



# A tax competition approach to resource taxation in developing countries<sup>☆</sup>

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## ABSTRACT

In this paper, we investigate the effect of cost misreporting of extractive firms on the optimal design of tax policies. We build a two-period, two-country model where governments aim to attract a foreign-owned multinational firm to raise tax revenues by levying a profit tax and a royalty. The firm overstates its production costs to reduce declared profits and it decides in which country to locate. We find that cost overstatement pushes royalties upward but remains detrimental for tax revenues as well as the capital invested by the firm. The mining country that attracts the extractive firm is often the country with the highest coefficient of overstatement. However, the firm may locate in the country with the lowest overstatement and lowest royalty if both countries have the same profit tax. Reinforcing expertise in mining sectors to reduce asymmetries of information between firms and tax authorities appears to be a priority in developing resource countries.

## 1. Introduction

The strong dependence of some developing countries on extractive resources is a well-known source of vulnerability. Most of these countries have low tax rates and often proceed by trial and error in using various instruments to tax the rent on non-renewal resources. Previous research suggests the use of both royalties and profit taxes (corporate income tax, for example) among a range of other tax categories for extracting resources (IMF, 2012). 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 interesting when considering the possibility for mining companies to reduce their taxable income by cost manipulation. Boadway and Keen (2010, 2015) justify the use of profit taxes and royalties in presence of asymmetries of information. This aspect is particularly relevant for low-income countries where governments have a severe informational disadvantage vis-à-vis resource extraction companies (Collier, 2010).

Among the open questions, an important one concerns the pressures from international tax competition for attracting mining companies on

resource tax policy. In this paper, we aim to give some insight into this issue. More specifically, we contribute to the research on tax design for extractive resources in low-income countries under international tax competition. We build a partial equilibrium model of two countries where the government sets royalties and profit taxes to attract a foreign extractive firm.

A number of signals and stylized facts observed in different developing countries suggests the presence of forms of international tax competition for attracting multinational mining companies<sup>1</sup> for instance, in sub-Saharan Africa reforms of mining codes began in the 1980s and were generalized across the continent in the 1990s.<sup>2</sup> They led to the widespread adoption of liberalized mining codes, the wholesale privatization of state companies, an end to foreign ownership restrictions. The new codes are designed to attract foreign investment through various incentives to foreign mining companies (Campbell, 2010; Besada and Martin, 2013; Moussa et al., 2015). Thus the framework for an international tax competition is in place. In 2014, the Ivorian Parliament approved a new mining code, with the aim of attracting more international investors in gold extraction, which has

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<sup>1</sup> To the best of our knowledge, there is no econometric analysis on international tax competition for resource extraction in developing countries. Unfortunately, despite the progress generated by the Extractive Industries Transparency Initiative (EITI), the available data do not allow for the construction of a relevant taxation indicator on an extended period.

<sup>2</sup> Similar reforms have occurred in Latin American countries (NSI, 2013).

long been neglected in this country, compared to its neighbors. A special tax on exceptional profits has been removed from the project.<sup>3</sup> In March 2016, the government of Ghana agreed to lower the corporate tax from 35% to 32.5% in addition to lowering the royalty rate for Gold Fields, a South African company that was reviewing a \$100 million expansion of gold mining operations in the country.<sup>4</sup> In addition, in Zambia, some initiatives were taken in 2015 to redesign the mining tax regimes in order to make the country more attractive to foreign investors.

According to the Mining Tax Database for Africa developed by Laporte et al. (2016), updated in 2018, covering 21 African gold-producing countries, the average rate of corporate income tax decreased from 30% to 25.9% on the period 2000–2018.<sup>5</sup> Ten countries, including Burkina-Faso, Côte d'Ivoire, Guinea, Mali, South Africa, have decreased their rate. In parallel, the average rate of royalties rose from 3.9 to 4.6% (14 pays have increased their rate; including Burkina-Faso, Côte d'Ivoire, Guinea, Mali, Mauritania, Zimbabwe). Note that these two opposite evolutions will be rationalized in our model.

The specialized press regularly reports issues typically associated with strategies consistent with international tax competition to attract mining companies. For example, the Fraser Institute conducts an annual survey asking managers of mining companies to grade countries and states according to their investment potential (Fraser Institute, 2015). An index of perceived attractiveness is constructed on the basis of 15 policy factors that influence company decisions to invest in various jurisdictions. Taxation features (including personal, corporate, payroll, capital and other taxes, and the complexity of tax compliance) appear prominently.<sup>6</sup>

In this paper, we set a model of tax competition between two countries that aim to attract a foreign-owned multinational firm. The firm chooses its location by taking into account the tax burden, royalties and rent tax to be paid in each country. Tax authorities in each country must rely on self-reporting by the firm to establish tax liabilities, which - though the government has an opportunity to audit those reports - puts firms in a position of informational advantage. This asymmetry is always present, but is particularly marked in the resource sector in developing countries. More specifically, following Boadway and Keen, we assume that the resource firm purposefully overstates its costs, with the aim of paying lower taxes. The tax authority in the developing country is unable to identify the overstatement. The two governments need to decide the optimal tax policy to attract the firm to their country while still collecting the highest possible tax revenue. A conflict is inherent because higher taxes increase tax revenues but may push the firm towards the other country. In such a setting, we analyze the role of royalties in tax competition. In the absence of information about how firms decide the rate of cost overstatement, we analyze two scenarios. In the first, the rate of overstatement of productions costs is a constant coefficient. In the second scenario, costs are overstated with a coefficient that depends positively on the profit tax in the country.

Our main result can be summarized as follows. Under a constant rate of overstatement, asymmetries of information are detrimental for all agents - for the governments as well as for the firms' profits. Furthermore, inefficiencies are amplified because in order to be attractive, a

<sup>3</sup> [www.mining.com](http://www.mining.com), 3.29.2016. *These new fiscal measures are greatly appreciated by the mining company, Randgold (based in Caïman), and can also be found in other African countries.*

<sup>4</sup> *This large mining company, with operations from Australia to Peru, had not yet decided whether to inject more cash into the project or keep the gold in the ground.*

<sup>5</sup> <https://fiscalite-miniére.ferdi.fr/>.

<sup>6</sup> *In regards to African countries, in the 2015 report, the changes in fiscal regimes is the most commonly mentioned topic in the comments made by top executives to justify their gradings, followed by corruption issues. According to a United Nations survey of mining companies in 2005, 60% of the top 10 decision criteria a prospective mining investor considers before undertaking a mining project are tax related (see Ernst & Young, Taxation of extractive industries in East and Central Africa. Are these in harmony? Africa Tax Conference, 2015.).*

country will decrease the profit tax rate and increase the royalty.

Our study contributes to two strands of the existing literature, namely the optimal tax policy design in extractive industries and the international public economics literature.

Since the pioneering work of Hotelling (1931) and Brown (1948), an abundant literature on resource taxation has focused on tax instruments capable of capturing a portion of the specific rents in the mining industry. Indeed, the distinctive features of extractive industries as the relatively fixed supply, collective ownership of resources and information asymmetry can legitimate an inefficient taxation as royalties (Boadway and Keen, 2010). Royalties involve inefficient resource exploitation (depletion) and tend to take complex forms in order to be more responsive to profitability (Garnaut and Clunies-Roos, 1975, 1983; Otto et al., 2006). Taxation engineering has been developed to model the effects of various taxes on extractive resources (cf. the survey by Smith, 2013). In our paper, following Boadway and Keen (2010, 2015), we are *not* interested in exploring the different types of royalties and rent taxes, but rather focus on a combination of a simple royalty and a profit tax introduced into a tax competition setting.

The tax competition literature has generally neglected the extractive industries. These industries, such as mining for instance, are unique and not easily compared to other generic sectors. Countries hosting mines must compete for highly mobile international exploration and development investment capital. Furthermore, many mines are hosted by developing countries that suffer from a lack of expertise in mining that negatively affects their ability to verify the tax declarations of foreign firms. Hence, classical tax competition models are unadapted to analyzing the effect of tax competition on tax design in the extractive sectors of developing countries. The objective of this paper is to offer a suitable setting to highlight the specificities of these industries and corresponding countries in the context of open economies. The classical tax competition literature concentrates on the size of the countries, finding that the firm always invests in the larger country when the home market effect is stronger than the tax incentives offered by the small country (Hauffer and Wooton, 1999). Market size plays a minor role when countries broaden their fiscal instruments by competing not only through taxes, but also through the level of infrastructure that boosts the profits of firms (Justman et al., 2001.; Hindriks et al., 2008; Pieretti and Zanj, 2011 among others). Barros and Cabral (2000) consider a subsidy game between asymmetric countries aiming to attract foreign direct investments to alleviate unemployment. In equilibrium, the winner is the country that gains the most in terms of employment for given transportation costs. Here, we outline a similar game where two countries where the government sets royalties and profit taxes to attract a foreign extractive firm in the context of cost overstatement by the firm.

The structure of the paper is as follows. Section 2 sets out the model. Sections 3 develops the analysis of tax decision under constant overstatement. In Section 4, we present the tax choices in the absence of cost overstatement to underscore the effect of these asymmetries of information. Conclusions are provided in Section 5.

## 2. The model

Consider a two-period model with two countries denoted by  $a$  and  $b$ . Each country hosts a mine that can be exploited by a foreign firm.<sup>7</sup> Each government imposes an *ad valorem* royalty at rate  $\theta_i$ ,  $i = a, b$  on the revenues of the extracting firm and a *profit tax* on reported rents/profits at rate  $\tau_i$ ,  $i = a, b$ . Tax authorities in each country rely on firm self-reporting to establish tax liabilities, putting the firm at a significant informational advantage as compared to the tax authority.

A resource firm decides which mine to exploit while operating in a

<sup>7</sup> *We focus on the effects of international tax competition on tax design and therefore make the simplifying assumption that only foreign multinational firms that are mobile can exploit the mine.*

competitive commodity market. Previous work has shown that the price of the extracted good, as for instance gold, is fixed on the global market.<sup>8</sup> It follows that the price  $p$  of the mineral is the same in both countries and normalized for simplicity.

The resource firm is a foreign-owned multinational that decides to locate its branch either in country  $a$  or in  $b$ . The monopoly condition of the mine is dictated by the nature of the market. As a matter of fact, the right to exploit a mine is usually given exclusively only to one firm. The firm is risk-neutral and capital markets are competitive and efficient.

The production technology is simplified so that the producer incurs capital costs for exploration and development in the *first period*, and only costs of extraction in the *second period*, when the resource is being exploited. Hence, the resource firm incurs an initial investment  $K$  in the first period in order to generate a quantity of the resource  $q(K)$  with certainty in the second period. The corresponding extractive costs in the second period are given by  $C[q(K)]$ ,  $\partial C[q(K)]/\partial K > 0$ ;  $\partial^2 C[q(K)]/\partial^2 K > 0$ . Finally, under competitive and efficient global credit markets, the 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 key assumption of the model is that the resource firm may overstate production costs by multiplying these costs by a factor  $\beta$  that exceeds one. Crucially, the tax authority is unable to know the nature of the extractive cost of the firm, hence it is unable to determine whether the factor  $\beta$  is cost overstatement or it is part of the production costs of the firm.

Two scenarios are analyzed. In the first, overstatement is country specific, *tax independent*, fixed coefficient  $\beta_i$

$$\beta_i \geq 1, \quad i = a, b,$$

whereas in the second scenario, the overstatement is assumed to be a linear function of the *profit tax*  $\tau_i$

$$\beta_i \tau_i \geq 1, \quad i = a, b.$$

In the second scenario, as in [Boadway and Keen \(2010\)](#) the higher the rent tax in the country, the higher the firm's incentive to overstate its costs. In both scenarios, we assume that the coefficient of overstatement is country specific. This suggests that overstatement does not depend on the firm but on features of the country such as the level of corruption in a country or the country's lack of expertise. Our hypothesis is that the higher the level of corruption and/or the weaker the expertise in mining technologies, the larger the door to cost overstatement. For readability of the paper, we relegate the analysis of the second scenario in [Appendix B](#).

The two governments are assumed to be risk-neutral, to be imperfectly informed, and to be able to commit to the tax policy they announce before location takes place. This time consistency of the tax policy may be guaranteed by international contracts law.

The objective function of the government intervention is to raise revenues as well as to attract the firm to its country. The two governments anticipate that the firm selects its location based on profits after tax and thus the governmental decision is affected by the classical horizontal tax externality that appears when tax competition for mobile tax bases induces a race to the bottom, resulting in inefficiently low tax receipts.

In the next section, we investigate the scenario of constant overstatement. First, we define the optimal tax policy and the corresponding capital investment, then we analyze the tax competition aspects. In [Section 4](#), we turn our attention to the scenario with absence of overstatement, where we again look at the optimal capital investment as well as the location decision of the firm in a tax competition setting. [Section 5](#) concludes.

<sup>8</sup> The price-taking behavior of the extractive firm in the market for the resource is documented in [O'Connor et al., \(2016\)](#).

### 3. Optimal tax design under constant overstatement

#### 3.1. Absence of tax competition

The firm select an amount of invested capital to maximize its *real* profit. To obtain closed form solutions, in line with the existing literature ([Boadway and Keen, 2010, 2015](#)), we assume that final transformation follows a linear function  $q(K) = \alpha K$  whereas extractive costs are, for simplicity, quadratic  $C(q(K)) = \frac{1}{2} \left[ \frac{1}{\alpha} q(K) \right]^2$ . The parameter  $\alpha$  is an efficiency measure.

The net profit of the firm writes as:

$$\Pi_i(\tau_i, \theta_i) = (1 - \tau_i) \left( -K_i + \frac{(1 - \theta_i)\alpha K_i - \frac{1}{2}K_i^2}{1 + r} \right), \quad i = a, b \quad (1)$$

The profit of the firm is composed of two parts. The first part is simply the initial capital  $K_i$  invested in the first period in country  $i$ ; the second part of the profit consists in the net present value of the total revenues from selling the final output quantity  $(1 - \theta_i)\alpha K_i$  minus the extraction costs  $\frac{1}{2}K_i^2$ .

Being concavity conditions satisfied, optimal capital investment as a function of taxes is given by:

$$K_i(\theta_i) = \alpha(1 - \theta_i) - r - 1 > 0, \quad i = a, b \quad (2)$$

We assume  $\alpha(1 - \theta_i) > 1 + r$ : the net productivity of the transformation technology  $\alpha(1 - \theta_i)$  in each country  $i$  is higher than the alternative investment of a unit of capital. This assumption guarantees that the firm has incentives to invest its capital to exploiting a mine rather than simply deposit it and receive the interest rate  $r$ . Clearly, the higher the royalty  $\theta_i$ ,  $i = a, b$ , the lower the invested capital.

The government in each country  $i$ ,  $i = a, b$ , selects the tax policy mix  $(\tau_i, \theta_i)$  to maximize the amount of tax revenues  $R_i(\tau_i, \theta_i)$ , namely,

$$R_i(\tau_i, \theta_i) = \frac{1}{1 + r} \left\{ \theta_i[\alpha K_i(\theta_i)] + \tau_i \left[ (1 - \theta_i)\alpha K_i(\theta_i) - \beta_i \frac{1}{2} [K_i(\theta_i)]^2 \right] \right\}, \quad i = a, b.$$

Governmental tax receipts are also composed of two parts. The first captures tax receipts from royalties  $\theta_i[\alpha K_i(\theta_i)]$ , levied over firms' revenues  $\alpha K_i(\theta_i)$ . The second part consists of tax receipts from levying the profit tax,  $\tau_i \left[ (1 - \theta_i)\alpha K_i(\theta_i) - \beta_i \frac{1}{2} [K_i(\theta_i)]^2 \right]$ . Differently from royalties, the profit tax is applied over the entire declared profit.

To obtain the optimal tax policy  $(\tau_i^*, \theta_i^*)$ ,  $i = a, b$ , we check that concavity conditions of  $R_i(\tau_i, \theta_i)$ . We find that the FOCs are satisfied with respect to the royalty leading to an internal solution, whereas the optimal profit tax is a corner solution. Since  $\partial R_i(\tau_i, \theta_i)/\partial \tau_i > 0$ ,  $i = a, b$ , it follows that each government fixes the highest possible profit tax named  $\tau_i^{\max}$ ,  $i = a, b$ .<sup>9</sup>

We can state the following result:

**Proposition 1.** *Assuming a constant coefficient of cost overstatement, a revenue maximizing government selects the highest profit tax possible  $\tau_i^{\max}$  and a royalty rate  $\theta_i^*$  given by*

$$\theta_i^* = \frac{(1 + r - 2\alpha + \beta_i(\alpha - r - 1))\tau_i^{\max} + (\alpha - r - 1)}{\alpha(2(1 - \tau_i^{\max}) + \beta_i\tau_i^{\max})}, \quad i = a, b \quad (3)$$

*Positivity of the optimal royalty is guaranteed under the condition*

$$\alpha > (r + 1) \frac{1 + \tau_i^{\max}(\beta_i - 1)}{1 + \tau_i^{\max}(\beta_i - 2)}. \quad (4)$$

<sup>9</sup> We remain agnostic about the level of such a tax  $\tau_i^{\max}$ ,  $i = a, b$ , 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.

**Proposition 1** shows that in the 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 asymmetries of information between the government and the firm(s).

To gain insights on how well the model predicts the tax decision of extractive countries, we simulate the tax decision using data from Mining Tax Database for Africa<sup>10</sup>(Laporte et al., 2016). This database focuses on gold-producing countries in Africa and it documents that profit taxes in extractive industries range between 5% to 35%. Considering this range of values for profit taxes and setting parameters  $\alpha = 1.7$  and  $r = 10\%$ , we show in Fig. 1, the optimal royalties rates given by our model in equation (3). More specifically, we graph the royalty rates (3) for country  $i$  and  $j$  as a function of the overstatement coefficient. Each graph in Fig. 1 corresponds to different pairs of profit taxes  $(\tau_i^*, \tau_j^*)$ . We start with the highest possible difference in profit taxes namely  $\tau_i = 35\%$ (red) and  $\tau_j = 5\%$ (black); then  $\tau_i = 35\%$ (red) and  $\tau_j = 15\%$ (black);  $\tau_i = 35\%$ (red) and  $\tau_j = 20\%$ (black);  $\tau_i = 35\%$ (red) and  $\tau_j = 25\%$ (black);  $\tau_i = \tau_j = 35\%$ .<sup>11</sup>

The resulting royalties produced by our model well match data observed in Mining Tax Database for Africa. Namely, as stated in this database, the royalty rates range between 1% to 15%. As one can observe through the graphs, the royalty  $\theta_j(\beta)$  gets smaller as the profit tax  $\tau_j$  moves from 5% to 35%. Furthermore, in line with Fig. 1, comparative statics on the optimal royalty rates suggest that the higher the overstatement coefficient, the higher the optimal rate of the royalty.

$$\frac{\partial \theta_i^*}{\partial \beta_i} = \tau_i^{\max} \frac{\alpha - (1 - \tau_i^{\max})(1 + r)}{\alpha(-2\tau_i^{\max} + \beta_i \tau_i^{\max} + 2)} > 0, \quad i = a, b$$

The intuition of this relationship is as follows. An increase of the overstatement coefficient  $\beta_i$  implies that the firm declares a smaller profit because it amplifies more 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 costs.

To discern the relationship between the royalty and the profit tax, we explore the sign of  $\frac{\partial \theta_i^*}{\partial \tau_i^{\max}}$ . If  $\beta_i > 2\frac{\alpha}{\alpha-r-1}$ ,  $i = a, b$ , then  $\frac{\partial \theta_i^*}{\partial \tau_i^{\max}} > 0$ , otherwise,  $\frac{\partial \theta_i^*}{\partial \tau_i^{\max}} < 0$ . When  $\beta$  is very high, the two tax instruments are complements: the higher the profit tax, the higher the royalty. By contrast, when  $\beta$  is small, the tax instruments are substitute: 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  $\beta$ , the government observes very large declared extraction costs and very reduced declared profits. Accordingly, to optimally collect tax receipts, 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  $\beta$  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

<sup>10</sup> The case of African gold-producing countries is particularly relevant to calibrate our model. In Latin American Mineral-producers countries have very comparable royalty and CIT rates (NSI, 2013), but we do not have a database as accurate as for Africa.

<sup>11</sup> All these values are consistent with condition (4).

overstatement is that  $\beta_i$ ,  $i = a, b$ , does not exceed two. Hence, for  $1 \leq \beta_i < 2$ ,  $i = a, b$ , the inequality  $\beta_i < 2\frac{\alpha}{\alpha-r-1}$  is always satisfied, leading to a negative relationship between the profit tax and the royalty.

Summarizing,

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

*The optimal capital investment obtains as*

$$K_i^* = \frac{\alpha - (1 - \tau_i^{\max})(1 + r)}{2(1 - \tau_i^{\max}) + \beta_i \tau_i^{\max}}, \quad i = a, b$$

Comparative statics on capital invested yield  $\frac{\partial K_i^*}{\partial \beta_i} < 0$  and  $\frac{\partial K_i^*}{\partial \tau_i^{\max}} > 0$  for  $\beta_i < 2$ . Hence,

**Lemma 2.** *The optimal level of invested capital depends negatively on the coefficient of overstatement and 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, profit tax implies lower royalties, which ultimately leads to an increase in the invested capital. Quite on the contrary, a higher  $\beta$ , implies higher royalty, and therefore by equation (2), lower invested capital.

Finally, we can evaluate both the real profit of the firm and the tax revenue for the government at the optimal taxes:

$$\Pi_i^* = \frac{(1 - \tau_i^{\max})}{2(1 + r)} \frac{(\alpha - r - 1 + \tau_i^{\max}(1 + r))^2}{(2 - \tau_i^{\max}(2 - \beta_i))^2} > 0, \quad i = a, b$$

and

$$R_i^* = \frac{1}{2} \frac{(\alpha - r - 1 + \tau_i^{\max}(1 + r))^2}{2 - (2 - \beta_i)\tau_i^{\max}} > 0, \quad i = a, b$$

As expected, the overstatement of extraction costs has clearly a negative impact on tax revenues  $\frac{\partial R_i^*}{\partial \beta_i} < 0$ . Unexpectedly, cost overstatement has also detrimental effects on firm's profits:  $\frac{\partial \Pi_i^*}{\partial \beta_i} < 0$ . In fact, cost overstatement induces the government to raise royalties to offset the negative impact of amplified extraction costs, ultimately leading to negative effects on firm's profits.

To conclude, in absence of tax competition threats, reducing cost overstatement is a win-win action for both stakeholders. It brings higher profits for the firm and higher tax revenues for the government.

### 3.2. Tax competition

In this section, we assume that the foreign firm can place its investment in one of two countries. What is the optimal policy mix  $(\tau^*, \theta^*)$  that allows the government not only to maximize tax revenues but also to attract the firm to its territory? The firm locates in country  $i$  if and only if  $\Pi_i^* > \Pi_j^*$ .<sup>12</sup> Note that even if our setting remains quite simple, there are several forces in place that attract or repel a firm from a country. For instance, it is unclear whether the magnitude of cost overstatement attracts a firm in a country. The size of  $\beta$  positively affects the royalty rate but it negatively impacts the invested capital. Similarly, it is unsure how the profit tax affects the decision of the firm where to locate. The profit tax obviously shrinks the net profit, but it also reduces the royalty rate, which in turn boosts invested capital and profit. What is the balance of these forces and under what conditions is that balanced

<sup>12</sup> It is important to notice that the location decision is made considering the real profit and not the declared one.

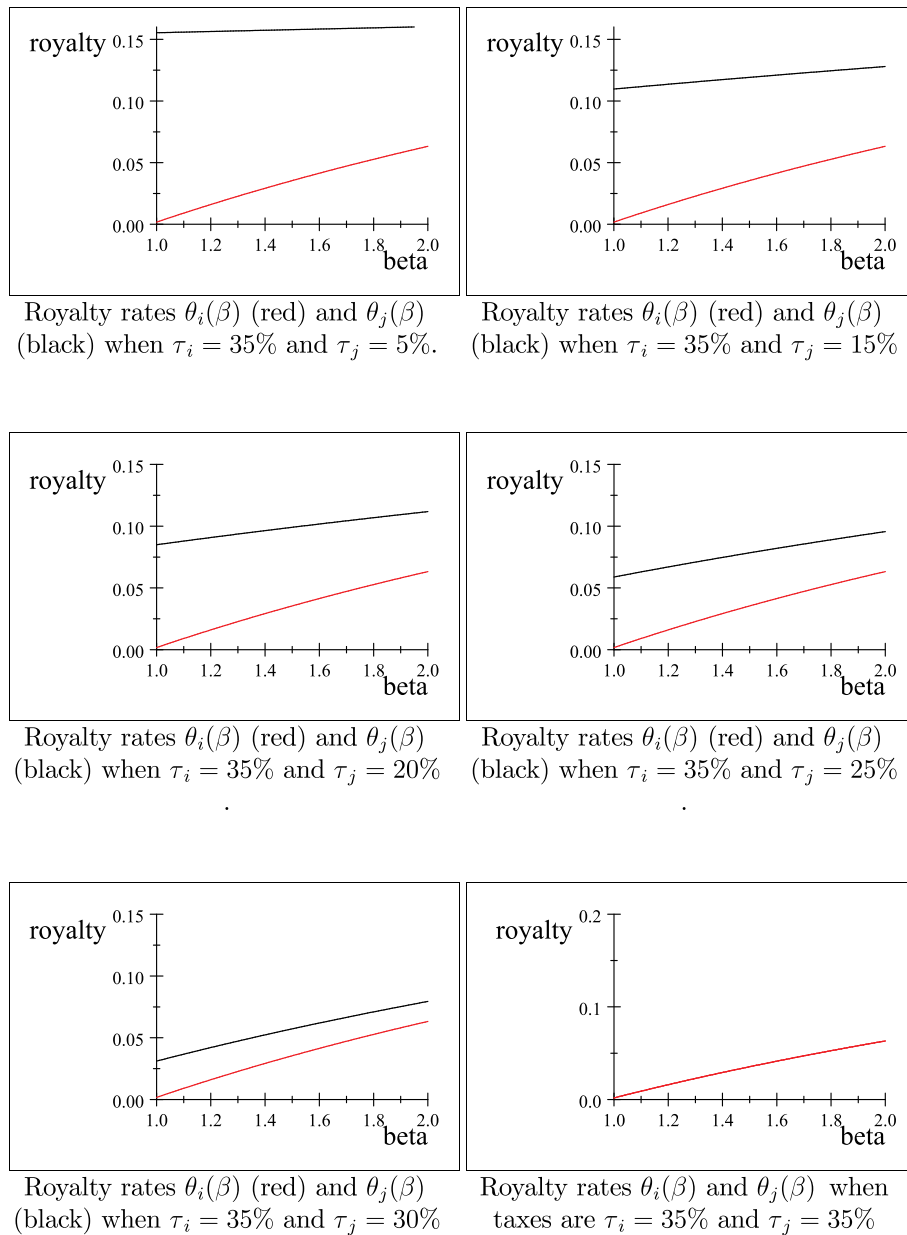


Fig. 1. Optimal royalty rates  $\theta_i(\beta)$  and  $\theta_j(\beta)$

reached is the topic of the analysis that follows.

We proceed in steps. We first offset the effect of the difference in overstatements by assuming countries are characterized by the same overstatement i.e.  $\beta_i = \beta_j = \beta$ . By doing so, we highlight the role of profit taxes in making a country attractive for foreign firms. The profit differential  $\Pi_i^* - \Pi_j^*$  is given by

$$\Pi_i^* - \Pi_j^* = \frac{1}{2(r+1)} \left( \frac{(1 - \tau_i^{\max})(\alpha - r - 1 + \tau_i^{\max} + r\tau_i^{\max})^2}{(-2\tau_i^{\max} + \beta\tau_i^{\max} + 2)^2} - \frac{(1 - \tau_j^{\max})(\alpha - r - 1 + \tau_j^{\max} + r\tau_j^{\max})^2}{(-2\tau_j^{\max} + \beta\tau_j^{\max} + 2)^2} \right), \quad j, i = a, b; j \neq i \tag{5}$$

To analyze the sign of the above difference notice that the expression (5) is simply the difference of the same function  $\Pi_i^*$ , evaluated at two different levels of the profit tax, namely  $\tau_i^{\max}$  and  $\tau_j^{\max}$ . Hence, to study the sign of the difference  $\Pi_i^* - \Pi_j^*$ , as a sufficient condition we check the

sign of the derivative  $\frac{\partial \Pi_i^*}{\partial \tau_i^{\max}}$ . We prove in [Appendix A](#) that this derivative can be either positive or negative depending on the level of profit taxes  $\tau_i^{\max}$  and  $\tau_j^{\max}$ . In [Appendix A](#), we define a threshold value  $\tilde{\tau}$  and show that the derivative  $\frac{\partial \Pi_i^*}{\partial \tau_i^{\max}}$  is positive for  $\max\{\tau_i^{\max}, \tau_j^{\max}\} < \tilde{\tau}$ , and negative for  $\max\{\tau_i^{\max}, \tau_j^{\max}\} > \tilde{\tau}$ . It follows that if  $\tau_i^{\max}$  and  $\tau_j^{\max}$  are both smaller than  $\tilde{\tau}$ , then  $\Pi_i^* - \Pi_j^* > 0$ . However, if both  $\tau_i^{\max}$  and  $\tau_j^{\max}$  exceed  $\tilde{\tau}$ , then  $\Pi_i^* - \Pi_j^* < 0$ .

The result is summarized in the following proposition:

**Proposition 2.** Assume countries have the same cost overstatement. Tax competition privileges the country offering the highest profit tax if profit taxes in both countries do not exceed a threshold value  $\tilde{\tau}$ . By contrast, if profit taxes are set higher than  $\tilde{\tau}$  in both countries, then the firm locates in the country with the lowest profit tax.

Surprisingly, having a higher profit tax does not hinder attracting a foreign firm. The reason is that the accompanying royalty rate is more advantageous than in the rival country. In fact, when  $\tau < \tilde{\tau}$ , the

attractive country  $i$  has the highest profit tax but the smallest royalty i.e.  $\tau_i^{\max} > \tau_j^{\max}$  but  $\theta_i^* < \theta_j^*$ ,  $i, j = a, b, i \neq j$ . By contrast, when  $\tau > \bar{\tau}$ , the attractive country  $i$  has the smallest profit tax and the has the smallest profit tax and the highest royalty, i.e. highest royalty, i.e.  $\tau_i^{\max} < \tau_j^{\max}$  but  $\theta_i^* > \theta_j^*$ ,  $i, j = a, b, i \neq j$ .

As an illustration, we run simulations of the profit functions displayed in Fig. 2. To do so, we use the same parameter values as above, namely  $\alpha = 1.7$  and  $r = 10\%$ . We consider as before several combinations of profit taxes:

$$(\tau_i^*, \tau_j^*) = (35\%, 5\%); (35\%, 15\%); (35\%, 20\%); (35\%, 25\%); (35\%, 30\%); (35\%, 35\%).$$

These values of profit taxes are in line with the real profit tax rates in Laporte et al., 2016. The profit in country  $i$  (in red) is higher than the profit  $\Pi_j^*$  (in black) the (in black) firm makes if located in country  $j$ . Therefore for all these combinations of profit taxes we have  $\Pi_i^* - \Pi_j^* > 0$ . This is the case because the threshold  $\bar{\tau}$  is given by  $\bar{\tau} = 57\%$ .

This means that setting any profit taxes in the range (5%, 35%), is a sufficient condition for country  $i$  to attract the firm, because for  $\tau_i$  and  $\tau_j$  in the range (5%, 35%),  $\Pi_i^* > \Pi_j^*$  implying  $\Pi_i^* - \Pi_j^* > 0$ . The reason is that country  $i$  offers a lower royalty rate than country  $j$ . For instance if the rival country  $j$  fixes a very low profit tax, say  $\tau_j = 5\%$ , and country  $i$  fixes a profit rate of 35%, royalty rate in  $i$  is 3% whereas country  $j$  has a royalty of 15%.

Hence, extractive countries may use interchangeably profit taxes or royalties as means of attractiveness. As long as the profit tax does not exceed a threshold value, then the high profit tax determines a low royalty, making the country with the highest profit tax attractive. The instrument of attractiveness is the low royalty. Quite on the contrary, when profit taxes in both countries are fixed at levels that exceed a certain threshold, then the firm tries to avoid the countries with the highest profit tax. In this range of values, the profit tax becomes the instrument of attractiveness, regardless of the corresponding level of the royalty.

We now turn to the role of the rate of overstatement in the tax competition game. To do so, for the time being, we switch off the role played by the profit tax differential assuming  $\tau_i^{\max} = \tau_j^{\max} = \tau$ .

Then, the firm decides where to locate by the sign of the profit differential:

$$\Pi_i - \Pi_j = (\beta_j - \beta_i) \frac{(1 - \tau)(\alpha - 1 - r + \tau(1 + r))^2}{2(1 + r)} - \frac{\tau(4(1 - \tau) + \tau(\beta_i + \beta_j))}{(2 + \tau(\beta_j - 2))^2(2 + \tau(\beta_i - 2))^2} \tag{6}$$

The study of the profit differential leads to the following result:

**Proposition 3.** Assume the same profit tax in each country. The firm locates in the country with the lowest cost overstatement.

**Proof 1.** The sign of the difference (6) is given by the sign of  $4 - 4\tau + \tau(\beta_i + \beta_j)$  and  $(\beta_j - \beta_i)$ . Since  $0 < \tau < 1$ , then  $4 - 4\tau + \tau(\beta_i + \beta_j) > 0$ , implying  $\Pi_i - \Pi_j > 0$  iff  $(\beta_j - \beta_i) > 0 \Leftrightarrow \beta_j > \beta_i$ ,  $i, j = a, b, i \neq j$ . ■

The intuition behind the above proposition lays in the relationship between the cost overstatement and the level of royalty. Recall that the lower cost overstatement, the lower the royalty. Therefore, when profit taxes of both countries are the same, the most attractive location corresponds to the country with the lowest cost overstatement, where the royalty is the lowest and invested capital is the highest.

As above, to illustrate, to illustrate our analysis, our analysis, we represent in Fig. 3, the profits  $\Pi_i^*$  (red) and  $\Pi_j^*$  (black) for any  $\tau \in (0, 1)$  with  $\tau_i^{\max} = \tau_j^{\max} = \tau$ , assuming  $\alpha = 1.7, r = 10\%$  and  $\beta_i = 1.5$ . Country  $i$  attracts the firm offering higher profits i.e.  $\Pi_i^* - \Pi_j^* > 0$  if  $\beta_j > \beta_i$ , whereas it does not attract the firm because  $\Pi_i^* - \Pi_j^* < 0$  if  $\beta_j < \beta_i$ .

The final scenario to consider embodies the interplay between the role played by the overstatement, which determines the royalty, and the magnitude of the profit tax. To disentangle these two forces, we need a direct comparison of the profits, which results to be quite cumbersome for any value of the overstatement coefficient and any value the profit tax. For this reason, we simulate the profit functions in country  $i$  and country  $j$  for admissible values of the parameters.

First, consider a high difference in profit taxes namely  $\tau_i^{\max} = 35\%$  and  $\tau_j^{\max} = 5\%$ . As before, set  $\alpha = 1.7$  and  $r = 10\%$ . Then, we ask which country attracts the firm and what is the role of  $\beta_i$  and  $\beta_j$ . In Fig. 4, the profit difference  $\Pi_i^* - \Pi_j^*$  is shown in the  $y$ -axis and the value of  $\beta_j$  in the  $x$ -axis. As far as it concerns  $\beta_i$ , we consider four different levels of  $\beta_i$ , 1.1; 1.3; 1.5; 1.7 and build four different curves  $\Pi_i^* - \Pi_j^*$ . The highest of curve corresponds to  $\beta_i = 1.1$ .

As the value of  $\beta_i$  increases, the curve  $\Pi_i^* - \Pi_j^*$  shifts down but it remains positive. Hence, country  $i$  with a much higher tax rate than country  $j$  attracts the firm in its territory, for any  $\beta_j, \beta_j \geq \beta_i$ . The reason of attractiveness is the lower royalty.

We reproduce the same simulations in Fig. 5 but we now consider a small difference in profit taxes namely  $\tau_i^{\max} = 20\%$  and  $\tau_j^{\max} = 18\%$ . As we can see, simulations display the existence of a threshold value  $\tilde{\beta}$ , where the curve of the profit difference  $\Pi_i^* - \Pi_j^*$  turns from negative to positive showing that there exists a value of overstatement such that the country  $i$  is attractive even though it has higher profit taxes. The firm locates in the country  $i$  with  $\tau_i^{\max} = 20\%$  and not in  $j$  with  $\tau_j^{\max} = 18\%$  if  $\beta_j > \tilde{\beta}$  (on the graph, on the right of  $\tilde{\beta}$ ,  $\Pi_i^* > \Pi_j^*$ ). Conversely, the firm locates in the country with the lowest profit tax if the rate of overstatement does not exceeds  $\tilde{\beta}$  (on the graph, on the left of  $\tilde{\beta}$ ,  $\Pi_i^* < \Pi_j^*$ ). As earlier, the reason for attractiveness is the lower royalty.

Hence.

**Proposition 4.** Assume the profit taxes in two countries do not differ much. If overstatement in a country remains relatively low, then a country is attractive for foreign firms through low royalty. If the rate of overstatement is relatively high, then a country is attractive for foreign firms through low profit tax.

Our analysis shows countries suffering from a high overstatement, the inefficiencies related to royalties are amplified. Indeed, to be attractive, these countries fix low profit taxes, which in turn increases royalties. This result is in line with our stylized facts displayed in the introduction concerning the evolution of the taxation of gold extraction in Africa.

To conclude, we observe that international attractiveness is not built using exclusively policy taxation, but rather, attractiveness also depends on the level of cost overstatement. A very low overstatement of costs (lower  $\beta$ ) combined with a certain level of profit tax (even greater than the level of profit tax in the rival country) leads to small royalties, which makes the country attractive. To be attractive, the government in a developing country either needs to reduce informational asymmetry by improving its expertise in extractive activities or fighting corruption.

In appendix B, we explore the effects of a different scheme of overstatement. We hypothesize that the coefficient of overstatement is a linear positive function of the profit tax namely  $\beta_i \tau_i$ . Under such assumption, the profit tax becomes an interior solution and a function of  $\beta_i$ . Under a variable cost overstatement, the mining country that attracts the extractive firm is the country with the highest coefficient of overstatement and the lowest royalty.

#### 4. Optimal tax design in the absence of overstatement

We are now in a position to underscore the distorting effects of cost overstatement on tax policies and the capital invested by the firm. To do so, we check the optimal tax policy in absence of cost overstatement. The capital invested as a function of the royalty is again given by the

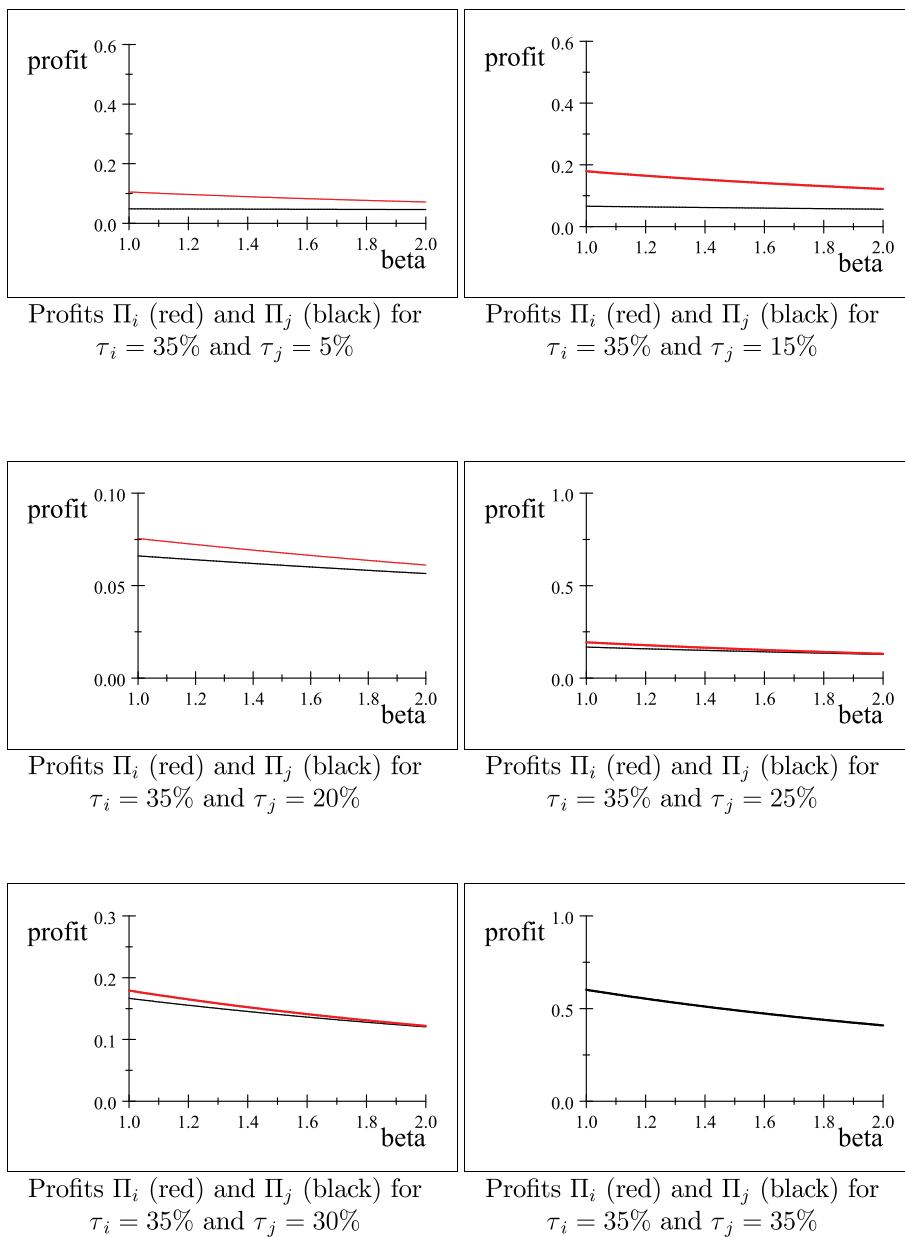


Fig. 2. Optimal profits  $\Pi_i^*(\beta)$  and  $\Pi_j^*(\beta)$

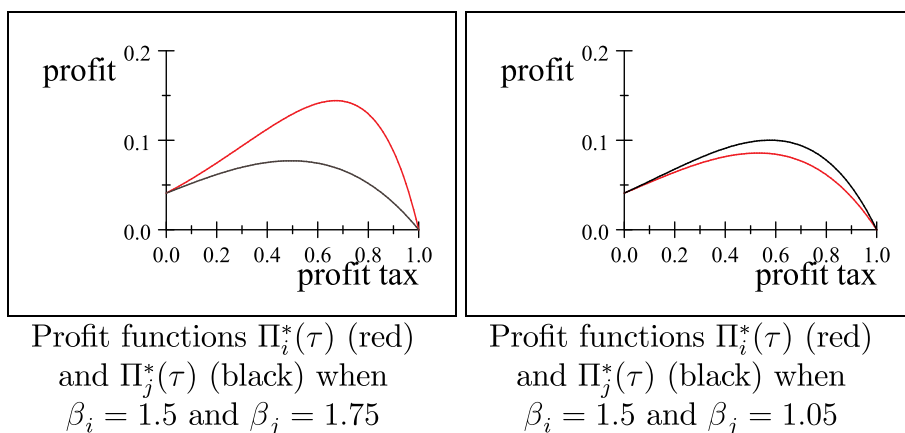


Fig. 3. Optimal profits  $\Pi_i^*(\tau)$  and  $\Pi_j^*(\tau)$

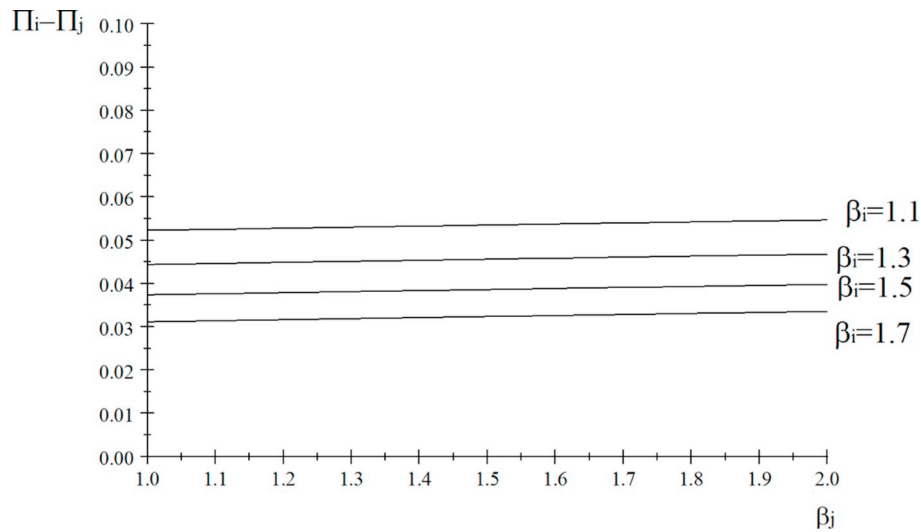


Fig. 4. The difference in profits when profit taxes differ very much

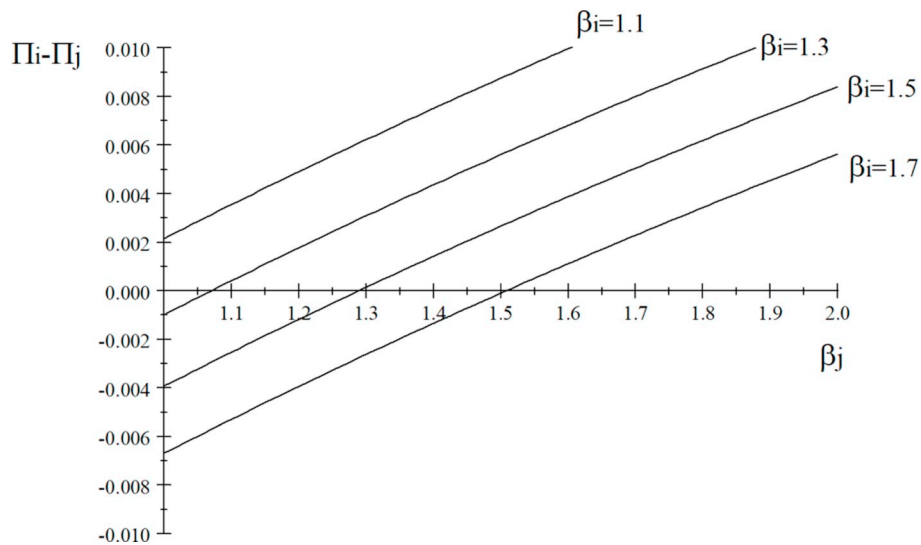


Fig. 5. The difference in profits when profit taxes are similar

expression (2). Thus, tax revenues write as

$$R_i(\theta_i, \tau_i) = \theta_i \left( \alpha K_i(\theta_i) + \tau_i \left( (1 - \theta_i) \alpha K_i(\theta_i) - \frac{1}{2} K_i(\theta_i)^2 \right) \right), \quad i = a, b$$

The maximization of tax revenues gives the following optimal choice for the government  $(\bar{\tau}_i, \bar{\theta}_i)$ :

$$\bar{\theta}_i = \frac{\alpha - 1 - r - \alpha \bar{\tau}_i^{\max}}{\alpha(2 - \bar{\tau}_i^{\max})}, \quad i = a, b$$

$$\bar{\tau}_i = \tau_i^{\max}, \quad i = a, b$$

Choosing the maximum possible profit tax yields the lowest possible royalty, since  $\partial \bar{\theta}_i / \partial \tau_i^{\max} < 0$ . The corresponding optimal capital invested is

$$\bar{K}_i = \frac{\alpha - r - 1 + \tau_i^{\max}(1 + r)}{2 - \tau_i^{\max}}, \quad i = a, b$$

As before,  $\frac{\partial \bar{K}_i}{\partial \tau_i^{\max}} > 0$ : higher profit taxes, imply higher invested capital, because higher profit taxes imply lower royalties.

Evaluating the profit for the firm and the tax revenues at the optimal

tax rates, we obtain

$$\bar{\Pi}_i(\theta_i, \tau_i) = \frac{1}{2} (1 - \tau_i^{\max}) \frac{(\alpha - r - 1 + \tau_i^{\max}(1 + r))^2}{(\tau_i^{\max} - 2)^2 (1 + r)}, \quad i = a, b$$

and

$$\bar{R}_i = \frac{1}{2} \frac{(\alpha - r - 1 + \tau_i^{\max}(1 + r))^2}{2 - \tau_i^{\max}}, \quad i = a, b.$$

To evaluate the impact of cost overstatement on taxes and capital invested by the firm, we compare governmental choices under overstatement and in the absence of overstatement. By direct comparison we obtain.

**Proposition 5.** *Constant overstatement of production costs puts upward pressure on the royalty and downward pressure on the capital invested, lowering both the firms' profits and the governments' tax revenues, as compared to the scenario with absent overstatement.*

**Proof 2.** *The difference in optimal royalties is given by  $\tau_i^{\max}(\beta_i - 1) \frac{\alpha - 1 - r + \tau_i^{\max} + r \tau_i^{\max}}{\alpha(2 - \tau_i^{\max})(2 - 2\tau_i + \beta_i \tau_i^{\max})} > 0$ ; whereas the optimal invested capital*



difference is  $-\tau_i^{\max}(\beta_i - 1) \frac{+\alpha - r + \tau_i^{\max} + r\tau_i^{\max} - 1}{(2 - \tau_i^{\max})(2 - 2\tau_i^{\max} + \beta_i\tau_i^{\max})} < 0$ . Moreover, the profit difference is  $\frac{1}{2}$   

$$\frac{-\tau_i^{\max}(1 - \tau_i^{\max})(\beta_i - 1)(4 - 3\tau_i^{\max} + \beta_i\tau_i^{\max})(\alpha - r + \tau_i^{\max} + r\tau_i^{\max} - 1)^2}{(\tau_i^{\max} - 2)^2 + (\beta_i\tau_i^{\max} + 2 - 2\tau_i^{\max})^2(r + 1)} < 0$$
; and finally, the difference in tax revenue is  

$$-\frac{1}{2}\tau_i^{\max}(\alpha - r + \tau + r\tau - 1)^2 \frac{\beta_i - 1}{(2 - \tau_i^{\max})(2 - 2\tau_i^{\max} + \tau_i^{\max}\beta_i)} < 0$$
. ■

**5. Conclusion**

It is widely acknowledged that mining industries hosted in developing countries suffer from serious asymmetries of information between the firms that exploit the mines and the government that levies several taxes – often distortive – to raise tax revenues. Asymmetries of information often concern the overstatement of production costs as a mean of reducing tax liabilities. This issue draws even more attention in the presence of a foreign multinational firm for at least two reasons. First, the multinational firm may have a technical advantage over the developing country’s experts. This technical advantage may be used to overstate costs. Second, by definition, the mobility of this type of firm is very high and justifies a tax competition framework. A multinational firm can exert pressure by threatening to exploit a mine in a different country in order to gain tax advantages. Hence, in such a setting, one may naturally ask what are the effects of asymmetries of information on tax policies in the presence of international tax competition that adds pressure on governments. Shedding light on this issue is the purpose of the present paper, which has yielded some interesting results.

Under a constant rate of overstatement of costs, if the country is affected by a strong asymmetry of information, the distortions caused by royalties are amplified and are detrimental to both the government and the firm’s revenues. Indeed, to be attractive, a country will decrease the profit tax rate and increase the royalty. If cost overstatement is a function of the profit tax however, asymmetries of information may bring advantages to the firm while remaining detrimental for tax revenues. In this case, variability in the overstatement rate neutralizes the role of the

profit tax in the attractiveness of the country and the foreign firm locates where she can overstate the most.

Whether constant or variable, cost overstatement puts downward pressure on government tax revenues.

From a tax policy point of view, it appears that the reduction of information asymmetries, with the aim of decreasing cost overstatement, is a key strategy to increase tax revenues and to reduce the distortive tax instruments. For several decades now, it is noted that lack of expertise in mining sector of developing countries represents a serious handicap.<sup>13</sup> This is what our model theoretically proves. The main international aid agencies have already led projects of mining sector capacity building notably in West Africa. These efforts for reinforcing expertise must be strengthened to achieve complementarity with the Extractive Industries Transparency Initiative (EITI).

Reinforcing expertise in mining sector for reducing asymmetries appears to be a priority over a tax harmonization process that could be a response to the negative effects of the tax competition showed in our model. To the best of our knowledge, Mansour and Swistak (2016) and Mansour and Rota-Graziosi (2014) are the only papers analyzing an eventual tax harmonization for extractive industries in developing countries. Both papers have great reservations on this issue. First, the costs of a regional coordination are very high and the importance of the resource revenue for the governments weakens the incentive for good policy practice. Second, coordination on one tax, statutory tax for instance, could shift competition to other instruments and notably to derogatory regimes. This last seems the main reason why tax coordination among West African Economic and Monetary Union States has not been effective.

Future empirical works can be envisaged that would test the main results of our model. The success of this empirical analysis relies on the careful approximation of the coefficient of cost overstatement. With a good proxy for  $\beta$ , it could be interesting to investigate how the intensity of asymmetries of information affect the tax policy and government tax revenues in mining countries.

**Appendix C. Supplementary data**

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.resourpol.2019.101519>.

**Appendix A. Derivation of threshold  $\tilde{\tau}$**

The sign of the derivative  $\frac{\partial \pi_i}{\partial \tau_i^{\max}}$  is given by the sign of the expression

$$(2r - r\beta + 2 - \beta)\tau^2 + (ap\beta - 2\alpha - \beta - r\beta - 4r - 4)\tau + (2r + 2ap + 2\beta + 2r\beta - 2ap\beta + 2)$$

which is a convex parabola with two positive roots given by

$$\tilde{\tau} = -\frac{1}{(\beta - 2)(r + 1)} \left( \begin{array}{l} 2r + ap + \frac{1}{2}\beta + \frac{1}{2}r\beta - \frac{1}{2}ap\beta \\ -\frac{1}{2}\sqrt{(2ap + \beta + r\beta - ap\beta)(2ap + 9\beta + 9r\beta - ap\beta)} + 2 \end{array} \right),$$

$$\tilde{\tau} = -\frac{1}{(\beta - 2)(r + 1)} \left( \begin{array}{l} 2r + ap + \frac{1}{2}\beta + \frac{1}{2}r\beta - \frac{1}{2}ap\beta \\ +\frac{1}{2}\sqrt{(2ap + \beta + r\beta - ap\beta)(2ap + 9\beta + 9r\beta - ap\beta)} + 2 \end{array} \right)$$

We prove that root  $\tilde{\tau}$  is positive and smaller than one and thus acceptable for our setting, whereas  $\tilde{\tau} > 1$ .

$$\tilde{\tau} < 1 \tag{7}$$

<sup>13</sup> “Burkina Faso has excellent geological potential as is evidenced by the interest showed by major international mining companies. However [...] Burkina Faso currently lacks a complete regulatory and fiscal framework, and the human and institutional capacity to effectively administer or to ensure adequate environmental management of mining.” World Bank 1997, Mining sector capacity building and environment management project, Report No. P 7048-BUR.

$$\left( \frac{2(r+1) + \alpha - \frac{1}{2}\beta(\alpha - r - 1)}{-\frac{1}{2}\sqrt{(2\alpha + \beta + r\beta - \alpha\beta)(2\alpha + 9\beta + 9r\beta - \alpha\beta)}} \right)^2 < (2 - \beta)(r + 1)$$

$$2\beta(r+1) + \alpha - \frac{1}{2}\beta \left( (\alpha - r - 1) \sqrt{(2\alpha + \beta + r\beta - \alpha\beta)(2\alpha + 9\beta + 9r\beta - \alpha\beta)} \right)$$

Both the LHS and RHS of the above inequality are monotone increasing functions of  $\alpha$ , under the assumptions of the model that  $\beta < 2$  and  $\alpha > 1 + r$ . Evaluated at the smallest value of  $\alpha$ , i.e.  $\alpha = 1 + r$  and  $\beta = 2$  (it actually holds for any  $\beta \in [1, 2]$ ) we have

$$5(1 + r) < \sqrt{36(r + 1)^2}$$

which is true. Evaluating the inequality for very large but finite values of  $\alpha$ , we have that

$$(1 - 0.5\beta)\alpha < (2 - \beta)\alpha$$

which is again true. Hence, for the lowest value of  $\alpha$  the RHS is bigger than the LHS. As  $\alpha$  increases, the RHS is always higher than the LHS. Hence, due to monotonicity of the RHS and LHS, the inequality (7) is always true for all admissible values of  $\alpha$ . It follows that  $\tilde{\tau} < 1$ . Clearly  $\tilde{\tau} > 0$ . Using the same method, we show easily that the other root  $\check{\tau}$  exceeds 1. It follows that in the interval (0,1) where  $\tau_i^{\max}$  lays, the parabola is first positive and then negative. Hence, for  $\tau < \tilde{\tau}$ , the derivative  $\frac{\partial \Pi_i}{\partial \tau_i^{\max}} > 0$ , and for  $\tau > \tilde{\tau}$ ,  $\frac{\partial \Pi_i}{\partial \tau_i^{\max}} < 0$ . QDE.

### Appendix B. Optimal tax design under variable overstatement

#### Absence of tax competition

In this section, we assume that the coefficient of overstatement is a function of the profit tax  $\tau_i$ , namely  $\beta_i \tau_i$ ,  $i = a, b$  as suggested by [Boadway and Keen \(2010\)](#). Hence, the higher the profit tax in the country, the higher the incentive for the firm to overstate its costs. As above, a firm maximizes the profit function given by expression (1) to determine the optimal capital investment as a function of taxes, given (as above) by

$$K_i(\theta_i) = \alpha(1 - \theta_i) - r - 1 > 0, \quad i = a, b. \tag{8}$$

The government maximizes tax revenues  $R_i(\tau_i, \theta_i)$  taking into account the real initial investments  $K_i(\theta_i)$  and the declared profits of the firm, which now include  $\beta_i \tau_i$ :

$$R_i(\theta_i, \tau_i) = \frac{1}{1+r} \left[ \theta_i \alpha K_i(\theta_i) + \tau_i \left( (1 - \theta_i) \alpha K_i(\theta_i) - \beta_i \tau_i \frac{1}{2} (K_i(\theta_i))^2 \right) \right]$$

In contrast to the scenario of constant overstatement, concavity conditions are satisfied for both the profit tax and the royalty, yielding interior solutions for both tax instruments. **Investigating the first order condition of the maximization problem  $\max_{\theta_i, \tau_i} R_i(\theta_i, \tau_i)$ , we obtain the following:**

**Proposition 6.** Under a variable cost overstatement, the government decides on the following optimal tax mix  $(\check{\theta}_i, \check{\tau}_i)$ .

$$\check{\theta}_i = \frac{\alpha(\beta_i - 1) - \beta_i(1+r)}{\alpha(2\beta_i - 1)}, \quad \check{\tau}_i = \frac{1+r+\alpha}{(1-\beta_i)(1+r) + \beta_i\alpha}, \quad i = a, b. \tag{9}$$

Positivity of the optimal royalty is guaranteed by the condition (4). Substituting 9 in equation (2), we obtain the corresponding optimal invested capital invested:

$$\check{K}_i = \frac{1+r+\beta_i(\alpha-r-1)}{2\beta_i-1}, \quad i = a, b.$$

Comparative statics with respect to the coefficient of overstatement lead to the following results

**Lemma 3.** The coefficient of overstatement  $\beta_i$  positively affects the profit tax but it reduces both the royalty and the optimal invested capital.

**Proof 3.** Taking the partial derivative, we obtain  $\frac{\partial \check{\tau}_i}{\partial \beta_i} = \frac{r+\alpha+1}{\alpha(2\beta_i-1)^2} > 0$ ;  $\frac{\partial \check{\theta}_i}{\partial \beta_i} = (r+\alpha+1) \frac{r+1-\alpha}{(-r+\beta_i+r\beta_i-\alpha\beta_i-1)^2} < 0$ ;  $\frac{\partial \check{K}_i}{\partial \beta_i} = \frac{-r+\alpha+1}{(2\beta_i-1)^2} < 0$ . ■

In contrast to the result obtain in Lemma 1, under variable overstatement, a higher  $\beta$  lowers the royalty. Finally, the firms' profits  $\check{\Pi}_i$  and the tax revenue for the government  $\check{R}_i$  evaluated at the optimal policy mix obtain as

$$\check{\Pi}_i = \frac{1}{2} \beta_i (\alpha - r - 1) \frac{\alpha(\beta_i - 1) - \beta_i(1+r)}{(2\beta_i - 1)^2 (1+r)}, \quad i = a, b^{14}$$

and

$$\check{R}_i = \frac{1}{2} \frac{(r - \alpha + 1)^2 \beta_i + 2\alpha(r + 1)}{2\beta_i - 1}, \quad i = a, b$$

As in Section 3.1, the overstatement of production costs still has a negative impact on tax revenues  $\frac{\partial \check{R}_i}{\partial \beta_i} < 0$ . However, in contrast to the preceding scenario, cost overstatement now has beneficial effects on the firm's profits. Indeed,  $\frac{\partial \check{\Pi}_i}{\partial \beta_i} > 0$ . Variable overstatement of costs induces the government to lower royalties, leading to a positive final effect on a firms' profits.

Tax competition

Taxes being interior solutions, in this scenario, the profit depends solely on the coefficient of overstatement,  $\beta_i, i = a, b$ . Furthermore, as just stated above  $\frac{\partial \pi_i}{\partial \beta_i} > 0$ . This implies that

**Proposition 7.** Assuming a variable cost overstatement, the mining country that attracts the extractive firm is the country with the highest coefficient of overstatement and the lowest royalty.

To summarize, under variable overstatement, the distortion of asymmetric information becomes even more accentuated. A firm decides to locate where overstatement is the highest, even if the profit tax is also the highest. Furthermore, this choice of location distorts the capital invested by reducing it considerably. Hence, variable overstatement not only distorts the tax choices of the government, but also the level of capital invested.

Comparison

We compare taxes and capital invested by the firm, as well as profits and tax revenues, in the presence and absence of overstatement. Nonetheless, comparing these two scenarios is now tricky because under variable overstatement the profit tax is an interior solution depending on  $\beta_i$ , whereas in absence of overstatement, the profit tax is a corner solution on the size of which we remain agnostic. To make this comparison possible, we will make the simplifying assumption that  $\tau_i^{\max} = \bar{\tau}_i$ .

By direct comparison, we obtain

**Proposition 8.** Variable overstatement of production costs puts upward pressure on the royalty and downward pressure on the capital invested. It always lowers the tax revenues but it may turn positive for the firms' profits.

**Proof 4.** The royalty comparison is  $(\beta_i \tau_i^{\max} - 1) \frac{r+\alpha+1}{\alpha(2-\tau_i^{\max})(2\beta_i-1)} > 0$ ; the optimal capital invested difference is  $-(r+\alpha+1) \frac{\beta_i \tau_i^{\max}-1}{(2-\tau_i^{\max})(2\beta_i-1)} < 0$ ; the difference in the firms' profits is

$$\frac{1}{2}((r+3\alpha+1)(r-\alpha+1)^2\beta_i+4\alpha^2(r+1))\frac{\alpha+\beta_i+r\beta_i-\alpha\beta_i}{(2\beta_i-1)^2(r-\alpha+1)^2(r+\alpha\beta_i+1-\beta_i-r\beta_i)}$$

which can be positive or negative; and the tax revenue comparison writes as

$$\frac{1}{2}(r+1)(r+\alpha+1)\frac{(r-\alpha+1)^2\beta_i+2\alpha(r+1)}{(2\beta_i-1)(\alpha-r-1)(-r+\beta_i+r\beta_i-\alpha\beta_i-1)} < 0 \text{ for } \alpha > 1 + r. \blacksquare$$

Variable overstatement may be profitable for the firm, whereas constant overstatement is always detrimental for both firms and governments.

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