Profit taxation and royalties: evidence from gold mines in Sub-Saharan Africa [1]

Luisito Bertinelli [2] Arnaud Bourgain[3] Skerdilajda Zanaj [4]

University of Luxembourg

December 2019

[1]We would like to thank Bertrand Laporte and the FERDI team for the access to the Mining Tax Database for Africa. We thank participants at the workshop on Public Policies and Development in Abidjan, 2019, and the participants of the "Global Production, Taxes and Trade" workshop in Beijing, 2019, for useful discussions. Special thank to Déborah Schwartz for her research assistance. The usual disclaimer applies.

[2]E-mail: arnaud.bourgain@uni.lu

[3]E-mail: luisito.bertinelli@uni.lu.

[4]Corresponding author: CREA, University of Luxembourg. Address: Campus Kirchberg. 6, rue Richard Coudenhove-Kalergi, L-1359 Luxembourg. Tel: (+352) 4666 44 6464; Fax (+352) 46 66 44 6341 email: skerdilajda.zanaj@uni.lu

Abstract

In this paper, we analyze theoretically and empirically the effects of tax changes on firms' profits in extractive industries. In the theoretical part, we assume a country that levies a profit tax and a royalty on the profits of extractive firms to maximize its tax revenues. The mining companies may reduce their taxable income by cost manipulation. By analyzing the optimal choice of the government and of the firms, we first establish the optimal tax policy and then we investigate the impact of the optimal fiscal policy on firms' profits.

In the empirical part of the paper, we estimate the effect of the profit tax and royalty on the extracting firms' profit in African countries during the period spanning from 2007 to 2018. We use the *Mining Intelligence* database to constitute a panel of annual individual data from a database of 363 gold mines located in 21 Sub-Saharan countries. We obtain an inverse relationship between the tax rate change of the two tax instruments and the profit of the firms.

Keywords: Resource countries, Resource taxation, Royalties, Cost misreporting, Extractive industries.
JEL Classification: H25, H32, O13

1 Introduction

Developing countries endowed with natural, non-renewable, resources are financially dependent on extractive industries and therefore they are in crucial need for optimal taxation policies. Several initiatives were taken in African countries including Côte d'Ivoire, Ghana, Zambia to redesign the mining tax regimes to improve the corresponding tax receipts. To what extent do such changes in taxation affect the declared profit of mining firms? The purpose of this paper is to address this question in low-income countries where governments have severe informational disadvantages vis-à-vis resource extraction companies (Collier 2010). In the empirical part of the paper, we focus the analysis on sub-Saharan African countries using an original database.

The distinctive features of extractive industries are fixed supply, collective ownership of resources and often information asymmetry between the tax authority and the firms and several types of taxations.[1] Previous research on extractive resource suggests the use of two taxation instruments, i.e. *profit taxes* and *royalties* (IMF 2012 ; Boadway and Keen 2010, 2015 ; Bourgain and Zanaj 2020). Profit taxes are standard corporate taxes that apply to any enterprise and which rate can be specific for extractive industries. Royalties are typical tax instruments applied in mining industries and they are levied only the firms' sales revenues. They shall be considered as a payment granting the firm with the right to exploit a non-renewable resource. On the one side, royalties play an important role as means of revenue mobilization for developing extractive countries. On the other, royalties are often blamed to be distortionary because they only apply to the sales and do not take into account the cost of exploration, development and extraction. In this research, we explore how profit taxes and royalties affect firms' declared profits when both tax measures are susceptible to information asymmetries between tax authorities and firms. To do so, we analyze theoretically and empirically the effects of tax changes on firms' profits in extractive industries.

In the theoretical part, we assume a country that levies a profit tax and a royalty on the profits

[1] Since the pioneering work of Hotelling (1931) and Brown (1948), an abundant literature on taxation engineering has been developed to model the effects of various taxes on extractive resources (cf. the survey by Smith 2013).

of extractive firms to maximize its tax revenues. While it is usually easy to show the distortive character of an ad-valorem tax levied directly on the extraction of the resource (the royalty), the analysis becomes more intricate, when considering a context of asymmetric information between mining companies and government. In this context, we consider the possibility for the mining company to reduce its taxable income by cost overstatement. We assume that the rate of cost overstatement does not depend on the firm but it is rather a feature of the mining country such as the country's lack of expertise or the level of corruption. The higher the level of corruption or the weaker the audit on mining industries, the greater the rate of cost overstatement in that country. By analyzing the optimal choice of the government and of the firm, we investigate the impact of the optimal royalty and profit tax rate on the profit of the firms.

In the empirical part of the paper, we estimate the effect of a change in profit tax and royalty on the declared profits of extracting firms in African countries during the period spanning from 2007 to 2017. We use the *Mining Intelligence* database to constitute a panel of annual individual data from a database of 363 gold mines located in 21 Sub-Saharan countries. Working at the mine level limits the availability of accounting information (usually only reported at the firm level) but enables us to consider the production conditions of each extractive site. Our dependent variable is a proxy of the declared profit for each mine. The total cash cost represents the main variable affecting the tax base, the realized price being the same for all producers. The changes in profit tax rate and royalty rate are our explanatory variables of interest. In all estimations, we obtain an inverse relationship between the tax rate change of our two tax instruments and the firm tax base. These results are robust to the introduction of various control variables and interaction terms. Finally, taking into account the multinational nature of most mining companies, we investigate whether the profit in a mine is sensitive to the change of the tax in other countries where the parent mining company has branches. We find no evidence of such a link in group-related mines.

This research contributes to the applied literature on extractive resource taxation in countries where the asymmetry of information between governments and mining firms is very high. To the best of our knowledge, we are the first to provide an empirical study on taxation using microdata in extractive industries. The scarce related studies usually rely on firm level accounting data (as opposed to the more disaggregate mine level data that we adopt here) in OECD countries (Kawano and Slemrod 2016 ; Dwenger and Steiner 2012 ; Gruber and Rauh 2007).

The structure of the paper is as follows. Section 2 sets out the model. The empirical analysis is presented in Section 3 and some conclusive remarks are provided in Section 4.

2 The model

Consider a two-period model and n resource firms each exploiting a mine. The extracted mineral, say gold, is traded in a competitive global market at a price p.[2] For simplicity, all firms share the same production function. More specifically, in the first period, the technology of each firm is composed by a fixed cash labor cost of exploration and development f_i and an initial capital investment K_i. In the second period, each firm faces only extraction costs. Hence, each resource firm generates a quantity of final processed gold $q(K_i)$ with certainty at the end of the second period. The corresponding extractive costs for each firm are given by $C\left[q(K_i)\right], \partial C\left[q(K_i)\right]/\partial K_i > 0; \partial^2 C\left[q(K_i)\right]/\partial^2 K_i > 0$.

Under competitive and efficient global credit markets, each resource firm can borrow and lend at a competitive risk-free interest rate r which constitutes its discount rate factor for future period profits.

The government of the country hosting the n mines imposes an *ad valorem royalty* at rate θ on the revenues and *a profit tax* τ on reported profits. The tax authority relies on self-reporting by the firms in order to establish its tax liabilities, putting each firm at a significant informational advantage compared to the tax authority.

The key assumption of the model is that the resource firms may overstate production costs by multiplying these costs by a factor β that exceeds one. The tax authority is unable to know the nature of the cost of the firm, hence it is unable to determine whether the factor β is due to cost

[2] The price-taking behavior of the extractive firm in the market for the resource is documented in O'Connor *et al.* 2016.

overstatement or it is part of the production costs of the firms. This is due either because of lack of expertise or because of corruption. The rate of overstatement β is a feature of the country and thus it is used by all mining firms located in the country.

The government is risk-neutral and it is able to commit to the tax policy it announces before investment decision. This time consistency of the tax policy may be guaranteed by international contracts law.

The objective function of the government intervention is to raise tax revenues. Each firm maximizes her *real* profit to fix the amount of capital to invest. To obtain closed form solutions, in line with the existing literature (Boadway and Keen 2010 and 2015), we assume that the final transformation process is a linear function $q(K_i) = \alpha K_i$ whereas extractive costs are, for simplicity, quadratic $C(q(K_i)) = \frac{1}{2}\left[\frac{1}{\alpha}q(K_i)\right]^2$ with α being an efficiency parameter. We assume $\alpha > 1 + r$: the productivity of the transformation technology pays more than the intertemporal investment of a unit of capital.

Given the tax policy (τ, θ), each firm maximizes the following profit function:

$$\Pi_i(\theta, \tau) = (1 - \tau)\left(-K_i - f_i + \frac{(1-\theta)\alpha K_i - \frac{1}{2}K_i^2}{1 + r}\right), \ i = 1, ..., n \tag{1}$$

where the extraction costs is $C(q(K)) = \frac{1}{2}\left[\frac{1}{\alpha}q(K_i)\right]^2 = \frac{1}{2}K_i^2$.

Concavity conditions being satisfied, each firm makes the same capital investment $K(\theta)$ given by:

$$K(\theta) = \alpha(1 - \theta) - r - 1 > 0 \tag{2}$$

The government decides the tax policy mix (τ, θ) anticipating the choice of the firms.

We assume that the government maximizes the amount of tax revenues $R(\tau, \theta)$ taking into account the real initial investments by each firm $K(\theta)$ and the declared profits under conditions of asymmetric information:

$$R(\tau, \theta) = \frac{n}{1+r}\left\{\theta\left[\alpha K(\theta)\right] + \tau\left[(1-\theta)\alpha K(\theta) - \beta\frac{1}{2}\left[K(\theta)\right]^2\right]\right\}$$

Due to cost overstatement the declared total extraction costs appearing in the tax revenue function are multiplied by the factor β. We check that concavity conditions are satisfied with respect to the royalty while the decision of the profit tax is a corner solution. As $\partial R(\tau, \theta)/\partial\theta > 0$, the optimal profit tax is the maximum possible rate. Name $\bar{\tau}$ the maximum rate that the government can fix as profit tax.[3]

The optimal policy mix is as follows:

$$\theta^* = \frac{(1 + r - 2\alpha + \beta(\alpha - 1 - r))\bar{\tau} + (\alpha - 1 - r)}{\alpha(2(1 - \bar{\tau}) + \beta\bar{\tau})} \tag{3}$$

$$\tau^* = \bar{\tau} \tag{4}$$

Positivity of the optimal royalty is guaranteed under the condition that

$$\alpha > (r + 1)\frac{1 - \bar{\tau}(1 - \beta)}{1 + \bar{\tau}(\beta - 2)}. \tag{5}$$

A close inspection of the optimal tax policy shows that in presence of cost overstatement, a revenue-maximizing government selects the highest possible profit tax and the lowest royalty. This property is reminiscent of well-known results in the existing literature on optimal taxation. Royalties bring distortive effects on tax revenues because they increase the burden of taxation on firm revenues while neglecting the firm's costs. The optimal tax policy that alleviates this distortion will privilege high-profit taxes while reducing royalties as much as possible. We confirm the same result in presence of cost overstatement.

Comparative statics on optimal royalty yields

$$\frac{\partial\theta^*}{\partial\beta} = \bar{\tau}\frac{\alpha - (1 - \bar{\tau})(1 + r)}{\alpha(-2\bar{\tau} + \beta\bar{\tau} + 2)^2} > 0,$$

The intuition of this relationship is as follows. An increase of the overstatement coefficient β implies that firms declare a smaller profit because they amplify more aggressively the declared extraction costs. This necessarily translates into smaller tax receipts deriving from the profit tax. As a consequence, the government increases the royalty over firms' revenues to compensate for the negative effect of amplified extraction costs. Put differently, our setting suggests that countries

[3] We remain agnostic about the level of such a tax $\bar{\tau}$, but one can imagine that the government fixes the profit tax in a larger fiscal policy concerning the whole economy and beyond the mining sector.

suffering from lack of expertise in mining industries or facing a high level of corruption (high β) will have higher royalty rates.

To discern the relationship between the royalty and the profit tax, we explore the sign of $\partial\theta^*/\partial\bar{\tau}$. If $\beta > 2\alpha/(\alpha - r - 1)$ then $\partial\theta^*/\partial\bar{\tau} > 0$, otherwise, $\partial\theta^*/\partial\bar{\tau} < 0$. When β is very high, the two tax instruments are complements: the higher the profit tax, the higher the royalty. By contrast, when β is small, the tax instruments are substitutes: the higher the profit tax, the lower the royalty. When overstatement is large, governments optimally select tax instruments that are complements to offset the large loss in tax revenues. More specifically, with high β, the government observes very large declared extraction costs and very reduced declared profits. Accordingly, to optimally collect tax revenues, the government increases the royalty rate on perfectly observable firm's revenues as well as the profit tax rate on profits, leading to a positive relationship between the two tax instruments. By contrast, when β remains low, an increase of the profit tax leads to a decrease of the royalty, recovering a classical result in public policy. In this case, the government is careful not to discourage the investment of the mining firm through high taxes. We believe that a reasonable assumption about the range of values for the coefficient of overstatement is that β does not exceed two. Hence, for $1 \leq \beta < 2$, the inequality $\beta < 2\alpha/(\alpha - r - 1)$ is always satisfied, leading to a negative relationship between the profit tax and the royalty.

Summarizing the properties of the optimal royalty, we have

Lemma 1. *The optimal royalty increases with the coefficient of overstatement but decreases with the optimal profit tax.*

Lemma 1 suggests that in a developing country hosting mines and whose government maximizes tax revenues, two forces exist that have opposing effects on royalties. The profit tax exerts a negative pressure on royalties, whereas the rate of cost misreporting pushes royalties up. This implies that different countries may have very different royalty rates due to either different profit taxes or different levels of cost overstatement.

Using the optimal tax policy $(\bar{\tau}, \theta^*)$, the optimal capital investment by each firm obtains as

$$K^* = \frac{\alpha - (1-\bar{\tau})(1+r)}{2(1-\bar{\tau}) + \beta\bar{\tau}}$$

Comparative statics on capital invested yield $\partial K^*/\partial\beta < 0$; and furthermore $\partial K^*/\partial\bar{\tau} > 0$ for $\beta < 2$. Hence,

Lemma 2. *The optimal level of invested capital depends negatively on the coefficient of overstatement but positively on the profit tax.*

The positive relationship between the invested capital and the profit tax is surprising. To grasp the intuition of this result, we must recall that the invested capital is a negative function of the royalty as shown in equation (2). In turn, the royalty decreases with the profit tax rate as shown in Lemma 1. Hence, a higher profit tax implies lower royalties, which ultimately leads to an increase in the invested capital. Quite on the contrary, a higher β, implies higher royalty, and therefore by equation (2), lower invested capital.

Finally, we can evaluate the real profit of each firm at the optimal taxes:

$$\Pi_i^* = \frac{(1-\bar{\tau})}{2(1+r)} \frac{(\alpha - r - 1 + \bar{\tau}(1+r))^2}{(2-\bar{\tau}(2-\beta))^2} - f_i > 0, \;\; i = 1, ..., n$$

which is positive for relatively low levels of the exploration cost.

We can now investigate the relationship between the profit of the firms and the tax rates. Starting with the effect of the profit tax, we prove that the derivative $\partial\Pi_i^*/\partial\bar{\tau}$ can take a positive or a negative value depending on the size of the overstatement coefficient. Let us define $\tilde{\beta}$

$$\tilde{\beta} = \frac{2(1-\tau)(\tau(1+r) - 1 - r - \alpha)}{((\alpha - r - 1)(-2+\tau) - \tau^2(r+1))}$$

We show that

Proposition 1 *The profit of the firm depends positively on the profit tax iff $\beta < \tilde{\beta}$ and negatively iff $\beta > \tilde{\beta}$.*

Proof. By taking the partial derivative $\frac{\partial \Pi^*}{\partial \tau}$ we check that the sign of this derivative is the sign of the expression $\Delta = ((\alpha - r - 1)(-2+\tau) - \tau^2 (r+1))\beta + 2(1-\tau)(1+r+\alpha-\tau(1+r))$. The coefficient multiplying β in this expression Δ, namely $(\alpha - r - 1)(-2+\tau) - \tau^2(r+1)$ is negative due to condition 5 and due to $\tau < 1$. It follows that $\Delta \gtrless 0$ iff $\beta \lessgtr \tilde{\beta}$. ■

The intuition behind Proposition 1 lays on the fact that the profit tax rate has a negative direct effect on profit and an indirect effect with opposite sign. We know from Lemma 1 that $\frac{\partial \theta^*}{\partial \tau} < 0$. Then, a change of profit tax, say a decrease, affects positively profits through a direct effect. By contrast, a decrease in profit tax increases the royalty θ^* which in turn affects negatively firms' profit. Proposition 1 shows that the direct effect offsets the indirect effect as long as the coefficient β does not exceed the threshold $\tilde{\beta}$. In this interval of values, the profit tax affects negatively profits. Beyond $\tilde{\beta}$, the indirect effect dominates the direct, leading to a positive relationship between the profit tax and profit.

As far as it concerns the effect of a change in royalties on the profit of the firms, we shall proceed by first reminding that the effect of royalties must be measured indirectly by considering the effect of the overstatement coefficient on royalties, which affects the profit of the firms.

Proposition 2 *An increase of the overstatement coefficient that increases the optimal royalty θ^* has detrimental effects on firms' profits.*

Proof. Simply taking the partial derivative $\frac{\partial \Pi^*}{\partial \beta} = -\tau(1-\tau)\frac{(-r+\alpha+\tau+r\tau-1)^2}{(r+1)(-2\tau+\beta\tau+2)^3} < 0$. ■

The mechanism is as follows. A change of the overstatement coefficient induces the government to raise royalties in order to offset the negative impact of amplified declared costs. The higher royalty affects negatively the optimal invested capital in the first period and the optimal level of output extracted in the second period ultimately decreasing the profit for each firm.

Notice importantly that results in Propositions 1 and 2 hold for both the real and the declared profits.

In the empirical part, we will test our theoretical priors on the effect of a policy change in profit taxes, in royalties on the profit function of extractive firms.

3 Empirical Analysis

3.1 Data and specification

Our theoretical prior (Proposition 1, 2, 3) is that under certain conditions, (declared) profits will move in the opposite direction of tax rates and royalties. In particular, the profit tax rate will have a negative effect on profit. Regarding the royalties rate, its expected effect on profit is negative (Proposition 2).

Following these theoretical predictions, our empirical specification is:

$$\Pi_{i,c,t} = f\left([\tau, \theta]_{c,t}, X_{i,c,t}, Z_{c,t}\right)$$

where $\Pi_{i,c,t}$ is the (declared) profit; $[\tau, \theta]$ are the profit and royalties rates, X and Z are mine resp. country specific variables, and indices i, c and t stand for mine, country and year.

The level of observation that we rely upon will be the mine level. Unlike mining companies which may be active across several countries, mine sites are clearly localized within a country or territory, allowing us to relate mines to national tax policies. On top of that, it allows us to control for a number of physical characteristics of mines, which contribute to the explanation of their profitability. From an econometric point of view, relying on disaggregate rather than macro data eliminates the potential reverse causality issue between the tax base and tax rates.

All mining related data stems from the Mining Intelligence Database, which is a private data supplier in the mining sector, mainly for private and institutional customers. The database documents 14000 mining companies, corresponding to 35000 mines; it entails information on stakeholders, mine physical characteristics, production, accounting information, the macroeconomic context among others. For our purpose, we extracted total cash costs and realized prices to obtain a proxy of profits for every mine site.[4] Furthermore, production conditions and physical covariates of mines have been exploited.

Tax regime data stems from the Mining Tax Database for Africa, initiated and developed by Laporte et al. (2015), and updated in 2018, and extended temporally and geographically by the

[4] Using mine level data reduces the availability of accounting information (available only at the company level) amongst other declared profits.

authors of this study. This tax and legal database specifies the tax regime applied to industrial gold mining companies in 21 African countries from the 1980s to 2016, and links each piece of tax information and its legal source. It provides information on the evolution, and allows to compare the gold mining tax systems of different African countries.

In our specification, we also control for macroeconomic factors as well as perception indicators, information on which has been extracted from the World Development Indicators. More precisely, we use the Regulatory quality indicator. Despite of being usually considered as poor regressors, these indicators are the best available measure for the cost overstatement of mining firms. As explained in Section 2, our theoretical prior is that the quality of the governmental regulation or the political stability of a country determine ultimately how easy it is to misreport the extraction costs when declaring profits for tax purposes. The lower the quality of regulations, the easier for a firm to amplify its costs with the purpose of decreasing her taxable profit.

The time span for every mine can of course be different, and not every mine does provide information on the variables of interest. As a result, we end up with an unbalanced panel dataset, which in its maximal extension, covers 18 years (2001-2018) and 11 countries (corresponding to 93 mines and 599 observations).

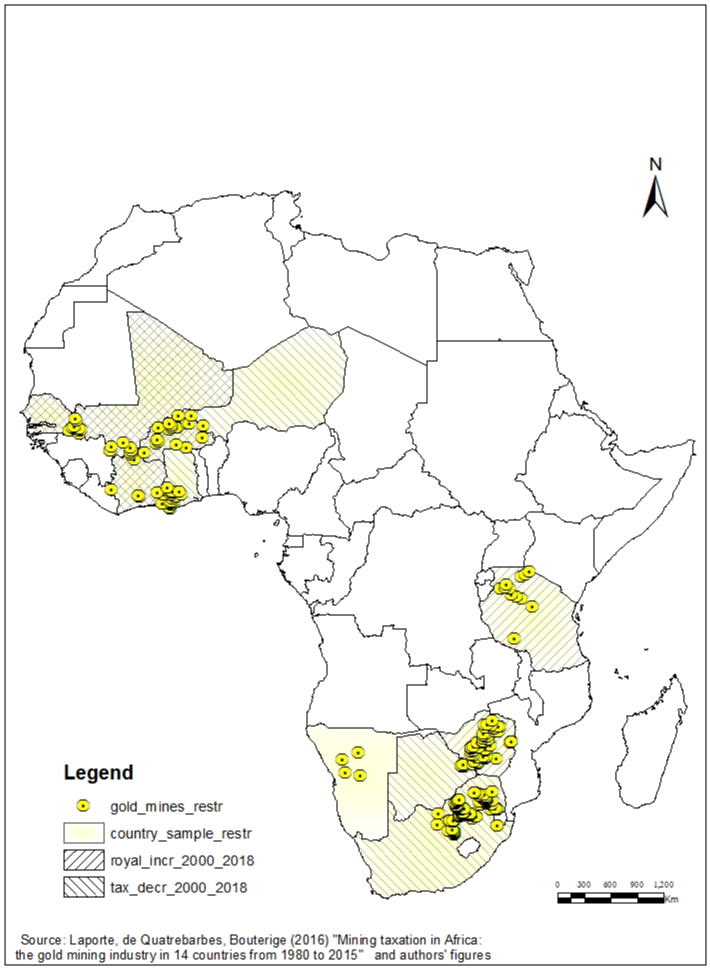

Figure 1: Evolution of taxes and royalties

Figure 1 provides a visual synthesis on mine data availability and variation in tax instruments. Dots represent gold mines in Africa (i.e. our data entails geographic coordinates of every mine complex), which appear in the tax database (i.e. corresponding countries are shaded). Countries hatched with increasing lines refer to situations in which there has been at least one increase in royalties during the period under scrutiny, while downward sloping hatches refer to cases where corporate taxes have decreased at least once. Hatched countries will hence be the treated countries on which we will rely for the identification of the impact of tax regime on profitability, while the remaining countries are our control group. While most of our countries do highlight a change in the tax regime, some countries only have changes in the tax or royalties rates, while others do highlight changes in both tax instruments. Interestingly however, not only did average profit tax rates decrease and average royalties rates increase through time (as can be grasped from Fig.2), this is also true for every country taken individually.

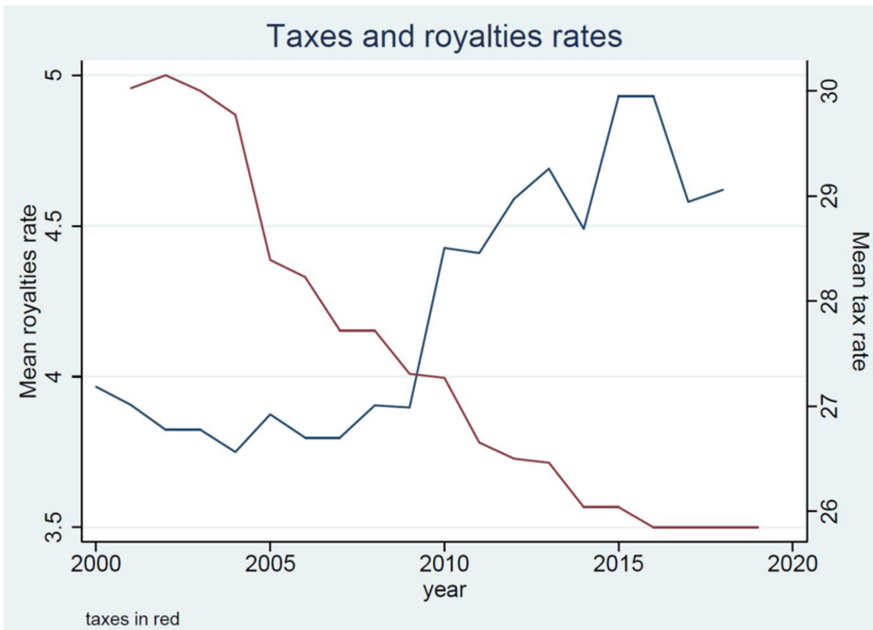

Figure 2: Evolution of taxes and royalties

Table 1 displays descriptive statistics of our variables of interest. We can notice a substantial variation of tax and royalties rates across countries and years. The same is true for mine sites, proxied by the production volumes. The cash cost indicator allows us to compute profits, and is the parameter through which firms adjust their profits according to tax policy changes. There are two physical characteristics of mines that may also influence profitability, and for which we will control in our regressions: the average grade of ore deposits and the estimated reserves of the mines. Lastly, the gold price has been steadily increasing during the period under scrutiny.

	Observations	Mean	Std. dev.	Min.	Max.
Tax rate (%)	599	26.8	5.4	15	37.5
Royalties rate (%)	599	4.0	0.9	3	8.8
Prod. (10^3 troy ounces)	599	203721.7	228862.6	538	1854200
Profit (USD/ozt)	599	498.9	244.7	2.6	1154.4
Gold price(USD/ozt)	599	1272.2	248.1	696.4	1668.9
Grade (g/t)	599	4.4	3.8	0.3	18.0
Reserves (t)	599	$6.54 \cdot 10^7$	$1.33 \cdot 10^8$	$2.50 \cdot 10^5$	$1.07 \cdot 10^9$
Cash cost (USD/ozt)	599	773.3	252.1	148.7	1613.3

Table 1: Descriptive statistics

In Table 2, average figures by country are displayed. We notice that a large majority of mines are located in South Africa, Burkina Faso, Ghana, Mali and Zimbabwe, while the remaining ones are distributed across the remaining 6 countries.

	# mines	Profit	Production	Reserves	Grade	Tax rate	Royalties rate	Reg. quality
		by mine				by country		
		(USD/ozt)	(10^3 ozt)	(t)	(g/t)	(%)	(%)	
Botswana	1	314.93	31305	727000	1.29	22.00	5.00	0.53
Burkina Faso	9	695.92	180424	50207023	1.71	17.56	3.93	-0.27
Ghana	11	533.13	278583	65029840	2.46	31.17	4.90	0.00
Ivory Coast	4	606.35	146810	33770348	2.02	25.09	3.72	-0.60
Mali	8	472.27	189888	35281819	3.09	28.64	3.95	-0.50
Namibia	1	542.36	72000	75030000	1.31	37.50	5.00	0.08
Niger	1	489.70	58950	4937400	1.23	32.50	8.75	-0.51
Senegal	1	736.87	199583	65442000	1.74	28.57	3.18	-0.14
South Africa	42	459.54	215562	81537300	6.30	28.00	3.75	0.33
Tanzania	4	565.47	151491	5046563	2.75	30.00	3.78	-0.42
Zimbabwe	11	555.46	116879	116951346	3.71	15.00	3.98	-1.81

Table 2: Descriptive statistics by country

3.2 Econometric results

In Tables 3 and 4, we display results related to Proposition 1 and 2 relying on OLS resp. FE estimators. In Table 3, all regressions control for country-specific, time-invariant effects, as well as for the *log* of production (accounting for (dis)economies of scale). Column (1) serves as the benchmark specification. We are specifically interested in the reaction of firms exploiting the mining sites following changes in profit taxes and royalties. We therefore model these fiscal policies as dummy variables, i.e. 0 to 1 in case of increase and 1 to 0 in case of decrease. Notice that given the short period under scrutiny, in the overwhelming majority of the cases we only had one fiscal policy change. In the rare occurrencies where it was not the case, we selected chronologically the first change. Furthermore, using dummies for policy changes allows us to circumvent the problem of tax rebates, i.e. cases where firms pay lower rates than the official rate. One may expect that changes in official rates, via domino effect, will translate in changes in the effective rates.

OLS regressions
Dep. Var : mine level profit

	(1)	(2)	(3)	(4)
Log(production)	38.15***	25.90***	20.94**	19.17**
	(7.330)	*(7.786)*	*(8.148)*	*(8.073)*
Tax	-98.93***	-96.96***	-94.34***	-127.0***
	(28.74)	*(28.34)*	*(28.28)*	*(29.31)*
Royalties	-66.95*	-1,070***	-1,003***	-1,086***
	(40.31)	*(240.4)*	*(245.2)*	*(243.5)*
Royalties·*Log*(prod.)		86.15***	80.49***	84.82***
		(20.37)	*(20.78)*	*(20.59)*
Reserves			1.76e-07**	1.83e-07**
			(7.36e-08)	*(7.28e-08)*
Grade			4.719	4.574
			(2.977)	*(2.944)*
Regulatory Quality				330.2***
				(88.51)
Constant	304.6***	425.8***	469.1***	610.8***
	(101.7)	*(104.2)*	*(106.4)*	*(111.9)*
Country FE	yes	yes	yes	yes
Observations	599	599	599	599
Nr. of mines	93	93	93	93
R-squared	0.169	0.194	0.203	0.222

Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 3: Results (OLS)

The coefficient on taxes is negative and significant: a decrease in tax rates induces an increase in the level of declared profits. This is in line with the result in Proposition 1 for a level of overstatement coefficient that exceed $\tilde{\beta}$. The same is true for royalties rates, once we account for the production channel through which royalties impact on profits (Column (2)). As highlighted in equation (1), since royalties apply only to firms' revenues we expect production level to adjust as a consequence of a royalty change. Column (3) displays results when accounting for physical characteristics of mines, i.e. the ore grade and the estimated reserves. In accordance with intuition, both coefficients have a positive sign, though the latter is marginally insignificant. Finally, in the last column, we tentatively control for perception indicators of institutional quality. Our theoretical model predicts that a decrease in overstatement coefficient, measured in the regressions by regulatory quality, leads to a decrease of royalties leading to an increase of capital invested and firms' profit. Indeed, regulatory quality appears with positive and statistically significant coefficients.

In Table 4, we have adopted a more restrictive specification, by adding mine fixed effects, which will control for any mine specific, time invariant characteristic. Results do remain qualitatively unchanged compared to the previous table, i.e. profit tax rates decreases induce an increase in declared profits, while royalties increases tend to reduce these profits, once we account for the interaction with production. Better institutions do contribute to higher profits, while the adoption of mine specific fixed effects already takes account of any mine characteristic like grade and reserves.

FE regressions
Dep. Var : mine level profit

	(1)	(2)	(3)	(4)
Log(production)	55.35***	31.04*	29.25	25.50
	(17.95)	*(18.63)*	*(18.71)*	*(18.87)*
Tax	-70.39***	-122.8***	-121.2***	-117.5***
	(26.61)	*(27.41)*	*(27.90)*	*(27.74)*
Royalties	-91.62**	-616.2*	-666.6*	-715.3*
	(37.58)	*(358.4)*	*(363.5)*	*(364.6)*
royalties·*Log*(prod.)		40.91	44.61	49.21
		(30.72)	*(31.07)*	*(31.17)*
Regulatory Quality		477.6***	490.5***	499.6***
		(84.85)	*(86.38)*	*(86.28)*
Tax foreign branches			-7.870	14.02
			(50.78)	*(50.77)*
Royalties foreign branches			46.40	72.27*
			(39.24)	*(40.61)*
Constant	-99.89	253.2	270.0	305.7
	(210.7)	*(221.0)*	*(221.6)*	*(223.2)*
Mine FE	yes	yes	yes	yes
Observations	599	599	599	599
Nr. of mines	93	93	93	93
R-squared	0.039	0.099	0.101	0.104

Standard errors in parentheses ; *** p<0.01, ** p<0.05, * p<0.1

Table 4: Results (FE)

Lastly, we have added two more explanatory variables to our specification, taking into account the multinational nature of most mining companies. The two variables Tax/Royalties foreign branches referring to columns (3) and (4) indicate whether mine i is related to another mine in a foreign country through the parent mining company, in which there has been a change in the tax/royalties rates in year t. More specifically, in column (3), the variables "Tax foreign branches" and "Royalties foreign branches" measure the proportion of countries where a parent mine is located and where there has been a change tax/royalties rates, while column (4) defines a dummy variable equal to one when at least one parent mine is located in a country where there has been a tax/royalties change. As can be seen, no such effect can however be highlighted from our results.

4 Conclusion

In this paper, we explore theoretically and empirically how tax changes affect firms' profits in gold mines in Africa. The main ingredient of our analysis is that governments have severe informational disadvantages vis-à-vis resource extraction companies who may overstate their extraction costs to decrease their declared profits. In a two-period model, we show how profit taxes and royalties affect the amount of capital invested to exploit a mine and ultimately the corresponding profits. This setting provides a better understanding of the effects and interactions of these two tax instruments. Our main result illustrates the crucial role of cost overstatement: the profit of the firm may depend positively or negatively on the profit tax depending on how severe is the rate of cost overstatement.

In the empirical analysis, we bring a novelty in the corresponding literature by using data at the individual mine level that allows considering production variables. Our estimations document a negative relationship between tax rate changes of the two instruments (profit tax and royalties) and the profit of the mine. Finally, recognizing the multinational nature of mining companies we investigate if the profit of a mine is sensitive to the tax change occurring in countries of sister-mines, belonging to the same mining company. This appears not to be the case in gold mines for the period under scrutiny.

From a tax policy point of view, these results underline the shortcomings of asymmetry of information for declared profit and consequently for government revenues. Reinforcing expertise of government in the mining sector appears to be a priority.

Several future research paths can extend our work. Firstly, it will be interesting to analyze the effect of tax changes in other developing countries where tax authorities may suffer from the asymmetry of information on extraction costs. Secondly, it could be interesting to explore more sophisticated forms of cost overstatement as suggested by Boadway and Keen (2015). This would imply deeper thinking of the corresponding empirical variables and it would depend on data availability.

References

[1] African Development Bank Group (ADBG), 2012, Gold Mining in Africa: Maximizing Economic Returns for Countries, Working Paper Series no. 147 (March).

[2] Boadway R., Keen M., 2010, Theoretical perspectives on resource tax design, in: Daniel P., Keen M., McPherson C. (eds.), *The taxation of petroleum and minerals*, London: Routledge.

[3] Boadway R., Keen M., 2015, Rent Taxes and Royalties in Designing Fiscal Regimes for Non-Renewable Resources, in: Halvorsen R., David F. Layton (eds.), *Handbook on the Economics of natural resources*, Cheltenham, UK.

[4] Bourgain A., Zanaj S., 2020, A tax competition approach to resource taxation in developing countries, *Resources Policy*, 65.

[5] Brown E. C., 1948, Business-Income Taxation and Investment Incentives, in: *Income, Employment and Public Policy: Essay in Honor of Alvin H. Hansen*, New York: Norton.

[6] Campbell B., 2010, Revisiting the reform process of African mining regimes, *Canadian Journal of Development Studies*, 30, 1-2, 197-217.

[7] Collier P., 2010, Principles of resource taxation for low-income countries, in: Daniel Ph., Keen M., McPherson Ch.(ed), *The taxation of petroleum and minerals*, London: Routledge.

[8] Dwenger N., Steiner V., 2012, Profit Taxation and the Elasticity of the Corporate Income Tax Base: Evidence from German Corporate Tax Return Data, *National Tax Journal*, March, 65 (1), 117–150

[9] Fraser Institute, 2015, Survey of Mining Companies, Annual Survey.

[10] Gruber J., Rauh J., 2007, How Elastic Is the Corporate Income Tax Base?, in: Auerbach A. J.; Hines J. R., Slemrod J., Taxing Corporate Income in the 21st Century, 2007, pp. 140-63, Cambridge and New York: Cambridge University Press

[11] Hotelling H., 1931, The Economics of Exhaustible Resources, *Journal of Political Economy*, Vol. 39, 137–175.

[12] IMF, 2012, Fiscal Regimes for Extractive Industries: Design and Implementation, August 15.

[13] Kawano L. and Slemrod J., 2016, How do corporate tax bases change when corporate tax rates change? With implications for the tax rate elasticity of corporate tax revenues, *International Tax and Public Finance*, 23:401–433.

[14] Laporte B., de Quatrebarbes C., 2015, What do we know about the mineral resource rent sharing in Africa?, *Resources Policy*, 46, 239-49.

[15] Laporte B., de Quatrebarbes C., Bouterige Y., 2016, La fiscalité minière en Afrique : Un état des lieux sur le secteur de l'or dans 14 pays de 1980 à 2015, FERDI Working Paper 164, Sept.

[16] Mansour M., Świstak A., 2016, Tax competition and coordination in extractive industries, in : Philip D., Keen M., Świstak A, (eds.), *International Taxation and the Extractive Industries,* New York: Routledge.

[17] Moussa S.N., Deyi J., Lin L., 2015, Analysis of Guinean new mining fiscal regime: Considerations for improvement, *Resources Policy*, 46, 113.126.

[18] O'Connor F.A., Lucey B.M., Baur D.G., 2016, Do gold prices cause production costs? International evidence from country and company data, *Journal of International Financial Markets, Institutions and Money*, 40, 186-196.

[19] Philip D., Keen M., Świstak A, (eds.), 2016, *International Taxation and the Extractive Industries: Resources without Borders,* New York: Routledge.

[20] Smith J., 2013, Issues in extractive resource taxation: A review of research methods and models, *Resources Policy*, 38, 320-331.

[21] Tilton J. E., 2004, Determining the optimal tax on mining, *Natural Resources Forum*, 28, 144-149.