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Version of Record: https://www.sciencedirect.com/science/article/pii/S0301420719309699
Manuscript_43cca172c44bf71909770464e34806dc

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April 3, 2020

*This paper benefited from the financial support of the FERDI (Fondation pour les Etudes et Recherches sur le Developpement international) and the program "‘Investissement d’avenir"’ of the French government. I am grateful to James Cust, Céline De Quatrebarbes, Samuel Guérineau, Alexandre Henry, Bertrand Laporte, David Mihalyi, Perrine Toledano, Jerome Valette, and the seminar and conference participants at the 2017 doctoral development days (CES, CERDI, DIAL, IHEID), 2nd Dundee Energy Forum (CEPMLP,Dundee). All remaining errors are mine.

†Mamadou_Tanou.Balde@etu.uca.fr ‖ btanou@yahoo.fr, Clermont-Auvergne University, CNRS, CERDI, F-63000 Clermont-Ferrand, France.

Abstract

This paper investigates the impact of taxation on the lead time from discovery to production by estimating duration models. Using a dataset of 188 gold mines, covering 24 developing countries from 1950 to 2017, both parametric *(Weibull)*, semi-parametric model *(Cox model)*, and non-parametric *(Kaplan-Meir estimate)* are applied to determine the role of taxation. The study contributes to the literature by showing empirically that according to the level of corporate income tax and royalty, and the nature of the fiscal regime used by a country to capture its share of the revenues stemming from the mineral extraction, the first gold pour take place sooner or later mainly when the corporate income tax is greater than 35% and the royalty rate above 5%. Most importantly, it documents that a progressive mineral regime shortens the length of time as well as a low-tax regime. Lastly, the findings suggest also that increasing prices at the time of discovery and the geological quality of the deposit play a critical role in encouraging investors to come into production earlier.

Keywords: Fiscal policy, Inter-temporal firm choice, Resources policy, Survival analysis.

JEL Classification: C41, D25, H32, Q38.

1 Introduction

For several decades, developing countries have been trying to foster the development of their mineral resources. They count on their mineral resource projects to mobilize more significant revenues and mainly to spur the development of their economies Otto (1992b, 1997); Mitchell (2009).

By liberalizing the sector in the middle of the eighties and adopting an increasingly lenient fiscal regime, particularly from 1992, they were willing to stimulate the growth of the sector Campbell, Akabzaa, and Butler (2004); McPherson (2008). In some countries, by doing so, the fiscal regime became over the years, more favorable to the resource industries than the other industries Boadway and Flatters (1993). Worse, Akabzaa (2004) and Sachs, Toledano, Mandelbaum, and Otto (2012) think that many countries were in a fiscal race to bottom to attract foreign direct investment.

The impact of the successive reforms of their fiscal regimes on the development of the mineral sector is not well documented in the literature, and continue to be a source of debate Haselip and Hilson (2005); Tilton (2004); Curtis and Lissu (2008); Campbell (2009).

It emerges from the debate on the effects of taxation on mineral development that almost all fiscal instruments have an impact on the life cycle of a mineral project, except the rents tax. According to the type of tax instruments implemented, such as royalties, corporate income tax, government equity, and its level, the effects can be significant for the profitability of mineral project Conrad and Hool (1981, 1984); Heaps and Helliwell (1985). By affecting the return of the project, "‘the fiscal regime influence therefore many aspects of investor’s plan of exploitation, including the scope of exploration and discovery, the timing and scale of initial development, the rate of production and decline, the timing and scale of enhanced recovery operations, the overall resource recovery factor, and the timing of final abandonment"’ Smith (2013).

If there is a lot of theoretical studies establishing a link between the underdevelopment of the mineral sector in developing countries, especially in sub-Saharan countries and their fiscal regimes, empirical studies on the impact of taxation on mineral development both for a single country, and a panel of countries are lacking. As far as we know, we do not find any empirical studies on the effects of taxation on the length of time between the discovery and development of industrial mineral projects in developing countries.

In a context with a considerable uncertainty where we have an increasing number of adjourned or postponed mineral projects, Shaukat Khan, Nguyen, Ohnsorge, and Schodde (2016), several governments could be attempted to reform, again and again, their fiscal regime or worse to give special incentives like a specific convention to some enterprises in order to invite them to come on stream sooner. This unreasonable temptation to give up revenues can be explained by the lack of understanding of the impact of their fiscal regime by policymakers in developing countries, and therefore, it is crucial to undertake this analysis in order to improve the understanding of the role of regulation especially the taxation Daniel, Keen, and McPherson (2010); Russell, Shapiro, and Vining (2010).

The objective of this paper is to investigate the effects of government fiscal regimes on mineral industries development by putting the focus in one of the most critical parts of the life cycle of projects for developing countries: the beginning of the extraction and exports of mineral resources. Indeed, the beginning of the extraction means for developing countries, all else equal, higher revenues, more employment, subsequently, growth.

For this purpose, both non-parametric *(Kaplan-Meir estimate)*, parametric *(Weibull)*, and semi-parametric model *(Cox model)* are performed on a sample of 188 gold mines closed or under production, covering 24 gold-rich developing countries in Sub-Saharan Africa, Latin-America, and Asia[1]. A set of variables is defined to capture the level of taxation (Low, intermediary and high), and the nature of the fiscal regime (progressivity) applied in each gold mine. Also, a set of economical, geological and institutional covariates are introduced to capture the heterogeneity across countries and gold mines.

The results are robust and suggest that the fiscal regime used by a country to get a part of the revenue stemming from the extraction of its natural resource endowment plays a significant role in determining whether or not the industrial extraction will take place earlier.

The three main contributions of this paper are as follows. First, to the best of our knowledge, it provides the first empirical evidence of the impact of taxation on the lead time from discovery to production. Second, the paper contributes to the ongoing debate by showing that a progressive fiscal regime can get as positive results as a low tax regime and, therefore, could be a reasonable tradeoff. It may allow countries to get more revenues, and at the same time, reduce

[1] see table 4 for the list of countries.

the tax incidence on the development lag. Third, it contributes to the literature by reducing the lack of empirical studies on the determinants of natural resource extraction. Also, the research complements previous studies by showing empirically the significant contribution of prices and geology in explaining the heterogeneity of the length of time from discovery to extraction.

The rest of the paper is organized as follows. Section 2, provides a review of previous studies. Section 3.1, summarizes the data and paves the way for empirical analysis. The following section 3.2 provides a description of the methodology and the empirical specification employed in the analysis. In section 4, we discuss the results and challenge their robustness. Section 5, concludes and gives some takeaways drawn from the key findings.

2 Review of previous studies

The study is related to three main pieces of literature. The first one is the literature on the impact of taxation on mining companies' behavior. Hotelling (1931), in his seminal work, brings to light that natural resources taxation has an incidence on the schedule and rate of production, and therefore policymakers can, through taxation, lead the mine-owner in an extraction path in line with government resource development agenda. On the same research agenda, focusing on the heterogeneous quality and endogenous reserves, then on the inter-temporal extraction of mineral resources, Conrad and Hool (1981, 1984) show that the variability of the tax rate (both profit tax and royalty) has a different incidence on the extraction pattern compared to the fixed-rate tax. Usually neutral, even profits tax, will affect the extraction rate and grade selection.

Thus, the reallocation for later periods is more considerable under constant-rate tax (unit-based royalty or ad valorem royalty), and the recovery is lower than under variable-rate taxation. Moreover, their findings suggest that even if they impact the economic reserves, ad valorem royalty tax incidence is not uniform either over time or across mineral. It depends both on the path of discounted mineral prices and the growth rate of prices compared to the rate of interest.

The second related literature contains studies on the determinants of mineral development, mining FDI and location. Otto (1992a, 2002) performs a global survey on one hundred mineral companies about the significant corporate determinants for mineral investment in countries. His results show that the method and level of tax levies, the ability to predetermine tax liability, the stability of fiscal regime were very important or important for mining projects for the totality of

Table 1: Resource taxation and mining companies behavior: Theoretical studies

Authors	Findings	Extraction profile	Period	Type of resources
Hotelling (1931)	Taxation induce the mine-owner to adopt a schedule of production more in harmony with the public good Severance tax (royalties) postpones exhaustion The imposition of a small severance tax increase the time of exploitation	Present to future	1931	All
Conrad and Hool (1981)	Taxes modify the inter-temporal profile of extraction Per unit severance on output or ore Ad valorem severance Pure profits taxes without depletion allowances are non-distortionary Profits tax with cost depletion Property taxes	Either direction Present to future Either direction* Neutral Future to present Future to present	1981	Mineral
Conrad and Hool (1984)	The variability in tax rates may create allocation incentives that are qualitatively different from those under fixed-rate taxation. If the tax rate is variable and has a sufficiently high growth rate, per unit severance taxes (royalties) induces a reallocation A variable-rate ad valorem tax may change the grade selection, alter the intertemporal profile, and increase total recovery. Progressivity destroys the neutrality of a profits tax with respect to grade selection, extraction rate, and recovery	Either direction Future to present Either direction** Either direction***	1984	Mineral

Notes: *Depends on the path of discounted prices (reallocation in the direction of the period of lower discounted market price); **depends both on the path of discounted mineral prices and the growth rate of prices compared to the rate of interest; ***depend qualitatively on the pre-existing path of profits.

the respondents. While, the tax allowance, such as the availability of tax holidays, accelerated depreciation, and reinvestment credit were judge not very important by respectively more than 25%, 12%, and 31% of the respondents. In the following years, Maponga and Maxwell (2001) show statistically that policy reforms have increased the inflows of foreign direct investment in mineral sectors in Africa.

In their analysis of the features of a competitive fiscal regime for foreign investors, Shimutwikeni (2011) by comparing Namibia and Botswana, reach the same conclusion. The progressivity of the profit taxation and the range of tax allowances allow these two countries to be attractive for mining FDI. Besides, they highlight the importance of the political and legal environment. Also, Saidu (2007), through a comparison fiscal regimes, finds that Indonesia attracts more investments than Niger. He concludes that an attractive mining tax regime is not sufficient to attract and sustain investment.

Curtis, Gemell, and Sykes (2015) perform a financial model of gold mine returns in five South American and five African countries and compare these results to industry perceptions

Table 2: Determinant of mineral development, mining FDI and location

Authors	Type of study	Findings	Period	Type of resources
Otto (1992, 2002)	Survey	The method and level of tax levies, the ability to predetermine tax liability, the stability of fiscal regime were very important or important for mining projects for the totality of the respondents. Tax allowance, such as the availability of tax holidays, accelerated depreciation, and reinvestment credit, were judge not very important by respectively more than 25%, 12%, and 31% of the respondents	1992	Mining
Maponga and Maxwell (2001)	Descriptive	Policy reforms have increased the inflows of FDI in mineral sectors in Africa	1970-2000	Mineral
Forster and Bills (2003)	Comparative	Fiscale regime on gold projects in Tanzania allowed the development of four new major gold mines. A project developed in Tanzania has 27% higher return to the shareholders compared to Burkina-Faso. The geological features also played a significant role.	2003	Gold
Shimutwikeni (2011)	Comparative	Namibia and Botswana both have attractive fiscal regimes. Botswana's fiscal regime is more attractive given the lower rate of CIT and Royalty. Political, legal and fiscal stability are key determinants for investors	2011	Mining
Saidu (2007)	Comparative	An unattractive mining tax regime can drive away investment. An attractive mining tax regime will not necessarily attract and sustain investment	2007	Mining
Tole and Koop (2010)	Empirical	Gold mining companies are attracted to regions that are close to their head office and have a low level of corruption, a transparent and stable environment for doing business	1975-2013	Gold
Russell et al. (2010)	Empirical	Canadian specific regulatory punctuations, mainly fiscal reforms, have shaped the evolution of their mining industry.	1929-2006	Mining
Asiedu and Lien (2011)	Empirical	Democracy facilitates FDI in countries where the share of natural resources in total exports is low, but has a negative effect on FDI in countries where natural resources dominate exports	1982-2007	Mineral-Oil
Cust and Harding (2014)	Empirical	Institutions strongly influence where oil and gas exploration takes place At borders, exploration companies choose to drill on the side with better institutional quality 58% of the time.	1966-2010	Oil
Curtis et al. (2015)	Financial	Potential negative correlation between the AETR and the rankings of Policy Perception and not on the country rankings of overall Investment Attractiveness Low AETR is associated with a good perception of mineral policy by foreign investors only for Guyana, Mali, Peru, Tanzania, Burkina-Faso, and Chile. However, despite the low level of taxation in certain countries, they did not find any correlation between the AETR	2015	Gold
Jara (2017)	Empirical	Geological potential and investment climate are crucial to explaining country's attractiveness.	2014	Mining

of mineral taxation regime. They find that there is a potential negative correlation between the Average Effective Tax Rate (AETR) and the rankings of Policy Perception[2] and not on the country rankings of overall Investment Attractiveness as compiled by the Fraser Institute. The low AETR is associated with a good perception of mineral policy by foreign investors only for Guyana, Mali, Peru, Tanzania, Burkina-Faso, and Chile. However, despite the low level of taxation in certain countries, they did not find any correlation between the AETR, and the indicators of attractiveness and suggested that it is due to other problems like mineral ownership, the security of tenure, and institutional factors.

When it comes to empirical studies, several authors document the determinants of mining investments. For instance, the study by Russell, Shapiro, and Vining (2010) shows that Canadian specific regulatory punctuations, mainly fiscal reforms, have shaped the evolution of their mining industry. Institutions play a significant role in explaining the industry evolution heterogeneity. Tole and Koop (2010) carried out an analysis of 700 gold mines and find that gold mining companies are attracted to regions that are close to their head office and have a low level of corruption, a transparent and stable environment for doing business. Cust and Harding (2014) stress empirically the importance of institution for attracting investment in natural resource exploration, primarily in the oil sector, while Asiedu and Lien (2011) mitigate it and show that it depends on the size of the natural resources in the total of exports both for oil and mineral. More recently, the findings by Jara (2017) show that Geological potential and investment climate are crucial to explaining country's attractiveness.

Finally, the study is related to the literature on the determinant of the development lag of natural resources between the discovery and the initial start of the production. According to Favero, Hashem Pesaran, and Sharma (1994), oil prices are the most important determinant of resource project development decisions in contrast to the geological heterogeneity across oil fields. They do not have a significant impact on triggering the process of irreversible investment. However, in the mining sector, the findings by Shaukat Khan, Nguyen, Ohnsorge, and Schodde (2016) suggest that higher commodity (Gold and Copper) prices do not have on their own a significant role, while sound macroeconomic policy and good quality of governance can shorten the lead time to production. However, they show that an upswing in Copper prices at the time

[2]rankings of Policy Perception as compiled by the Fraser Institute 2015.

of discovery accelerates the development. The study by Favero, Hashem Pesaran, and Sharma (1994) shows that the delay period is not significantly affected by the geological differences. Their findings are in line with those by Schodde (2014), focusing on the mining sector.

Table 3: Survival analysis in the extractive sector

Authors	Type of study	Findings	Period	Type of resources
Favero et al. (1994)	Theoretical Empirical	Oil prices are the most important determinant of resource project development decisions. The delay period is not significantly affected by the geological differences.	1989	Oil
Schodde (2014)	Descriptive	The average delay between discovery and mine start up is 12.4 years The conversion rate and delay period vary by commodity In the copper sector, brownfield discoveries tend to be quicker to get into production (15.6 years), and 18.4 years In the gold mining sector, there is no material difference in the delay period for greenfield vs. brownfield gold projects The delay period was not significantly affected by the size of the deposit or the depth cover. Brownfield discoveries were quicker for copper but not significantly so for gold Country risk was critically important	1950-2013	Copper-Gold
Shaukat Khan et al. (2016)	Empirical	Higher commodity prices do not have on their own a significant role However, the upswing in Copper prices at the time of discovery accelerates development. Sound macroeconomic policy and good quality of governance can shorten the lead time to production.	1950-2014	Copper-Gold

3 Data and methodology

3.1 Descriptive analysis

In this section, we present the data, describe the construction of the dependent variable, main variables of interest, and carry out the first level of analysis.

3.1.1 Data and variable

We carry out the study with a sample of 188 gold mines closed or under production, covering 24 gold-rich developing countries in Sub-Saharan Africa, Latin-America, and Asia.[3] The choice of gold mines rather than other precious metals is motivated by the fact that the gold mining industry provides a rich information context in analyzing the firm or multinational location decisions

[3] see table 4 for the list of countries.

Tole and Koop (2010). The selection of mines was guided by the availability of data and the effective starting of gold extraction during the period ranging from 1950 to 2017.

Therefore in the sample, there is no right censoring as for all gold mines included in the study, we observe their failure event, in others words, the beginning of the production.

The data have been gathered from different sources mainly from MinEx consulting database for the geological data, FERDI (Foundation for Studies and Research on International Development) tax legislation in the gold-mining sector database developed by Laporte, De Quatrebarbes, and Bouterige (2016) and in the exhaustive review of legal and fiscal frameworks for exploration and mining conducted by Naito, Williams, Remy, and World Bank Group. (2001) for the fiscal data. The United States Geological Survey (USGS) reports from 1994 to 2014 and other reports are mobilized to complete, both geological and fiscal data. The World Development Indicators (WDI) and the Bank of England (BoE) database for the economic data and other sources such as policy IV for institutional data.

Dependent variable: The primary dependent variable is the "‘period of time"’ between the discovery of the gold mine and the extraction of its reserves. It is measured as the difference between the year of starting gold production and the year of discovery. It is noted t and is expressed in years.

Variables of interest: Three kinds of measures are used to assess the singularity of each fiscal regime. First, we generate a set of dummies variables (taxregim1 to taxregim4) according to the level of the two main components of fiscal regimes (corporate income tax and royalty). We define $taxregim1$ as equals one if minimum corporate income tax is equal to or below 25% and minimum royalty is less than 2%; $taxregim2$ equals one if minimum corporate income tax ranges from 25% to 35% and minimum royalty is greater than 2% and less 5%; $taxregim3$ equals one if the minimum corporate income tax is greater than 35% and minimum royalty is higher than 5%, and taxregim4 for all other fiscal regimes not fitting with the three previous tax bracket. Then, we focus on the three "‘clear fiscal regime"’ taxregim1 to taxregim3 and call them, respectively low-tax regime, intermediate-tax regime, and high-tax regime.

Second, we put the focus on the type of fiscal regime by generating a dummy variable $tprofitbase$. Following that, the regime is exclusively based on profit (corporate income tax), the $tprofitbase1$ equals one or zero otherwise. We then relieve the constraint and introduce countries with profit based royalty and generate a second variable $tprofitbase2$.

Third, we introduce a dummy variable $taxflex$ to take into account the variability of the mineral regime. The $taxflex$ is set to be equal to one if the corporate income tax rate or the royalty is determined according to a certain price threshold or any profit threshold.

These three indicators $tprofitbase1$, $tprofitbase2$, and $taxflex$ will allow us to tackle the critical issue of progressivity in natural resource taxation and examine its role in accelerating the development of an industrial gold project. As the revenue of the government is linked to the profitability of the gold project, a shorter span of time both for high profitable mines and marginal projects could be expected.

Other covariates: The rest of the covariates is divided into three categories. It includes economical, geological, and institutional variables. They allow us to capture the individual heterogeneity of each gold mine at the national level and across countries.

First, we include geological variables. They are key determinants in the process of triggering the initial irreversible investment in natural resource projects. The first variable related to the geology of the mine is the quantity (million troy ounces) of gold in the deposit. We note it $Pmrqtymoz$. The second geological variable, $Goldgrade$, allows us to measure the grade and, consequently to assess the impact of the quality of the gold deposit on time to starting production. A variable is also used to sum up all these other geological characteristics and take into account the cost extraction profile of each gold mine. We call the variable $Depverpro$ *(deposit very profitable)*. The $Depverpro$ equals one if the deposit is large and has a low cost of extraction "‘low-cost mine"’, and zero otherwise.

As suggested in the literature, the geological quality of a deposit is a critical but not sufficient determinant of the extraction of its resources. For this reason, we introduce the variable $Price$, which is the price of one troy ounce gold at the London metal exchange (LME) the year before the discovery. A high level of gold prices increases the feasibility of the project and, therefore, is a key trigger for gold project developments Schodde (2014). Furthermore, in order to capture the dynamic effect of the price on the anticipation of the investors, we add two "‘price-related"’ variables. The first one is the price standard deviation $Pricesd$. It allows us to capture price volatility during the three years preceding the mine discovery. We assume that the price uncertainty increases the commercial risk and can consequently slow down the development of a gold extraction project. The second one $priceup$ has a positive impact on the anticipation of an investor and therefore can foster the development of the project. We define $Priceup$ as a dummy variable. It is equal to one if gold prices were increasing during the five years preceding the year of discovery and zero otherwise.

To take into account the heterogeneity across countries, such as the political environment and the level of infrastructure development, the following variables are added. The variable $Polity$ from policy IV dataset ranging from -10 (strongly autocratic country) to +10 (strongly democratic country) to capture the institutional quality of the country where the mine is located. Beyond the geological and commercial risks, a gold extraction project faces high degrees of political risk, especially the time consistency compared to other sectors because of the substantial sunk costs involved in the extraction project development Baunsgaard (2001). All else equal, fearing that the government confiscates or changes the tax system after making the initial irreversible investment, a mining company can decide to postpone the development of a given extraction project even if the project is profitable at the time of discovery. The situation is even worse in low-income countries where the credibility of the government is weak Collier (2010b). Furthermore, the relation between politics and the exploitation of natural resource deposits is not in one direction. The discovery of a substantial natural resource asset can also affect politics and generally deepen the political problem Collier (2010a).

In this study, the variable polity is introduced to assess the effects of the political environment on time to starting gold production. Relatedly, we will only be interested in the situation prevailing before the discovery to avoid the reversal causality Shaukat Khan, Nguyen, Ohnsorge, and Schodde (2016). For this purpose, the score before the discovery of the gold deposit is preferred.

Infrastructures play an essential role in the time delay between the discovery and the development. The energy cost or the accessibility to the gold mine, mainly when there is no electricity, is determinant. Due to the lack of data on the quality of infrastructures, such as the energy costs, access to electricity, or asphalt road covering the period of this study (1950-2017), we assume as Tole and Koop (2010), that the quality of a telecommunication system of a country would reflect the quality of its infrastructure in general. Also, according to Canning (2001), telephone (telecommunication) is a better measure of infrastructure stock. However, he raises the concern that the paved roads and total roads are not fairly complete database, particularly for the period ranging from 1950 to 1990, and may not be a good proxy given the considerable variation of quality. Therefore the $Fixedphone$ is used as a proxy for the infrastructure. The proxy is measured as the percentage of fixed telephone subscriptions per 100 people. In the same logic, we lastly introduce three dummies to capture the heterogeneity across the three main developing regions $Africa$, $Asia$, and $Latinam$ for South-America.

3.1.2 Descriptive statistics

Table 4 reports the summary statistics of the data used in the study. It shows that the span of time between the gold mine discovery and the effective commencement of the production in the sample is, on average, higher than ten years during the period ranging from 1950 to 2017. The development lag was even more pronounced before 1975, and after the liberalization in the nineties, it falls progressively. The time to starting gold production was equal to 13.59 (15.89 in Africa and 16.75 in Asia)[4] in the seventies and since 2005, for instance, is about 6.5 years on average and even less in Latin America. The lead time to starting gold production is, on average, 5.42 years in this region.

Thus, due to the singularity of the duration data, the average is not relevant. Therefore we will use the Kaplan-Meier estimator to get the median, and it will provide us an interesting summary of the data. Even more, it will allow us to shed light on the individual impact of taxation on the lead time to production before performing the multivariate analysis.

We can see in Table 9 that the median is very different from the average. Half of the gold mines get into production after eight years. When we stratify the sample in groups according to the level or nature of the fiscal regime prevailing at the time of the discovery, we can see that there is a huge heterogeneity across durations.

As a matter of fact, in a country where the corporate income tax is equal to or below 25% and the royalty equal to or below 2% ($Low - taxregime$), the probability of starting gold extraction in a new gold mine sooner is greater than all other fiscal regimes. More than 51% of gold mines discovered in these countries experienced their first gold production after five years, while more

[4]see table 8 for more details

Table 4: List of mines by country and statistics

	Country	Observations	Percent	Survival time							
				Mean	25%	50%	75%	Min	Max	Skewness	Kurtosis
1	– Argentina	5	2.66	10.4	8	9	10	5	20	1.08	2.81
2	– Botswana	1	0.53	6	-	-		-	-	-	-
3	– Brazil	32	17.02	5.66	1	3.5	10.5	1	17	0.6	1.88
4	– Burkina Faso	9	4.79	14.78	9	13	19	7	27	0.67	2.01
5	– Chile	11	5.85	9.91	2	7	13	1	33	1.38	4.07
6	– Colombia	1	0.53	11	-	-	-	-	-	-	-
7	– Congo (DRC)	2	1.06	12	10	12	14	10	14	0	1
8	– Cote d'Ivoire	5	2.66	15.6	8	14	17	7	32	0.91	2.47
9	– Ghana	11	5.85	8.09	4	7	12	3	16	0.52	2.08
10	– Guinea	3	1.6	9.33	5	6	17	5	17	0.69	1.5
11	– Indonesia	9	4.79	9.44	7	8	13	5	17	0.66	2.08
12	– Laos	2	1.06	13	11	13	15	11	15	0	1
13	– Liberia	2	1.06	12.5	8	12.5	17	8	17	0	1
14	– Mali	13	6.91	11.69	6	10	20	2	23	0.32	1.56
15	– Mauritania	1	0.53	11	-	-		-	-	-	-
16	– Mexico	20	10.64	11.35	7	11	16	2	20	0.05	1.89
17	– Namibia	2	1.06	10	4	10	16	4	16	0	1
18	– Niger	1	0.53	15	-	-	-	-	-	-	-
19	– Papua New Guinea	7	3.72	13.43	7	10	22	6	24	0.52	1.69
20	– Peru	12	6.38	8.25	2	6	15.5	1	19	0.38	1.54
21	– Philippines	11	5.85	10.82	1	2	16	1	48	1.58	4.39
22	– Senegal	1	0.53	28	-	-	-	-	-	-	-
23	– South Africa	20	10.64	12.15	7.5	10	14.5	4	35	1.65	5.21
24	– Tanzania	7	3.72	9.43	5	8	13	4	21	1.19	3.21
	Total	188	100	10.29	5	8.5	14	1	48	1.36	6.11
	Region										
1	– Africa	78	41.49	11.77	7	10	15	2	35	1.14	3.91
2	– Asia	29	43.09	11.17	5	8	15	1	48	1.9	7.51
3	– Latin America	81	15.43	8.54	3	8	13	1	33	0.81	3.66

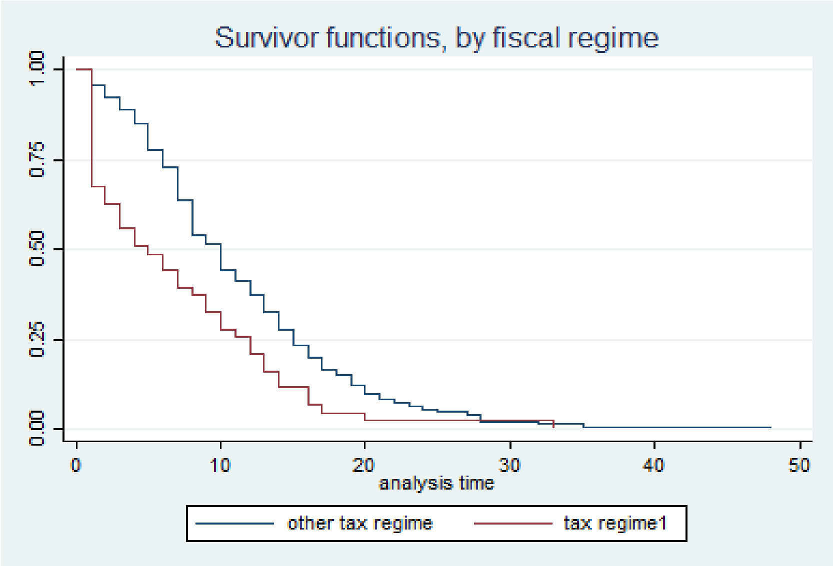
Notes: This table reports the list of mines by country and the associated statistics of the observed survival time. The span of time from the gold mine discovery to the first extraction. Source: author's elaboration on data from Minex Consulting, USGS.

than 51% of gold mine located in other fiscal jurisdictions do not achieve their first gold pour after nine years.

The time to starting gold production is, in contrast, lengthen when the corporate income tax is higher than 35% and royalty rate higher than 5% $(High-taxregime)$, as we can see in figure 3. None of the gold mines located in theses countries poured their first gold after six years, while about 35% of other gold mines located in countries where the fiscal regime is more favorable get into production in the meantime.

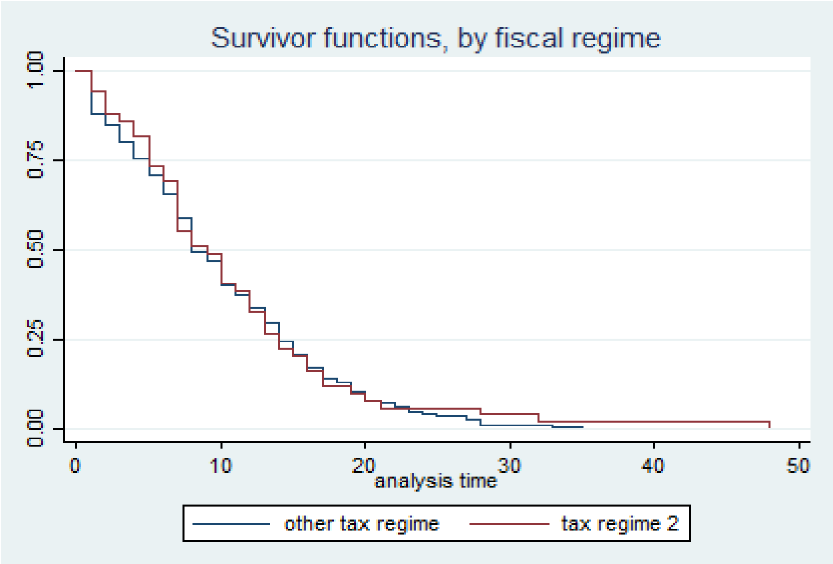
The delay period between the discovery and the beginning of the extraction does not depend only on the level of taxation. Figures 5 and 6 show that the shape of profit base taxation and variable tax regime do not merge with the other fiscal regimes. In addition to the above graphs, Tables 12 and 13 show that countries where the corporate income tax or royalty are variables see their gold mine discoveries getting into production sooner compared to other countries. Only

Figure 1: Kaplan-Meier estimates of time duration by Tax regime (Low-tax regime)



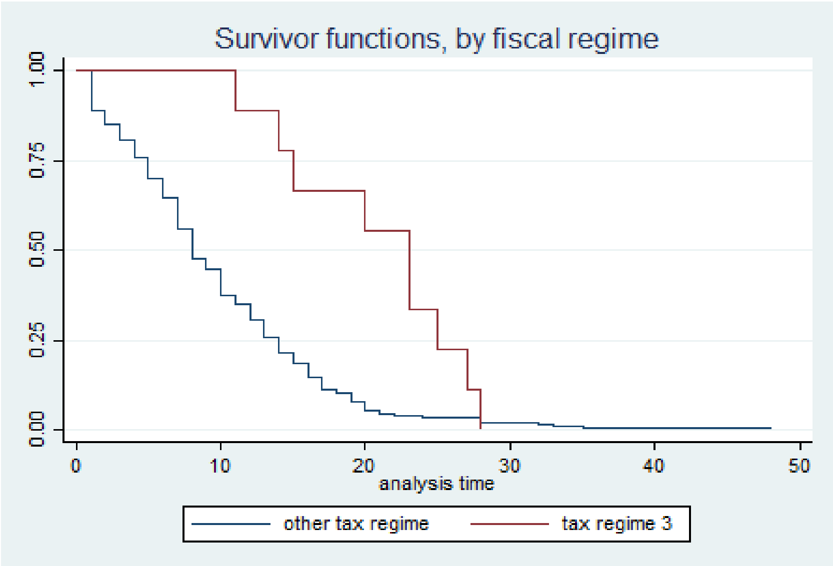
Notes: This figure provides a graphical illustration of the large difference in the survival time distribution between the "‘Low-tax regime"’ and the other types of regimes. Author’s elaboration on data from Minex Consulting, USGS, FERDI tax database on gold.

Figure 2: Kaplan-Meier estimates of time duration by Tax regime (Intermediate-tax regime)



Notes: Author’s elaboration on data from Minex Consulting, USGS, FERDI tax database on gold. This figure provides a graphical illustration of the weak difference in the survival time distribution between the "‘Intermediate-tax regime"’ and the other types of regimes.

Figure 3: Kaplan-Meier estimates of time duration by Tax regime (High-tax regime)



Notes: Author's elaboration on data from Minex Consulting, USGS, FERDI tax database on gold. This figure reports the stratified KM survivor function curve. The graph provides a graphical illustration of the large difference in the survival time distribution between the "'High-tax regime"' and the other types of regimes.

60% of new gold discovery remain untapped in variable-tax rate jurisdiction countries after six years against more than 70% for constant fixed-rate tax regime.

The differences across durations from the discovery of new gold deposits and the beginning of the extraction, when we perform a log-rank test, are statistically significant both for $taxregime1$, $taxregime3$, and $Flextax$, respectively at 1% for the first two variables and 5% for the last one.

Thus, if for countries where the $taxregim1$, $taxregim3$, and $Flextax$ are in force at the time of the discovery, the distinction between their survival time distribution is apparent; it is not the case in countries where the $taxregim2$, $Tprofitbase1$, or $Tprofitbase2$ are in force. The graphs and both log-rank test and Wilcoxon (Breslow) test in table 12 and 13 do not allow the identification of significant differences across their survivor functions.

To definitely determine the role of taxation on industrial mineral development, we will perform in the following section an empirical analysis in order to take into account the impact of other covariates such as mine or country characteristics in the time to starting gold production.

3.2 Methodology and empirical specification

3.2.1 Methodology

To empirically appraise this relation, we assume that all else equal, if country-specific policy impacts the lead time between the discovery and the initial development as suggested in the literature Tole and Koop (2010), Shaukat Khan, Nguyen, Ohnsorge, and Schodde (2016) among others, the national mining taxation can, therefore, explain the time delay recorded by some gold mine projects. For this purpose, we carry out a fully parametric analysis to investigate this relation. Furthermore, to make sure that the model is convenient for the data, we perform a set of background analyses. Firstly we argue that once a mine is discovered in a given country, the extraction probability of the discovered resource is, all else equal, set to be growing over the years. Therefore, we will assume that the shape of the hazard form is monotonic.

Accordingly, both the Gompertz or Weibull models can be used to estimate the coefficients. To do so, we perform estimates using the two preceding models and four others (Exponential, Log-Normal, Log-Logistic, Generalized Gamma) and compare their statistics, mainly the AIC. The AIC criterion for all equations suggests that the Weibull model fits the data adequately (see table 5). We will then, consequently, perform a Weibull model. The model is specified as follows:

$$h(t, X) = h_0(t)\exp(\beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + ... + \beta_k X_k) \tag{3.1}$$

Where $h(t, X)$ is the hazard or the probability of starting gold production at the time t. X is a set of K variables introduced to take into account the differences between the mines and countries. The β_k coefficients called hazard ratio, appraise the impact of each covariate on the hazard rate, in other words, on the probability of developing the gold production. A hazard ratio greater than one indicates that an increase of a covariate will lead to an increase of the event hazard (decrease of the survival length), while a hazard ratio below one will lead to a decrease of the event probability (an increase of the survival time). The baseline hazard is noted $h_0(t)$. It is the value of hazard when all the coefficients β_k of the K variables are equal to zero. It also gives us information about the shape of the hazard function. When we rewrite the specification

(3.1), we obtain the factor parameter.

$$h(t, X) = \alpha t^{\alpha-1} \exp(\beta_k X) \tag{3.2}$$

When the parameter α is higher than one ($\alpha > 1$), the probability of starting gold production rises monotonically and reversely when the factor α is less than one.

3.3 Empirical specification

The baseline model derives from the theoretical model developed by Favero, Hashem Pesaran, and Sharma (1994). We introduced progressively four variables, the three sets of tax regimes *(taxregim1, taxregim2, taxregim3)*; $depverpro$ to capture both the grade, the quantity of gold and facility of extraction, and prices.

The duration model can be written as follows:

$$\begin{aligned} h(t|taxregim, X) = h_0(t) \exp(\beta_0 + \sum_{i=1}^{3} \beta_i Taxregim_i + \beta_4 Ggrade + \beta_5 Depverpro \\ + \beta_6 Reserveoz + \beta_7 Price + \beta_8 Priceup + \beta_9 Pricesd) \end{aligned} \tag{3.3}$$

We add successively to the baseline model 3.3 a set of covariates and get the underneath equation :

$$\begin{aligned} h(t|taxregim, X) = h_0(t) \exp(\beta_0 + \sum_{i=1}^{3} \beta_i Taxregim_i + \beta_4 Tprofitbase + \beta_5 Flextax \\ + \beta_6 Ggrade + \beta_7 Depverpro + \beta_8 Reserveoz + \beta_9 Pmrqtymoz \\ + \beta_{10} Priceup + \beta_{11} Price + \beta_{12} Price_s d + \beta_{13} Polity \\ + \beta_{14} Fixedphone + \beta_{15} Africa + \beta_{16} Asia) \end{aligned} \tag{3.4}$$

Where $\beta_i Taxregim_i$, $\beta_4 Tprofitbase$, $\beta_5 Flextax$ are the variables of interest and their coefficients; $\beta' X_k$ a set of covariates explaining potentially the time lag between the time to starting gold production.

4 Results and robustness

Tables 5 and 6 present the results of the estimates from the Weibull model. The first set of equations (1 to 7) in table 5 includes only the structural covariates (geological and economical), and the following equations include the rest of the covariates progressively.

4.1 Time to starting mineral production: does the taxation matter?

The overall result stemming from the estimates, as assumed intuitively at the beginning, is that the probability of starting the extraction of gold discoveries increases over time. The statistics $ln(p)$ below each equation is statistically significant at 1%, and the value of p is above one. It implies that the hazard is increasing monotonically, and consequently, the Weibull parametric model is appropriate for modeling the data.

These findings suggest that according to the level and the nature of tax instruments used by a country to get a share of their resources, the fiscal regime has an incidence on the lead time to the production of a new gold mine. The hazard ratio for countries with a corporate income tax equal or below 25% and a royalty not exceeding 2%, is always statistically significant and greater than one in all estimates. It implies that in these low-tax jurisdictions, the gold mines discovered will get into production sooner. In contrast, when the mining corporate income tax rate is greater than 35% and the royalty beyond 5%, the probability that the gold mines discovered remain untapped is more likely. The hazard ratio is largely below 1 (around 0.4) for all estimates.

The variability of the tax regime seems to spark initial investments in developing discoveries sooner and, in some cases, as much as the low-tax regime $Taxregim1$. As columns 7, 8, and 9 show, the development is more likely when the deposit has been discovered in a country where the level of tax change according to a particular economic criterion, such as the price or the level of profit.

Also, this study documents that differences in the survival time distribution between gold mines are also explained by differences in the nature of fiscal regimes in force in each mine and country. A more progressive fiscal regime incites investors to start the extraction of discoveries sooner. The variable $Tprofitbase$ has a hazard ratio above the threshold one, suggesting that a profit base fiscal regime shortens the lead time from discovery to production. The coefficient becomes significant, particularly when we take into account countries levying a profit based royalty on gold production, such as Ghana.

Table 5: Time to starting gold production: Hazard ratio from Weibull Model

	Equations						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Taxregim1	1.562**	1.838**	1.484**	1.684***	-	-	-
	(0.284)	(0.449)	(0.265)	(0.301)	-	-	-
Taxregim3	0.435**	0.292***	0.416***	0.464**	-	-	0.332***
	(0.151)	(0.112)	(0.144)	(0.161)	-	-	(0.132)
Tprofitbase1	-	-	-	-	1.223	-	-
	-	-	-	-	(0.253)	-	-
Tprofitbase2	-	-	-	-	-	1.511**	-
	-	-	-	-	-	(0.301)	-
Flextax	-	-	-	-	-	-	1.506**
	-	-	-	-	-	-	(0.318)
Depverpro	1.175*	1.244**	-	1.193**	1.190*	-	-
	(0.101)	(0.130)	-	(0.103)	(0.122)	-	-
Goldgrade	-	1.050***	-	-	1.050**	1.054***	1.058***
	-	(0.020)	-	-	(0.020)	(0.021)	(0.020)
Goldreserve	-	-	0.999	-	-	-	-
	-	-	(0.007)	-	-	-	-
Priceup	-	-	-	1.725**	-	-	-
	-	-	-	(0.456)	-	-	-
Price_us	1.001**	1.001*	1.001**	-	1.003***	1.003***	1.002***
	(0.000)	(0.001)	(0.000)	-	(0.001)	(0.001)	(0.001)
Price_sd3	-	-	-	-	0.993***	0.992***	0.994*
	-	-	-	-	(0.003)	(0.003)	(0.003)
Constant	0.0201***	0.007***	0.023***	0.025***	0.006***	0.006***	0.006***
	(0.000)	(0.003)	(0.007)	(0.007)	(0.003)	(0.003)	(0.003)
/Ln_p	0.370***	0.574***	0.361***	0.367***	0.536***	0.536***	0.578***
	(0.057)	(0.071)	(0.057)	(0.056)	(0.072)	(0.072)	(0.072)
p	1.448	1.776	1.435	1.443	1.709	1.709	1.783
N	188	124	188	188	124	124	124

Notes: (*), (**), (***) denote significance at respectively 10%, 5% and 1%. Robust standard errors are in parentheses. Taxregim2 "‘the intermediary tax regime"’, is the variable of reference for the dummy variable Taxregim. Source: author’s elaboration on data from Minex Consulting, USGS.

4.2 The role of geology and economic environment

The results also suggest that the time to starting gold production depends on the geological characteristics of the mine and the economic conditions prevailing at the time of discovery. Thus as suggested in the literature, when a substantial potential and low-cost extraction deposit of gold is discovered, all else equal, the initial development of the mine occurs sooner. The coefficients of variables $Depverpro$, $Goldgrade$ and slightly $Goldreserve$ confirm these findings and allow us to conclude that the geological characteristics are determinant on the lead time to starting production.

The findings also show that on their own, except the $Goldgrade$, and the $Depverpro$, the impacts of $Goldreserve$ are positive but not statistically significant. Columns 1, 2, and 3 in table 5 suggest that without introducing the grade of the resource, the reserve quantity is not determinant. For example, a deposit with a million troy ounces gold with a low grade could lead indeed to a high cost of extraction and processing, and therefore may be less profitable for an investor. The profitability may be even more affected if it is a deep mine. Furthermore, we notice that the coefficients of the variable $Depverpro$ are higher than the hazard ratio of the variables $Goldgrade$, and even more for the covariate $Goldreserve$. Accordingly, the geological quality of the deposit and its low-cost extraction profile are more determinants than the quantity on its own.

Similarly, as we can see in each column, the coefficients of the variable $Price$ are higher than one and significant at 1%. The role of price in triggering the irreversible investment in a gold mine is even more perceptible when we introduce the variable $Priceup$. These findings suggest that when a gold mine is discovered in a thriving economic context for mining investors, it is more likely that it starts production earlier. The hazard ratios of the variable $Priceup$, as we can see them in columns 4, 10, and 11, are significant and are, on average, higher than the variable $Taxregim1$, suggesting that prices foster more the lead time to starting extraction than the low taxation fiscal regime. We find, in contrast to Shaukat Khan, Nguyen, Ohnsorge, and Schodde (2016), that increasing prices at the time of discovery accelerates the development of a gold mine project.[5]. The results are in line with the findings by Favero, Hashem Pesaran, and Sharma (1994). On the contrary, the uncertainty of gold prices postpones the development of gold mine discoveries. The hazard ratios are significant, and slightly below one for the volatility and more than one for the variable $price$.

Although the importance of political situation and infrastructure in the process of developing a mineral project, we find a weak impact on the lead time to production. Investors may turn a blind eye to the political situation, or even worse, take advantage of the current political situation for their profits. Moreover, for infrastructures, the mine area can look like an enclave, as documented by several studies. Investors use in many cases, a helicopter or a jet to carry gold mines production.

Lastly, we find mixed results about the contribution of regional specificity on the lead time

[5]However, they found that the price has a significant impact when interacted with copper mine size

Table 6: Time to starting gold production: Hazard ratio from Weibull Model(2)

	Equations					
	(8)	(9)	(10)	(11)	(12)	(13)
Taxregim1	-	-	1.470*	1.536**	2.069***	-
	-	-	(0.336)	(0.297)	(0.532)	-
Taxregim3	-	-	0.480**	0.452**	0.375**	0.503*
	-	-	(0.178)	(0.164)	(0.151)	(0.190)
Flextax	1.57***	1.598**	-	-	-	1.542***
	(0.276)	(0.343)	-	-	-	(0.266)
Depverpro	1.20**	-	1.201**	1.183**	1.214*	1.189*
	(0.103)	-	(0.106)	(0.102)	(0.126)	(0.112)
Goldgrade	-	1.047**	-	-	1.061***	-
	-	(0.020)	-	-	(0.020)	-
Goldreserve	-	-	-	-	-	0.995
	-	-	-	-	-	(0.109)
Priceup	1.549	-	1.765**	1.602*	-	-
	(0.445)	-	(0.480)	(0.444)	-	-
Price_us	1.001**	1.001**	-	1.001*	1.002***	1.001***
	(0.000)	(0.001)	-	(0.000)	(0.001)	(0.000)
Price_sd3	-	-	-	-	0.994*	-
	-	-	-	-	(0.003)	-
Polity2	1.000	1.018	1.001	1.003	0.998	1.001
	(0.014)	(0.018)	(0.016)	(0.016)	(0.021)	(0.016)
Fixedphone	-	-	0.999	1.003	1.019	0.988
	-	-	(0.24)	(0.020)	(0.031)	(0.024)
Africa	0.627***	0.666**	1.063	-	-	-
	(0.106)	(0.136)	(0.243)	-	-	-
Latinam	-	-	1.265	-	-	1.444*
	-	-	(0.366)	-	-	(0.301)
Asia	0.783	-	-	0.912	-	1.039
	(0.177)	-	-	(0.201)	-	(0.247)
Constant	0.019***	0.008***	0.022***	0.019***	0.005***	0.014
	(0.006)	(0.004)	(0.007)	(0.006)	(0.002)	(0.005)
/ln_p	0.387***	0.538***	0.372***	0.384***	0.608***	0.393***
	(0.058)	(0.072)	(0.057)	(0.57)	(0.072)	(0.058)
p	1.473	1.713	1.451	1.468	1.837	1.482
N	188	124	188	188	124	188

Notes: (*), (**), (***) denote significance at respectively 10%, 5% and 1%. Robust standard errors are in parentheses. Taxregim2, the intermediary-tax regime, is the variable of reference for the dummy variable Taxregim. Source: author's elaboration on data from Minex Consulting, USGS.

to production. The findings suggest that for a new gold deposit, being discovered in Africa increases the probability of being an untapped deposit. The hazard ratios are significant at 1% and are about 0.6 largely below one, implying that being discovered in Africa lengthen the delay before the development. In contrast, as we can see in column 13, gold mines discovered in $Latinamerica$ are more likely to come out of the ground earlier. The probability is significant at 10%. Concerning $Asia$, the results are mixed and weak.

4.3 Alternative estimation using a Cox proportional hazard model

To assess the robustness of the results, we will not set any shape to the probability of starting gold production in a given field. One may assume that the shape of the hazard form is non-monotonic. Accordingly, he may assume that the probability of developing a gold mine project increases in the following months after the discovery and fall after that and vice-versa. Therefore, we will perform a cox proportional hazards model. This model allows us to re-estimate the preceding model without assuming any particular statistical distribution. The estimate of the relationship between the probability of starting gold production and the covariates without defining any shape is written as follow :

$$h(t|taxregim, X) = h_0(t)\exp(\beta_0 + \sum_{i=1}^{3} \beta_i Taxregim_i + \beta_4 Ggrade + \beta_5 Depverpro + \beta_6 Reserveoz + \beta_7 Price + \beta_8 Priceup + \beta_9 Pricesd) \quad (4.1)$$

The main equations are re-restimated, and as the previous estimates, four variables have been picked up in the dataset. It includes, the four sets of tax regimes *(taxregim1, taxregim2, taxregim3, taxregim4)*; $depverpro$ to capture both the grade, the quantity of gold and ease of extraction and the price. Then, a set of covariates are added successively to the baseline model. The equation is as follows :

$$h(t|taxregim, X) = h_0(t)\exp(\beta_0 + \sum_{i=1}^{3}\beta_i Taxregim_i + \beta_4 Tprofitbase + \beta_5 Flextax$$
$$+ \beta_6 Ggrade + \beta_7 Depverpro + \beta_8 Reserveoz + \beta_9 Pmrqtymoz$$
$$+ \beta_{10} Priceup + \beta_{11} Price + \beta_{12} Price_s d + \beta_{13} Polity$$
$$+ \beta_{14} Fixedphone + \beta_{15} Africa + \beta_{16} Asia) \quad (4.2)$$

Where $h(t|taxregim, X)$ is the probability of starting gold production, t is time lag between the gold mine discovery and the starting production; $h_0(t)$ is the baseline hazard, which is the probability of starting gold production when all the coefficients of the covariates equal zero. $\beta_i Taxregim_i$, $\beta_4 Tprofitbase$, $\beta_5 Flextax$ denote the variable of interest and their coefficients; and $\beta' X_k$ a set of covariates, which may help us to explain the time lag between the time to starting gold production. To facilitate the interpretation, we will keep the coefficients in the hazard ratio $(\exp^{b_i})$. Thus a coefficient higher than one implies that the first gold pour will come sooner and vice versa.

Table 7 presents the results of the estimates without assuming any shape of the baseline hazard function. While the coefficients are less significant in certain cases, the main findings remain consistent even though the Cox-model is not fitted to the data.

5 Conclusion

In this paper, we analyze the impact of taxation on time to starting industrial mineral project development in developing countries. Using a sample of 188 gold mines discovered in 24 gold-rich developing countries from 1950 to 2018, we contribute to the literature by determining empirically through a survival model analysis, the impact of taxation on the lead time to production.

As suggested by the theoretical literature, we find empirically that the taxation can either foster the development of a gold mine project when the country fiscal regime has a corporate income tax equal to or below 25% and a royalty equal to or below 2%, or slow down the development when the corporate income tax and the royalty rate are respectively higher than 35% and 5%. Most importantly, our research show also that the type of fiscal regime, especially a

Table 7: Time to starting gold production: Hazard ratio from semi-parametric Cox-model

	Equations						
	(1b)	(2b)	(3b)	(4b)	(5b)	(6b)	(7b)
Taxregim1	1.543**	1.842**	1.462**	1.645***	-	-	-
	(0.282)	(0.454)	(0.261)	(0.295)	-	-	-
Taxregim3	0.429**	0.262***	0.410**	0.450**	-	-	0.303***
	(0.151)	(0.105)	(0.144)	(0.158)	-	-	(0.126)
Tprofitbase1	-	-	-	-	1.245	-	-
	-	-	-	-	(0.261)	-	-
Tprofitbase2	-	-	-	-	-	1.515**	-
	-	-	-	-	-	(0.0307)	-
Flextax	-	-	-	-	-	-	1.577**
	-	-	-	-	-	-	(0.341)
Depverpro	1.177*	1.256**	-	1.186***	1.196	-	-
	(0.102)	(0.134)	-	(0.102)	(0.123)	-	-
Goldgrade	-	1.043**	-	-	1.045**	1.050***	1.055***
	-	(0.020)	-	-	(0.020)	(0.021)	(0.020)
Goldreserve	-	-	0.999	-	-	-	-
	-	-	(0.007)	-	-	-	-
Priceup	-	-	-	1.631*	-	-	-
	-	-	-	(0.431)	-	-	-
Price	1.001*	1.001*	1.001*	-	1.003***	1.003	1.003***
	(0.000)	(0.001)	(0.000)	-	(0.001)	(0.001)	(0.001)
Pricesd	-	-	-	-	0.992***	0.992***	0.994**
	-	-	-	-	(0.003)	(0.003)	(0.003)
N	188	124	188	188	124	124	124

Notes:This table is a re-estimation of table 5 using a semi-parametric Cox-model. (*), (**), (***) denote significance at respectively 10%, 5% and 1%. Robust standard errors are in parentheses. Taxregim2, "‘the intermediary-tax regime"’ is the variable of reference for the dummy variable Taxregim. Source: author’s elaboration on data from Minex Consulting, USGS.

variable tax regime and profit base taxation, is very favorable to the first extraction of a gold deposit. Overall, all else equal, the more progressive the fiscal regime is, the sooner the extraction will occur.

Another significant evidence is the importance of the economic environment and geological characteristics in inciting mining investors to trigger the development of gold mine projects earlier. These findings are consistent with the literature and suggest that a thriving economic environment, such as an increase of gold prices, abundant reserves, and low-cost extraction, lead to an earlier beginning of the production.

Furthermore, the study emphasizes the dilemma faced by developing countries. How to get a fair share of the mineral rent and accelerated the development of the mineral potential, which is underdeveloped in many low-income countries. Many developing countries have a tendency, mainly during the decline of commodity prices, to give up a part of their revenue in order to reduce the duration of their mineral projects development. Relatedly, during the cyclical upswing, attempt desperately to reform the tax regime to get a fair share of their resource.

In light of our findings, we can guard policymaker, particularly in low-income countries against the fiscal regime "‘High-tax regime"’, given the risk of having an untapped mine is more likely. Without investors they are not able to undertake the initial investment. For the second one, "‘low-tax regime"’, even if it may allow countries to develop their discoveries quickly, leads to a few resource mobilization.

Finally, the only practical and non-hostile fiscal policy implication of our findings is progressivity. A more progressive fiscal regime based on profit or involving a part of variability can conciliate both getting a good share of the revenue stemming from the exploitation of the deposit and fostering the development of the project.

Another takeaway from our investigation is that patience could be a virtue. Trying to foster the development at all costs, particularly for mines with great potential, will not permit a country to benefit from its endowment Curtis and Lissu (2008).

Accepting a certain delay, and using other policy instruments other than tax like the political environment or infrastructure, could help the country to get a fair share of their resources and make the best out of their resources. While they are not statistically significant, they are at least beyond one in almost all our estimates, and that gives reason to believe that a good political environment and infrastructures can foster the extraction.

This paper benefited from the financial support of the FERDI (Fondation pour les Etudes et Recherches sur le Developpement international) and the program "‘Investissement d’avenir"’ of the French government. I am grateful to James Cust, Céline De Quatrebarbes, Samuel Guérineau, Alexandre Henry, Bertrand Laporte, David Mihalyi, Perrine Toledano, Jerome Valette, and the seminar and conference participants at the 2017 doctoral development days (CES, CERDI, DIAL, IHEID), 2nd Dundee Energy Forum (CEPMLP,Dundee). All remaining errors

are mine.

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Appendix

Table 8: Descriptives statistics by period

		1950'–1975	1975'–1990	1990'–2005	2005'–2018
Total sample					
	–Observations	29	65	80	14
	–Mean	13.59	9.57	10.35	6.43
	–Min	1	1	2	1
	–Max	48	33	21	12
	–25%	7	3	7	3
	–50%	10	7	10	6.5
	–75%	20	14	21	10
By Region					
– Africa					
	–Observations	18	13	40	7
	–Mean	15.89	12.69	10.38	7.43
	–Min	4	3	3	2
	–Max	35	28	21	12
	–25%	8	5	7	5
	–50%	13.5	7	10	8
	–75%	23	21	14	10
– Asia					
	–Observations	4	16	9	-
	–Mean	16.75	10.75	9.44	-
	–Min	1	1	2	-
	–Max	48	28	17	-
	–25%	1.5	5	7	-
	–50%	9	9	8	-
	–75%	32	14.5	13	-
– Latin America					
	–Observations	7	36	31	7
	–Mean	5.86	7.92	10.58	5.42
	–Min	1	1	2	1
	–Max	19	33	20	11
	–25%	1	1	6	1
	–50%	2	6	10	6
	–75%	19	12.5	15	10

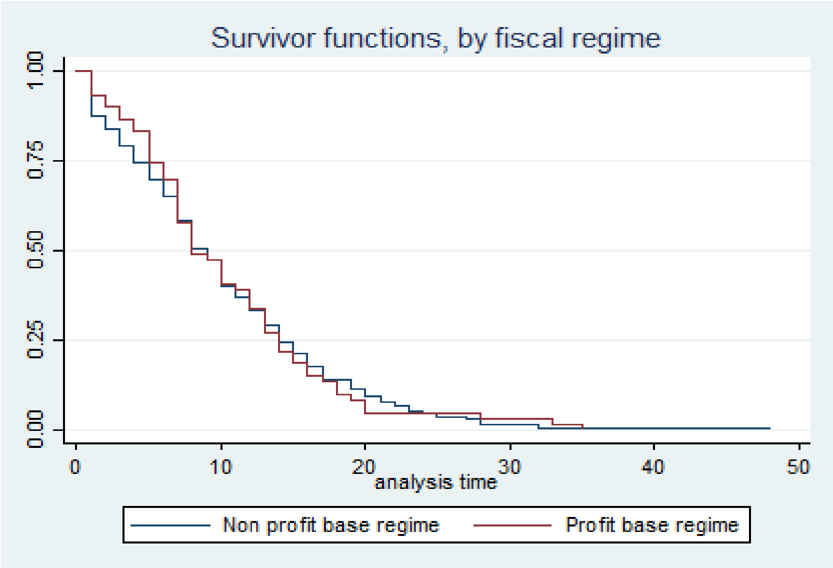
Notes: This table shows the difference in the length of time from the discovery to starting industrial mineral production between regions and periods. Source: author's elaboration on data from Minex Consulting, USGS.

Table 9: KM survival estimation

Time	Total mine	Start	Survivor Function	Std. Error	[95% Conf. Int.]	
1	188	20	0.8936	0.0225	0.84	0.93
2	168	7	0.8564	0.0256	0.7976	0.8992
3	161	8	0.8138	0.0284	0.7504	0.8626
4	153	8	0.7713	0.0306	0.7044	0.8249
5	145	11	0.7128	0.033	0.6423	0.7718
6	134	9	0.6649	0.0344	0.5925	0.7274
7	125	16	0.5798	0.036	0.5059	0.6466
8	109	15	0.5	0.0365	0.4266	0.5689
9	94	5	0.4734	0.0364	0.4006	0.5427
10	89	13	0.4043	0.0358	0.3339	0.4734
11	76	5	0.3777	0.0354	0.3086	0.4464
12	71	8	0.3351	0.0344	0.2686	0.4028
13	63	9	0.2872	0.033	0.2244	0.3529
14	54	9	0.2394	0.0311	0.1811	0.3023
15	45	6	0.2074	0.0296	0.1528	0.268
16	39	7	0.1702	0.0274	0.1205	0.2273
17	32	6	0.1383	0.0252	0.0935	0.1917
18	26	2	0.1277	0.0243	0.0847	0.1797
19	24	4	0.1064	0.0225	0.0675	0.1553
20	20	5	0.0798	0.0198	0.0467	0.1241
21	15	2	0.0691	0.0185	0.0387	0.1113
22	13	1	0.0638	0.0178	0.0348	0.1049
23	12	2	0.0532	0.0164	0.0272	0.0917
24	10	1	0.0479	0.0156	0.0236	0.0851
25	9	1	0.0426	0.0147	0.02	0.0783
27	8	1	0.0372	0.0138	0.0165	0.0715
28	7	3	0.0213	0.0105	0.0071	0.0501
32	4	1	0.016	0.0091	0.0044	0.0427
33	3	1	0.0106	0.0075	0.0021	0.0349
35	2	1	0.0053	0.0053	0.0005	0.0272
48	1	1	0	–	–	–

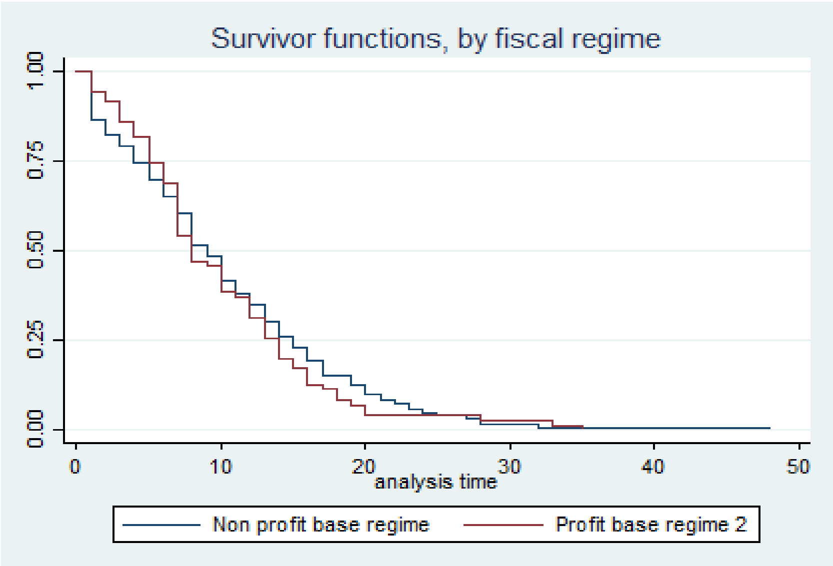
Notes: The Kaplan-Meier survivor function estimates non-parametrically the probability of remaining in the ground for a new gold mine discovery beyond the year t. Source: author's elaboration on data from Minex Consulting, USGS.

Figure 4: Kaplan-Meier estimates of time duration by Tax regime (Profit base fiscal regime)



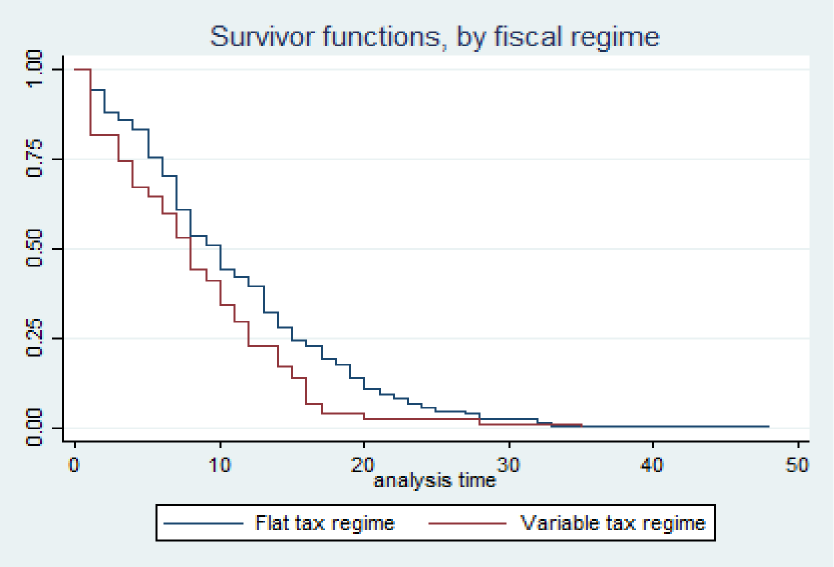
Notes: Author's elaboration on data from Minex Consulting, USGS, FERDI tax database on gold. This figure provides a graphical illustration of the mixed and weak difference in the survival time distribution between the "'Profit base fiscal regime"' and the other types of regimes.

Figure 5: Kaplan-Meier estimates of time duration by Tax regime (Profit base fiscal regime 2)



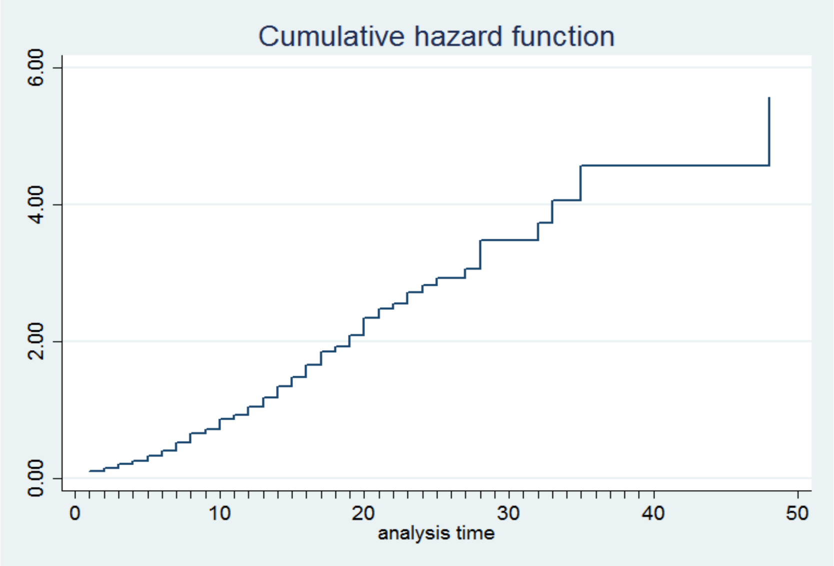
Notes: This graph as, the last one shows the Kaplan-Meier survivor function curve evolution. We observe in contrast to the Tprofitbase1 more distinctly the difference in the survival time distribution between the Tprofitbase2 and the other types of regime. Author's elaboration on data from Minex Consulting, USGS, FERDI tax database on gold.

Figure 6: Kaplan-Meier estimates of time duration by Tax regime (Variable tax regime)



Notes: This stratified graph shows the Kaplan-Meier survivor function curve evolution of "‘Flextax"’ and the other types of regime. We observe that there is a clear distinction in the survival time distribution between the progressive fiscal regime and the other types of regime which are regressive (Flat tax). Author’s elaboration on data from Minex Consulting, USGS, FERDI mining tax database.

Figure 7: Cumulative Hazard function



Notes: Author’s elaboration on data from Minex Consulting, USGS. This figure shows that the probability of starting a new gold mine deposit extraction is low at the time of discovery and increases afterward.

Table 10: Time to starting gold production: Hazard ratio from semi-parametric Cox-model (2)

	Equations					
	(8b)	(9b)	(10b)	(11b)	(12b)	(13b)
Taxregim1	-	-	1.476*	1.520**	2.116***	-
	-	-	(0.338)	(0.295)	(0.554)	-
Taxregim3	-	-	0.466**	0.446**	0.339***	0.489*
	-	-	(0.174)	(0.164)	(0.142)	(0.187)
Flextax	1.551***	1.696**	-	-	-	1.509**
	(0.274)	(0.364)	-	-	-	(0.264)
Depverpro	1.196**	-	1.194**	1.183*	1.225*	1.192*
	(0.104)	-	(0.105)	(0.103)	(0.129)	(0.110)
Goldgrade	-	1.044**	-	-	1.060***	-
	-	(0.021)	-	-	(0.020)	-
Goldreserve	-	-	-	-	-	0.995
	-	-	-	-	-	(0.008)
Priceup	1.477	-	1.666*	1.532	-	-
	(0.423)	-	(0.453)	(0.424)	-	-
Price	1.001**	1.001**	-	1.001*	1.002	1.001*
	(0.000)	(0.001)	-	(0.000)	(0.001)	(0.000)
Pricesd	-	-	-	-	0.993*	-
	-	-	-	-	(0.003)	-
Policy2	1.001	1.024	1.004	1.003	1.002	1.000
	(0.014)	(0.018)	(0.016)	(0.016)	(0.021)	(0.016)
Fixedphone	-	-	1.001	1.004	1.018	0.991
	-	-	(0.024)	(0.020)	(0.031)	(0.024)
Africa	0.64	0.702**	1.035	-	-	-
	(0.109)	(0.144)	(0.239)	-	-	-
Latinam	-	-	1.187	-	-	1.399
	-	-	(0.347)	-	-	(0.292)
Asia	0.805	-	-	0.934	-	1.043
	(0.185)	-	-	(0.210)	-	(0.251)
N	188	124	188	188	124	188

Notes: This table is a re-estimation of table 6 using a semi-parametric Cox-model. (*), (**), (***) denote significance at respectively 10%, 5% and 1%. Robust standard errors are in parentheses. Taxregim2 "‘the intermediary tax regime"’ is the variable of reference for the dummy variable Taxregim. Source: author's elaboration on data from Minex Consulting, USGS.

Table 11: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
taxregim1	188	0.229	0.421	0	1
taxregim2	188	0.261	0.440	0	1
taxregim3	188	0.048	0.214	0	1
pmr_qtymoz	188	7.356	11.233	0.902	93.191
HeadGradeP t	124	4.565	4.982	0	27.74
tprofitbase	188	0.314	0.465	0	1
tprofitbase2	188	0.372	0.485	0	1
rentable	188	0.654	0.885	0	2
pg4	188	0.085	0.280	0	1
price_us	188	344.788	185.175	34.628	1225.46
price_sd3	188	43.928	45.395	0.00026	168.48
polity2	188	0.665	5.793	-9	9
fixed_phone	188	3.954	4.873	0.01	24.43001

Notes: This table provides summary statistics of our data. Author's elaboration on data from Minex Consulting, USGS, FERDI mining tax database.

Table 12: Survivor Function by fiscal regime

Survival times (years)	Survivor Function by fiscal regime					
	Other regimes	Lower tax regime	Other regimes	Intermediate-tax	Other regimes	High-tax
1	0.9586	0.6744	0.8777	0.9388	0.8883	1
6	0.731	0.4419	0.6547	0.6939	0.648	1
11	0.4138	0.2558	0.3741	0.3878	0.352	0.8889
16	0.2	0.0698	0.1727	0.1633	0.1453	0.6667
21	0.0828	0.0233	0.0719	0.0612	0.0447	0.5556
26	0.0483	0.0233	0.036	0.0612	0.0335	0.2222
31	0.0207	0.0233	0.0144	0.0408	0.0223	–
36	0.0069	–	–	0.0204	0.0056	–
41	0.0069	–	–	0.0204	0.0056	–
46	0.0069	–	–	0.0204	0.0056	–
51	–	–	–	–	–	–
Observations	145	43	139	49	179	9
Log-rank test (χ^2)	9.91 ***		0.13		9.25***	
Wilcoxon test (χ^2)	17.08 ***		0.06		11.27***	

Notes: This table reports the difference in survival time between the different groups. The log-rank test and Wilcoxon test allow us to reinforce our visual impression of the distinction between the curve. The null hypothesis is that there no difference between the survival, otherwise the probability of starting gold extraction after the discovery is the same in all fiscal jurisdictions. (*), (**), (***) denote significance at respectively 10%, 5% and 1%. Source: Author's elaboration on data from Minex Consulting, USGS, FERDI mining tax database.

Table 13: Survivor Function by fiscal regime (2)

Survival times (years)	Survivor Function by fiscal regime					
	Non-profit base	Profit base 1	Non-profit base	Profit base 2	Constant tax	Variable-tax
1	0.876	0.9322	0.8644	0.9429	0.9407	0.8143
6	0.6512	0.6949	0.6525	0.6857	0.7034	0.6
11	0.3721	0.3898	0.3814	0.3714	0.4237	0.3
16	0.1783	0.1525	0.1949	0.1286	0.2288	0.0714
21	0.0775	0.0508	0.0847	0.0429	0.0932	0.0286
26	0.0388	0.0508	0.0424	0.0429	0.0508	0.0286
31	0.0155	0.0339	0.0169	0.0286	0.0254	0.0143
36	0.0078	–	0.0085	–	0.0085	–
41	0.0078	–	0.0085	–	0.0085	–
46	0.0078	–	0.0085	–	0.0085	–
51	–	–	–	–	–	–
Observations	129	59	118	70	110	78
Log-rank test (χ^2)	0.00		0.3		5.36**	
Wilcoxon test (χ^2)	0.08		0.01		5.37**	

Notes: This table reports the difference in survival time between the different groups. The log-rank test and Wilcoxon tests allow us to reinforce our visual impression of the distinction between the curve. The null hypothesis is that there no difference between the survival, otherwise the probability of starting gold extraction after the discovery is the same in all fiscal jurisdictions. (*), (**), (***) denote significance at respectively 10%, 5% and 1%. Source: Author's elaboration on data from Minex Consulting, USGS, FERDI mining tax database.

Table 14: AIC and BIC values for each model

	Model					
	exponential	weibull	gompertz	lognormal	loglogistic	gamma
Obs	188	188	188	188	188	188
AIC	509.2258	472.9019	479.6959	482.7057	488.0621	474.39
BIC	548.0631	514.9756	521.7697	524.7795	530.1358	519.7002
Obs	124	124	124	124	124	124
AIC	319.5866	263.2692	265.0596	278.3956	279.4282	264.3391
BIC	353.43	299.9329	301.7233	315.0593	316.0918	303.823

Notes: This table presents the Akaike's Information Criterion (AIC) and his alternative Bayesian information criterion (BIC). A lower AIC or BIC corresponds to better-fitting models. Source: Author's elaboration on data from Minex Consulting, USGS, FERDI mining tax database.