Selection of Zambia's optimal copper mining excess profit tax

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Mineral taxation is an important revenue-generating instrument for the Zambian government. A good combination of tax instruments in a fiscal regime will help a mineral resource-rich country to generate revenue needed for economic development. This paper selects Zambia's optimal copper mining excess profit tax. The choice was made between variable profit tax and windfall tax. This was attained by using the fuzzy analytic hierarchy process (AHP) and fuzzy technique order of preference by similarity to ideal solution (TOPSIS) methods. The selection process was anchored on four evaluation criteria: administrative efficiency, investor risk, government risk, and progressivity. Results show that windfall tax is technically superior to variable profit tax. Therefore, windfall tax was selected as Zambia's optimal copper mining excess profit tax.

Keywords

Zambia, analytic hierarchy process, windfall tax, variable profit tax, copper

INTRODUCTION

Mining is one of Zambia's most important economic sectors, and plays a key role in contributing to the economic prosperity of the State. A slump in mineral prices often propagates ripple effects throughout the economy. One such significant effect is the reduction in mineral tax revenue accruing into State coffers. Mineral tax is one of Zambia's largest revenue-generating instruments, despite the existence of tax instruments in other sectors. Mining taxation is Zambia's largest conduit to capture revenue from the country's mineral wealth. However, there is still intense debate in Zambia about the fairness of the country's mine taxation system and whether it had been optimally designed to serve the best interests of all stakeholders. In the past, this has led to frequent mineral tax reforms to address the concerns of the citizenry. Zambia's mining taxation system has evolved in important ways in recent years. The authorities have changed major components of the tax regime in response to the changing market conditions and evolving public policy needs. Zambia has undergone seven mineral tax reforms since the privatization of its mines in 1997 and 2000 (Table I).

The changes to the mining taxation regime since privatization were aimed at optimizing the country's benefit from the copper mining sector. However, it is important to understand that a fiscal regime must exhibit stability to attract mineral investment and provide a fair return to investors. This will be less likely to lead to any renegotiation pressure between the state and investors. The ultimate goal of any mining tax system is to ensure the greatest possible benefit to the state while ensuring continued investment in the mineral sector. Mineral taxation policy must aim to collect a fairly reasonable amount of revenue from mining companies and at the same time allow them to retain enough finances for continued growth through exploration, development, and exploitation of mineral deposits. Hogan (2008) noted that the aim of mineral taxation policy is to enable governments to collect a reasonable return from the extraction of the country's mineral resources, while ensuring that industry outcomes remain efficient.

Table I. Features of Zambia's mining fiscal regime (Banda and Besa, 2016).

		Mineral taxation regimes						
Type of tax		DA	2008	2009	2012	2015	Post-2015	2016
Profit-based tax								
Company income tax (% of profit base)								
Mineral processing and tolling (%)		35	35	35	35	30	35	35
Mining operations (%)		25	30	30	30	0	30	30
Variable profit tax in effect?		No	Yes	Yes	Yes	Yes Industrial minerals	Yes	No
Profit tax base details								
Capital depreciation allowance		100	25	100	25	25	25	25
Loss carry forward (maximum years)		5-10	10	10	10	10	10	10
Allowed debt to equity ratio		2:1	3:1	2:1	2:1	3:1	3:1	3:1
Revenue tax types								
Mineral royalty (%)	Underground mining	0.6	3	3	6	8	6	4% - 6%
	Opencast mining	0.6	3	3	6	20	9	4% - 6%
Windfall tax in effect?		No	Yes	No	No	No	No	No
Other tax types								
Customs duty		Exempted in most cases						
Export duty (on copper anodes)		No	15% but with some waivers					

Note: DA = Development agreements

Host countries and mining firms usually have contradictory objectives. The goal of the mining firm is to maximize profit while that of the host country is materially concerned with maximizing tax revenue. Maintaining an appropriate balance between these two extremes is cardinal. However, achieving this is no easy task. Nevertheless, policy formulators need to see to it that a robust taxation regime is designed. The tax system must encapsulate tax instruments that give financial relief to investors in times of low mineral prices while capturing a substantive amount of mineral tax revenue for the government in times of high mineral prices. To attain the latter objective, excess profit taxes need to be designed and implemented.

Excess profit taxes are instituted for the sole purpose of capturing unexpected high revenue gains enjoyed by mining companies in times of good economic conditions. Windfall tax is one of the most commonly applied excess profit taxes. It can be defined as a levy that governments employ to extract additional rent generated by mining corporations during times of windfall profits (Appiah, 2013). Since windfall gain is an unanticipated piece of good fortune it should accrue to the citizens of the host country where mining is being undertaken. However, tax experts argue against this tax instrument as this fortune should accrue to the mining firms in order to provide an incentive to undertake exploration in areas previously inaccessible (Aarsnes and Lundstol, 2013). The second argument against this tax is that it has the potential to wipe out mining profits on marginal deposits. Windfall tax has found little or no application in most jurisdictions. This can be attributed to the fact that no country has implemented it correctly. Most countries that have legislated this tax instrument have done so with flaws in its design. Some of these countries include Zambia, Mongolia, and the USA (Aarsnes and Lundstol, 2013).

Zambia has applied two excess profit taxes mining in the past, namely, windfall tax and variable profit tax (see Table I). The Zambian government introduced a mining windfall tax in 2008 and repealed it in 2009. The justification for this action was that the mining windfall tax was weak in design and caused the entire 2008 tax regime to have an average effective tax rate (AETR) beyond normal. It is estimated that the marginal effective tax rate (METR) of the 2008 tax regime was above 80% in some cases, while the AETR was 47% (Economic Association of Zambia (EAZ), 2008). The weakness of the mining windfall tax is embedded in the fact that it was not treated as a deductible expense in the income statement. This meant that in times of high mineral prices a mining firm had to pay windfall tax and corporate income tax (CIT). Just like windfall tax, the variable profit tax was introduced in 2008. This tax instrument was revoked in April 2016 because it failed to generate any revenue for the government. The challenge in capturing profits from this tax instrument is due to the fact that it allows deductions just like CIT. These deductions, as indicated by Manley (2013), include depreciation allowances and loss carry forward provisions, and since mining operations typically incur large costs upfront, these deductions can ensure that taxable profits are zero for many years.

The current mineral taxation regime (2016) does not encapsulate any excess profit tax. This has led to a growing concern among the citizenry about the fairness of the Zambian taxation system. They seem to be in favour of some form of excess profit tax. This raises the question of which form of excess profit tax is the most robust. In this paper, the fuzzy analytic hierarchy process (AHP) and the fuzzy technique order of preference by similarity to ideal solution (TOPSIS) multi-criteria decision-making (MCDM) tools were applied to select Zambia's optimal copper mining excess profit tax between windfall tax and variable profit tax.

BACKGROUND THEORY

Selection of an optimal mineral tax among a set of tax instruments involves taking into consideration a number of factors. The selected tax must maximize revenue generation on the part of the State, and at the same time it must enable mining firms to retain sufficient profit to continue undertaking exploration, development, and exploitation of mineral deposits. Literature has presented several criteria for evaluating mineral tax. The common ones are administrative efficiency, investor risk, government risk, progressivity, neutrality, and revenue raising potential.

Administrative Efficiency

An administrative-efficient tax is one that translates into maximal compliance between the government and taxpayer. Compliance cost increases with complexity and sophistication of the taxation system, and this is the reason why implemented mineral taxation regimes need to be based on simple formulations (Guj, 2012). Simplicity of mineral tax structures can enhance administrative efficiency and increase tax revenue collections. It is important to understand that the effective execution of any tax depends on whether it is easily communicated to a common taxpayer.

Investor Risk

Mining projects have a relatively high risk compared to other ventures. This can be attributed to the unique factors surrounding these projects, such as high initial capital investment and long pre-production periods. Some of the risks common to a mining investment include volatile mineral prices, long payback period, and technical risks associated with geology. The fiscal policy in place may also shape investor perception of risk. For example, a taxation regime that possesses an excessively high effective average tax rate (EATR) has the potential render mining unprofitable. High investor risk can make prospectors look elsewhere for jurisdictions that offer a favourable investment climate. Therefore, it is imperative for host countries to implement a tax policy that is internationally competitive. Arguably, mineralization is usually given a high preference over fiscal policy. This is because an investor will seldom invest in a country that has the best fiscal policy but poor mineralization.

Government Risk

In excess profit taxation, government risk entails the susceptibility of tax instruments to manipulation by mining companies. Investors sometimes engage in tax planning schemes to reduce tax liability. This translates into narrowed tax revenue generation by the host country. Some of the common tax planning schemes include misreporting of grade and production values, debt repayment abuse, and transfer pricing. Curbing of these schemes poses a major challenge to any tax authority. However, an increase in administrative capacity helps in reducing this challenge. Tax instruments also dictate the susceptibility of a fiscal regime to manipulations. For example, profit-based taxes are generally susceptible to tax planning schemes because both revenue and cost are manipulated. Revenue-based taxes, on the other hand, are mildly vulnerable to tax avoidance.

Progressivity

Mohammed (2012) described a progressive tax system as one that increases government take when the rate of return (ROR) is high and gives financial relief to investors when the ROR is low. Progressivity is based on the ability-to-pay principle. According to this principle, business entities that generate high income must be in a position of paying more tax. Conversely, those with a low generated income must incur a lesser tax liability. Progressive tax instruments limit the distortion of investor decisions because they are based on the ability to pay. Achieving a robust tax system that is totally progressive is no easy task. Land (2007) stated that most taxation systems tend to be mildly regressive, despite the collection of fiscal and quasi-fiscal instruments that could be used to attain progressivity.

Other Tax Evaluation Measures

There are a myriad of factors that can be employed to evaluate fiscal regimes. Other common measures used in assessing mineral taxation regimes include the following.

(a) Neutrality

Daniel *et al.* (2008) defined a neutral tax as one that causes minimal distortions in private economic decisions that ought to have been made in its absence. Many authors (Baunsgaard 2001; Watkins 2001; Nakhle 2004) have described a neutral tax as one that does not change the ranking of projects once introduced. In the mining context, a neutral tax does not affect decisions concerning exploration, development, and exploitation of mineral deposits. According to Guj (2012) the optimal size of reserves, which includes all blocks of ore with a grade equal to or greater than the mining cut-off grade, will not be affected by changes in tax rate. A non-distorting tax gives rise to either (Guj, 2012):

- Insufficient extraction of the mineral resource. This can be attributed to high-grading brought about by the introduction of production-based tax (*ad valorem* mineral royalty), or
- Over-exploitation of the mineral resource.

Although taxes can lead to distortion of investor decisions, there are some instances where their imposition can bring about positive social-economic change by correcting negative externalities.

(b) Revenue-raising Potential

The main objective of any tax instrument is to generate a substantial amount of revenue for the government. The generated tax revenue dispenses income needed for economic development. Appiah (2013) noted that there are few developing countries that can settle for a tax instrument that results in great loss of revenue, no matter its desirability from other perspectives. However, a balance needs to be maintained between the interests of the government and investors. The tax instrument must generate enough revenue for the government and at the same time it must retain enough finances for the mining companies to continue with operations. Overtaxing the mines today has the effect of narrowing the tax base in the future. This is because most companies will be driven out of business. The presence of resource rent makes the mining sector a potential contributor to government revenue (Daniel *et al.*, 2008). This calls for the implementation of tax instruments that can initiate satisfactory capture of this rent. However, Daniel *et al.* (2008) pointed out that it is difficult to tax economic rent adequately because of the following reasons:

- Possible presence of quasi rents
- Inaccurate estimation of economic rent base
- Continued demand by mining companies for incentives to fuel their operations.

REVIEW OF ZAMBIA'S MINING EXCESS PROFIT TAXES

This section undertakes an in-depth technical review of Zambia's mining windfall tax and variable profit tax. These profit taxes were introduced in 2008 to increase revenue generation by capturing the excess profits enjoyed by mining companies in times of high mineral prices. The review has been performed solely for the purpose of setting out the technical application of the tax instruments to Zambia's copper mining sector.

Windfall Tax

This tax instrument was applied to copper and cobalt mineral commodities. Any corporate entity solely carrying out mineral processing activities was exempted from this tax. However, mineral processing that was done in conjunction with mining constituted mining operations and therefore was liable for windfall tax. The payable amount in terms of this tax instrument was supposed to be remitted on a monthly basis when the average monthly price exceeded some defined trigger price (Table II).

Table II. Trigger prices of windfall tax.

Description of trigger price	Amount (US\$ per ton)
First trigger price (FTP)	5 512
Second trigger price (STP)	6 614
Third trigger price (TTP)	7 716

Definition of Technical Parameters

The following are the definitions of the parameters used in the equations for windfall tax applied to copper.

- Ruling exchange rate (RER)*: This is the Bank of Zambia (BOZ) monthly average kwacha to US dollar currency exchange rate.
- Monthly average price (MAP)*: This is the weighted average London Metal Exchange (LME) copper price in a calendar month expressed in US dollars per metric ton. It is calculated using Equation [1].

$$MAP = \frac{Q_1P_1 + Q_2P_2 + Q_3P_3 + \dots + Q_{n-1}P_{n-1} + Q_nP_n}{Q_n} \quad [1]$$

where Q_n is the quantity of copper or recoverable copper sales in a calendar month (tons), P_n is the corresponding LME daily closing cash seller price for Grade A copper cathode (US dollars per ton) and n is the aggregate number of copper or recoverable copper sales invoiced in the relevant calendar month.

Framework of Windfall Tax Computation

The following provides the computation framework of the copper mining windfall tax:

- Where MAP does not exceed the FTP, windfall tax is not payable.
- Where MAP exceeds the FTP but does not exceed the STP, windfall tax is calculated using Equation [2]:

$$\varphi = (RER * Q_n)[25\% (MAP - FTP)] \quad [2]$$

where φ is the monthly payable amount of windfall tax (US dollars) and Q_n is the quantity of copper or recoverable copper sales in a calendar month (tons).

- Where MAP exceeds the STP but does not exceed the TTP, windfall tax is computed from Equation [3]:

$$\varphi = (RER * Q_n)\{[25\% (STP - FTP)] + [50\%(MAP - STP)]\} \quad [3]$$

(iv) Where MAP exceeds the TTP , windfall tax is computed from Equation [4]:

$$\varphi = (RER * Q_n)\{[25\% (STP - FTP)] + [50\% (TTP - STP)] + [75\% (MAP - TTP)]\} \quad [4]$$

Variable Profit Tax

A 15% variable profit tax was introduced concurrently with the mining windfall tax. This tax was to be applied when the ratio of taxable income to gross sales exceeded 8%. The variable profit tax allowed mining investors to generate profits equivalent to 8% of their gross sales revenue before the tax kicked in. This tax instrument was inapplicable to income subjected to windfall tax in that assessment year. It was launched in 2008 and was repealed in 2016 because it did not generate substantive mining tax revenue for the Zambian government. The payable amount of variable profit tax is computed from Equation 5.

$$\beta = \gamma \times \alpha \quad [5]$$

where β is the payable amount of variable profit tax (US dollars), γ is the taxable income (US dollars), and α is the variable tax rate (%). α can be calculated using Equation [6].

$$\alpha = 30\% + [15\% - (\frac{1.2\% \times \tau}{\gamma})] \quad [6]$$

where γ is the taxable income (US dollars) and τ is the gross sales value (US dollars).

The idea behind the introduction of the variable profit tax in conjunction with windfall tax was to make the copper mineral tax regime more progressive (Manley, 2013). However, Conrad (2012) argued that the ratio of taxable profits to gross sales is marginally related to the concept of excess profit and thus does not convey any economic sense insofar as progressivity is concerned. To understand this claim, Conrad (2012) expressed the ratio of taxable income to gross sales as unity less the ratio of average cost to price for any given level of production. Equations [7], [8], and [9] illustrate the derivation process.

$$\frac{\gamma}{\tau} > 8\% \quad [7]$$

where γ is the taxable income (US dollars) and τ is the gross sales value (US dollars). Equation [7] can further be expressed as:

$$\frac{(\sigma * \lambda) - (\mu * \lambda)}{(\sigma * \lambda)} > 8\% \quad [8]$$

where σ is the unit price of copper (US dollars per ton), μ is the average cost of copper production (US dollars per ton), and λ is the quantity of copper production (tons). Equation [8] can further be simplified as:

$$1 - \frac{\mu}{\sigma} > 8\% \quad [9]$$

From Equation [9], it can be inferred that the ratio of taxable income to gross sales depends on the proportionality increase of the average cost (μ) to the unit price of copper (σ). A situation of very high average cost of production in relation to copper price can render the variable profit tax inapplicable. It is also possible to have a situation where the copper unit price is not necessarily high but the mining firms' average cost of production is relatively very low. Such a situation can cause the tax to kick in and effectively tax the cost savings of the mining firm.

MULTI-CRITERIA DECISION-MAKING (MCDM) TECHNIQUES

The MCDM process encompasses several criteria and alternatives to be evaluated in decision-making. The main goal is to aid the decision-maker in choosing the best and most suitable alternative from a set of feasible alternatives using multiple criteria and diverse priorities. MCDM techniques are very useful in situations where information is non-obtainable, non-quantifiable, and imprecise. These techniques use semi-qualitative and semi-quantitative approaches for selecting the best alternative.

Fuzzy AHP Method

The fuzzy analytic hierarchy process (AHP) method applies fuzzy set theory to the classical AHP process developed by Saaty (1980). It involves solving convoluted problems by representing alternatives in a hierarchical framework. The notion behind the fuzzy AHP is to develop a preference weighting for

each alternative. Linguistic variables represented by triangular fuzzy numbers (TFNs) are used to specify these preferences. TFNs introduce fuzziness in the decision-making process. This fuzziness is cardinal in solving problems that are characterized by imprecise, inaccurate, and non-obtainable information. Rating of one alternative in relation to another is achieved using a nine-point scale of importance (Table III). The steps of the fuzzy AHP process are as follows.

1. *Generate a fuzzy comparison matrix*

Using the data in Table III, construct the fuzzy pairwise comparison matrix for the main criteria by applying appropriate linguistic variables.

$$\tilde{A} = \begin{bmatrix} 1 & \cdots & \tilde{a}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \cdots & 1 \end{bmatrix} \quad [10]$$

Table III. Membership functions of linguistic scales (modified from Ayhan, 2013).

Scale of interest	Fuzzy number	Linguistic variable	Membership function
1	1	Equally important	(1,1,1)
2	2	Less weakly important	(1,2,3)
3	3	Weakly important	(2,3,4)
4	4	Less strongly more important	(3,4,5)
5	5	Strongly more important	(4,5,6)
6	6	Less very strongly important	(5,6,7)
7	7	Very strongly important	(6,7,8)
8	8	Less extremely important	(7,8,9)
9	9	Extremely important	(9,9,9)

2. *Define fuzzy geometric mean*

The fuzzy geometric mean is calculated using Equation [11] (Buckley, 1985):

$$\tilde{r}_i = (\tilde{a}_{i1} \otimes \tilde{a}_{i2} \otimes \dots \otimes \tilde{a}_{in})^{i/n} \quad [11]$$

where $\tilde{r}_i$ represents triangular values, and $\tilde{a}_{in}$ is a value of the fuzzy comparison matrix from criterion i to n .

3. *Calculate the fuzzy weight for each criterion*

The fuzzy weights ($\tilde{W}_i$) (global fuzzy numbers) of each criterion i are calculated using Equation [12].

$$\tilde{W}_i = \tilde{r}_i \otimes (\tilde{r}_1 \oplus \tilde{r}_2 \oplus \dots \oplus \tilde{r}_n)^{-1} \quad [12]$$

Fuzzy TOPSIS Method

The fuzzy TOPSIS method derives its origin from the TOPSIS method developed by Hwang and Yoon (1981). Both methods are built on the concept that the most viable alternative is one that has the shortest distance from the positive ideal solution (PIS) and farthest distance from the negative ideal solution (NIS). The only difference between the fuzzy TOPSIS method and the TOPSIS method is that the former deals with triangular fuzzy numbers while the latter deals with crisp values. The steps of the fuzzy TOPSIS MCDM technique are as follows.

1. *Develop a fuzzy decision matrix ($\tilde{D}$) by applying appropriate ratings of linguistic variables*

$$\tilde{D} = \begin{bmatrix} \tilde{X}_{11} & \cdots & \tilde{X}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{X}_{m1} & \cdots & \tilde{X}_{mn} \end{bmatrix} \quad [13]$$

where $\tilde{X}_{ij}, i = (1, 2, \dots, m), j = (1, 2, \dots, n)$ are fuzzy numbers, and $\tilde{X}_{ij} = (a_{ij}, b_{ij}, c_{ij})$. That is, $\tilde{X}_{ij}$ is the performance rating of the i^{th} alternative, A_i , with respect to the j^{th} criteria, C_j .

2. Normalize the fuzzy decision matrix $\tilde{D}$ into matrix $\tilde{R}$ as:

$$\tilde{R} = \begin{bmatrix} \tilde{r}_{11} & \cdots & \tilde{r}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{r}_{m1} & \cdots & \tilde{r}_{mn} \end{bmatrix} \quad [14]$$

The normalization process can be attained by:

$$\tilde{r}_{ij} = \left(\frac{a_{ij} b_{ij} c_{ij}}{c_j^* c_j^* c_j^*} \right), i = 1, \dots, n; j \in B \quad [15]$$

$$\tilde{r}_{ij} = \left(\frac{\bar{a}_j \bar{a}_j \bar{a}_j}{c_{ij} b_{ij} a_{ij}} \right), i = 1, \dots, n; j \in C \quad [16]$$

where B and C are the set of benefit criteria and cost criteria respectively, and

$$c_j^* = \max_i c_{ij}, \text{ if } j \in B \quad [17]$$

$$\bar{a}_j = \min_i a_{ij}, \text{ if } j \in C \quad [18]$$

3. Calculate the weighted normalized fuzzy decision matrix as:

$$\tilde{V} = \tilde{r}_{ij} \otimes \tilde{w}_j \quad [19]$$

where $\tilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$ is a fuzzy weight obtained from the AHP method (step 3 of the AHP method).

4. Define the fuzzy positive ideal solution (FPIS) (A^+) and fuzzy negative ideal solution (FNIS) (A^-) as:

$$A^+ = \{\tilde{v}_1^+, \dots, \tilde{v}_n^+\} \quad [20]$$

$$A^- = \{\tilde{v}_1^-, \dots, \tilde{v}_n^-\} \quad [21]$$

where $\tilde{v}_j^+ = (1, 1, 1)$ and $\tilde{v}_j^- = (0, 0, 0), j = 1, 2, \dots, n$

5. Determine the distance of each alternative from (A^+) and (A^-) using:

$$d_i^+ = \sum_{j=1}^n d(\tilde{v}_{ij}, \tilde{v}_j^+), i = 1, 2, \dots, m \quad [22]$$

$$d_i^- = \sum_{j=1}^n d(\tilde{v}_{ij}, \tilde{v}_j^-), i = 1, 2, \dots, m \quad [23]$$

If $\tilde{a} = (a_1, a_2, a_3)$ and $\tilde{b} = (b_1, b_2, b_3)$ are two triangular fuzzy numbers, then the distance between $\tilde{a}$ and $\tilde{b}$ is:

$$d(\tilde{a}, \tilde{b}) = \sqrt{\frac{1}{3} [(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2]} \quad [24]$$

6. Calculate the closeness coefficient (CC_i) of each alternative to the ideal solution as:

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-} \quad i = 1, \dots, m \quad [25]$$

7. Rank the alternatives in terms of the value of CC_i . The best alternative is the one with the greatest value of CC_i . This means it has the closest distance to the FPIS and farthest distance from the FNIS.

Related Works on Fuzzy AHP and Fuzzy TOPSIS Methods

The fuzzy AHP technique first made its appearance in the works of van Laarhoven and Pedrycz (1983). It is a fuzzy extension of the classical AHP method developed by Saaty (1980). Fuzzy AHP has been applied to a myriad of MCDM problems. For instance, Chan and Kumar (2007) applied the method in the supplier selection problem; Tang and Lin (2011) applied the technique in the lead-free equipment selection problem; Rouyendegh and Erkan (2012) applied the method in the human resource sphere of selecting academic staff; Ayhan (2013) applied the approach in the supplier selection problem. The fuzzy TOPSIS is another common MCDM approach. This technique extends the classical TOPSIS method by considering a fuzzy environment. This extension was successfully pursued by Chen (2000). Many applications of the fuzzy TOPSIS method exist in the literature. Deng, Yeh, and Willis (2000) applied the technique in intercompany comparison; Tsuar, Chang, and Yen (2002) applied the method in the risk assessment of tunnelling projects; Chu (2002) applied the technique in a facility location

problem; Namin *et al.* (2008) applied the approach in the selection of a mining extraction method; Asr *et al.* (2015) applied the MCDM technique in selecting the optimum tunnel support.

The fuzzy TOPSIS method is an extension of the TOPSIS technique. In this extension, fuzzy numbers are used to describe linguistic variables. A fuzzy number is a convex fuzzy set defined by an interval of real numbers, each with a membership value between 0 and 1 (Taylan *et al.*, 2014). The classical TOPSIS technique uses crisp values for all ratings and weights of the criteria. These values are known with a considerable degree of precision. However, crisp data is inadequate for modelling real-life situations (Saghafian and Hejazi, 2005). This is because human judgements, including preferences, are often unclear. A more realistic approach calls for the use of linguistic variables instead of numerical values. The fuzzy TOPSIS method was devised to strengthen the classical TOPSIS method by encapsulating fuzziness in the decision-making process. There are many examples of the application of the fuzzy TOPSIS technique in the literature (Deng, Yeh, and Willis, 2000; Tsuar Chang, and Yen, 2002; Chu, 2002; Wang and Liang, 2004; Abo-sina and Amer, 2005; Fouladgar, Yazdani-Chamzini, and Zaradska, 2012; Yazdani-Chamzini, 2012; Asr *et al.*, 2015).

SELECTION OF ZAMBIA'S OPTIMAL COPPER MINING EXCESS PROFIT TAX

The fuzzy AHP and fuzzy TOPSIS methods were used to select Zambia's optimal copper mining excess profit tax. The selection process was based on four criteria: administrative efficiency (C_1), investor risk (C_2), government risk (C_3), and progressivity (C_4). The tax evaluation factors ($C_1 - C_4$), tax alternatives ($A_1 - A_2$), and the goal of the decision-making process are represented as a hierarchical structure illustrated in Figure 1.

Figure 1. Hierarchical structure of MCDM problem.

Application of Fuzzy AHP Method

The following steps involve the application of the fuzzy AHP method to determine the fuzzy weights of each criterion.

Step 1: Linguistic weightings in Table III were employed to determine the level of importance of each criterion in relation to another by forming a pairwise comparison matrix (Table IV).

Step 2: The geometric mean of fuzzy comparison values of each criterion is calculated by Equation [11]. Results are summarized in Table IV.

Step 3: The relative fuzzy weights ($\tilde{w}_i$) are calculated using Equation [12] by summing and reversing the geometric means (Table V).

The pairwise comparison matrix (Table IV) shows different weightings of the evaluation criteria. The weightings have been established based on the current economic context of Zambia. Zambia is highly dependent on mining tax revenue to undertake its social-economic programmes. Therefore, government risk has been assigned the highest fuzzy weight (Table V). Investor risk ranks second because long-term tax revenue generation from the mining industry depends on the long-term survival of mining enterprises. Administrative efficiency ranks third, because this will determine the revenue raising potential of a tax instrument both in the short and the long run. A tax instrument that is technically sound but poses administrative challenges to the Zambian government will generate inadequate tax receipts. Therefore, putting in place an administratively efficient excess profit tax can enhance generation of mineral tax revenue from Zambia's copper mining sector. Progressivity evaluation criterion ranks last because this is not considered a major factor in excess profit taxation. This is because excess profit taxes are perceived to have the same degree of progressivity.

Table IV. Pairwise comparison matrices for weights.

	C ₁	C ₂	C ₃	C ₄
C ₁	(1,1,1)	(1,1/2,1/3)	(1/2,1/3,1/4)	(1,2,3)
C ₂	(1,2,3)	(1,1,1)	(1,1/2,1/3)	(2,3,4)
C ₃	(2,3,4)	(1,2,3)	(1,1,1)	(3,4,5)
C ₄	(1,1/2,1/3)	(1/2,1/3,1/4)	(1/3,1/4,1/5)	(1,1,1)

Table V. Criteria geometric means and relative fuzzy weights.

Criteria	$\tilde{r}_i$	$\tilde{w}_i$
C ₁	(0.84,0.75,0.71)	(0.16, 0.16, 0.17)
C ₂	(1.19,1.31,1.41)	(0.23, 0.28, 0.34)
C ₃	(1.57,2.21,2.78)	(0.30, 0.46, 0.67)
C ₄	(0.63,0.45,0.35)	(0.12, 0.09, 0.08)
Total	(4.23, 4.72, 5.25)	
Reverse (Power of -1)	(0.24, 0.21, 0.19)	
Increasing order	(0.19, 0.21, 0.24)	

Application of Fuzzy TOPSIS Method

The fuzzy TOPSIS method has been employed to determine the closeness coefficient of each tax alternative. The optimal excess profit tax is that which gives the highest closeness coefficient. This means it has the closest distance to the PIS and farthest distance to the NIS. The following steps constitute the application of the fuzzy TOPSIS method in selecting Zambia's optimal excess profit tax.

Step 1: A committee of three tax mining experts (D₁, D₂, and D₃) was formed to help formulate a decision matrix ($\tilde{D}$).

Step 2: The decision-makers (D_1 , D_2 , and D_3) employed the linguistic weightings in Table VI to assess the ratings of alternatives with the respect to criteria. Table VII summarizes the average linguistic ratings for alternatives with respect to criteria.

Step 3: The linguistic evaluation shown in Table VII was converted into average triangular fuzzy numbers to construct a fuzzy decision matrix shown in Table VIII.

Step 4: The fuzzy decision matrix (Table VIII) was normalized using Equation [15] to generate the fuzzy normalized decision matrix (Table IX).

Step 5: The fuzzy weighted normalized decision matrix (Table X) of the two tax alternatives was obtained by multiplying the elements of the fuzzy normalized decision matrix with the fuzzy AHP weights in Table V.

Step 6: The FPIS (A^+) and FNIS (A^-) were defined as:

$$A^+ = [(1,1,1), (1,1,1), (1,1,1), (1,1,1)]$$

$$A^- = [(0,0,0), (0,0,0), (0,0,0), (0,0,0)]$$

Step 7: The distances of each tax alternative from the FPIS and FNIS were calculated using Equations [23] and [24], respectively (Table XI).

Step 8: Values of CC_i were calculated using Equation [25] (Table XI and Figure 2).

Table VI. Linguistic variables (Chen, 2000).

Very poor (VP)	(0,0,1)
Poor (P)	(0,1,3)
Medium poor (MP)	(1,3,5)
Fair (F)	(3,5,7)
Medium good (MG)	(5,7,9)
Good (G)	(7,9,10)
Very good (VG)	(9,10,10)

Table VII. Linguistic ratings of tax alternatives.

Criteria	Alternative	Decision-makers		
		D_1	D_2	D_3
C_1	A_1	MP	F	MG
	A_2	G	P	MP
C_2	A_1	F	MG	G
	A_2	MP	F	MG
C_3	A_1	F	MP	MG
	A_2	MG	F	G
C_4	A_1	P	F	VP
	A_2	MG	G	MG

Table VIII. Fuzzy decision matrix of tax alternatives.

	C_1	C_2	C_3	C_4
A_1	(3,5,7)	(5,7,8.7)	(3,5,7)	(1,2,3.7)
A_2	(2.7,4.3,6)	(3,5,7)	(5,7,8.7)	(5.7,7.7,9.3)

Table IX. Fuzzy normalized decision matrix of tax alternatives.

	C ₁	C ₂	C ₃	C ₄
A ₁	(0.4,0.7,1)	(0.6,0.8,1)	(0.3,0.6,0.8)	(0.1,0.2,0.4)
A ₂	(0.4,0.6,0.9)	(0.3,0.6,0.8)	(0.6,0.8,1)	(0.6,0.8,1)

Table X. Fuzzy weighted normalized decision matrix of tax alternatives.

	C ₁	C ₂	C ₃	C ₄
A ₁	(0.06,0.11,0.17)	(0.14,0.22,0.34)	(0.09,0.28,0.54)	(0.01,0.02,0.03)
A ₂	(0.06,0.09,0.15)	(0.07,0.17,0.27)	(0.18,0.37,0.67)	(0.07,0.07,0.08)

According to the CC_i values in Table XI and Figure 2, windfall tax (Alternative 2) ranks higher than variable profit tax (Alternative 1). To this extent, windfall tax should be selected as the optimal excess profit tax to be applied to Zambia's copper mining sector provided it is designed in such a way that problems similar to those experienced in 2008 are avoided.

Table XI. Distance measurements.

	A ⁺	A ⁻	CC _i
A ₁	(3.36)	(0.75)	0.18
A ₂	(3.28)	(0.82)	0.20

Figure 2. Fuzzy TOPSIS rating of excess profit tax alternatives.

DISCUSSION OF RESULTS

Windfall tax has a relative closeness value of 0.2, which is 0.02 points higher than that of variable profit tax (0.18). Of the following four criteria, numbers (i), (iii), and (iv) indicates that windfall tax is preferred to variable profit tax. Only criterion (ii) supports the variable profit tax.

- (i) Windfall tax administration entails monitoring variables such as price and production. Administration of variable profit tax, on the other hand, involves monitoring the taxable income and gross sales. The trigger ratio of variable profit tax encapsulates variables such as price, quantity,

and average cost (Equation [8]). Due to the cost element, variable profit tax has the potential of constituting a greater administrative challenge to the Zambian tax revenue authority than windfall tax. This is because the tax authority needs to monitor cost in addition to price and production values. To this extent, windfall tax has a higher administrative efficiency than variable profit tax.

- (ii) Windfall tax is revenue-based. Variable profit tax, on the other hand, is based on revenue and cost. Since the latter is based on profit it depends to a high degree on an investor's ability to pay tax. This means the variable profit tax takes into account the costs of the mining firms and therefore does not distort their profit structures. In public finance, tax needs to be based on the ability to pay principle. A tax that is not anchored on this principle will distort an investor's financial decisions (non-neutral).
- (iii) Variable profit tax is more susceptible to tax planning schemes than windfall tax. Since the variable profit tax trigger ratio is based on revenue and cost (Equation [8]), financial and technical parameters such as production, metallurgical recovery, grade, and operating and capital expenditure can easily be manipulated to reduce the tax incidence. On the other hand, windfall tax trigger prices cannot be manipulated because they are referenced to the LME. The only parameter that is susceptible to manipulation in the windfall tax scheme is production (Equations [2]–[4]). Tax planning schemes reduce government tax revenue and exert financial pressure on the national budget. This constitutes a high financial risk to the government as its ability to meet its obligation of service delivery may be constrained.
- (iv) Windfall tax applies a cumulative tax rate that increases as the trigger price increases (Equations [2]–[4]). Variable profit tax, on the other hand, applies a fixed tax rate to the taxable income base (Equation [5]). A progressive tax instrument is one in which the tax rate increases as the taxable amount increases. By this definition, windfall tax is more progressive than variable profit tax.

Taking all these points into consideration, windfall tax is technically superior to variable profit tax. In this regard it should be chosen as the optimal excess profit tax to be applied to Zambia's copper mining sector, provided it is designed in such a way that problems similar to those experienced in 2008 are avoided.

CONCLUSION

In this study, Zambia's copper mining excess profit taxes were analysed and the optimal tax instrument selected. The choice was between windfall tax and variable profit tax. Based on the fuzzy AHP and fuzzy TOPSIS MCDM tools it was concluded that windfall tax is technically superior to variable profit tax. This conclusion is based on four tax evaluation criteria, namely administrative efficiency, investor risk, government risk, and progressivity. However, structural deficiencies attributed to windfall tax need to be rectified before this tax instrument can be reintroduced.

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