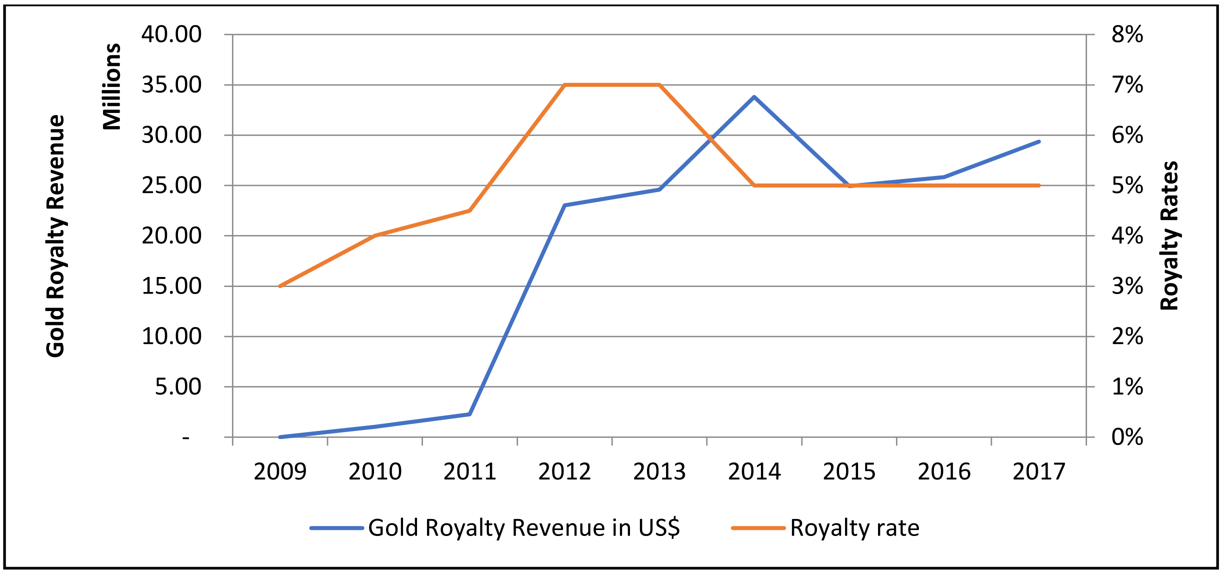
International Monetary Fund (IMF). The remittance of royalties on gold with effect from August 2009 was also prompted by the increase in mineral prices during this period (Ministry of Finance and Economic Development, 2009)

The international price of gold continued on an upward trend between 2010 and 2013, and this further prompted the Government to increase the royalty rates on precious metals from 3% to 3.5% effective from January 2010 (Ministry of Finance and Economic Development, 2010). This review lasted for 9 months since the rate was subsequently increased to 4% effective October 2010 (Ministry of Finance and Economic Development, 2010). In view of developments in the international metal prices, the Government in 2011 further increased the royalty rate on gold from 4% to 4.5% (Ministry of Finance and Economic Development, 2011). The new rate only lasted for one year after which Government further reviewed the royalty rate for gold from 4.5% to 7% in 2012 in order to maximise the share of gold revenue accruing to the fiscus (Ministry of Finance and Economic Development, 2012).

However, the new royalty regime threatened viability of productive mining operations, since the international metal prices declined. In view of the concerns raised by the mining industry in 2014, particularly small-scale miners, government introduced a two-tier royalty system for small-scale producers and large-scale producers. Consequently, the royalty rate was reviewed from 7% to 5% and 3% for large scale and small scale gold miners respectively (Ministry of Finance and Economic Development, 2014). A lower royalty rate of 3% on small-scale gold producers, whose output did not exceed 0.5 kg per month, was introduced as an incentive for small-scale gold producers to sell their produce through formal channels. The royalty rate for small-scale miners was further reduced to 1% in order to curb leakages effective from September 2015 (Ministry of Finance and Economic Development, 2015).

In 2016, the Government reduced the royalty rate from 5% to 3% on incremental output of gold using the previous year’s output as the base year (Ministry of Finance and Economic Development, 2016). This was introduced as an incentive to encourage production; however, the policy might have significant impact on the effective royalty rate for various companies. The royalty reviews were aimed at maximising gold royalty revenue collections. Figure 4 shows a graph of gold royalty revenue collected at various rates.

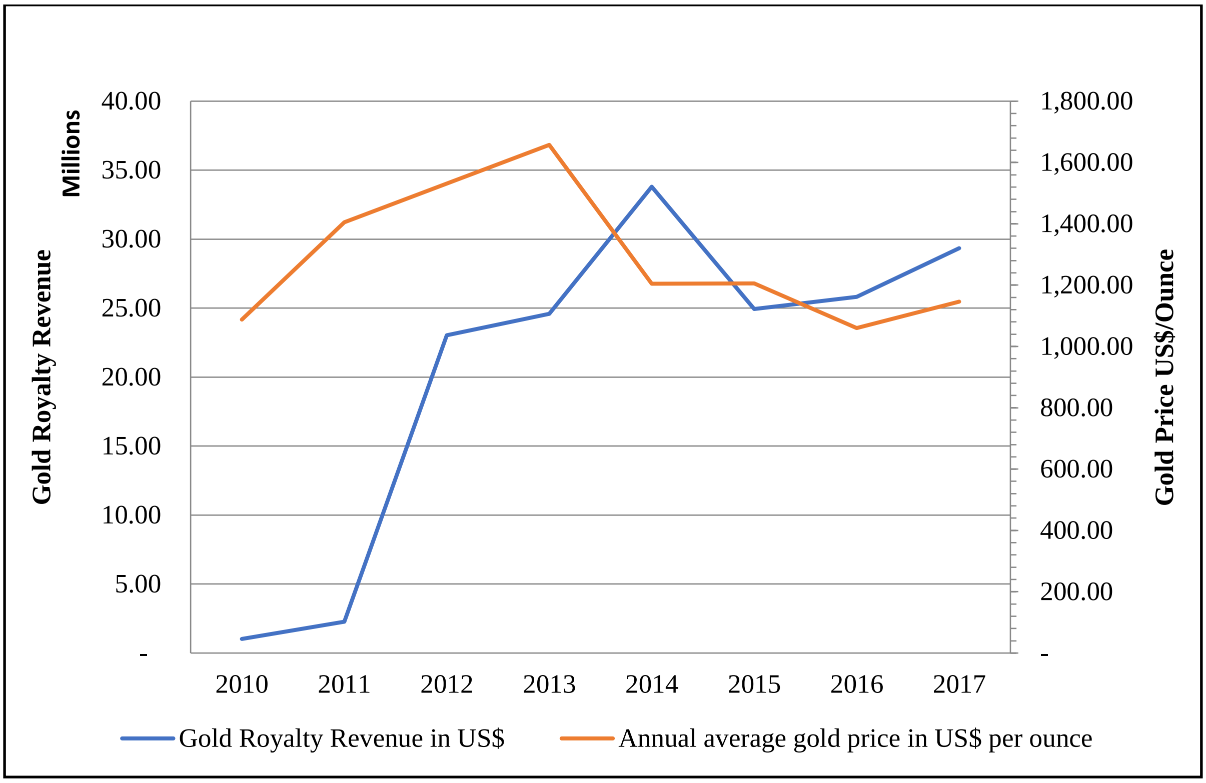
Figure 4: Gold revenue at various royalty rates



Source: Ministry of Finance & Economic Development, Zimbabwe

It is clear from Figure 4 that Gold Royalty Revenue persistently increased with increases in the royalty rate between 2009 and 2013. However, maximum revenue collection was recorded in 2014 when the royalty rate was lowered to 5%. It is possible that the optimal royalty rate is closer to 5%. Notwithstanding the impact of the royalty rate on revenue collections, volatility of the gold price also plays an important role since royalties are levied at an *ad valorem* rate. Figure 5 shows a graph of royalty revenue collection at various gold prices.

Figure 5: Royalty revenue at various gold prices



Source: Ministry of Finance & Economic Development, Zimbabwe

Figure 5 depicts a positive association of gold royalty revenue and gold prices during the period 2010 to 2013, which became relatively weak between 2014 and 2017, indicating the effect of policy changes particularly concessions, which were availed to small-scale gold producers. Despite these concessions, there seems to be a strong positive association between gold royalty revenue and gold prices as shown on the following correlation matrix.

Table 2: Correlation Matrix: Revenue, Royalty Rate and Gold Prices

	Gold price	Royalty Rate	Revenue
Gold price	1		
Royalty Rate	0.648	1	
Revenue	0.569	0.779	1

The above correlation matrix attests to the positive correlation between revenue and gold prices and between revenue and royalty rates. This suggests that revenue responds positively to increases in either prices or royalty rates.

2.3 Summary

It is notable that the mining sector contributes a significant share of the Gross domestic product of Zimbabwe. Furthermore, gold significantly contributes to total exports. However, mineral extraction reduces the value of the available stock of wealth, thereby making the country poorer unless the value of exports could be harnessed through an optimal tax system so that revenue is invested in alternative productive assets. Furthermore, the royalty regime for gold in Zimbabwe has undergone frequent reviews. The reviews tend to alter investment appraisal indicators such as Net Present Value, Payback period and Internal Rate of Return upon which most projects are premised. As a result, frequent review of the royalty regime creates instability and unpredictability that deter both existing and potential investors. This also negatively affects revenue-generating capacity of government. This justifies the need for an optimal royalty rate that guarantees fiscal stability and predictability whilst at the same time guaranteeing the maximum possible resource revenue to the government.

3. LITERATURE REVIEW

3.0 Introduction

The optimal taxation of natural resources is underpinned by the economic theory of extractive industries and the theory of optimal taxation. This section reviews the various theories and empirical findings in relation to the optimal royalty rate for gold in Zimbabwe. This section presents the classical and the Austrian view on taxation of exhaustible resources. It also provides the Laffer tax rate-tax revenue analysis of optimal taxation and a survey of empirical studies on optimal royalty rate for gold in the context of developing countries like Zimbabwe.

3.1 Theoretical Literature

Classical View

The thrust for the efficient extraction and governance of mineral resources traces its origin from the classical school of thought as put forward by Gray (1914) who postulated that, for a specific mineral, production in the current period precludes future production. He emphasised that mineral resources are exhaustible; hence can only be produced in the future only if they are not produced today. The observation prompted pro-environmental scientific pressure groups to advocate for conservation and less resource intensive production. However, Hotelling (1931) advanced that the extraction of exhaustible resources should be managed through regulation and taxation in order to engender sustainable and efficient resource extraction. The author postulated that a price premium for a depleting resource, known as the resource rent or Hotelling Rent was a revenue stream that a fixed exhaustible supply would command. From this observed premium, Hotelling (1931) deduced a rule called the Hotelling Rule which states that exhaustible resources attract relatively high prices and royalty rates as they become scarcer through exploitation.

The classicalists advanced that the royalty or right to extract an exhaustible resource could be determined in a manner analogous to real wage rate or real rate of profit. Underpinning this analogy is the idea of negotiation of the wage, which presumes the role of economic power in influencing what the rate would be. Pursuant to this argument, Bidard and Erreygers (2001) proposed a simple model to investigate the elementary properties of an economy employing exhaustible resources. Their analysis assumes a competitive economy producing goods and services using an exhaustible resource as a circulating capital good which maintains its physical properties if not used in production. The analysis also assumes that the existing deposits of the exhaustible resource are privately owned.

The following conditions are also assumed to obtain in the economy

- The produced quantity of commodities remains fairly stable
- A single production method is known in each industry
- Basket of goods that constitutes real wage
- The exhaustible resource is overabundant, in the sense that, at the beginning of each cycle, the available quantity of the resource continues to be largely in excess of the overall requirements of the productive sector. The resource thus gradually becomes scarce.

Bidard & Erreygers (2001) pointed out that the determination of the price (royalty) for the use of the exhaustible resource is different from other resources that can be re-used. They postulated that if the exhaustible resources had indestructible powers such as land, that is, re-emerging intact from production processes, then, competition among owners would cause its price to tend to zero. They argued that it is doubtful that competitive bidding on the part of owners of exhaustible resources would generally drive its price towards zero. They further argued that owners would not sell in the present at an arbitrarily low price if there was a possibility that in the future, the repetition of production processes would make the resource scarce and most likely to be sold at a considerably higher price.

Consistent with this view, Parrinello (2001) also argued that competition among owners of exhaustible resources would not drive the price of the use of the resource toward a persistently upward trend but would rather engender a tendency of the royalty to grow overtime at a rate equal to the rate of profit or interest. Assuming that owners aim at allocating their resource endowments overtime in order to secure for themselves an optimal flow of income, and the royalty rate is constant overtime, owners would have an incentive to dispose their endowment and invest the proceeds at the going rate of profits or interest.

The classical theory thus suggests that, under the hypothesis of competition, the royalty of an exhaustible resource tend to some strict positive level. However, the classical theory is criticised because of its assumptions. Bratland (2000) argued that the assumptions upon which the theory was established were exactly wrong for the real world that the authors intended to inform. Bratland (2000) argued that relaxing the assumptions to allow for technological change, capital investment, resource substitution and entrepreneurial adjustment renders the classical theory inadequate to explain real world dynamics. Furthermore, Ravagnanani (2008) pointed out that the absence of correct forecasts on the part of owners implies that competition cannot presumably enforce a theoretical path of royalties.

Austrian (Libertarian) School View

In view of the shortfalls of the classical approach, Bradley (2007) argued that the Austrian school provides a robust explanation to changes in mineral resource scarcity than the classical depletionism and offered a wide research agenda for current debates over resource production, usage and future availability. The Austrian school is, largely informed by the works of Mises (1940) and Hayek (1960) who refuted the notion of market failure and the need for government planning to ensure sustainable exploitation of exhaustible resources.

Mises (1940) challenged the argument of market failure from overproduction of irreplaceable resources and argued that by conserving exhaustible resources, the current generation might be depriving itself without giving any advantage to the future generation, mainly due to technological progress. Hayek (1960) argued that exploiting depleting resources promotes future progress because wealth is created from present usage. The author suggested that natural resources, though exhaustible, should not be preserved for future generations to exploit them but should be converted into other productive assets. Hayek, (1960, p. 374) stated that any natural resource represents just one item of our total endowments of exhaustible resources and our problem is not to preserve this stock in its particular form but to maintain it in a form that will make the most desirable contributions to total income. The existence of a particular natural resource merely means that, while it last, its temporary contribution to our income will help us to create new one which will similarly assist us in the future..

Hayek's ideas suggest that revenue from exhaustible resources should be invested in order to convert natural resources into other sustainable productive assets that can be available to future generations. This is consistent with the Hartwick Rule for sustainability which states that exhaustible resource revenue should be invested in produced capital such as buildings, roads and knowledge stocks which are needed to exactly offset declining stocks of non-renewable resources (Hartwick, 1977).

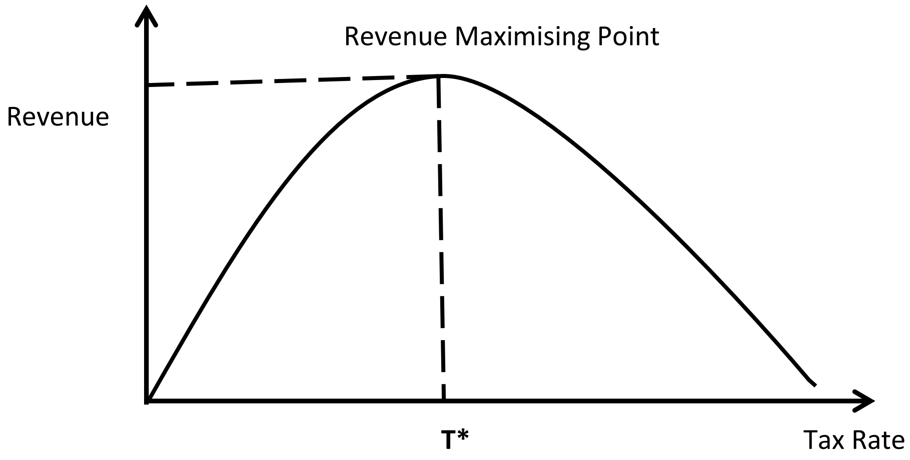
Contrary to the Austrian school, Pigou (1932) postulated that converting natural resource wealth into other productive assets requires the government to design resource governance policies including a tax regime that ensures that the maximum potential revenues are generated. Pigou (1932) postulated that it is the duty of the government which is the trustee for unborn generations as well as its present generation to watch over and if need be by legislative enactment to defend exhaustible natural resources of the country from rush and reckless disposition. The author, thus, puts the role of institutions into perspective. This implies that the free market economy is not efficient in ensuring that resource exploitation confers economic benefits to future generations, prompting the regulation and taxation of the exhaustible resource extraction.

Laffer tax rate-tax revenue hypothesis

The aspect of optimal taxation is largely informed by the Laffer curve. Laffer (2004) argued that tax revenue is a function of the tax rate. The author illustrated that changes in tax rates have two effects on tax revenues, that is, the arithmetic effect and the economic effect. The arithmetic effect implies that if tax rate is reduced, tax revenue will be reduced by the magnitude of the decrease in the rate, whilst an increase in tax rates increases revenue by the same magnitude.

The economic effect, however, recognizes the positive impact that lower tax rates have on investment and the tax base, by providing incentives to increase these activities. The theory shows that there is a maximum limit on the extent to which increase in tax rate can generate additional revenue, since relatively high tax rates tend to penalise participation in the taxed activities thereby inducing the opposite economic effect. The effects of tax rate on revenue is illustrated in Figure 6.

Figure 6: The Laffer Curve



Source: Laffer (2004) *The Laffer Curve: Past, Present and Future*

Figure 6 shows that there is a limit to which Governments can adjust the tax rate without inducing opposite economic effects. The mining industry, however, is peculiar in the sense that it involves installation of huge capital investment, which is relatively immobile. The mining industry may thus respond to tax increases by extracting high-grade ores or suspending operations until such a time when mineral prices increase to levels where extraction becomes viable.

However, Laffer's argument assumes an environment where investors cannot negotiate fiscal terms with the government. Forward-looking mining investors usually negotiate fiscal terms and sign fiscal stability clauses that are legally binding commitments by the host country's government (Daniel & Sunley, 2008). Such contractual obligations limit government discretion to adjust the tax rates.

Boadway & Keen (2010) pointed out that the design of mining taxation policy requires that the distinctive features of resource activities and the interplay between the interests of powerful stakeholders be considered. The authors identified the features, which may also affect other industries, but are peculiar to mining in terms of severity as follows:

(a) Uncertainty

Mining projects are characterised by uncertainties that affect the investor particularly in relation to the geology and mineral prices at all stages from exploitation through to development and extraction. Prices fluctuate depending on various factors, some of which are beyond the control of the mining company, whilst geology poses uncertainty of the quantum of available resource and its accessibility.

(b) Asymmetric Information

There exists information asymmetry between policy makers and mining investors. Policy makers are generally less well-informed of the geological and commercial circumstances at all stages of particular resource project than those who undertake the exploration, development and extraction. These asymmetries of information make resource extraction potentially far more difficult to tax than would otherwise be the case, since mining investors have no direct interest in sharing their superior information with government. They may have an interest in understating the likely stock of the resource and overstating the difficulty of its extraction.

c) Exhaustibility

Natural resources are finite in nature implying that the more extraction happening now, the less extraction is expected in the future. As a result, the marginal cost to which the marginal benefit from extraction is optimally equated reflects not only the current production costs but the opportunity cost (marginal user cost) in terms of future extraction forgone.

d) High Sunk Costs and long Production periods

Discovering, developing and exploiting a mineral resource cost hundreds of millions of dollars and may take long periods of time. Often the expenses are incurred to a larger degree in the early stages of the project, before the generation of positive cash flows. Exploration costs are sometimes sunk. This feature poses a fundamental problem of time consistency in mineral taxation. Boadway & Keen (2010) argued that government has an incentive to offer relatively generous treatment at the planning stage when the tax base is relatively elastic, but much less generous treatment after plant installation when the tax base becomes relatively inelastic. This creates a potential inefficiency in resource extraction.

Consistent with Boadway & Keen (2010), Guj (2012) recognised that installed mining equipment is relatively immobile; as a result, higher levels of taxes can be levied on current operating mines which are captive to the country in which resources are located. However, Guj argued that this would discourage future exploration and development investment in the country, as mobile capital tends to be redirected to countries with more attractive and stable mining fiscal regimes. Consequently, government would rely on revenue from a few mines, which are heavily taxed.

Although the choice of extracting minerals from a certain jurisdiction is largely dependent on the availability of mineral ores in that jurisdiction, Guj's argument suggests that the possibility of tax competition in the mining sector is still high. Furthermore, capital can be attracted to alternative non-mining investments. As a result, a balance must be established where the inflow of necessary exploration and development capital would support future mining project developments. Capital investments into the mining industry imply more potential government revenue and socio-economic benefits that optimise social welfare.

Otto *et al.* (2006) advanced that the overall tax system should be designed in a manner that is balanced to both the Government and the investor as well as being globally competitive. They posited that extremely high royalty rates may encourage mining of high-grade ores at the expense of average grade ore, often referred to as picking-the-eye problem. In this regard, the authors highlighted that Governments should carefully weigh the immediate fiscal benefits resulting from high levels of tax, including royalty, against the long term benefits of a sustainable mining industry that will contribute to long-term development, infrastructure, and economic diversification.

This analysis points that a fair view of the fiscal regime should also include the economic benefit accruing from mining activities such as infrastructure development and economic linkages that are created with other industries. However, in the context of African countries, low technological development and limited local processing of minerals has negatively affected the degree of backward and forward linkages, hence economic diversification (AMDC, 2017). Considerations should, therefore, be made to ensure that rates of royalties are designed in a manner that generates maximum fiscal benefits whilst not deterring new investment or mineral exploration activities which would otherwise defeat the revenue maximising goal of government.

From the literature outlined above, it is evident that a royalty regime is one that maximises government revenue without making the mining activity unviable. Ideally, governments should target mineral rent, that is, the margin realised by a mining company after netting off from gross revenue all the costs of production as well as the minimum required rate of return on capital required to attract capital and retain it in the project (Otto *et al.*, 2013). However, for most developing countries with relatively weak Tax Administration Authorities, mineral rent is relatively difficult to recognize, hence the preference for an ad valorem royalty rate on gross revenue. The next section explores an empirical analysis of studies on optimal taxation of gold.

3.2 Empirical Literature

Broadway & Flatter (1993) proposed a special resource tax precisely levied on resource rents. They argued that a tax on resource rent is non-distortionary and therefore efficient. Resource rent can be taxed up to 100 percent without distorting investment decisions and therefore provides ideal policy options for natural resources. However, in the context of Zimbabwe where tax administration capacity is relatively weak (ECA, 2016), a resource rent tax may not be a plausible policy option.

Several models have been applied to estimate optimal royalty rates in the context of developing countries. Saji (2010) estimated the optimal royalty tax for gold in Mali using the Optimal Control Theory which was developed by Heaps (1985). The author uses a dynamic optimization taxation model to analyse the tax instruments used in the mining sector and numerically calibrate the model to compute the optimal level of taxation for Mali. The study conducted dynamic optimal control simulations of the net present value of revenue accumulating to the government in order to determine the royalty rate that maximises the net present value of government revenue given production constraints that mining companies face. The result shows that the optimal royalty rate for gold in Mali is about 3.5 percent.

Ibrahim-Shwilima & Konishi (2014) also modelled the behaviour of gold mining firms in Tanzania in order to establish the impact of royalty tax on firm production decisions using optimal control theory. The analysis shows that the royalty rate of 3% was below optimal and was insignificant to influence firms' production decisions. The study concluded that a relatively higher rate of royalty could be applied on gold without inducing gold mining firms to alter production decisions.

Cawood (2010) argued that there should be an acceptable minimum royalty rate that ensures that the state receives compensation for its exploited resources even when the mining operation is unprofitable. The author further proposed that there should be a maximum royalty rate which targets surpluses during times of high profitability. In view of these arguments, Cawood (2010) advanced that a sensible royalty formula could, therefore, be stated as follows:

Y% = A + B, where

Y% is the royalty rate applied at any given time,

A is the minimum rate and

B is the allowance for higher royalty in times of higher profitability. **B** is calculated as the (profitability ratio in the current year)/ (factor to achieve the maximum rate).

Using data from South Africa, Cawood (2010) conducted royalty simulations for both refined and unrefined gold, at various levels of profitability and concluded that the royalty rate applicable to gold mining in South Africa should not exceed a maximum rate of 3%.

Gajigo *et al.* (2012) estimated the impact of royalty charges on both project cost and profitability of gold mining companies in Africa using semi-parametric equations. The study analysed data from 29 mines drawn from Botswana, Burkina Faso, Ghana, Guinea, Mali and South Africa between 2008 and 2010. The study estimated the effect of royalties on profitability using a panel regression. The ultimate test of the burden of royalties is their effect on profitability. As such, the effect of royalties was estimated while the effect of other variables such as location, mine grade, year of production were controlled.

The study controlled for country fixed effects for all time-invariant (over the sample period) country level variables that affect mining such as fiscal regimes, macroeconomic climate, state of the infrastructure, environmental and labour regulations. The year dummies also captured changing commodity prices. The results show that there is a weak relationship between royalties and profitability, once mine grade, country and year effects are controlled. The study shows that the level at which royalties as a share of total cost begins to have a significant impact on mine profitability is above the prevailing average rate 3%. The study thus concluded that there is scope for an upward review of the royalty rate, however, falls short in terms of indicating the optimal rate above which the mining industry will consider projects to be unprofitable.

Cawood (2010) and Gajigo *et al.* (2012) analysed royalty rates in terms of their impact on company profitability, indicating that royalty regimes should ensure that mining companies attain a reasonable return on their capital investment. However, the studies differ in scale, methodologies and findings. Cawood's findings are based on simulations of royalty rates applicable at various levels of profitability in South Africa, whereas Gajigo *et al.* (2012)'s findings are based on panel regression of various gold mining companies drawn from a number of gold-producing countries. The different findings suggest that there are specific effects in

South Africa that affect the royalty rate that can be applied; hence the estimation of the royalty rate should take into account country specific factors that affect gold revenue in Zimbabwe.

Altunoz (2017) estimated the optimal tax rate for the Turkish economy using the Laffer curve equation model. Altunoz (2017) constructed a regression equation in order to determine Turkey’s optimal rate of corporate tax over the period 1980-2014. The regression equation used tax revenue as the dependent variable whilst the tax rate and the square of the tax rate were the explanatory variables. The regression equation constructed did not include a constant term since government cannot collect any revenue at a tax rate of zero percent. The results show that the optimal corporate tax for Turkey is 17%. Annuar *et al*. (2018) modified the Laffer Curve model constructed by Altunoz (2017) into an Autoregressive Distributed Lag (ARDL) Model in order to estimate the optimal Corporate Income Tax rate for Malaysia. The modified model included lagged variables of the tax rate, the square of the tax rate and a dummy variable that captured the effect of crisis periods on corporate income. The study showed that the optimal corporate income tax rate for Malaysia is 25.5%.

In summary, both theory and empirical evidence affirms the importance of designing optimal mining tax regimes. Due to the high capital costs and uncertainties that characterise the mining sector, most developing countries particularly Zimbabwe require foreign direct investment in order to tap the economic value in the extractive industry. However, the desired investment must confer fiscal benefits to the host Government. There is consensus among governments and civil society groups on getting a fair share of natural resource revenue. However, little effort has been put to estimate the optimal taxation regime.

4. METHODOLOGY

4.0 Introduction

This section presents the methodology applied in the estimation of the optimal royalty rate for Zimbabwe. Several approaches have been applied to estimate the optimal royalty rate. These include the optimal control theory, simulation models based on profitability, multiple regression analysis, semi-parametric estimation techniques and the Laffer Curve model. The Optimal Control theory provides useful insights into the estimation of optimal royalty rate for gold especially when the resource stock (gold deposits) are known and extraction rate is known to the effect that the time to resource extinguishing can be estimated. However, gold production in Zimbabwe has over the years, been gradually increasing[4] indicating that the rate of extraction is not uniform. Furthermore, new discoveries of gold make it relatively difficult to estimate the resource stock with certainty.

Furthermore, it has been observed that approaches applied by Cawood (2010) and Gajigo *et al.* (2012) were based on firm level cost and profitability, which variables were not accessible for this study. This paper could not apply such modelling framework due to lack of firm level data. Profitability is oftentimes an unreliable yardstick of firm performance due to challenges of manipulation of tax returns through tax avoidance schemes.

The Laffer Curve model provides a strong theoretical foundation for the determination of optimal tax rates, which has been supported by empirical studies such as Karas (2012), Altunoz (2017), Jayasooriya (2017), and Annuar *et al.* (2018). Notwithstanding that, the level of the royalty rate is an important variable in the determination of royalty revenue, gold royalty revenue is often affected by gold output and the prevailing gold prices. Consistent with the model constructed by Altunoz (2017), the Laffer Curve model has been extended into a dynamic Laffer Curve model that takes into account the complexities of the relationship, through an Autoregressive Distributed Lag (ARDL) Model. The extended Laffer Curve Model accounts for the dynamic effects of prices and output on royalty revenue whilst capturing the non-linear relationship, which makes it a more robust model than the simple Laffer Curve model.

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[4] See Figure 3 in Chapter 2

An ARDL model was used to estimate a government revenue function to determine the optimal royalty rate for gold in Zimbabwe. The estimation is based on a model constructed in the determination of the optimal corporate income tax rate for the Turkish economy by Altunoz (2017). In order to check for robustness of the methods, the optimal royalty was estimated using two approaches, that is, a replication of the Altunoz (2017) model and an extended Altunoz (2017) model that takes into account other variables that are important determinants of royalty revenue in Zimbabwe.

4.1 Data Sources

The optimal royalty rate was estimated using secondary data collected from the Zimbabwe Revenue Authority, Ministry of Finance & Economic Development, the Reserve Bank of Zimbabwe and online sources such as www.kitco.com. The study used monthly data for the period January 2009 to December 2017. The following table summarises the variables and their sources

Table 3: Variable Description

Variable	**Description**	**Source**
Log Royalty Revenue (Lr)	The amount of monthly royalty revenue generated by Government from gold sales	Ministry of Finance and Economic Development, Zimbabwe
Royalty Rate (rr)	The rate of royalty charged on gross gold revenue	Ministry of Finance and Economic Development, Zimbabwe
Log Gold Output (lgo)	The quantity of gold output produced per month	Reserve Bank of Zimbabwe
Log Gold Price (lgp)	The international average monthly gold price	www.kitco.com

4.2 Model Specification

To estimate the optimal royalty rate for gold in Zimbabwe, this research applied the Altunoz (2017) model. The model expresses government revenue as a quadratic function of the tax rate. The model conforms to the theoretical framework of the Laffer Curve which states that government revenue positively responds to increases in the tax rate only to a certain point where further increase in the tax rate yields a decline in government revenue. The regression equation used tax revenue as the dependent variable whilst the tax rate and the square of the tax rate as explanatory variables as shown on the following equation:

Revenue = f(tax rate, square of the tax rate)………………………………Equation 1

The rate of tax applied is an important determinant of government revenue. Consistent with equation 1 above, the royalty rate for gold and its squared term are important variables determining the optimal royalty rate. The first model replicated the Atunoz (2017) model in the gold mining sector of Zimbabwe to determine an optimal royalty rate as follows:

Revenue = f(royalty rate, square of royalty rate)…………………………Equation 2

However, the Altunoz model was applied to firms across all industries, some of which have market power to influence prices. Contrary to this, gold mining firms in Zimbabwe are price takers, that is, they sell at the going international gold price. Furthermore, a royalty payment is made as compensation for extracting a finite resource, hence should also depend on the quantity of the resource extracted. These unique characteristics of the royalty tax prompted the researcher to include quantity of gold produced, international gold price and their lagged values as key explanatory variables in the model. The study extended the Altunoz model to estimate an Autoregressive Distributed Lag (ARDL) Model in order to capture the dynamic effects of royalty rates, gold output and gold prices.

Alternatively, the study could have applied the Threshold Autoregressive (TAR) Model to capture non-linearity and to allow for the parameters to change in the model according to the number of segments or breaks, thereby allowing different variances for all segments that exist within the data (Tong, 1978). However, the period under study represents a period where the country was using multicurrency. The TAR model would thus be important if the period under study included period before or after the multicurrency in depicting structural changes in the economy. Furthermore, the TAR model would have been ideal if the government implemented different royalty regimes in different periods such as ad valorem based, unit based or profit based royalties.

The ARDL Model estimates the dynamic marginal effects, including the magnitude and timing of the effects. Nkoro and Uko (2016) pointed out that the ARDL cointegration technique is most suitable where variables are integrated of different order, that is, if variables are stationary in level or after first differencing or if a combination of level and first difference stationary variables exist. However, this technique is not applicable where variables are stationary after second differencing (Nkoro and Uko, 2016). The ARDL model is robust when there is a single long run relationship between the underlying variables in a small sample size.

4.2.1 Stationarity Test

To ascertain on the preconditions necessary for an ARDL model, stationarity tests of key variables that influence royalty revenue generation were established. These variables include the *revenue*, *royalty rate*, *gold prices* and *gold output*. The stationarity tests were informed by the Augmented Dickey fuller Test based on the Schwarz Information Criteria. Since the research uses monthly data, a maximum lag of 12 was applied on all variables.

An increase in the royalty rate would instantaneously increase revenues as long as a new rate is applied. However, the ARDL Model takes into account the time lag taken by mining firms to adjust their production decisions which impact on the quantity of gold output and consequently on government revenue generation potential. Otto (2013) pointed out that firms may gradually adjust by sterilizing low grade minerals in pursuit of high-grade ore while marginally producing firms may be forced to suspend operations and place the mine under care and maintenance until such a time production becomes profitable. The ARDL Model captures such firm behavior that may gradually reduce government revenue, since government generates revenue only when firms are producing.

4.2.2 Lag Length Selection

The lag length criteria provides an indication of how previous period values of the endogenous and exogenous variables affect current revenues. The number of lags of both the dependent and the exogenous variables to be included were automatically generated based on the model with the lowest Akaike Information Criteria. The results suggest that an ARDL model of the form *ARDL (1, 3, 0, 0, 3*) was ideal for estimating a revenue function of the form *lr =f(rr, lgp, lgo,,rr_sqd).*

Based on the lag length selected above, a full specification of the ARDL model of the Government Revenue Function that captures both short run and long run dynamics was specified as shown below.

$Lr_t = f(lr_{t-1}, rr_t, rr_{t-1}, rr_{t-2}, rr_{t-3}, , lgp_t, lgo_t, rr\_sqd_t, rr\_sqd_{t-1}, rr\_sqd_{t-2}, rr\_sqd_{t-3})$……………………………………………………….*Equation 3*

Where: lr_t is the log of royalty revenue generated from gold;

lr_{t-1} is the lagged log of royalty revenue

rr_t is the current month royalty rate;

rr_{t-1} is the lagged month royalty rate

rr_{t-2} is the second lag of royalty rate

rr_{t-3} is the third lag of royalty rate

lgp_t is the current month gold prices

lgo_t is gold output in the current month

rr_sqd_t is the current month square of the royalty rate;

rr_sqd_{t-1} is the previous month square of the royalty rate;

rr_sqd_{t-2} is the second lag of the square of the royalty rate;

rr_sqd_{t-3} is the second lag of the square of the royalty rate;

The equation that captures the government revenue dynamics was thus constructed as follows:

Government Revenue function

$\Delta Lr_t = \beta_1 * \Delta rr_t + \beta_2 \Delta rr_{t-1} + \beta_3 \Delta rr_{t-2} + \beta_4 \Delta rr_{t-3} + \beta_5 * \Delta lgp_t + \beta_6 * \Delta lgo_t - \beta_7 * \Delta rr\_sqd_t - \beta_8 * \Delta rr\_sqd_{t-1} + \beta_9 * \Delta rr\_sqd_{t-2} + \beta_{10} * \Delta rr\_sqd_{t-3} + error_t$………………….. *Equation 4*

The differenced variables in the model captures the short run effects while the lagged variables capture the long run dynamics of changes in royalty rates, gold prices and gold output on royalty revenue. The model excludes an intercept term since government cannot generate royalty revenue when the royalty rate, output or price is zero.

Royalty revenue usually responds positively to increases in royalty rates, gold price and gold output, hence coefficients are expected to be positive parameters. Coefficients of *rr_sqd* and its lagged terms are negative parameters hence fulfil the conditions of a maximising optimal revenue. The parameters β_2, β_3, β_4, β_8, β_9 and β_{10} are long run coefficients.

From equation 4, the instant effect of royalty rate on revenue was measured by β_1 whilst β_2, β_3 and β_4 measure the dynamic impact of royalty rate on revenue. The cumulative effect of royalty rate on revenue is measured by $\beta_1 + \beta_2 + \beta_3 + \beta_4$. Likewise, β_7 measures the instant effect of *rr_sqd* on revenue while β_8, β_9 and β_{10} captures the dynamic effect.

4.2.3 Non Linearity Test

However, it is notable that Equation 4 above contains *rr_sqd* which makes the equation a polynomial regression of order 2. To ensure that the correct functional form is specified, the model was tested for non-linearity. To test for non-linearity, a Likelihood Ratio (LR) Test was carried out. The LR test examines if the included squared variable is redundant or not. The LR tests the power of the model with the squared term (unrestricted model) against the model excluding the squared term or the restricted model. The LR test is an asymptotic test distributed as a chi-squared with degrees of freedom equal to the number of excluded variables. The decision criteria of the LR test is reject the null hypothesis if the p-value associated with the chi-squared test is less than 0.05, otherwise we fail to reject the null hypothesis.

4.2.4 Cointegration Test

The Wald test detects if the underlying variables have a long run relationship. The long run relationship is established when the estimated F-statistic obtained from the test exceeds the Pesaran (2001) critical upper bound value, whilst a long run relationship is ruled out when the F-Statistic is below the lower bound critical value. If the F-statistic obtained exceeds the critical value, the variables will be cointegrated hence a cointegration equation is estimated. Engle & Granger (1987) defined cointegration as the existence of a long-run relationship amongst given non-stationary variables or a combination of stationary and non-stationary variables. Thus, two or more non-stationary time series are co-integrated if a linear combination of these variables converges to a long-run equilibrium overtime. The results obtained suggest that the variables have a long run relationship. The residuals from the estimated equation were generated and tested for stationarity and normality. The results obtained suggest that the residuals are stationary and normally distributed leading to the estimation of a cointegration equation.

The estimated cointegration equation was tested for serial correlation, heteroscedasticity, multicollinearity, stability, specification errors to ensure that the estimated results can be relied upon.

4.2.5 Optimal Royalty Rate

After the estimated short run equation was tested for serial correlation, heteroscedasticity, stability and specification error, the optimal royalty rate was derived. The optimal royalty rate was derived through the application of first order conditions. The optimal royalty rate was estimated at the point where the marginal revenue function equals zero (Wooldridge, 2004).

$d(\Delta lr_t)/d(\Delta rr_t) = \beta_1 - 2\beta_2 * rr_t = 0$……………………………………..*Equation 5*

Solving for Royalty

$2\beta_2 * rr_t = \beta_1$ ……………………………………………………………….*Equation 6*

$rr_t = \beta_1 / 2\beta_2$ ……………………………………………………………….*Equation 7*

4.3 Justification of Variables

Royalty Rate

The Laffer curve suggests that the tax rate, in this case the royalty rate, influences firms' production decision. Daniel *et al*. (2010) also argued that if the royalty rate applied is too high, the tax base is likely to shrink, as investors tend to shift investment to other alternatives because operations become less profitable. The royalty rate is, thus, an important determinant of revenue, hence has been included as an explanatory variable in the model.

Furthermore, firms consider existing government policies to make production decisions. Expectations about future changes in the royalty rate tend to influence firms' production behaviour as well as decisions to hold stocks of gold output. In order to capture such behaviour, the estimated model thus included a lagged royalty rate as a dependent variable.

Gold Price

Royalty revenue in Zimbabwe is levied on an ad valorem basis. This implies that gold price fluctuations influence the amount of revenue collected. Medina (2010) estimated the effects of commodity prices on fiscal revenues for Latin American countries and concludes that fiscal revenues react strongly to commodity prices. In order to capture the impact of commodity price fluctuations, average monthly gold price was included as an explanatory variable in the model.

There is often a time lag between selling of gold and collection of revenue by government mainly due to the administrative processes involved. As a result, previous period prices tend to influence current period revenue collection by government. Lagged gold price has thus been included in the model to capture such dynamics.

Gold Output

Guj (2012) defined royalties as payment made to the government for the right to extract a finite resource. This implies that government generates royalty revenue only when mining firms are producing. The gold output is therefore an important determinant of royalty revenue collected by government hence was include in the model.

There is often a lag time between production and selling of gold output mainly due to the refining processes. Furthermore, some mining firms may hold stock of gold output for speculative purposes, especially when expectations about future price increases are high. As a result, previous periods' gold output tends to determine current period government revenue.

Furthermore, previous period revenue collections indicate the installed capacity of gold mining firms hence current potential output. In this regard, the model included a lagged variable of the dependent variable.

4.4 Conclusion

The outlined methodology is consistent with theory and empirical studies hence provides tax policy with useful insights on the optimal royalty rate for gold. The study examined post diagnostics tests of serial correlation, heteroscedasticity, stability and specification test before conclusions on the dynamic effects of royalty rate on gold revenue were drawn. The study, thus, provides a direction towards a stable and predictable royalty regime, which is an important element considered for long-term investment in natural resource extraction.

5. DATA ANALYSIS AND PRESENTATION OF RESULTS

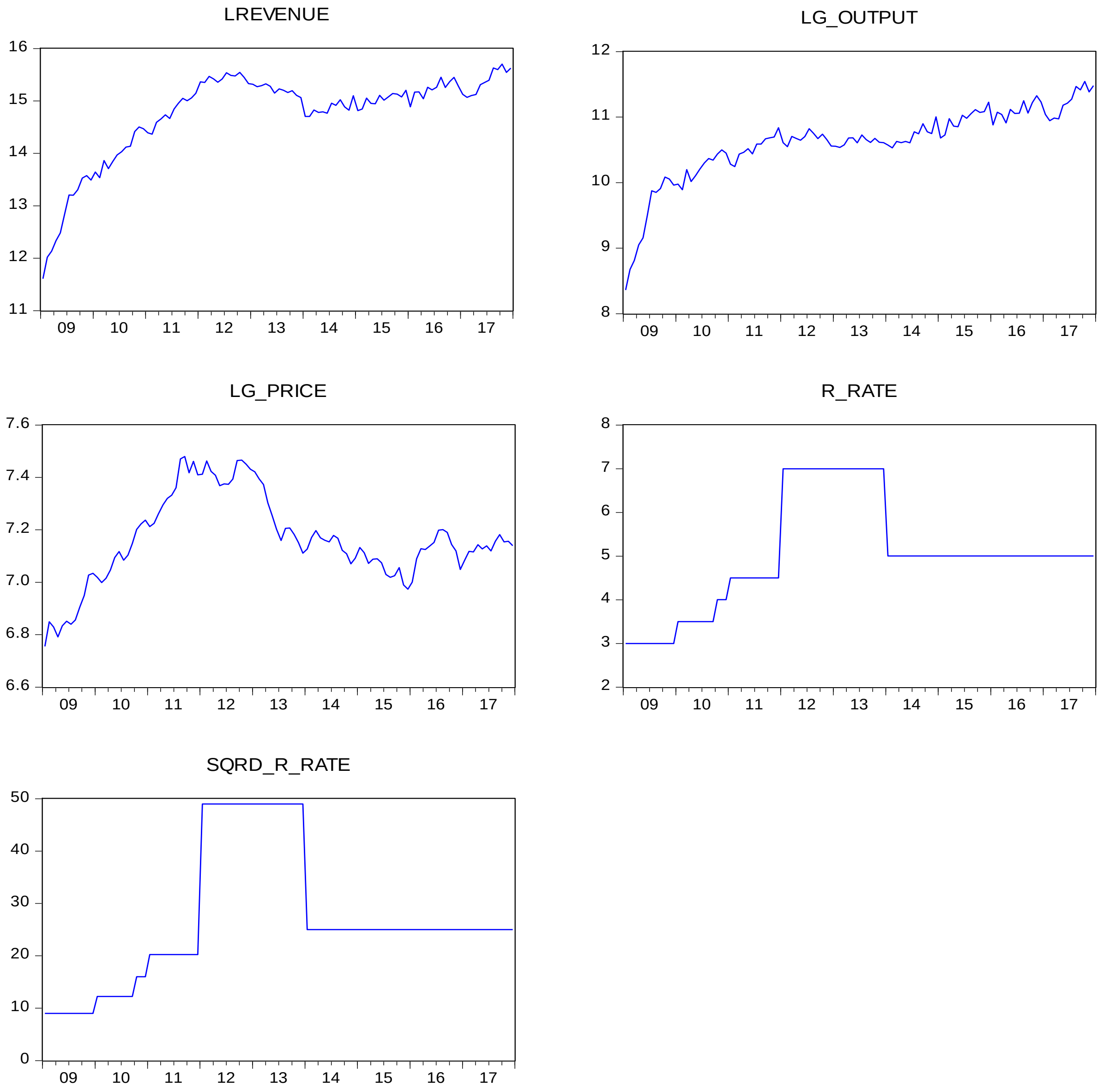
5.0 Introduction

This section presents data analysis and study results based on an Autoregressive Distributed Lag (ARDL) Model. The ARDL model included variables such as gold output, gold prices and their lagged values, which are important determinants of royalty revenue, where rates of royalties are applied on an *ad valorem* basis, as is the case in Zimbabwe.

5.1 Pre-estimation diagnostic Tests

In order to estimate the optimal royalty rate, properties of the variables were examined. Trends of the estimated variables provide a fair view of the nature of the data. Figure 7 below show trends in the variables of interest over the period 2009 to 2017.

Figure 7: Trends in royalty revenue, gold price and royalty rates



The graphs in Figure 7 provide a bird's-eye view of the behavioral characteristics of the variables over the study period. Revenue from royalties trended upwards over the period 2009 to 2012 reflecting the combined effect of the increase in international price of gold and upward review of royalty rates. The sustained increase in government revenue also reflects the sustained increase in gold output over the entire period.

The gold price displays volatility with sustained peaks and slumps. The dip in royalty revenue between 2013 and 2016 reflects the sharp decline in gold prices over the same period. It is worth noting that revenue decline was lower than the price decrease because a higher royalty rate of 7% was applied. Royalty revenue seems to respond to gold prices and output growth after 2016 mainly because there were no major changes in the royalty rates.

However, there is need to carry out stationarity tests in order to establish if the mean, variance and autocovariance of the variables are time invariant. The Augmented Dick Fuller (ADF) test was carried out based on the Schwarz Information Criteria which automatically selected a maximum lags of 12. Table 1 below summarises results of the stationarity tests obtained.

Table 4: Stationary Tests

	In level		After First Differencing			
Variable	**ADF Test Statistic**	**Critical values**	**ADF Test Statistic**	**Critical Values**	**Order of Integration**	**Nature of Stationarity**
Lr***	-4.153381	-4.046925 -3.452764 -3.151911			**I(0)**	With Trend and intercept
rr***	-1.813423	-3.493129 -2.888932 -2.581453	-10.23320	-3.493129 -2.888932 -2.581453	**I(1)**	With intercept
rr_sqd***	-1.765194	-3.492523 -2.888669 -2.581313	-10.21512	-3.493129 -2.888932 -2.581453	**I(1)**	With intercept
Lgp***	-1.973657	-3.493129 -2.888932 -2.581453	-8.378898	-3.493129 -2.888932 -2.581453	**I(1)**	With intercept
Lgo***	-4.811612	-4.048682 -3.453601 -3.152400			**I(0)**	With trend and intercept

Note: ***Means $p < 0.01$; ** Means $p < 0.05$; * Means $p < 0.1$

The stationarity tests indicate that variable *lr* (log revenue) and *lgo* (log gold output) are stationary in level form. *Lr* is stationary with an intercept term whilst *lgo* is stationary in level form but with a trend and intercept. These variables are therefore **I(0).** Due to the observed volatile nature of gold price, the variable *lgp* is stationary after first differencing with intercept. The royalty rate and its squared term reflect deliberate policy changes by the government hence are stationary after first differencing with an intercept, hence are **I(1)**.

Results of the stationarity test show that some variables such as *revenue* and *gold output* were stationary in levels, while *gold price, royalty rate* and *squared royalty rate* were stationary after first differencing. Since no variable was stationary after second differencing, ARDL Model was estimated.

5.2 Model Estimation

The estimations of the optimal royalty rate for gold requires the estimation of the revenue function associated with the royalty rate. To estimate the general form of the revenue function, the simple Laffer Curve model applied by Altunoz (2017) to the Turkish economy was applied in the determination of the optimal royalty rate for gold in Zimbabwe. To replicate the model in the context of the optimal royalty rate, the study estimated revenue as a function of the royalty and the square of royalty rate. The results of the Simple Laffer Curve are appended as Appendix I. However, due to the differences in the nature and application of corporate tax and royalty tax, mainly the fact that royalty tax is a tax on sales while corporate tax is a net profit tax, the Laffer Curve was extended to estimate an ARDL model taking into account that variables were stationary at different levels.

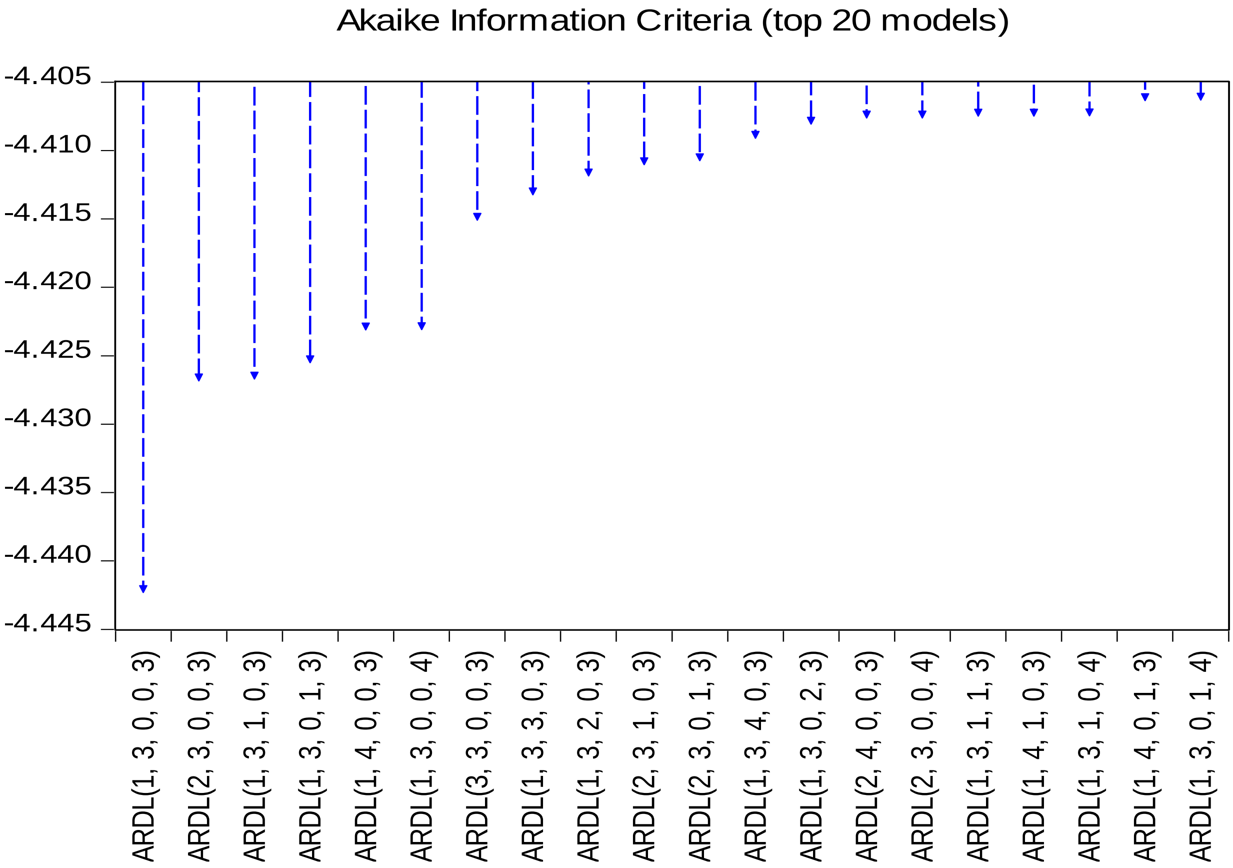
To take into account the impact of variations in gold output and fluctuations in the international commodity price for gold, an extended model was estimated. The model expresses revenue as a function of royalty rate, square of royalty rate, gold output and gold prices as illustrated by the following equation:

Lr = f(rr, lgp, lgo, rr_sqd)…………………………………………………………….Equation 8

5.2.2 Lag Length Selection Results

The estimation of an ARDL model requires the selection of the appropriate maximum lag length, which is the extent to which past values influence current values. The maximum lag length for each variable was automatically generated by Eviews, based on the lowest Akaike Information (AIC). The results of the lag selection criteria are illustrated by figure 8 below:

Figure 8: Lag Selection Criteria



The figure 8 above suggests that the ideal model to capture government revenue dynamics, is an ARDL (1, 3, 0, 0, 3) since it is the model with the lowest AIC. An ARDL (1, 3, 0, 0, 3) model was estimated with lagged variables of the dependent *lr* up to a maximum lag of 1, exogenous variables *rr* and *rr_sqd* up to a maximum lag of 3. The following table summarizes the results of the estimation

Table 5: ARDL Model Results

Dependant Variable: Lr

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LR(-1)	-0.005077	0.017064	-0.297513	0.7667
RR	0.586684	0.140045	4.189239	0.0001
RR(-1)	-0.057951	0.087927	-0.659082	0.5115
RR(-2)	0.328800	0.376543	0.873206	0.3848
RR(-3)	-0.456626	0.310332	-1.471411	0.1446
LGP	1.017133	0.026418	38.50176	0.0000
LGO	1.019453	0.020186	50.50365	0.0000
RR_SQD_C	-0.035386	0.011934	-2.965127	0.0038
RR_SQD_C(-1)	0.005000	0.007553	0.662005	0.5096
RR_SQD_C(-2)	-0.028263	0.032237	-0.876714	0.3829
RR_SQD_C(-3)	0.039161	0.026545	1.475266	0.1435
C	-5.288021	0.189779	-27.86416	0.0000

R^2 = 0.998901, DW =1.964617

The results of the estimated ARDL model show that several estimated parameters were economically and statistically significant at the 5% level. However, coefficients of the lagged variable are not statistically significant. Detailed results of the estimated model are appended as Appendix II.

5.2.1 Non-Linearity Test results

The estimated equation is a polynomial regression of order 2. The model was thus tested for non-linearity to ensure that the correct functional form is specified. To test for non-linearity, a Likelihood Ratio (LR) Test was carried out under the following hypothesis.

H_0: The variable *rr_sqd* is redundant
H_1: The variable *rr_sqd* is not redundant

The LR tests the power of the model with the squared royalty term, that is, the unrestricted model against the model excluding the squared term or the restricted model. The LR test is an asymptotic test distributed as a chi-squared with degrees of freedom equal to the number of excluded variables. From the results obtained, the p-value associated with the chi-squared test is less than 0.05, hence we reject the null hypothesis and conclude that the variable *rr_sqd* is not redundant. The results obtained suggest that the government royalty revenue function is a non –linear function of the royalty rate. The results obtained are attached as Appendix II.

5.2.3 Cointegration Test Results

It is notable from the ARDL test that coefficients of the lagged variables are not statistically significant at the 5% level. It is therefore important to ascertain if there exists a long run relationship among the variables. The Wald test is a plausible test to detect the long run relationship of the underlying variables. Following the estimation of the ARDL model, it was necessary to establish if a long run relationship revenue function exists or not. The estimated model included the lagged terms of the dependent and independent variables, which captures the long run relationship that may exist between the royalty revenue and royalty rates, gold output and gold prices. Wald Test attempts to ascertain if the coefficients of the lagged variables are jointly different from zero based on the Pesaran critical tables (Pesaran, 2001). The test was based on the following hypothesis:

H_O: coefficients are jointly equal to zero
H_1: coefficients are jointly different from zero

Where coefficients are jointly equal to zero, we fail to reject the null hypothesis and conclude that a long run relationship does not exist. In this regard, a short run equation will be estimated. However, if the coefficients are jointly different from zero, a long run equation could be estimated. The decision criteria is informed by the Pesaran critical values, that is, the lower and upper bound values. The critical values are as follows:

Table 6: Pesaran Critical Tables

	Lower Bound	Upper Bound
1%	3.74	5.06
5%	2.86	4.01
10%	2.45	3.52

Source: Pesaran *et al.*, (2001)

The F-statistic obtained from the Wald Test is **237.0557** (See Appendix IV)**.** The value obtained is higher than the upper bound Pesaran critical value of **4.01** at the 5% significance level, suggesting that the coefficients of the lagged terms are jointly different from zero. This shows that the variables have a long run relationship, hence the following cointegration equation was estimated.

$\Delta Lr_t = \beta_1 * \Delta rr_t + \beta_2 * \Delta rr_{t-1} + \beta_1 * \Delta rr_{t-2} - \beta_2 * \Delta rr\_sqd_t + \beta_3 * \Delta rr\_sqd_{t-2} + \beta_4 ** \Delta rr\_sqd_{t-2} + \beta_5 * CointEq(-1) + error_t$………….. *Equation 9*

To estimate the error correction model, residuals of the ARDL model were generated and tested for stationarity. The results of the stationary test are depicted Table 6 below:

Table 7: Stationarity Test: Residual Term

Variable	**ADF Test Statistic**	**Critical values**	**Order of Integration**
Resid01***	-9.923068	-3.494378 -2.889474 -2.581741	**I(0)**

Note: ***Means $p < 0.01$; ** Means $p < 0.05$; * Means $p < 0.1$

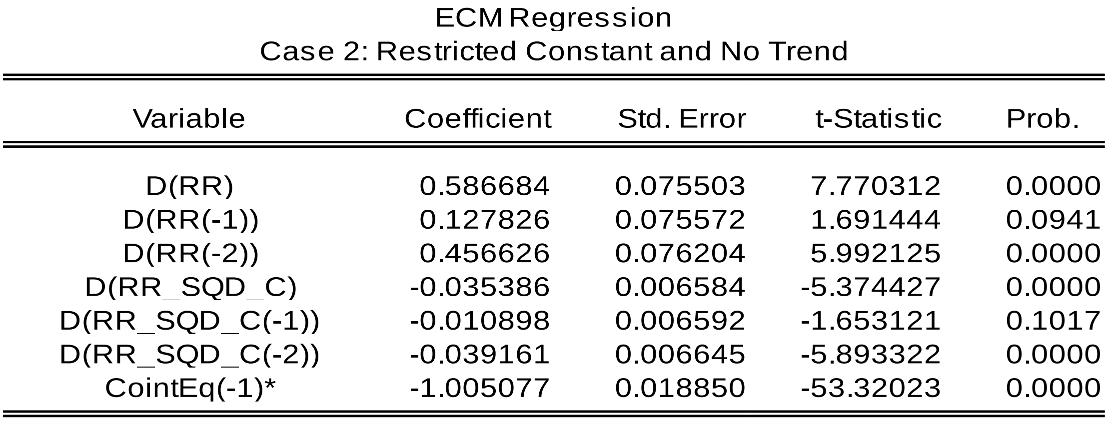
Table 6 above show that the generated residual term is stationary in levels. The detailed results of the test are appended as Appendix V. Given that the residuals from the estimated equation are stationary in level, we can construct an error correction model. Engle and Granger (1987) argued that cointegrated variables can be jointly represented in an error correction framework which reconciles the long run and the short run. The long run represents a steady state relationship such that if a shock occurs, there will be a temporary divergence from the steady state, but such a shock will eventually die, and the relationship will revert to the stead state.

5.2.4 ARDL Error Correction Model

In order to capture the long run revenue dynamics, an error correction model was estimated. The summary results of the cointegration equation model are illustrated by the following table.

Table 8: Summary Results of the ARDL Error Correction Model

Dependent Variable: D(Lr)



ECM Regression
Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(RR)	0.586684	0.075503	7.770312	0.0000
D(RR(-1))	0.127826	0.075572	1.691444	0.0941
D(RR(-2))	0.456626	0.076204	5.992125	0.0000
D(RR_SQD_C)	-0.035386	0.006584	-5.374427	0.0000
D(RR_SQD_C(-1))	-0.010898	0.006592	-1.653121	0.1017
D(RR_SQD_C(-2))	-0.039161	0.006645	-5.893322	0.0000
CointEq(-1)*	-1.005077	0.018850	-53.32023	0.0000

$R^2 = 0.97003$. DW = 1.964617

The results show that there is a positive relationship between royalty rate and revenue whilst a negative relationship exist with the square of the royalty rate. This is consistent with *a priori* expectations; hence the results are economically significant. Furthermore, the variables rr, rr_{t-2}, rr_sqd_c, $rr\_sqd\_c_{t-2}$ *are* statistically significant at the 5% level of significance. The lagged terms rr_{t-1} and $rr\_sqd\_c_{t-1}$ are however not statistically significant at the 5% level. The R^2 value of 0.97 suggests that 97% of the variation in revenue is explained by the included variables whilst 3% is explained by other factors. The error correction coefficient is negative and statistically significant at the 5% level, suggesting that royalty revenue adjusts to a long run equilibrium after a shock in royalty rates. The ECT shows convergence although there is a very marginal tendency towards overcorrection 0.5% of previous discrepancy between long run and short run values of royalty revenue. Detailed error correction model results are appended as Appendix VI.

To ensure that the results obtained from the short run model can be relied upon, the model was tested for heteroscedasticity, serial correlation, stability and specification errors whilst the explanatory variables in the model were tested for multicollinearity.

5.2.5 Multicollinearity Test

The variables were tested for multicollinearity using a correlation matrix and a variance inflation factor. The multicollinearity test identifies linear relationship among the explanatory variables. When explanatory variables have a strong linear relationship, variance of individual coefficients tend to be inflated, thereby affecting the results of the model.

Table 9: Correlation Matrix

	RR	LGO	LGP	RR_SQD
RR	1			
LGO	0.496	1		
LGP	0.666	0.408	1	
RR_SQD	0.990	0.396	0.644	1

The correlation matrix showed that there exist strong positive correlation between *rr* and *rr-sdq*. In order to detect the extent to which the correlations affect the standard errors of the A Variance Inflation Factor (VIF) were also estimated in order to measure the extent to which variances of individual coefficients are inflated as a result of multicollinearity.

Table 10: Variance Inflation Factors

Variance Inflation Factors
Date: 11/23/19 Time: 11:55
Sample: 2009M01 2017M12
Included observations: 108

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
RR_SQD	8.26E-07	9.143657	1.774042
LGO	0.000319	449.8121	1.245601
LGP	0.005216	3348.921	1.794822
C	0.245233	3066.897	NA

The estimated uncentred (without intercept) Variance Inflation Factors (VIF) are greater than 10, suggesting that the variance of estimated coefficients are greatly inflated by the existence of multicollinearity. However, the centred (with intercept) VIF show that variance of estimated coefficients are inflated by a magnitude of less than 2 which is within the acceptable magnitude of 10.

It has been observed from the correlation matrix that the nature of multicollinearity is structural, which arises in polynomial regression equations due to the fact that *rr_sqd* is generated from *rr*. Given that *rr_sqd* is an important variable in the determination of the optimal rate, the variable could not be dropped. In order to deal with multicollinearity, the variable *rr_sqd* was transformed by using its deviation from the mean. Gujarati (2007) stated that multicollinearity is substantially reduced if polynomial terms in the explanatory variables are expressed in deviations from the mean. In this regard, the variable was transformed from *rr_sqd* to *rr_sqd_c*, which is a deviation from the mean.

5.2.6 Heteroscedasticity Test

The estimated model was tested for heteroscedasticity to ensure that the variance of the error term conditional upon the explanatory variables is constant. Where the variance is time variant, the standard errors tend to be biased, hence the T-test and the F-test statistics. In this regard, the Breush-Pagan-Godfrey Test was carried out. The p-value associated with the F-statistic is less than 0.05 suggesting that the estimated model suffers from heteroscedasticity. Results of the test are appended as Appendix VII. In order to resolve this problem, The ARDL cointegration equation was estimated using the Heteroscedasticity Autocorrelation Consistent (HAC) estimators (Newey-West, 1987).

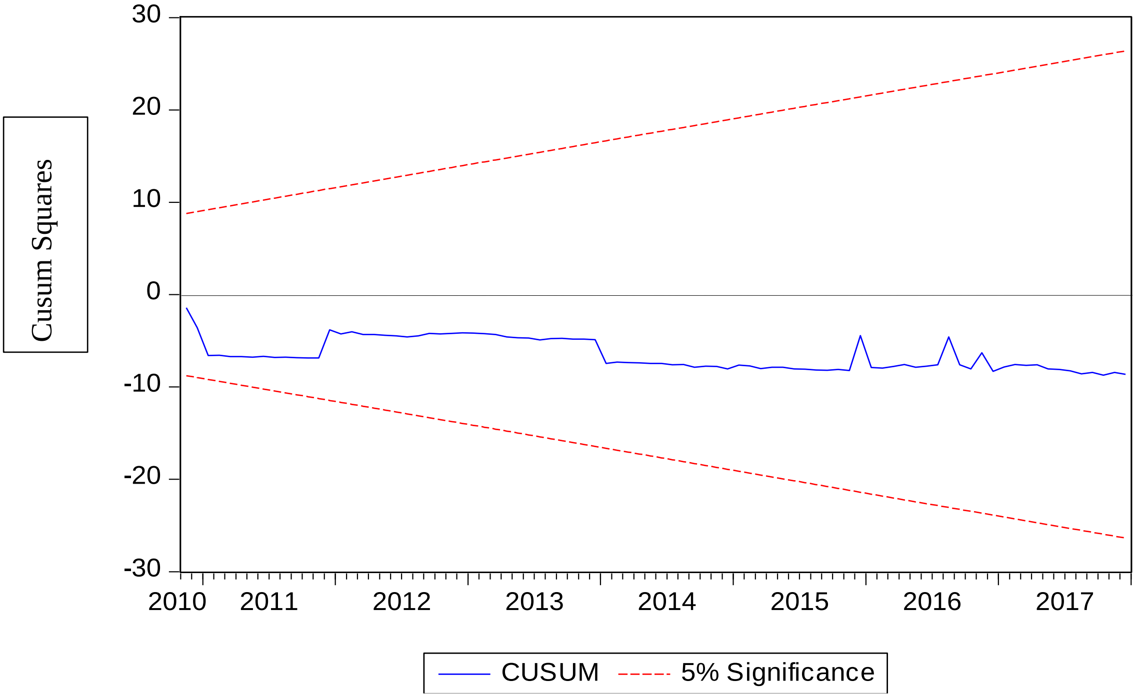
5.2.7 Serial Correlation Test

The estimated model was tested for serial correlation using the Breush-Godfrey Serial Correlation LM Test. The Breusch-Godfrey Serial correlation test regresses lagged error terms on the regression error term to establish if the successive error terms are dependent. The p-value associated with the F-statistic is observed. From the results obtained, the p-value associated with the F-statistic is 0.8336 suggesting that successive terms of the error term are independent. Detailed results of the test are appended as Appendix VIII.

5.2.8 Stability Test

To detect if parameters of the estimated short run model are not affected by random movements, which do not reflect structural changes in the parameter, the CUSUM test was carried out. The following graph shows the results of the test.

Figure 9: Stability Test



The Stability test results show that the estimated parameters are fairly stable at the 5% level of significance, hence the model results can be relied upon.

5.2.9 Ramsey's Regression Specification Error Test (RESET)

Furthermore, the Ramsey's Regression Specification Error Test (RESET) test was carried out to detect if the model is correctly specified. If the model is wrongly specified, any added powers of the predicted variable should be significant in explaining the dependent variable. To ascertain if the model was correctly specified or not, predicted (fitted) values of the dependent variable were included as explanatory variables in the model. The p-value associated with the F-statistic generated is **0.7426,** which is greater than 5% suggesting that added fitted values of the dependent variable are jointly insignificant hence the model is correctly specified. Detailed results of the RESET Test are in Appendix IX.

5.3 Analysis of Results

The results from the Simple Laffer Curve show that revenue responds positively to increases in royalty rates whilst a negative relationship exists between revenue and the square of royalty rates. This is consistent with the results obtaining under the ARDL Model, which also shows that revenue is positively related to gold output and gold prices. This is in line with prior expected signs hence the variables are economically significant. Under the ARDL model, the p-values associated with *royalty rate*, *square of royalty rate*, *gold price* and *gold output* are below 5% indicating that the variables are statistically significant. The negative coefficient on *square of royalty rate* suggests that there is a maximum point after which further increase in royalty rate will reduce government revenue. However, the coefficients of the lagged variables lr_{t-1}, rr_{t-1}, rr_{t-2}, rr_{t-3}, $rr\_sqd\_c_{t-1}$, $rr\_sqd\_c_{t-2}$ and $rr\_sqd\_c_{t-3}$ in the ARDL model are not statistically significant at the 5% level.

To ascertain on the existence of a long run relationship a Wald Test was carried out. The results of the Wald Test show that the variables have a long run relationship, hence the ARDL Error Correction Model was estimated. The coefficient of the error correction term, indicates the speed of adjustment of royalty revenue to the long-run equilibrium as a result of a shock in prices, output or royalty rates. The error correction coefficient of -1.005077 is negative as expected, showing that the equation converges into a long run steady state equilibrium. Furthermore, the error correction coefficient is statistically significant at the 5% level. The error correction coefficient indicates that 100% of the shock is corrected in a month's period.

To determine the optimal royalty rate, the first order condition of differential calculus requires that, the marginal revenue generated by government be equal to zero (Wooldridge, 2004). Based on the ARDL Error Correction Model, the derivative of the revenue function with respect to the changes in the royalty rate is calculated as follows:

$$d(\Delta lr_t) / d(\Delta rr_t) = 0.586684+0.127826+0.456626+2(-0.035386* \Delta rr_t) +2(-0.010898* \Delta rr_t) +2(-0.039161* \Delta rr_t) = 0$$

$$rr_t^* = -1.171136 / -0.17089$$

$$\mathbf{= 6.85316\%}$$

The results show that the optimal royalty rate for gold in Zimbabwe is approximately **6.85%**. This implies that the government can only increase the royalty rate for gold to a maximum rate of 6.85%. The results indicate that royalty rates above 6.85% penalise participation in gold mining activities thereby inducing a negative return on government revenues.

5.4 Discussion of Results

The optimal royalty rate for gold in Zimbabwe has been estimated from a social planner's perspective. The estimation assumes that gold mining firms have already considered other production related costs to the extent that only changes in the royalty rate would significantly affect the firm's cost structure, hence the viability of the sector. To unpack the optimal royalty rate, the study employed an ARDL cointegration equation model. The results are discussed as below.

The model was estimated using monthly royalty revenue collected over period 2009 to 2017, regressed on the royalty rate, the square of royalty rate, gold output and gold price and the lagged terms of royalty rates and the square of the royalty rate. The results obtained show that the optimal royalty rate for gold is approximately 6.85%. The results to some extent reinforce sentiments by the Chamber of Mines (2015) that the royalty rate of above 7% is too high from a firms' profit maximising perspective. Government can thus, increase royalty rate to a maximum of 6.85%. This effectively means reducing profitability levels of gold mining firms to some level below the current levels. However, an optimal rate of 6.85% implemented over a long period or a mine life cycle will be akin to a stabilisation clause, which brings certainty.

The results obtained are also consistent with the findings of Gajigo *et al.* (2012) who concluded that gold producing countries in Africa can increase their royalty rates to levels above 3%, without distorting mining production decisions. The current royalty rate for gold in Zimbabwe is 5%. This is approximately 1.85 percentage points below the estimated optimal. Based on the results obtained, the government has the potential to collect more revenue by adjusting the royalty rate towards the optimal level. There is therefore scope for Zimbabwe to increase the royalty rate for gold by approximately 1.85% without distorting investment in the gold sector.

However, the estimated optimal rate is from the revenue maximising perspective of government. The model used in the study did not have a private investor behavioural rule that would act as a constraint to the royalty determination power of government and the size of the optimal rate. Furthermore, different gold mining companies often have different cost structures depending on the geological structure and terrain of the mine. This paper could not account for these factors due to lack of access to firm data on costs and profits that could have been used to construct such a behavioural rule.

Furthermore, the royalty rate variable was not a freely evolving variable since it was dependent on government decision to change policy, hence its stepped nature reduced the degree of variability which filtered through to the quality of the causal outcomes.

5.5 Policy Lessons for the MEFMI Region

A survey of royalty rates reviews in the MEFMI region showed that a number of countries frequently reviewed their royalty rates with Zambia reviewing five times between 2008 and 2017 while Tanzania reviewed three times over the same period. Zambia, in 2014, introduced a record high royalty rate of 20% on open cast mining (Government of Zambia, 2014). Rakner et al. (2015) reported that this review forced some mining companies to suspend operations. Following these developments, the Government reduced the mineral royalty rate from 20% to 9% for open cast mines, and from 8% to 6% for underground mines (Government of Zambia, 2015). The royalty regime was further amended in 2016 to ensure that a uniform royalty rate of 6% is applied for both open cast and underground mining. The frequent review of the mining tax regime in Zambia has affected policy predictability and has negative impacts on mining sector investment (CMI Brief, 2016).

Tanzania's gold sector has also been affected by royalty rate reviews. Following an upward review of royalty rate for gold from 3% to 4% in 2010, the Tanzanian Government further reviewed the royalty rate on gold from 4% of gross revenue to 6% of gross revenue in 2017 (Government of Tanzania, 2017). This resulted in the fall of share prices of gold mining companies that were listed on the London Stock Exchange indicating that investors were sceptical of the new mining fiscal regime (Acacia Mining Plc, 2017).

As has been articulated in Chapter 2 of this paper, Zimbabwe's royalty rate has been reviewed seven times between 2009 and 2017. It is worth noting that royalty rate reviews largely responded to gold price movements. However, there always exists a time lag between policy inception and actual policy implementation to the extent that reviews triggered by mineral price movements are usually implemented in the period after the price peak thereby distorting mining activity.

These reviews suggest that the determination of optimal rates is critical for each country in the region to generate maximum benefits from its finite resource endowments. Governments have a single opportunity to maximise benefits from such finite resources as gold. In order to generate maximum potential revenue, it is important to ensure that the royalty rates charged are optimal. The optimal rate ensures that risks and benefits are fairly shared between the Government and the investor. Determination of the optimal rate fosters policy stability, which is an important consideration for long term investment, hence revenue generation.

Other gold producing countries in the MEFMI region particularly Namibia had fairly stable royalty regimes that enabled the country to generate a significant amount of revenue through taxes for which rates applied across the sector are generally regarded as fair and equitably applied across the sector (Crawford *et al.*, 2018).

The mining industry, thus, requires a stable and predictable royalty regime that facilitates investment decisions and production plans. An ever-changing royalty regime creates uncertainty for investors and is detrimental to revenue generation. In some cases, mining companies negotiate Mining Development Agreements (MDAs) in order to ensure that fiscal terms are fixed over the life of a mine. It is important for MEFMI member countries to ensure that the fiscal terms in the agreement reflect the optimal estimated rates of royalties and other taxes as may be included.

6. CONCLUSIONS AND RECOMMENDATIONS

6.0 Introduction

This section presents the conclusion, recommendations and areas of further research based on the results presented in Chapter 5 of this paper.

6.1 Conclusions

The Economic Commission for Africa encourages resource rich African countries to leverage on the extractive sector to mobilise domestic resources and promote development. This requires application of optimal fiscal regimes and efficient implementation of the regimes so as to minimise aggressive tax avoidance schemes (ECA, 2016). The higher the taxes paid by the mineral sector, the greater the share of the wealth created by the government from the existing mines. However, a higher government tax reduces profit for, and potential investment by, companies. Rising tax rates, thus, undermine the incentives of companies to carry out exploration, develop new mines and remain in production. It is, therefore, critical to determine the optimum level of mineral taxation.

Mining companies often make investment appraisals on potential mining activities. However, there are always uncertainties associated with mining activities, which can negatively affect the mining activity. Uncertainty can be policy or price related. Policy uncertainty can however be minimised if the government can estimate optimal rates of tax and ensure that the fiscal regime is stable.

The gold mining sector in Zimbabwe has experienced frequent royalty rate reviews, which could have been avoided had an optimal rate been determined. Based on monthly data from 2009 to 2017, the optimal royalty rate for gold has been estimated at 6.85% from the government revenue maximising perspective.

The optimal rate obtained is relatively higher than rates obtaining in the region particularly gold producing countries such as Namibia with 3% royalty rate, while Mozambique and Tanzania charge a royalty rate of 6%. In Australia rates of royalties for gold are different in different states ranging from 2.5% to 7.5% mainly due to variation in geology hence, the difficulty in extracting the ore.

6.2 Recommendations

Optimal revenue collection requires both determination of optimal rates and efficient collection mechanism. This research provides useful insights on the optimal royalty rate for gold in Zimbabwe, which is estimated at 6.85%. The estimated optimal rate indicates the maximum chargeable rate after which further increases become a disincentive for gold producers to continue producing. In order to maximise government revenue from gold production, it is recommended that the applicable royalty rate should be as close to the optimal rate as is possible. Furthermore, application of the optimal rate should be accompanied by efficient revenue collection strategies that eliminate revenue leakages.

It is also important for the government to ensure that the royalty rate applied is stable to facilitate long-term investment thereby maximising revenue. More so, revenue maximisation should not be an end in itself, but should be accompanied by efficient and effective revenue management rules to ensure that proceeds from the finite resource are transformed into sustainable income generating assets.

6.3 Areas of Further Research

This research has estimated the optimal royalty rate from a social planner's perspective. It would inform policy if the estimated optimal rate could be compared with optimal rate estimated from a profit maximising perspective of gold producing firms. There is thus need for a study that captures cost structures of various gold producing firms. This could go a long way in achieving a delicate balance between the government and the investors' take.

Furthermore, future studies may explore the use of non-linear models such as the Threshold autoregressive (TAR) models to capture structural changes in the economy such as currency reforms. Such models are also useful to capture changes in royalty regimes.

Furthermore, application of an optimal royalty rate cannot be a guarantee for maximising revenue collections by government but should be accompanied by effective administration of royalty regime. There is, thus, need for a study to reflect on the best approaches to the effective collection and administration of royalty revenue. This will, to a greater extent, complement this study thereby enhancing domestic resource mobilisation from finite natural resources.

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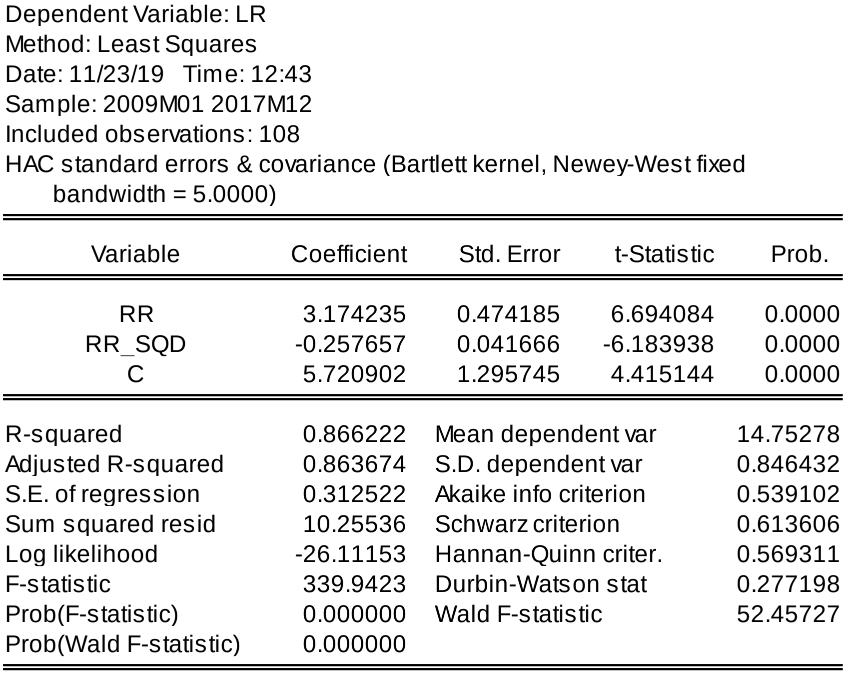
8. APPENDICES

Appendix I: Simple Laffer Curve Results

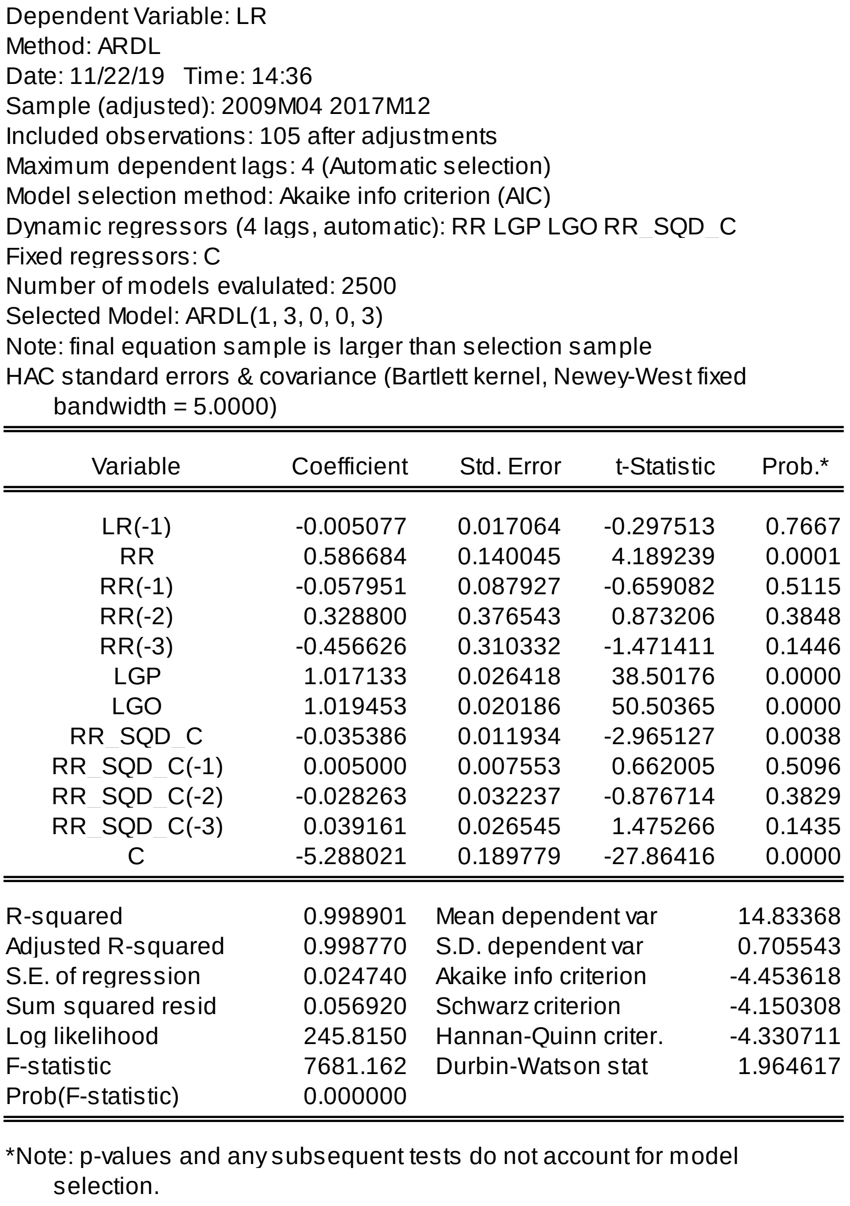


```
Dependent Variable: LR
Method: Least Squares
Date: 11/23/19   Time: 12:43
Sample: 2009M01 2017M12
Included observations: 108
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed
        bandwidth = 5.0000)
===================================================================
        Variable        Coefficient    Std. Error    t-Statistic    Prob.
===================================================================
          RR              3.174235      0.474185      6.694084     0.0000
        RR_SQD           -0.257657      0.041666     -6.183938     0.0000
           C              5.720902      1.295745      4.415144     0.0000
===================================================================
R-squared                 0.866222   Mean dependent var        14.75278
Adjusted R-squared        0.863674   S.D. dependent var        0.846432
S.E. of regression        0.312522   Akaike info criterion     0.539102
Sum squared resid         10.25536   Schwarz criterion         0.613606
Log likelihood           -26.11153   Hannan-Quinn criter.      0.569311
F-statistic               339.9423   Durbin-Watson stat        0.277198
Prob(F-statistic)         0.000000   Wald F-statistic          52.45727
Prob(Wald F-statistic)    0.000000
===================================================================
```

Appendix II: Non Linearity Test Results

```
Redundant Variable Test
Equation: EQ01
Redundant variables: RR_SQD_C
Specification: LR  LR(-1) RR RR(-1) RR(-2) RR(-3) LGP LGO RR_SQD_C
        RR_SQD_C(-1) RR_SQD_C(-2) RR_SQD_C(-3) C
Null hypothesis: RR_SQD_C is not significant
=======================================================================

                             Value          df        Probability
t-statistic                4.855050         93          0.0000
F-statistic                23.57151      (1, 93)        0.0000
=======================================================================

F-test summary:
                           Sum of Sq.       df       Mean Squares
Test SSR                   0.014427         1          0.014427
Restricted SSR             0.071347         94         0.000759
Unrestricted SSR           0.056920         93         0.000612
=======================================================================


Restricted Test Equation:
Dependent Variable: LR
Method: Least Squares
Date: 11/23/19   Time: 15:35
Sample: 2009M04 2017M12
Included observations: 105
=======================================================================

         Variable          Coefficient   Std. Error   t-Statistic    Prob.
=======================================================================

          LR(-1)            0.012249     0.023369     0.524155     0.6014
            RR              0.179387     0.009062     19.79486     0.0000
          RR(-1)            0.280806     0.094660     2.966458     0.0038
          RR(-2)            0.338561     0.123513     2.741096     0.0073
          RR(-3)           -0.436872     0.091199    -4.790298     0.0000
           LGP              1.009945     0.032433     31.13954     0.0000
           LGO              1.007121     0.025240     39.90153     0.0000
       RR_SQD_C(-1)        -0.024895     0.008166    -3.048724     0.0030
       RR_SQD_C(-2)        -0.029085     0.010769    -2.700867     0.0082
       RR_SQD_C(-3)         0.037534     0.007964     4.712989     0.0000
            C              -5.162594     0.213274    -24.20634     0.0000
=======================================================================

R-squared                   0.998622    Mean dependent var       14.83368
Adjusted R-squared          0.998475    S.D. dependent var       0.705543
S.E. of regression          0.027550    Akaike info criterion   -4.246760
Sum squared resid           0.071347    Schwarz criterion       -3.968726
Log likelihood              233.9549    Hannan-Quinn criter.    -4.134096
F-statistic                 6811.361    Durbin-Watson stat       2.173482
Prob(F-statistic)           0.000000
=======================================================================
```

Appendix III: ARDL Model Results



```
Dependent Variable: LR
Method: ARDL
Date: 11/22/19   Time: 14:36
Sample (adjusted): 2009M04 2017M12
Included observations: 105 after adjustments
Maximum dependent lags: 4 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (4 lags, automatic): RR LGP LGO RR_SQD_C
Fixed regressors: C
Number of models evalulated: 2500
Selected Model: ARDL(1, 3, 0, 0, 3)
Note: final equation sample is larger than selection sample
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed
     bandwidth = 5.0000)
=========================================================================
        Variable          Coefficient    Std. Error    t-Statistic   Prob.*
=========================================================================

          LR(-1)           -0.005077      0.017064     -0.297513     0.7667
            RR              0.586684      0.140045      4.189239     0.0001
          RR(-1)           -0.057951      0.087927     -0.659082     0.5115
          RR(-2)            0.328800      0.376543      0.873206     0.3848
          RR(-3)           -0.456626      0.310332     -1.471411     0.1446
           LGP              1.017133      0.026418      38.50176     0.0000
           LGO              1.019453      0.020186      50.50365     0.0000
        RR_SQD_C           -0.035386      0.011934     -2.965127     0.0038
      RR_SQD_C(-1)          0.005000      0.007553      0.662005     0.5096
      RR_SQD_C(-2)         -0.028263      0.032237     -0.876714     0.3829
      RR_SQD_C(-3)          0.039161      0.026545      1.475266     0.1435
            C              -5.288021      0.189779     -27.86416     0.0000
=========================================================================

R-squared                   0.998901    Mean dependent var         14.83368
Adjusted R-squared          0.998770    S.D. dependent var         0.705543
S.E. of regression          0.024740    Akaike info criterion     -4.453618
Sum squared resid           0.056920    Schwarz criterion         -4.150308
Log likelihood              245.8150    Hannan-Quinn criter.      -4.330711
F-statistic                 7681.162    Durbin-Watson stat         1.964617
Prob(F-statistic)           0.000000
=========================================================================

*Note: p-values and any subsequent tests do not account for model
     selection.
```

Appendix IV: Cointegration Test Results

Wald Test:
Equation: EQ01

Test Statistic	Value	df	Probability
F-statistic	237.0557	(7, 93)	0.0000
Chi-square	1659.390	7	0.0000

Null Hypothesis: C(1)=0, C(3)=0, C(4)=0, C(5)=0,C(10)=0,
C(11)=0,C(12)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(1)	-0.005077	0.017064
C(3)	-0.057951	0.087927
C(4)	0.328800	0.376543
C(5)	-0.456626	0.310332
C(10)	-0.028263	0.032237
C(11)	0.039161	0.026545
C(12)	-5.288021	0.189779

Restrictions are linear in coefficients.

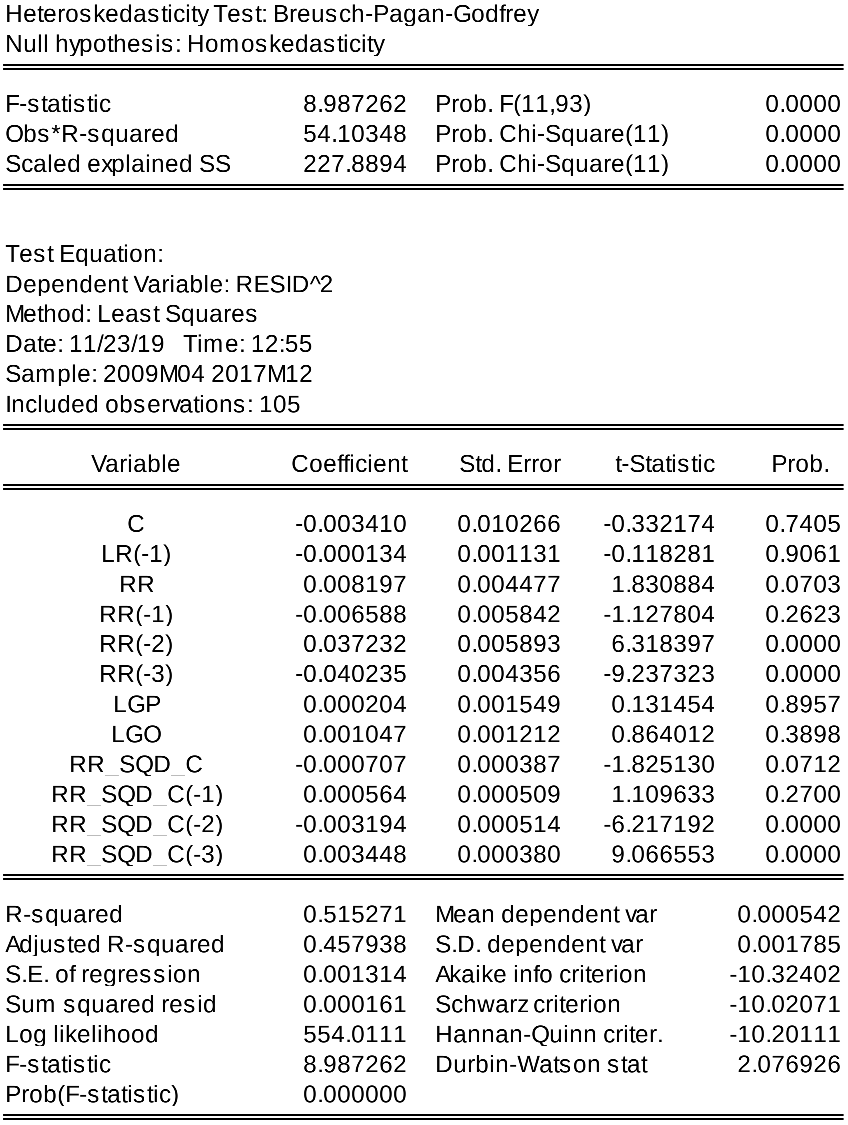
Appendix V: Residual Test for Stationarity

```
Null Hypothesis: RESID01 has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=12)
=========================================================================
                                                 t-Statistic    Prob.*
=========================================================================

Augmented Dickey-Fuller test statistic           -9.923068      0.0000
-------------------------------------------------------------------------
Test critical values:        1% level            -3.494378
                             5% level            -2.889474
                             10% level           -2.581741
=========================================================================

*MacKinnon (1996) one-sided p-values.


Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RESID01)
Method: Least Squares
Date: 11/21/19   Time: 09:27
Sample (adjusted): 2009M05 2017M12
Included observations: 104 after adjustments
=========================================================================
        Variable         Coefficient   Std. Error   t-Statistic   Prob.
=========================================================================

      RESID01(-1)        -0.983676     0.099130     -9.923068     0.0000
           C             -2.85E-05     0.002316     -0.012288     0.9902
=========================================================================

R-squared                 0.491189   Mean dependent var        -0.000146
Adjusted R-squared        0.486200   S.D. dependent var         0.032950
S.E. of regression        0.023618   Akaike info criterion     -4.634559
Sum squared resid         0.056897   Schwarz criterion         -4.583706
Log likelihood            242.9971   Hannan-Quinn criter.      -4.613957
F-statistic               98.46728   Durbin-Watson stat         1.995561
Prob(F-statistic)         0.000000
=========================================================================
```

Appendix VI: ARDL Error Correction Model Results

```
ARDL Error Correction Regression
Dependent Variable: D(LR)
Selected Model: ARDL(1, 3, 0, 0, 3)
Case 2: Restricted Constant and No Trend
Date: 11/23/19   Time: 13:01
Sample: 2009M01 2017M12
Included observations: 105
==========================================================================
                              ECM Regression
                  Case 2: Restricted Constant and No Trend
==========================================================================
        Variable           Coefficient    Std. Error    t-Statistic   Prob.
==========================================================================
         D(RR)              0.586684      0.075503      7.770312     0.0000
       D(RR(-1))            0.127826      0.075572      1.691444     0.0941
       D(RR(-2))            0.456626      0.076204      5.992125     0.0000
      D(RR_SQD_C)          -0.035386      0.006584     -5.374427     0.0000
    D(RR_SQD_C(-1))        -0.010898      0.006592     -1.653121     0.1017
    D(RR_SQD_C(-2))        -0.039161      0.006645     -5.893322     0.0000
      CointEq(-1)*         -1.005077      0.018850     -53.32023     0.0000
==========================================================================
R-squared                   0.970083   Mean dependent var         0.033225
Adjusted R-squared          0.968252   S.D. dependent var         0.135257
S.E. of regression          0.024100   Akaike info criterion     -4.548856
Sum squared resid           0.056920   Schwarz criterion         -4.371926
Log likelihood              245.8150   Hannan-Quinn criter.      -4.477161
Durbin-Watson stat          1.964617
==========================================================================

* p-value incompatible with t-Bounds distribution.


F-Bounds Test                          Null Hypothesis: No levels relationship
==========================================================================
Test Statistic                Value         Signif.          I(0)       I(1)
==========================================================================
F-statistic                 449.6656          10%             2.2       3.09
k                              4               5%            2.56       3.49
                                             2.5%            2.88       3.87
                                               1%            3.29       4.37
==========================================================================
```

Appendix VII: Heteroscedasticity Test Results



```
Heteroskedasticity Test: Breusch-Pagan-Godfrey
Null hypothesis: Homoskedasticity
=====================================================================
F-statistic            8.987262   Prob. F(11,93)              0.0000
Obs*R-squared          54.10348   Prob. Chi-Square(11)        0.0000
Scaled explained SS    227.8894   Prob. Chi-Square(11)        0.0000
=====================================================================

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 11/23/19   Time: 12:55
Sample: 2009M04 2017M12
Included observations: 105
=====================================================================
      Variable         Coefficient   Std. Error   t-Statistic   Prob.
=====================================================================
         C              -0.003410    0.010266     -0.332174    0.7405
       LR(-1)           -0.000134    0.001131     -0.118281    0.9061
         RR              0.008197    0.004477      1.830884    0.0703
       RR(-1)           -0.006588    0.005842     -1.127804    0.2623
       RR(-2)            0.037232    0.005893      6.318397    0.0000
       RR(-3)           -0.040235    0.004356     -9.237323    0.0000
         LGP             0.000204    0.001549      0.131454    0.8957
         LGO             0.001047    0.001212      0.864012    0.3898
      RR_SQD_C          -0.000707    0.000387     -1.825130    0.0712
    RR_SQD_C(-1)         0.000564    0.000509      1.109633    0.2700
    RR_SQD_C(-2)        -0.003194    0.000514     -6.217192    0.0000
    RR_SQD_C(-3)         0.003448    0.000380      9.066553    0.0000
=====================================================================
R-squared              0.515271   Mean dependent var        0.000542
Adjusted R-squared     0.457938   S.D. dependent var        0.001785
S.E. of regression     0.001314   Akaike info criterion    -10.32402
Sum squared resid      0.000161   Schwarz criterion        -10.02071
Log likelihood         554.0111   Hannan-Quinn criter.     -10.20111
F-statistic            8.987262   Durbin-Watson stat        2.076926
Prob(F-statistic)      0.000000
=====================================================================
```

Appendix VIII: Serial Correlation Test Results

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 2 lags

F-statistic	0.182420	Prob. F(2,91)	0.8336
Obs*R-squared	0.419287	Prob. Chi-Square(2)	0.8109

Test Equation:
Dependent Variable: RESID
Method: ARDL
Date: 11/23/19 Time: 12:42
Sample: 2009M04 2017M12
Included observations: 105
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LR(-1)	-0.001799	0.022286	-0.080727	0.9358
RR	0.004552	0.087115	0.052253	0.9584
RR(-1)	-0.010565	0.112504	-0.093908	0.9254
RR(-2)	0.006190	0.112648	0.054952	0.9563
RR(-3)	0.000535	0.082739	0.006469	0.9949
LGP	0.001943	0.030131	0.064473	0.9487
LGO	0.001842	0.023712	0.077694	0.9382
RR_SQD_C	-0.000415	0.007559	-0.054844	0.9564
RR_SQD_C(-1)	0.001045	0.009840	0.106220	0.9156
RR_SQD_C(-2)	-0.000618	0.009836	-0.062785	0.9501
RR_SQD_C(-3)	-4.24E-05	0.007224	-0.005872	0.9953
C	-0.010527	0.199408	-0.052789	0.9580
RESID(-1)	0.021107	0.112490	0.187629	0.8516
RESID(-2)	-0.063190	0.108867	-0.580430	0.5631

R-squared	0.003993	Mean dependent var	-1.53E-15
Adjusted R-squared	-0.138293	S.D. dependent var	0.023395
S.E. of regression	0.024960	Akaike info criterion	-4.419524
Sum squared resid	0.056693	Schwarz criterion	-4.065663
Log likelihood	246.0250	Hannan-Quinn criter.	-4.276133
F-statistic	0.028065	Durbin-Watson stat	1.989947
Prob(F-statistic)	1.000000		

Appendix IX: Regression Specification Error Test (RESET)

```
Ramsey RESET Test
Equation: EQ01
Omitted Variables: Powers of fitted values from 2 to 3
Specification: LR  LR(-1) RR RR(-1) RR(-2) RR(-3) LGP LGO RR_SQD_C
     RR_SQD_C(-1) RR_SQD_C(-2) RR_SQD_C(-3) C
===========================================================================

                          Value          df        Probability
F-statistic             0.298510      (2, 91)       0.7426
Likelihood ratio        0.686619         2          0.7094
===========================================================================

F-test summary:
                        Sum of Sq.       df       Mean Squares
Test SSR                0.000371         2         0.000185
Restricted SSR          0.056920        93         0.000612
Unrestricted SSR        0.056549        91         0.000621
===========================================================================

LR test summary:
                          Value
Restricted LogL         245.8150
Unrestricted LogL       246.1583
===========================================================================


Unrestricted Test Equation:
Dependent Variable: LR
Method: Least Squares
Date: 11/23/19   Time: 12:40
Sample: 2009M04 2017M12
Included observations: 105
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed
     bandwidth = 5.0000)
===========================================================================

       Variable          Coefficient    Std. Error    t-Statistic    Prob.
===========================================================================

        LR(-1)            0.007039      0.034264      0.205445     0.8377
          RR             -0.992771      3.170361     -0.313141     0.7549
        RR(-1)            0.098911      0.307586      0.321572     0.7485
        RR(-2)           -0.559315      2.037459     -0.274516     0.7843
        RR(-3)            0.755126      2.650044      0.284948     0.7763
         LGP             -1.687894      5.547787     -0.304246     0.7616
         LGO             -1.684005      5.557637     -0.303007     0.7626
       RR_SQD_C           0.060446      0.190293      0.317648     0.7515
     RR_SQD_C(-1)        -0.008520      0.026553     -0.320859     0.7491
     RR_SQD_C(-2)         0.048108      0.175144      0.274678     0.7842
     RR_SQD_C(-3)        -0.064777      0.227235     -0.285069     0.7762
          C               21.12341      54.46854      0.387809     0.6991
       FITTED^2           0.191520      0.388345      0.493168     0.6231
       FITTED^3          -0.004575      0.009164     -0.499270     0.6188
===========================================================================

R-squared                 0.998908   Mean dependent var       14.83368
Adjusted R-squared        0.998752   S.D. dependent var       0.705543
S.E. of regression        0.024928   Akaike info criterion   -4.422062
Sum squared resid         0.056549   Schwarz criterion       -4.068201
Log likelihood            246.1583   Hannan-Quinn criter.    -4.278671
F-statistic               6401.442   Durbin-Watson stat       1.979466
Prob(F-statistic)         0.000000
===========================================================================
```