Dealing with Expropriations:
General Guidelines for Oil Production Contracts\textsuperscript{1}

Roberto Rigobon

Sloan School of Management, MIT
and NBER

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1 Introduction

In the last decade, a new round of renegotiation of contracts occurred in the oil industry. In fact, most contracts involved some form of expropriation, and certainly all of them implied some degree of conflict. Bolivia and Venezuela where perhaps the most notorious ones. In these cases their governments violated significant portions of the production contracts, and sizeable expropriations took place. On the other hand, less publicized cases (such as England) mostly changed the corporate tax rates. This is not the first round of contract renegotiations that has taken place in the industry, nor the last one. Contracts in the oil industry are indeed as volatile as its price.

One attitude toward the recontracting is simply that contracts are meant to be violated. In other words, it is possible to argue that writing a complete contract is extremely difficult (or impossible); and therefore it is well understood, ex-ante, that it will be violated.\(^1\) In this sense, renegotiation is just the natural outcome of the incompleteness. However, there are several features of the oil industry that hint to alternative explanations. First, the renegotiation of these contracts seems to be more disruptive than other private ones. In fact, institutions to deal with the "exceptions" are not guaranteeing the rights of one of the agents involved in the transaction. Most of these renegotiations are occurring between governments and foreign firms, which are not equally treated (or represented) within the judicial system in several of these countries. Second, renegotiations occur within heavily politicized environments – which usually leads to the most visible action as opposed to the most efficient renegotiation. For instance, new government with populists messages are the ones expropriating. Third, and equally important, when contracts are analyzed in detail there are several dimensions in which they could have been improved to reduce the incentives for expropriation. In fact, the mixture of taxes and transfers is always regarded as one of the most important areas of improvement. One typical line of argument is that the optimal

\(^1\)See Aguion’s paper in this volume.
taxation of the oil industry is one where the taxes are fully procyclical. This is a very
simplistic view of the problem, because two problems arise: First, when there is investment
and in certain price paths the investment is not recovered, then the optimal tax involves
subsidies to the oil industry. Second, governments care about the variance of the revenue
stream when they are unable to hedge the price risk. The optimal tax, in this regard, implies
variances that are even higher than the volatility of the price itself. For these two reasons
governments might find convenient to deviate from the optimal tax.

In this paper, I want to understand the motives behind the contracting problem faced by
the government, try to rationalize the choices of instruments that are used in practice, and
find areas of improvement in the “typical” contract. Primarily, the objective is to rationalize
some of the mixture of taxes we observe. At the onset it is important to highlight that this
is a simulation exercise; and therefore, it is not precise enough to offer implications to actual
contract formulations. The objective is to indicate how some elements of the contract can be
introduced in the discussion in order to reduce the incentives to renegotiate, and to reduce
their disruptions.

Of course this task cannot take into consideration all possible elements – nor activities in
the oil industry. The first simplification is that I will concentrate exclusively on production
contracts. Exploration and development of oil fields is an important activity in the industry.
However, the problems in those are different in nature to the production one. Furthermore,
most of the expropriations and renegotiations are affecting the production activity by itself.
Nevertheless, this is a dimension that is not included in the present discussion.\(^2\)

Which elements I consider in the design of a contract for production of hydrocarbons?
First, efficiency. Production of hydrocarbons is heavily distorted by the choice of taxes.
Indeed, hydrocarbon contracts always involve an over-tax, and the private response to such

\(^2\)See Manzano (2001) for a comprehensive discussion of the exploration and development of reserves. Future
research should continue studying these important aspects.
structure significantly affects production plans. Most of the time, this distortion is reflected in under-exploitation of the natural resource. This is costly because recovery operations are very expensive; and therefore, resources left under the ground are likely to remain there. One important question is why oil contracts need the over-tax. I discuss this in detail in the paper, but the short explanation is that when a project is being auctioned to the private sector governments collect less than its social value. The government has credibility and commitment problems, and the private sector pays less than the social value in anticipation of a renegotiation. In this environment, the private sector assigns a probability of default, that lowers the revenue collected by the government, making expropriation a desirable social outcome. This is one reason why the private sector makes abnormal returns, and also is behind why governments try to extract those rents through the tax system. Those taxes create inefficiencies and choosing the optimal structure is an important part of the contract design.

Second, rents. The main motivation behind expropriation is the perception (by the public sector) that the private sector is receiving “excessive” rents in some states of the world. This is in general why the round of expropriations usually happens when commodity prices are very high;\textsuperscript{3} and this is why the recontracting has a heavy load of politics and populism. In fact, contracts that leave “too many” rents in the hand of the private sector, at least in some state of nature, are more likely to be renegotiated when it becomes evident that those states will be reached. A good contract is one that leaves reasonable rents in the hand of the private sector in all states of nature, reducing the incentives of both sides to renegotiate.

Third, stability of revenues. Several countries design their tax systems to smooth revenues. Although fiscal revenue stability might be a desired feature of any economy, it is not clear why the smoothness should be achieved through the tax system as opposed to other institutions providing the necessary insurance. In other words, stabilization funds and

\textsuperscript{3}See Manzano and Monaldi (2007) for a political economy explanation of this phenomenon.
transactions in future markets are clearly more efficient mechanisms to stabilize revenues than the tax code. Nevertheless, few governments use alternative institutions to stabilize fiscal revenues, and most of the stability objectives end up affecting the way tax codes are designed. For instance, one of the most cited benefits of royalties is that – a sales tax – is that it is more stable than income taxes – which can be affected by agency costs, and other sources of fluctuation. Regardless if this argument is true or not, the point is that in general the pursue of stabilization has affected the contract design.

In this paper I take this last point seriously. I compare how the contract is affected by the stabilization objective, and study how it interacts with expropriations. In fact, these two objectives are inherently opposing each other. A very simple example highlights this tension. Assume that the only uncertainty is in prices, and for simplicity assume that production is fixed. The most stable revenue is one in which the government collects a fix tax per unit of production. However, this means that when prices are very high the firm will have large profits. This could motivate an expropriation based on the fact that the firm is earning “too much”. On the other hand, assume that the government collects taxes in such a way that the firm receives a fix profit in all states of the world. In this contract the firm has constant profits and will never be expropriated (or less likely), but all the uncertainty of the price fluctuation is born by the government revenues. In this example, minimizing the probability of expropriation increases the revenue variance, while minimizing the volatility of taxes increases the probability of expropriation. In this paper I extend this simple intuition to the case when the firm is solving a dynamic stochastic problem choosing its production level.

Finally, agency costs. Taxes and rents transferred to the public sector can be significantly reduced by companies expenditure and investment behavior. For instance, several oil and gas contracts have incentives for investment, which are (mis)used by the private sector to reduce the tax burden. The case of Bolivia is one of the most interesting ones in this regard. The contracts on gas included investment incentives that the firms used when prices where
increasing as means to reduce the tax pressure. For instance, the fiscal burden was 37 percent of the international price in 96-98 when international prices were relatively low. It decreased to 24 percent between 99-01, and further down to 15 percent in 02-04. The effective tax rate as a percentage of the price was declining with price increases! Given that an important part of the taxation were levied on profits this can only be explained if the costs increased faster than international prices in the last decade. This is unlikely. The most plausible explanation is that in times of high prices the firms found easier to undertake in large investment projects that reduced the tax burden. Some of these investment might have been profitable, but some of them responded to tax issues rather that social or private returns.\textsuperscript{4}

The paper starts with a simple setup where income taxes are non-distorsionary and there is almost no efficiency lost. The problems start when the government is concerned about revenue stabilization. Income taxes produce a more volatile revenue than royalties and a government worried with revenue volatility shifts the tax mixture toward royalties – a more distortionary tax. Not only production plans are affected, but more importantly private profits become more extreme, and price paths in which private profits are “extremely” large are more likely. This increases the probability of expropriation.

The paper has the following main recommendations.

1. Use a stabilization fund to deal with revenue uncertainty. Changes in the tax structure to provide income insurance produce undesirable outcomes. Nevertheless, it is understood that stabilization funds are costly and will never provide full stabilization and hence they have to be complemented.

2. Build a local constituency to mitigate the expropriation incentives. If the transfers to the locals are procyclical – which is equivalent to have a procyclical tax rate – then expropriation incentives are reduced.

\textsuperscript{4}See Manzano and Monaldi (2007) for a detail description of the events.
3. Government sharing ownership has been highlighted as a possible vehicle to reduce agency costs. This assumes that the government incurs less agency costs than the private sector – which seems as a strong assumption. The problems of agency costs are reduced by relying on sales taxes, and indeed that has been the response of several government. The elimination of investment subsidies, and depreciation subsidies will go a long way in reducing the agency costs than plague the industry, and they are more efficient that involving the government in the production process or shifting to less than optimal taxes.

In the end, the paper argues that even though the optimal tax from the efficiency point of view involves a procyclical tax rate, from the political and social point of view they are hard to implement. The fact that governments are concerned with the volatility of the revenue stream, and also with the presence of agency costs implies that the mixture of taxes deviates from the efficient one to a tax that relies more on more distortionary – but more stable – taxes. This in turn creates paths where excessive profits are too large for the government to avoid the temptation to expropriate. Hence, expropriation and inefficient taxes are to be expected.

As mentioned above several aspects have been excluded from the analysis. The political economy of the expropriation has been severely simplified. I assume that expropriation occurs when private profits are “too large”. This is clearly part of the expropriation decision, but certainly it is not enough. As is discussed in this volume repeatedly aspects of fairness, efficiency, and composition of investment have indeed being part of the expropriation. Second, the model I solve has no investment at all. Exploration and development are expression of some of those investments. This is an important simplification. I believe a first step toward understanding the optimal contract requires analyzing the simplest problem when investment is not part of the decision problem, although future research has to address this important issue.
The paper is organized as follows: Section 2 presents the simple model and discusses the assumptions by summarizing the relevant theoretical and empirical literature. Section 3 presents the results from the simulations. Section 4, concludes.

2 A simple organizing framework

I assume that a foreign firm contracts with a government to produce a mineral – which for most of the discussion is going to be oil. I abstract from all interactions at the firm level. Indeed, several problems that arise in the exploitation of natural resources refer to externalities at the firm level. I will abstract from all those issues and consider exclusively the problem between the firm and the government.

2.1 Setup

An infinitively lived firm is a price taker in the international markets and can only make the choice of production, and later in this paper about “wasted expenditures”. The firm has a known amount of reserves to exploit. These reserves are certain and cannot be changed. The decision of exploration and development of oil fields, for example, relaxes this assumption. This is an important simplification of this paper – I do not deal with the problems that arise from the investment in reserves. Hence, in the baseline model, the firm just chooses how much to produce.

2.1.1 Prices

I assume the price of the commodity is described by a random walk with no drift. This assumption is not essential for the analysis, although mean reversion might diminish some
of the effects highlighted here. Prices are given by

\[ p_t = \begin{cases} 
  p_{t-1} + \delta \frac{w}{p} & \alpha \\
  p_{t-1} - \delta \frac{w}{p} & 1 - \alpha
\end{cases} \]

where \( p_t = 0 \) is an absorbing barrier. I assume that there is a maximum price \( \bar{p} \) which is also an absorbing barrier. This price is large enough that the firm will produce the entire field in one period, meaning that higher prices are just not interesting for the present analysis. Furthermore, I initialize the model and simulations at a point in which the upper bound price is never reached.

### 2.1.2 Cost structure

The firm has a cost of production that has increasing marginal costs on two arguments: the production in each period and the amount of reserves left. The idea of the second assumption is to capture the fact that in general the marginal cost of the production increases the lower the reserves are underground. Not only this assumption is reasonable given the properties of most natural resource exploitation, but most importantly, it is a crucial assumption to generate significant distortions by the different taxes.

The cost function is

\[ c(q_t, Q_t, Q) = c_0 \cdot q_t + c_1(Q_t/Q) \cdot q_t^2 \] (1)

where \( q_t \) is the quantity produced at time \( t \), \( Q_t \) is the cumulative production that has taken until time \( t \), and \( Q \) is the total original reserves in the field. I assume that the cost function is convex and that its degree of convexity is what changes when the reserves are being depleted.

From the practical point of view, making the function \( c_1 \) increasing is enough to capture the distortions the paper is trying to highlight.
2.1.3 Taxes in the typical contract

One of the objectives of this paper is to study the impact that different taxes have on the production plan, the tax revenue volatility, and the profits left in the hands of the private sector. There are literally thousands of possible taxes and arrangements between the private sector and the government. Just to reflect some of the diversity, Table 1 summarizes some of the aspects in oil and gas contracts in Latin America. Trying to design the optimal contract by looking at the actual clauses is an impossible task. Contracts usually involve taxes (sales, royalties, assets and income), depreciation clauses, investment incentives, participation shares, and fees. Far too many dimensions to consider.

In this paper, I concentrate on two forms of taxation: royalties and income taxes. These are possibly the two most prevalent forms of taxation in natural resources. The royalties are taxes levied on sales. Sometimes they are a fixed payment for unit produced – similar to the fees – but nowadays most of the royalties are similar to sales taxes – where the tax rate is constant. The other tax, income tax, is always part of the contract. Sometimes the tax rate is the same as the corporate taxes, however, most contracts always specify an overtax.

These contracts do not include all the possible mechanisms that are now used. For instance, profit sharing arrangements are becoming more prevalent – in the form of join ventures, or specific sharing rules. From the taxation point of view, a profit sharing rule might seem similar to an income tax, but the fact that one pays taxes for sure, and the other one just declares dividends makes the distortions of the second one smaller. Having a government as a partner in the production of oil and gas produces other distortions that I do not discuss in this paper. Indeed, it is not clear that the literature has an agreement on the type of distortions that might arise because of JV’s.

The other important ingredient missing in the discussion are investment incentives – given that I do not have investment, subsidies would be irrelevant. Nevertheless, I will try to capture the “bad" aspect of those subsidies – meaning the agency costs that arise from
them. The reason is that income taxes and investment incentives create similar behaviors to the firm and I can capture them with the income tax alone.

In summary, I consider the choice of two tax rates. Royalties levied on the total sales, and income taxes levied on total private profits. I assume that the tax rates are not contingent to prices, production, or reserves – which is mostly how contracts are specified in reality.

2.1.4 Royalties and Income taxes

The problem of taxation of the oil industry has, in general, a very simple answer from the economists point of view: procyclical dividend transfers. For instance, the optimal contract is one in which the firm pays its costs, and it can retain a “reasonable” return on its capital. If the firm is subject to enough regulation such that it does the optimal investment, and uses the factors optimally, then all the other sources of revenue constitute the rent and should be transferred to the government – preferably in the form of dividends which are less distortionary than taxes. This is indeed the basis of optimal regulation.

However, there are two problems with this mechanism. First, when oil prices are low enough it is possible that the firm needs subsidies. In other words, the oil companies need subsidies when oil prices are too low and investment is not recovered. The likelihood of this happening in an emerging market is zero. In fact, the paper by Engel and Fischer in this volume deals with this aspect of the optimal contract under investment. Second, and equally important, the optimal transfer is more volatile than oil prices and sales. If the government is concerned with revenue stability because it is costly to hedge, or the cost of borrowing increases when oil prices decrease, then the optimal tax is not optimal for the government. These two reasons imply that the optimal tax from the efficiency point of view is almost never implemented. In the set up developed below the optimal tax (from efficiency) is one that depends entirely on income tax (or corporate taxes); when the volatility concerns are introduced the implication is that the government implements a different mixture, where
royalties and other forms of sales taxes are favored.

As reported in Table 1, notice that all contracts in Latin America have royalties and fees for production and exploration, and almost all have either asset and sales taxes. In comparison, England and Alaska depend almost exclusively on corporate taxes. One reason is that in those countries/estates oil revenues are a smaller share of all fiscal income and therefore they need less stabilization than Venezuela of Equatorial Guinea, but the second one is that England and Alaska have access to better financial and insurance markets; and hence have the luxury to implement a better tax mixture.

2.2 Maximization Problem

The firm maximizes expected profits given prices, taxes, and the total reserves. The firm operates, initially, under the assumption that there is no default on the contract. The objective is to analyze the impact of the different taxes on the production plan, expected profits, etc.

The firm solves the following Bellman equation

$$V(Q_t, p_t) = \max_q \left( \pi (q_t, Q_t, \tilde{Q}, p_t, \tau_r, \tau_\pi) + \frac{1}{1 + \beta} E \left[ V(Q_{t+1} + q_t) | p_t \right] \right)$$

where $\tau_r$ is the royalty tax rate, and $\tau_\pi$ is the income tax rate. Profits at the firm level are given by

$$\pi (q_t, Q_t, \tilde{Q}, p_t, \tau_r, \tau_\pi) = [p_t q_t (1 - \tau_r) - c(q_t, Q_t)] (1 - \tau_\pi)$$

I solve this standard maximization problem by discretization of the state space and solving for the fixed point problem of the value and policy functions.

2.2.1 Agency costs

When I add agency costs to the problem I assume that the firm can take actions that are costly from the profit stand point of view, but that they can lower the tax burden.
In reality those actions involve deviating from the optimal investment plan, or increasing expenditures, they mostly reduce the tax burden of income taxes, and they rarely have an impact on royalties. Indeed, several policy makers indicate that one of the benefit of royalties is the fact that they are subject to less manipulation by the firms.

In this paper I capture the agency costs in a very stark form. I assume that the firm can take an action that has a cost in terms of private profits, but reduces the income taxes that have to be paid. My assumption is that these actions are useless from the production point of view, they only reduce the tax burden.

2.2.2 Government’s Problem

The theoretical public finance literature studies tax choices and tax incidence problems by specifying an objective function that tries to minimize the distortion introduced by the taxation, and where one constraints is to achieve the desired level of taxation, among other constraints. Sometimes the problem actually maximizes the consumer’s utility. This is the case when the distortions are several and it is complicated to decide on one specific one. In the example discussed in this paper there is no consumer and the most important distortion that arises is the change in the production plan.\footnote{This procedure is the standard one followed in the public finance literature and the one I use in this paper.}

The problem of the government is to determine which combination of taxes maximizes its objective function. I assume that in the maximization problem tax revenues, stabilization objectives, and probability of renegotiation enter the objective function.

I assume the government chooses fixed tax rate – fixed in terms of the state variable (which includes the price of the commodity). In fact, the optimal contract would always imply a contingent income tax, where the tax burden is procyclical.\footnote{See, for instance, Rigobon (2006).} However, as is clear from Section 2.1.3, production contracts involve constant fees and tax rates. I keep this
assumption throughout the paper.

Assume that the government cares about the efficiency (minimizes the distortion in the production plan) subject to a minimum expected tax revenue and a maximum expected variance in the tax revenue constraints. This is indeed the standard objective function used in public finance. This is equivalent to maximize the agents utility.

For simplification, and to be able to solve the model in the simulations, I assume that the only distortion the government is concerned with is how taxes affect the production plan. The distortion in my case will be one in which the government compares the expected path of the field with taxes ($q_t$) and without taxes ($q^0_t$).\(^7\)

Specifically,

\[
\min_{\tau, \tilde{\pi}} E \sum_{t=0}^{\infty} \frac{1}{(1 + \beta)^t} (q_t - q^0_t)^2
\]

\[
E \sum_{t=0}^{\infty} \frac{1}{(1 + \beta)^t} \tau_t \geq \tilde{\tau}
\]

\[
Var \left( \sum_{t=0}^{\infty} \frac{1}{(1 + \beta)^t} \tau_t \right) \leq \tilde{\nu}
\]

where $\tilde{\tau}$ is the target tax collection, and $\tilde{\nu}$ is the maximum variance the government is willing to suffer. In this problem I have not specified how agency costs enter the problem and how the probability of expropriation affects the government choices. I leave that extension for later when I clarify how the expropriation decision is made. Let me concentrate for the

\(^7\)In the first version of the paper I concentrated on the total production distortion. In other words, the objective function was

\[
\min_{\tau, \tilde{\pi}} \left( Q - E \sum_{t=0}^{\infty} q_t \right)
\]

Notice that in this objective function increasing production at one time and reducing it later has no impact on the optimization. Here the government is uniquely concerned with the total cumulative production.

The objective function that I have now put weight both on the total production but also on the timing. I thank all the discussion at the conference which pointed out to me this improvement.
moment in how the concern for stabilization affect the tax mixture.

In the set up, the optimal tax is the one that reduces the distortion when there are no concerns for stabilization ($\tilde{\nu} \to \infty$). This taxation implies a mixture where only income taxes are used. The reason is that income taxes do not change the first order condition of the firm, while royalties do. However, in this model income tax revenues are more volatile than royalty revenues. Therefore, when the variance constraint binds, the optimal choice of taxes is extremely simple, royalties are increased and income tax rates are reduced to keep total revenue constant and reduce its variability. The solution is always a corner solution given the assumptions I have made.

### 3 Simulations

The first step of the simulation is to show the degree of distortion that the different taxes – and mixture of taxes – generates. The second step is to solve the problem of the government and study volatility of tax revenues, efficiency, and probability of default.

In the simulation I assume that the price of the commodity fluctuates between 0.1 and 2, where the initial price is 1. I assume that the step in the random walk ($\delta$) is 0.1 every period. The probabilities of increases and decreases are equal (1/2) – hence there is no drift. The discount rate is assumed to be equal to 5 percent. The initial reserves are equal to 20, and the cost function has parameter $c_0 = 0.75$; while the function $c_1$ is $0.1 \left(1 + \frac{Q_t}{Q_0}\right)$. As was mentioned above the choice of the $c_1$ function highlights the increasing marginal cost when reserves are depleted.

The first step in the simulation is to solve the firm problem given taxes and the parameters and functional choices just highlighted. The solution for the problem are not discussed here and the value function, as well as the policy functions for the no tax case are not shown here.\(^8\) As opposed to studying the policy functions and their changes when taxes are modified, here

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\(^8\)There is nothing particularly interesting in the policy choices. The solutions are very standard indeed.
I analyze how the pattern of production and tax revenues changes in a Monte-Carlo exercise. The simulation consists of 500 histories of 100 periods each. All simulations start at the same state (price of commodity and reserves left).

3.1 Tax distortions

The first step is to highlight the different distortions that the taxes produce in the firms decision. These aspects have been heavily discuss in the regulatory literature. Here, I just want to just indicate the different problems that appear. The simulation involves two exercises. First, assuming that the income taxes are zero, royalties are increased from zero to 30 percent. Second, I set royalties to zero and vary income taxes in the same range.

After solving for the value and policy functions for each tax rate I simulate the dynamic response of the firm using Monte-Carlo. The price process feed to all simulations is exactly the same; hence the only differences arise from the firm responses. Each history has 100 periods, and start exactly at the same point.

3.1.1 Measures

There are several measures I am interested in evaluating. First, what is the expected total production. As I said in the beginning, the firm starts with 20 units under the ground. The question is how much of that is actually extracted for each price path. Assuming all paths are equally likely, it is possible to compute the total expected quantity that has being exploited.

This is an important measure of the distortions that the tax system produces. In fact, most of the distortions are reflected in under exploitation of the field. This is because the assumptions I have made will lead to this conclusion. If investment incentives are included in

The interesting aspects is how those policy choices interact with the taxes, and that exercise is what is highlighted in the paper.
the discussion and they affect the development of reserves, then overproduction is possible. Nevertheless, here I am more concern with understanding the degree of the distortion rather than its direction, and have chosen the most conventional one.

Second, what is the expected net present value of tax revenues. This is a measure of how much is unconditionally collected by the government. One salient issue is the Laffer curve that arises in the royalty case. This is because at certain tax level the quantity distortion is so severe that it reduces total revenues.

Finally, I study how the different combinations of taxes affect the volatility of the tax revenues. In this case, I compute the taxes for each of the Monte-Carlo simulations, and compute the net present value for each of them. The variance is then computed across all 500 paths. In other words, I do not compute the time series variation as part of this measure. The reason is that I believe that governments are primarily concern with the total collection of taxes first, and then its timing second. This is clearly an assumption but I wanted to concentrate on only one of the sources of variation. Otherwise the analysis becomes cumbersome and it is hard to separate what is actually changing the variance of the tax revenues. In this case, I am certain the variation is coming across the different paths of prices.

3.1.2 Results

The first set of results concern with the distortions that are created by the different taxes. In the governments objective the distortion is measured as the net present value deviation of the production plan with and without taxes. There is another interesting dimension of the distortion which is the total amount of barrels extracted. The first one is presented in Figure 1 and the second one is presented in Figure 2.

Figure 1 shows the net present value of the production plan change as computed by equation (2). The continuous-thick line is the distortion generated by increasing the corporate
Figure 1: Expected Net Present Value of Production Plan Change
tax rate, while the dashed-thin line is the distortion when the royalties are increase. Tax increases produce larger distortions in both cases. However, as it is clearly seen, the increase in the distortion due to the income tax is extremely small in comparison to the distortion that occurs when the royalties are raised. A larger portion of the distortion comes from the fact that royalties decrease the absolute value of the total production. In other words, for a given amount of reserves, increases in royalties reduce the total barrels extracted.

Indeed, Figure 2 shows the expected total production for the different royalties and the income taxes. In the x-axis I present the tax rate (for both the royalties and the income taxes). The continuous line corresponds to the expected production under income taxes, while the dashed line is the total expected production for the royalty case.

Even in the absence of taxes, the firm leaves some resources under the ground. Given the parameters chosen the optimal total extraction is 19.86. The reason why some resources are left is because there are some paths in which the prices are so small that do not pay the marginal cost. Furthermore, the more has been exploited the larger the marginal cost of the next unit – exacerbating the problem.

As can be seen, the income taxes have a negligible distortion. This is by construction. The way income taxes enter is by proportionally changing all profits in all states of the world, not affecting the first order conditions faced by the firm. Indeed, the small differences that actually exist in the simulation are of the fourth order of magnitude, and I believe they are mostly the outcome of the approximation.

On the other hand, notice the severe distortion that exists when royalties are levied. In fact, there are tax rates that are so high that almost no production takes place. For taxes above 30 percent production is indeed zero. This is a standard problem in regulation of natural resources.

Having seen the impact of the tax rates on the firm choices, it should be obvious that a Laffer curve exists for the royalties. Figure 3 shows the net present value tax revenue for each simulation. The x-axis is as before, and similar to the previous graph the continuous
Figure 2: Expected Total Production
line reflects the tax revenues from using only income taxes, while the dashed one is the tax revenues from royalties.

As should have been expected, notice the Laffer curve in the royalties. Nevertheless, also notice that collection of revenues is much faster – and effective – using royalty taxes rather than income taxes. An important question that arises is if the Laffer curve actually exists in reality. The case of Bolivia in recent years is an example that some Laffer curve indeed exists. In this case, the increase in prices was accompanied by increases in investments and tax credits such that the effective tax rate actually came down as opposed to increase. The case of Venezuela in the late 60’s is another piece of evidence, however, this is mostly anecdotal. During that time increases in taxes reduced investment and tax collection. In fact, most oil experts (such as Ramon Espinasa) believe that the debacle of the tax system was an important motivation for the nationalization.

Finally, Figure 4 presents the volatility of those taxes. I computed the coefficient of variation of the tax revenues for each choice of taxes. As can be seen, for relatively large tax rates (very large indeed) the royalty has a higher volatility than the income tax. However, for the range of taxes in which it is usually fluctuating the sales taxes, it is the case that the royalty is less volatile than the corporate tax.

This is a raw comparison between the two taxes. The real question to compare the two different forms of taxation is to fix the expected total revenues collected, and compare the variances. This is the objective of the next subsection.

### 3.2 Volatility, private profits, and expropriation

In this subsection as opposed to move independently the two taxes, I fixed the total expected tax revenues (I choose 0.75), and determine the different mixtures of taxes that achieve such revenue. I vary the royalties from 0 to 10 percent, and compute what is the income tax that will set the expected revenue to the target.
Figure 3: Expected Tax Revenues
Figure 4: Expected Volatility of Tax Revenues computed as the coefficient of variation.
This is a very time consuming process. The optimization is done by searching along the different income taxes. For each proposed tax the whole value and policy functions are solved, the Monte-Carlo exercises are computed, and the expected revenue is calculated. That means that each proposed pair requires the full solution of the problem.

3.2.1 Impact of taxes on private profits

The tax mixtures are shown in Figure 5. The thick continuous line on the top is the expected total taxes (almost constant at 0.75, the only errors are for numerical approximation and are of the order of the fourth decimal). The thin continuous line is the royalty tax rates, and the dashed line is the income taxes.

Notice that for very high royalties actually there is an income subsidy. This is innocuous in terms of the message that the section pretends to convey. As the royalties are increase, as it should be obvious, the income taxes are reduced.

The next step is to compare the tax revenue volatility and the sensitivity of the production plan. Figure 6 shows the variance of tax revenues (the thick line measured in the right hand side axis) and the variance of the production plan (dashed line measured in the left hand side). The variance of the tax revenues is computed path by path. Interestingly, when royalties are increased the variance of the tax revenues drops. The intuition of this result is that royalties because they are levied on sales has a smaller volatility than profits. In fact, the coefficient of variation of royalties is smaller than the coefficient of variation of income taxes.\footnote{By forcing the tax mixture to collect exactly the same amount of resources the exercise is comparing the implicit coefficients of variation.
}

At the same time, the variance of the quantity produced increases with the royalties. The reason is that when royalties are higher, quantities are more sensitive to price fluctuations. In fact, there are several paths in which quantities are severely reduced – almost zero.
Figure 5: Tax Mixtures and Expected Total Tax Revenues.
sensitivity of the quantities produced is reflected in the increase of the unconditional variance of the total production.

In general government care about the variance of the tax revenues as opposed to the volatility of production and the degree of inefficiency. In other words, here it can be seen that an increase in the reliance of royalties stabilizes fiscal revenues – some stabilization – sacrificing on efficiency – lower production and higher sensitivity of production to price fluctuations. Because the cost of the inefficiency is mostly born by the private sector the government cares very little about it.

In Figure 7 I present the expected private profits. As should have been expected, they are decreasing with the royalty rate. This is a reflection that the private sector is the one paying for the distortion.

There is, however, another dimension that the royalty affects negatively. In Figure 8 I present two measures of the profits of the firm that reflect extreme events. The continuous thick line represents the number of times the profits in the private sector are excessively high.\(^\text{10}\) The thick line is measured in the left vertical axis. The dashed line measures the maximum profit across all times and paths and is measured in the right vertical axis. As can be seen, even though the average profit by the private sector drops with the increase in the royalty rate, the “extreme” events are more frequent. As was discussed before, if the probability of expropriation depends on conditional private profits, the change in the tax mixture toward royalties increases the frequency of larger profits, raising the expropriation motives.

In summary, the shift from pure income taxes toward royalties has one advantage – so far. The royalties provide a more stable source of income to the government. On the other hand, they bring bigger distortions in the production plan, and higher dispersion of private profits – which might end up implying more probability of default. In the following section

\(^{10}\)In this simulation the assumption is that the profits are above 0.10 in any given period.
Figure 6: Tax Mixtures and Volatility: Tax Revenues and production plan.
Figure 7: Tax Mixtures and Expected Private Profits.
I extend the present model to discuss another “positive" aspect of the royalties – mainly the interaction between the tax code and the agency costs.

### 3.2.2 New maximization problem

When the probability of default or expropriation is introduced in the problem the maximization that the firm and the government face is as follows:

$$V(Q_t, p_t) = \max_q \left( \pi(q_t, Q_t, \bar{Q}, p_t, \tau_r, \tau_\pi, \Phi_t) + \frac{1}{1 + \beta} E[V(Q_t + q_t, p_t') | p_t] \right)$$

$$\pi(q_t, Q_t, \bar{Q}, p_t, \tau_r, \tau_\pi) = \left[ p_tq_t(1 - \tau_r) - c(q_t, Q_t, \bar{Q}) \right] (1 - \tau_\pi) \Phi_t$$

$$\Phi_t = \phi(q_t, Q_t, \bar{Q}, p_t, \tau_r, \tau_\pi)$$

where $\Phi_t$ is the probability of expropriation. I assume that the firm loses everything and collects zero after the expropriation takes place.

The government solves the exact same problem as before:

$$\min_{\tau_r, \tau_\pi} \mathbb{E} \sum_{t=0}^\infty \frac{1}{(1 + \beta)^t} (q_t - q_t^0)^2$$

$$\mathbb{E} \sum_{t=0}^\infty \frac{1}{(1 + \beta)^t} \tau_t \geq \bar{\tau}$$

$$\text{Var} \left( \sum_{t=0}^\infty \frac{1}{(1 + \beta)^t} \tau_t \right) \leq \bar{\nu}$$

where it cares about the expropriation only to the extent that it affect the distortion, the tax revenues, and its volatility.

As I said before, the expropriation decision has been simplified;

$$\exp = \begin{cases} 
1 & \text{if } \pi_t > \bar{\pi} \\
0 & \text{o.w.}
\end{cases}$$

where $\bar{\pi}$ is some threshold. The idea is that the expropriation (or default on the contract) occurs when the government perceives that the private sector is receiving “excess" profits.
Figure 8: Tax Mixtures and Expropriation. Maximum profit and number of path with profits larger than threshold.
An alternative specification (proposed by Ricardo Hausmann during the discussion of the paper) is to base the expropriation decision on the value of the firm. In other words, as opposed to make decisions on the profits at some period of time, it makes sense that the expropriation occurs when the value of the firm is higher than some threshold. The reason why I chose the specification above is twofold: first, it simplifies tremendously the problem of simulation. It is the case that I am computing the value function already, but conditioning the probability of expropriation in some state of nature only to current profits is much simpler. Second, and probably more important, is the fact that in this problem I am solving the problem of only one project that has finite reserves – which means that the value function is decreasing in expected value. This implies that almost all expropriation occur at time zero if the expropriation rule is based on the value function.

Notice that the impact of this problem only affects the firm choices. Because the expropriation is very costly for the firm, the firm chooses a production plan that makes profits in all states of the world less or equal than $\bar{\pi}$.

When this constraint is added to the maximization problem it is possible that no solution is found for particular price paths. The intuition is as follows: assume there are only two price paths, one that implies very high profits and the other one very low. Because tax rates are not contingent to the price level, expropriation takes place when prices are high. The firm reduces its profits in that path by cutting down production, which reduces tax revenue. If the government wants to keep taxes constant and volatility at the limit, then it has to increase both taxes, but it has to increase royalties more than income taxes. The change in the tax mixture increases the probability of entering a default state, and depending on parameter values this increase can be sufficiently large that the shift deteriorates the probability of default. In those cases, there is no solution. In other words, let me be more precise, for the tax revenue target there is no solution. Obviously, in those circumstances it is the case that
government will decrease their objectives — finding a solution.\textsuperscript{11}

\section*{3.3 Introducing small agency costs}

In this section, I introduce small agency costs. The main reason why I concentrate on smaller costs is because if agency incentives are severe, then the income tax also exhibits a Laffer curve; complicating significantly the analysis.

The idea behind the agency costs is to model private decisions that are wasteful but are able to reduce the tax burden. As I argued before, most of those actions are “expenditures” and therefore affect the income tax efficiency more than sales taxes. In this paper the wasteful expenditure is costly in terms of profits, but reduces the tax burden proportionally to the tax rate. Therefore, if the income tax rate is large, the benefits of the wasteful expenditure are bigger and the firm find profitable to incur them.

The only source of inefficiency that I study is the reduction in taxation that takes place because of the agency costs. Figure 9 shows the ratio between the tax collection without agency costs and the tax collection when agency costs are present. This figure is similar to those in Section 3.1.2. Each tax was increased independently from zero up to 15 percent. On the x-axis the tax rate is presented. The thick continuous line is the tax reduction when income taxes are used and the dashed line is the ratio when royalties are used.

Notice that the drop in taxes when royalties are present is extremely small. It is always less than 1.2 percent. The reason why this is not exactly one is because there are some paths in which the reduction in taxes is beneficial given the extremely high price level. This reduction in taxes allows for further production, and therefore, only on those extremes the firm finds profitable to throw away money.

On the other hand, when income taxes are in place, the distortions are much larger. All taxes drop by more than 10 percent, and the drop increases with the tax rate. Meaning,

\textsuperscript{11}I thank Federico Sturzenegger and Bill Hogan for raising this point.
Figure 9: Reduction in expected tax revenue when small agency costs are introduced.
that higher tax rates incentivate worse behavior.

4 Policy Lessons

The previous simulations can be summarized as follows:

First, when governments have problems dealing with the volatility of tax revenues, the optimal regulation of oil and gas activities imply a tax mix that deviates from the one that minimizes the distortions. In the example developed in this paper, corporate taxes is the optimal taxation from the economic point of view, but because these taxes tend to be very volatile, the government shifts taxation toward sales and royalties – which are less volatile but more distortive.

Second, this tax mix implies more volatile private profits. The reason is simple: tax mixtures that imply a more stable stream of tax revenues transfer the volatility to private profits. The increase in the volatility of private profits implies states of natures when profits are “extremely” large culminating in a renegotiation of the contract, or an expropriation.

Third, the firm to avoid the expropriation reduces production – distorting the production plan even further, or incurs in agency costs to reduce profits and the tax burden.

In summary, royalties are more distortionary and might create larger expropriation probability, but they are more stable and mitigate agency costs. On the other hand, corporate or income taxes are move volatile and induce agency costs, but they are more efficient and reduce the chances of expropriation. In this paper, income taxes are exactly the same as any form of government ownership, hence, the benefits and costs of income taxes are also transferrable to the setup analyzed here.

So far, these are the alternatives the firm have given the maximization problems I have specified. In this section, I would like to conjecture another possibility.

In order to avoid the expropriation the firm would be willing to keep production at the
optimum level and pay additional taxes. This is clearly Pareto improving. Why wouldn’t the firm do it? Because paying taxes in the good times would increase the volatility of taxes, violating one of the constraints of the government. In fact, in this model, the anticipation of that “additional" transfer would change the tax mixture ex ante. Therefore, the firm is willing to make a transfer but it cannot do it to the government given the volatility concerns. One possibility is to make the transfer to the society directly. This can have the form of financing NGO’s that will then deliver important improvements to the environment or the society. It is crucial to remember that these transfers to the NGOs are extremely volatile – this is not a recurring expenditure, it occurs only in booms and it fluctuates with the private profits. Nevertheless, it creates a local constituency that might defend the oil and gas industry at the time an expropriation is likely to occur. In other words, when the government is ready to expropriate the industry (during booms) is when the transfers to the NGOs are the largest. This alternative, although not formally studied, produces less inefficiencies than the ones highlighted in this paper – which involves changing the production plan.

5 Conclusions

This paper has discussed how optimal taxation is affected by three issues that are likely to appear in natural resource extractions. The desire to stabilize revenues, the need to reduce agency costs, and the expropriation incentive. I argue that those aspects have negative effects on efficiency, and that trying to find a solution by changing the mixture of taxes is probably inappropriate. Although, in practice this is the solution most countries pursue.

In this paper problems start when the government is concerned about revenue stabilization. Indeed, one lesson from this exercise is that stabilization should be achieve by a different institution. Taxes, in the case of natural resource extraction, cannot handle the task. The implementation of a stabilization fund is crucial to be able to design a proper
production contract. If the stabilization fund does not exist, or it is not credible, the implication is that the government will have incentives to distort the tax mixture making agency costs and expropriation more likely.

The problem of expropriation cannot be solved using the standard contracting tricks; taxes are contingent, and profits in the private sector are driven to zero. Both are unrealistic. Which means that in the end other arrangements are required. Government will set fit taxes and therefore, it is in the best interest of the firms to create a local constituency that could be severely damaged in case of an expropriation. Some oil companies indeed spend on local services, but the experience in Alaska might suggest that transferring lump sum to local agents could be a more efficient and long lasting strategy. Furthermore, if those transfers are tax deductible (like expenditures) then it is in the best interest of the firm to actually develop the local support.

Finally, sharing ownership has been highlighted as a possible vehicle to mitigate agency costs. This assumes that the government incurs in less agency costs than the private sector.\textsuperscript{12} The problems of agency costs are reduced by relying on sales taxes, and indeed, that has been easily one of its most important benefits. Although this is an alternative, it is clear that future research should continue in this area. Nevertheless, the elimination of investment subsidies, and depreciation subsidies will go a long way in reducing the agency costs that plague the industry.

\textsuperscript{12}Maybe possible in Switzerland, but hard to believe in Latin America
References


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<th>Bolivia</th>
<th>Colombia</th>
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<tr>
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<td>~20$ per sq.km.</td>
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<td>Fees Production</td>
<td>~420$ per sq.km.</td>
<td>~200$ per sq.km.</td>
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<td>Royalties Oil</td>
<td>12%</td>
<td>18%</td>
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<tr>
<td>Royalties Gas</td>
<td>15% to 30%</td>
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<td>5% to 25%</td>
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<td>Depreciation Development</td>
<td>10% straight line</td>
<td>20% straight line</td>
<td>20% straight line</td>
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<td>Depreciation Facility</td>
<td>10% straight line</td>
<td>12.5% straight line</td>
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<td>Sales Tax</td>
<td>1% to 3%</td>
<td>13% (VAT)</td>
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<td>25%</td>
<td>30% after royalties</td>
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<tr>
<td>Investment Uplift</td>
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<td>100%</td>
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Table 1: Typical contracts. Authors summary of contract’s descriptions. Source of the contracts: Several World Bank reports