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### **Resource Extraction Contracts Under Threat of Expropriation: Theory and Evidence**

*Johannes Stroebel and Arthur van Benthem*



# Resource Extraction Contracts Under Threat of Expropriation: Theory and Evidence<sup>\*</sup>

Johannes Stroebel<sup>†</sup>

Arthur van Benthem<sup>‡</sup>

## Abstract

*We use unique data on 2,466 oil extraction agreements in 38 countries to study contracts between resource-rich countries and independent oil companies. We analyze why expropriations occur and what determines the degree of oil price exposure of host countries. With asymmetric information about a country's expropriation cost even optimal contracts feature expropriations. Near-linearity in the oil price of real-world hydrocarbon contracts also helps to explain expropriations. We show theoretically and verify empirically that oil price insurance provided by contracts is increasing in a country's cost of expropriation, and decreasing in its production expertise. The timing of actual expropriations is consistent with our model.*

## 1 Introduction

The sharp increase in the oil price between 2003 and 2008 brought back a phenomenon commonly observed in the 1960s and 1970s: countries expropriating assets of independent oil companies (IOCs), or surprising them with large windfall taxes. For example, in 2006 the government of Bolivia passed the Hydrocarbon Law 2058, essentially undoing the privatization of the previous decade. Control over oil resources was transferred to the state agency Yacimientos Petroliferos Fiscales Bolivianos. Other countries with recent expropriations include Ecuador (2007), Algeria (2006), Russia (2006, 2007), China (2006), and Venezuela (2001, 2006, 2007). The subsequent collapse of the oil price emphasized how exposed many

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<sup>†</sup>Department of Economics, Stanford University, stroebel@stanford.edu

<sup>‡</sup>Department of Economics, Stanford University, arthurvb@stanford.edu

countries are to oil price fluctuations. Government budgets were slashed in response to the lower oil price. Gabon's government, for example, had to cut its 2009 budget by 13 percent. Similarly sizable budget cuts happened in Algeria, Chad, Equatorial Guinea and other countries.

Resource rich countries and IOCs negotiate contracts that specify future tax payments that the company will make to the host country in exchange for the right to produce hydrocarbons. In addition to operational expertise, these contracts could in principle provide a country with valuable insurance against oil price risk.<sup>1</sup> At low oil prices, the country receives positive tax payments from what may have otherwise been an unprofitable project. At high prices, the IOC will request a share of the profits in return. However, at these high prices governments will be most tempted to expropriate and capture all immediate benefits.<sup>2</sup>

Most optimal contracts studied by macroeconomists are structured such that expropriations will be avoided in all contingencies, and that some risk is transferred from one party to the other (Kocherlakota, 1996; Ljungqvist and Sargent, 2004). Contracts with countries that cannot credibly commit to honoring the agreed terms involve higher payments to the government when the resource price is high, reducing the incentives to expropriate. To keep the expected value of the contract to the IOC unchanged, such contracts also involve lower payments to the government when the resource price is low and the incentive to renege is limited. This means that countries that suffer from a lack of commitment carry most of the resource price risk. Herein lies the trade-off between insurance and expropriation. This motivates the main questions of this paper. First, why do expropriations occur in practice when they are ruled out by standard models? Second, what determines how much insurance a country can obtain by contracting with a foreign company?

These are important questions for at least two reasons. First, expropriations entail high deadweight loss, including losses from reduced foreign investment and reduced production efficiency, as well as time and legal costs from arbitration procedures. Second, limited oil price insurance can greatly disrupt a government's operations and planning ability.<sup>3</sup> Understand-

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<sup>1</sup>Alternative insurance mechanisms, such as oil stabilization funds, explicit fiscal rules and futures markets are likely to be less effective than insurance through IOCs (see Appendix A for details).

<sup>2</sup>In practice, expropriations can take on a number of forms, from the outright expropriation of the oil company's invested capital (as was the case in Bolivia and Venezuela) to partial expropriation by increasing government take through taxes or by changing the revenue division rule. For example, Russia forced Shell to reduce its share in the Sakhalin field from 55% to 27.5% for \$7.5 billion in 2006, which was considered deeply below market value.

<sup>3</sup>This welfare cost is particularly large for countries in which hydrocarbon revenues constitute a large share of the government's budget. In the period 2000-2007, 72% of Algeria's, 73% of Congo-Brazzaville's and 77% of Equatorial Guinea's government revenues were hydrocarbon-related (Boadway and Keen, 2009). Had the oil price in 2005 been one standard deviation lower, the average fiscal balance of oil producing countries in a sample studied by the IMF would have been nearly 10 percentage points of GDP lower, and about half of the countries would have recorded overall fiscal deficits (IMF, 2007).

ing why expropriations occur and what determines the degree of insurance in hydrocarbon contracts can shed light on how to possibly avoid these costs in the future.

We address our two main questions using a novel data set of fiscal terms between countries and companies for a large number of hydrocarbon fields, embedded in a tax simulator. First, we analyze real-world contracts to establish that – despite a myriad of different taxes – the resulting profile of tax payments from IOCs to the government can be closely approximated by a linear function of the oil price. The reason is that tax terms rarely condition explicitly on the oil price, but instead are functions of variables such as revenue and production. Since these are either independent of, or rise linearly with, the oil price, total tax revenues increase linearly in the oil price. When non-linear taxes are present, they play a minor role.

Second, we set up a model to solve for the optimal hydrocarbon contract. In this model, countries want and IOCs can provide oil price insurance and operational expertise. The optimal contract trades off the benefits of insurance against the cost of expropriation. Expropriation is endogenous, and happens whenever the country’s direct benefits of reneging on the contract exceed the cost of expropriation. This happens at high oil prices or when expropriation costs are low. We show that incomplete information about a country’s expropriation cost leads to an optimal contract in which expropriations occur with positive probability. We then restrict our attention to the linear contracts that we observe in practice. This allows us to derive a number of additional predictions: the model shows that the empirical reality of linear contracts can lead to additional expropriations at very high oil prices. This completes the answer to the first main question: expropriations are inevitable in an optimal contract, but also can occur at high oil prices due to the linearity of real-world contracts. The model also predicts that expropriations are more likely at high oil prices, in countries with high local hydrocarbon production expertise, and in countries with low expropriation costs. We test these predictions empirically, and find statistically significant evidence for them.

To address the second main question regarding the determinants of how much price insurance a country can obtain, we use the model to generate further predictions about contract structure. These predictions are independent of whether we impose linearity. First, insurance in hydrocarbon contracts is higher for countries for which the direct costs of expropriation are higher. Second, countries that are more efficient in hydrocarbon production will obtain less insurance. We empirically test these implications. To do this, we use the hydrocarbon tax simulator and data on expropriation costs, hydrocarbon production and GDP for 2,466 contracts in 38 countries to run regressions analyzing the degree of contract insurance. We find that the observed structure of hydrocarbon contracts is consistent with the model’s predictions. The model also predicts that decreasing hydrocarbon dependence and increasing per capita GDP have two opposing effects on contract insurance: the immediate

benefit of expropriation decreases, but the cost of punishment (autarky) also declines. We find empirically that the immediate effect dominates for the countries in our sample. The results provide suggestive evidence that the strength of domestic legal institutions, hydrocarbon production expertise, dependence on hydrocarbons, and per capita GDP are important drivers of insurance in hydrocarbon contracts.

The remainder of this paper proceeds with a literature review. In Section 3 we analyze important properties of real-world hydrocarbon contracts. Section 4 presents a model for the optimal hydrocarbon contract and its comparative statics. Section 5 describes the data employed, and Section 6 empirically tests the model implications. The final section concludes.

## 2 Literature Review

The first main question of this paper is: why do expropriations occur in practice? Earlier literature has argued that with optimal contracts and complete information, costly expropriations should never happen in equilibrium (Thomas and Worrall, 1994; Ljungqvist and Sargent, 2004). These models provide a useful benchmark, but are unable to explain what is observed in practice. Other models assume an exogenous probability of expropriation, but cannot fully answer why expropriations occur. For example, Engel and Fischer (2010) assume an exogenous probability of expropriation that is increasing in project profits. Aghion and Quesada (2010) use the assumption of a fixed probability of expropriation. In Rigobon (2010), expropriations occur when company profits exceed an exogenously set benchmark, which is not derived from a country's utility maximization problem.

Rather than *assuming* expropriations, to understand their occurrence requires endogenizing such events so that they result from rational economic behavior. Guriev et al. (2010) provide a model with risk-neutral agents in which expropriations occur in equilibrium, resulting from the assumption that the IOC can choose to retain all revenues in a given period and refuse to pay taxes (i.e., the *company* reneges on the contract). Therefore, taxes cannot be too high, which generates expropriations at high oil prices. In our model, expropriations result from a risk-averse *government* reneging on a contract that provides valuable insurance at low oil prices. Expropriations are the result of rational decision making, and occur because of asymmetric information with respect to a country's expropriation costs and because of the linearity of real-world contracts.

The second main question of this paper is: what determines how much price insurance a country can obtain by contracting with an IOC? A theoretical literature has begun to address this question, but we are not aware of any existing empirical work.

Aghion and Quesada (2010) analyze a model in which production depends on unobservable effort on the part of the IOC. The first-best contract involves constant payments to the government, with the IOC being the residual claimant to ensure full effort. Insurance is irrelevant in this model, since both the IOC and the country are risk-neutral.

Rigobon (2010) concludes that the optimal contract choice will involve partial insurance for a risk-averse government. In his model, a government chooses between non-distortionary but volatile income taxes and distortionary but less volatile royalties. The trade-off between distortions and volatility results in a partial risk transfer from the government to the IOC.

Engel and Fischer (2010) argue that (exogenous) expropriations involve a social cost (e.g., from legal procedures) that is increasing in the present value of the project. They find that the optimal contract avoids states with a high probability of expropriation, by making the government the residual claimant on project cash flows in high-revenue states. Insurance in this model is irrelevant since the government is risk-neutral.

None of these papers addresses the question of how the structure of the optimal contract depends on country characteristics. Moreover, the common assumption of a risk-neutral government makes insurance irrelevant. However, as discussed above, there exists extensive evidence that governments have an incentive to reduce revenue volatility. In addition, the approach adopted by the existing literature has been almost purely theoretical, since "trying to design the optimal contracts by looking at the actual clauses is an impossible task," because there are "far too many dimensions to consider" (Rigobon, 2010).

Our paper contributes in the following ways. First, we use a unique tax simulator to present the first comprehensive overview of what hydrocarbon tax structures in non-OPEC countries look like. Second, we argue that governments value oil price insurance, and present a model in which expropriations are endogenous and depend on various country-specific characteristics – the cost of expropriation, hydrocarbon production expertise, current production and GDP. Third, we empirically test the model's implications. This allows us to answer the second main question of what determines the degree of insurance in hydrocarbon projects. To the best of our knowledge, this is the first empirical test of an optimal resource taxation model.

### **3 Real-World Hydrocarbon Contracts**

Real-world hydrocarbon contracts are complicated combinations of taxes on production, revenue, profits and/or "windfall profits." As an example, consider the tax structure in Egypt. Tax terms vary widely by field and company, and over time. Taxes include royalties (negotiable, and varying with location and production rates, but typically between 45% and

63.75% of total production), petroleum revenue taxes (generally 10%), bonuses (fixed annual payments to the government, depending on the level of production as well as "signature bonuses" at the start of new exploration activities), and corporate income taxes (40%). In addition, companies can carry forward any losses to future tax years (WoodMackenzie, 2009).

### 3.1 The Tax Simulator

It is clear by now that determining the total tax payments from the IOC to the government is an involved task. We obtained a large fiscal terms data set for hydrocarbon projects, provided generously by the energy consulting firm WoodMackenzie. This data set, consisting of WoodMackenzie's unique and proprietary data, covers current and historical tax information for 1,167 fields (2,466 contracts) in 38 non-OPEC countries in Europe, Africa, Central Asia and Far East Asia. It is essentially a tax simulator for hydrocarbon projects. Given an oil price projection, the simulator calculates cash flows to companies and governments. In particular, it allows us to calculate the present value of the projected total government revenue stream from a certain hydrocarbon project, given a projection for future oil prices, output, production costs and the relevant fiscal terms. We use the tax simulator to isolate one element of the many different aspects of real-world contracts: we determine how host country pay-offs vary with the oil price, keeping other parameters such as output fixed. More details on the tax simulator are provided in Appendix C.

Figure 1 shows example outputs from the tax simulator for fields in Algeria (Adrar Project) and France (Cazaux Project). The tax simulator takes account of the plethora of different taxes and fees described above, to show how the tax revenue profile varies with the oil price. Table C2 in Appendix C provides an overview of the present value of government revenues from all fields by country at different oil prices.

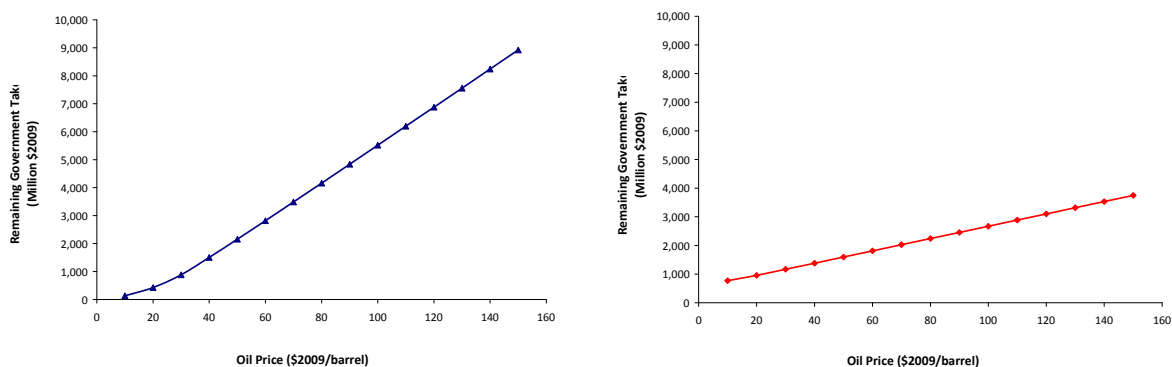


Figure 1: Hydrocarbon Contract Structure for Adrar (Algeria) and Cazaux (France)

## 3.2 The Shape of Real-World Contracts

We find the tax payments from the IOC to the host country to be nearly linear in the oil price. The reason is that, for the countries in our sample, most real-world contracts do not explicitly condition on the oil price. Instead, they are comprised of taxes on other outcomes, which are either fixed or rise linearly with the oil price. Prominent examples are taxes on production, revenues, corporate income or profits (with refunds on losses).

A few countries apply taxes that explicitly condition on the oil price in a non-linear fashion. First, windfall profits taxes (e.g. in Algeria and China) introduce non-linearities at a specific oil price, although tax payments become linear again at higher prices. Second, a few countries employ elements of rate-of-return taxes. By considering all (both linear and non-linear) taxes, the tax simulator generates payment profiles from all fields and companies. This allows us to investigate the overall importance of any non-linear elements in the tax code. In Table 1, we present two measures of the degree of linearity in these payment profiles: differences in slopes and the standard deviation of the slope.

### 3.2.1 Linearity Measure 1: Comparing Slopes

The first measure to assess linearity is a comparison of slopes. A perfectly linear contract has a constant slope of the payment profile at different prices. To compute the contract slope  $\gamma_i(p)$  at oil price  $p$  for country  $i$ , we define the incremental revenue related to a permanent per barrel oil price increase of  $\Delta p$  as:

$$\gamma_i(p) = \left( \frac{TGR_i(p + \Delta p) - TGR_i(p)}{\Delta p} \right) / RR_i \quad (1)$$

where  $TGR(p)$  is the the total undiscounted government revenue over the life time of the project, assuming the oil price is constant at  $p$ . Furthermore,  $RR$  represents remaining reserves measured in barrels that will be produced. This gives  $\gamma$  an easy interpretation: at a specific oil price  $p$ ,  $\gamma_i(p)$  indicates the additional revenue per barrel the government gets for a permanent \$1 increase in the oil price. For a linear contract,  $\gamma_i(p) = \gamma_i$  for all  $p$ .

### 3.2.2 Linearity Measure 2: Standard Deviation of the Slope

The second measure computes the standard deviation of the slope  $\gamma_i(p)$  using  $n$  equally spaced oil prices. A drawback of this measure is that a relatively high value could both

indicate a progressive tax scheme, or just variance around a constant slope.

$$\sigma(\gamma_i(p)) = \sqrt{\sum_{j=1}^n (\gamma_i(p_j) - \bar{\gamma}_i)^2 / (n-1)} \quad (2)$$

Table 1 presents  $\gamma_i(60)$ ,  $\gamma_i(100)$ , the difference in slope (measure 1). We chose these values, since the average oil price in 2009 was approximately \$60/barrel and in 2008 it was \$100/barrel. We also show the standard deviation of the slope (measure 2) for all countries in our sample.<sup>4</sup> The standard deviation is computed using values of  $\gamma_i(p)$  computed at oil prices from \$20 - \$100, with \$10 increments.

Country	Slope at \$60	Slope at \$100	Difference in slope	St.dev. of slope
Algeria	0.553	0.566	0.013	0.033
Angola	0.648	0.760	0.112	0.116
Azerbaijan	0.675	0.668	-0.007	0.034
Brunei	0.521	0.521	0.000	0.000
Bulgaria	0.054	0.080	0.027	0.024
Cameroon	0.626	0.619	-0.006	0.086
Chad	0.555	0.550	-0.005	0.034
China	0.487	0.494	0.007	0.066
Croatia	0.056	0.056	0.000	0.008
Democratic Republic of Congo	0.629	0.630	0.000	0.023
Denmark	0.565	0.569	0.004	0.026
Egypt	0.389	0.390	0.001	0.026
Equatorial Guinea	0.522	0.523	0.001	0.031
France	0.345	0.349	0.003	0.128
Gabon	0.644	0.653	0.009	0.033
Georgia	0.270	0.270	0.000	0.000
Germany	0.388	0.388	0.000	0.013
Hungary	0.238	0.238	0.000	0.000
Indonesia	0.537	0.537	0.000	0.025
Ireland	0.143	0.146	0.003	0.061
Kazakhstan	0.509	0.538	0.029	0.110
Kirgizstan	0.502	0.502	0.000	0.000
Libya	0.693	0.709	0.016	0.028
Malaysia	0.471	0.488	0.017	0.028
Myanmar	0.420	0.416	-0.004	0.009
Netherlands	0.336	0.339	0.003	0.034
Norway	0.632	0.633	0.001	0.029
Philippines	0.376	0.376	0.000	0.003
Poland	0.099	0.099	0.000	0.003
Republic of Congo	0.496	0.497	0.001	0.014
Romania	0.253	0.253	0.000	0.002
Thailand	0.295	0.297	0.002	0.006
Tunisia	0.398	0.402	0.004	0.028
Turkmenistan	0.522	0.501	-0.021	0.044
Ukraine	0.204	0.204	0.000	0.018
United Kingdom	0.451	0.452	0.001	0.008
Uzbekistan	0.540	0.503	-0.036	0.062
Vietnam	0.538	0.544	0.005	0.040

Table 1: Measures of Linearity of Contracts Between Countries and IOCs

<sup>4</sup>As a third measure of linearity, one could calculate the  $R^2$  of the regression of government take per barrel on a constant  $\phi_1$  and the oil price  $p$  for each country  $i$ :

$$\frac{TGR_i(p)}{RR_i} = \phi_1 + \phi_2 p + \varepsilon$$

In our sample,  $R^2$  varies between 0.95 and 1.

Despite the complicated tax codes, measure 1 (difference in slope) presented in Table 1 shows that tax revenues can be closely approximated by a linear function for oil prices in excess of \$60. In fact, for the majority of countries, this linear relationship holds already for much lower oil prices. The vast majority of countries (37 out of 38 in our data set) have a taxation structure that results in a tax schedule that is almost linear in the oil price. Non-linear elements in the tax code may be present, but play a minor role. Angola is the only clear exception. Besides a number of linear taxes, Angola employs a rate-of-return tax.<sup>5</sup> IOCs' profit share decreases from 75% to 10% when the rate of return increases from 0% to 40% (WoodMackenzie, 2009).<sup>6</sup> Some fields, like Adrar in Figure 2, exhibit non-linearities in the tax payments at low oil prices. This explains why measure 2 (standard deviation of the slope) is relatively high for France, Kazakhstan, Cameroon, China and Uzbekistan. These countries have progressive taxes for low prices only, or a noisy tax system that does not exhibit progressivity at high oil prices. This observation of near-linearity is as strong as it may be surprising, and is discussed in the next section.<sup>7</sup>

## 4 The Optimal Contract

In this section, we determine theoretical properties of the optimal contract between an IOC and a host country. We show that incomplete information about a country's expropriation cost leads to an optimal contract in which expropriations occur with positive probability. We then restrict our attention to contracts that are linear in the oil price, as observed in the data. We find that the near-linearity of contracts provides an additional explanation for expropriation. We also find that insurance is increasing in a country's cost of expropriation, and decreasing in its relative production efficiency.

### 4.1 Model Set-Up

We consider a single risk-neutral IOC that is offered a contract to extract oil in a risk-averse host country. Countries in which a significant part of the budget is financed by oil exports suffer from large swings in oil-related revenues. Problems associated with this justify

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<sup>5</sup>Kazakhstan and Tunisia also have rate of return taxes in their tax codes, but the tax simulator shows that the resulting profile still lacks progressivity at high oil prices.

<sup>6</sup>Bulgaria and Kazakhstan have slightly increasing slopes, while Turkmenistan and Uzbekistan have slightly decreasing slopes between \$50 and \$100. However, these differences are negligible. Also the slope becomes constant at oil prices above \$80.

<sup>7</sup>To the best of our knowledge, this paper is the first to empirically demonstrate the linearity in hydrocarbon contracts for a wide geographical range of contracts. However, others have commented on the lack of progressivity for specific cases (Land, 2008; Lovas and Osmundsen, 2009).

the assumption of risk-aversion with respect to revenues, especially for low-income countries (Daniel, 2001; Boadway and Keen, 2009). In our model we assume the IOC to be risk-neutral for simplicity reasons. Even with two risk-averse agents however there are welfare gains from risk sharing. Therefore our comparative statics are unaffected by this assumption.

We assume that the host country extracts all the rents from oil production (since there are  $n \geq 2$  IOCs bidding for the contract). An IOC can credibly commit to any contract that has at least a net present value of zero, since it could be sued in its country of incorporation if it reneged on the contract. The host country can expropriate the company at any point in time.

Consider in addition the following assumptions:

**[A1]** The country's one-period utility function is given by  $u(g)$  where  $u$  is increasing, concave and twice differentiable and  $g$  represents the country's GDP. The GDP is the sum of the country's non-oil GDP,  $g_0$ , and its oil-related GDP,  $g^{oil}$ , which equals the product of the country's oil production  $q$  and the per barrel price received by the country  $p$ :

$$g = g_0 + g^{oil} = g_0 + pq \tag{3}$$

For the remainder of the paper, we assume:

$$u(g) = \frac{g^{1-\eta}}{1-\eta} \tag{4}$$

with  $\eta \in [0, 1]$ , which is the constant relative risk aversion power utility function for moderate levels of risk aversion.

**[A2]** The oil price  $p$  is identically and independently distributed over time with mean  $\bar{p}$  and domain  $[0, \infty)$ .  $f(\cdot)$  represents the probability density function of the oil price.

**[A3]** Production  $q$  does not vary with the oil price.

This assumption is a good approximation for the non-OPEC countries that are the focus of this paper. Non-OPEC countries generally produce and export as much oil as possible at any given price (IEA, 2009). The geological properties of oil and gas fields are such that the lifetime production profile can only be adjusted within very small bounds. Too much pressure on the field can damage the field and harm future production rates. Oil fields thus typically produce flat out during their entire lifetime, largely independent of the current oil price (Engel and Fischer, 2010). In other words, "geology sets maximum production rates, not economics" (Leighty, 2008). The small short-term global spare capacity largely stems

from a few OPEC fields that can be shut down temporarily. Hence, fixing production is a reasonable assumption. Also note that the fixed oil production assumption is a convenient but not material simplification. If production could be adjusted upwards in response to the oil price, it would make expropriation more attractive at high oil prices. The comparative statics of the model are unaffected.

[A4] Annual production costs are normalized to zero.

[A5] The country faces utility cost  $\mu > 0$  upon expropriation. In each period there are two potential values,  $\mu_L$  and  $\mu_H$ , drawn from an i.i.d. Bernoulli distribution with probabilities  $\pi_{\mu_L}$  and  $\pi_{\mu_H}$  known to both parties. The realization of this cost is unobservable to the IOC, but known to the country after  $\mu$  and  $p$  are simultaneously determined.

In practice, there are a number of factors that contribute to this cost. First,  $\mu$  reflects the cost of domestic legal challenges to expropriation (Engel and Fischer, 2010). Second, the company might recover some of its loss through international arbitration, imposing costs on the expropriating country.<sup>8</sup> Third,  $\mu$  includes the loss of a country's international reputation following an expropriation. This reputation loss has been shown to depress foreign direct investment (Eaton and Gersovitz, 1984; Bohn and Deacon, 2000; Azzimonti and Sarte, 2007) and lead to less favorable terms in the international credit market (Cole et al., 1995).  $\mu$  also contains the benefits or costs of expropriation in light of domestic politics.

[A6] After expropriation, the host country will revert to autarky: it will produce oil and sell at the world oil price forever. Moreover, it will incur a relative efficiency loss of  $\delta$ .

This assumption is a stylized version of what happens in practice. Oftentimes, after a number of years and potentially a regime change, international investors may return to the country. This does not change the qualitative predictions of our model. The efficiency loss  $\delta$  reflects that IOCs possess specific operational or technical knowledge that allows them to extract oil at lower cost than the host country (Opp, 2008; Wolf, 2009). The larger the efficiency advantage  $\delta$  of the IOC, the more costly it is for the host country to expropriate.

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<sup>8</sup>An IOC usually does not have full recourse against the sovereign host country in the event of a breach of contract. The doctrine of foreign sovereign immunity provides that a foreign state is generally immune from the jurisdiction of the courts of another sovereign state. In the United States and Western Europe, this sovereign immunity is limited to "public acts" (*acta jure imperii*) only. "Private acts" (*acta jure gestionis*), including commercial activities, are not covered. In case of an expropriation, only "commercial assets" could be seized in an arbitration procedure (Davis, Graham & Stubbs, 2006). This asset class is quite restrictive: it excludes assets held by the foreign central bank, and the inclusion of assets of state-owned companies is under dispute. Therefore, the value of technically seizable assets that many of the countries in our sample hold overseas is likely to be far below the IOC's loss at expropriation. Recourse in practice is partial at best, and recovery of expropriated value by IOCs is extremely uncertain.

[A7] The contract can only be conditioned on the observed oil price,  $p$ , not on the realization of the unobserved value  $\mu$ . The contract is fully described by the function  $y(p)$ , which captures the contractual government revenues at each price.

[A8] The IOC never makes a loss in expectation:  $E_{p,\mu}[p - y(p)] \geq 0$ .

[A9] There is no up-front investment cost.

This assumption can be thought of as a normalization. A model extension could involve an exploration phase before a production phase, and both would be covered by the contract. The firm then needs to recover its exploration investment  $I$  in expectation, which corresponds to  $E_{p,\mu}[p - y(p)] \geq I > 0$  instead of [A8]. This does not qualitatively impact the comparative statics of contract structure.

#### 4.1.1 The Country's Expropriation Decision

At each point in time, upon realizing the current oil price  $p$  and its expropriation cost  $\mu$ , a country has two options. It can expropriate the IOC, thereby receiving revenues  $pq$  while facing a utility cost  $\mu$ . After expropriation, the country will remain in autarky forever. Given [A5] and [A6], the value function for the country when expropriating is given by:

$$V_e(p, \mu) = u(g_0 + pq) - \mu + \beta V_{aut} \quad (5)$$

where  $\beta$  is the time discount factor and the value of autarky,  $V_{aut}$ , is defined as:

$$V_{aut} = E_p \left[ \sum_{t=0}^{\infty} \beta^t u(g_0 + (1 - \delta)pq) \right] = \frac{1}{1 - \beta} \int_0^{\infty} u(g_0 + (1 - \delta)pq) f(p) dp \quad (6)$$

Note that since the oil price is i.i.d,  $V_{aut}$  is a constant. Alternatively, the country can choose to honor the terms of the contract, earning contract pay-off  $y(p)$  today, while facing the same option to expropriate in the next period. The value of honoring the contract is given by:

$$\begin{aligned} V_h(p) &= u(g_0 + y(p)q) + \beta E_{p,\mu} [\max(V_e(p, \mu), V_h(p))] \\ &= u(g_0 + y(p)q) + \beta V_e \end{aligned} \quad (7)$$

The incentive compatibility constraint for the host country at a certain oil price  $p$  and realization of  $\mu$ , which we denote by  $IC(p, \mu)$ , binds if  $V_h(p) = V_e(p, \mu)$ .

### 4.1.2 The IOC's Participation Constraint

Since the problem is stationary, the firm's participation constraint has no dynamic elements to it. In every period, the IOC must be at least ex-ante indifferent between accepting the contract or leaving.  $\Pi$  is the set of  $(p, \mu)$  combinations for which the country chooses to honor the contract, that is, for which  $V_h(p) \geq V_e(p, \mu)$ . The IOC's participation constraint then becomes:

$$\int \int_{(p, \mu) \in \Pi} (p - y(p)) f(p) f(\mu) dp d\mu \geq 0 \quad (8)$$

## 4.2 Expropriation under the Optimal Contract

In this section we show that in the presence of asymmetric information about a country's  $\mu$ , expropriations cannot always be avoided, even under the optimal contract. To simplify the intuition, assume at first that in each period there are only two possible oil prices,  $p_L$  and  $p_H$ , drawn from an i.i.d. Bernoulli distribution with probabilities  $\pi_{pL}$  and  $\pi_{pH}$ . Following [A7], the contract specifies tax payments  $y(p_L)$  and  $y(p_H)$ . The timing of the contracting game is as follows:

1.  $y(p_L)$  and  $y(p_H)$  are agreed upon.
2. Each period, the oil price  $p$  and the cost of expropriation  $\mu$  are simultaneously realized.
3. The country has three choices: to expropriate immediately at cost  $\mu$ ; to take the contractual payment  $y(p)$ ; or to enter into renegotiation at time cost  $\eta$  (Waelde (2008) points out that the time and litigation costs of renegotiations are high).
4. If the country wants renegotiation, the company makes a take-it-or-leave-it counteroffer  $x(p)$ , which the country can accept or reject. A rejection leads to expropriation at cost  $\mu$ . Successful renegotiation incurs a cost of  $\phi(\mu)$ , where  $\mu > \phi(\mu) > 0$ . Reputational costs will still be incurred, even if legal procedures can be avoided.

Note that this multi-period problem is stationary. Since  $p$  and  $\mu$  are i.i.d., the game repeats itself at the beginning of each period. Therefore, in the discussion below we focus on the simple one-period problem. We determine some of the key features of the optimal contract under the assumptions specified above, by looking for perfect Bayesian equilibria. If the country's actions do not reveal its  $\mu$  in equilibrium (by choosing different actions at  $\mu_L$  and  $\mu_H$ ), the company's beliefs follow Bayes' Rule and are  $\pi_{\mu L}$  and  $\pi_{\mu H}$ .

**Proposition 1.** *There will never be renegotiation in equilibrium.*

**Proposition 2.**  $y(p_L) > p_L$ . There are two possible optimal values for  $y(p_H)$ , defined by binding incentive compatibility constraints  $IC(p_H, \mu_L)$  and  $IC(p_H, \mu_H)$ :

1.  $y(p_H)$  is such that expropriation never happens;
2.  $y(p_H)$  is such that expropriations will only happen at  $\mu_L$ .

**Proofs.** See Appendix B. ■

Proposition 1 argues that the optimal contract will never lead to renegotiation,<sup>9</sup> and Proposition 2 states that it may involve expropriation at  $\mu_L$ . Note that there are two possible equilibria at  $p_H$ : a no-expropriation contract, and a contract with expropriation at  $\mu_L$  only, both subject to the company's participation constraint  $\pi_{p_L}(p_L - y(p_L)) + \pi_{p_H}(p_H - y(p_H))(1 - \pi_{\text{exp}})$ , where the probability of expropriation  $\pi_{\text{exp}} = 0$  for the no-expropriation contract and  $\pi_{\text{exp}} = \pi_{\mu_L}$  for the expropriation contract. The optimal contract is the one that maximizes the country's utility. Whether this optimal contract will involve expropriations in equilibrium depends on the distribution of  $\mu$ .<sup>10</sup> In Appendix B we relax the assumption of only two values for  $\mu$ .

This result has an important implication. With incomplete information about a country's cost (or willingness) to expropriate, it is possible that expropriations are part of an optimal contract. In such a situation, no a priori efficiency gain is possible by always avoiding them. A partial answer to our first main question is therefore: expropriations may happen because they can be part of the equilibrium behavior under an optimal contract.

The intuition for why expropriations could occur in the optimal contract is as follows. Given the country's risk aversion, the contract ideally redistributes government revenues from high

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<sup>9</sup>This conclusion is robust to allowing multiple rounds of IOC counteroffers. Unraveling still occurs, since given the best counteroffer the company will ever make, renegotiation is never optimal for the  $\mu_L$  country.

We also consider an alternative renegotiation mechanism in which the country makes an offer to the IOC in the renegotiation process. We assume that the country cannot commit to actual expropriation if its offer is rejected. In this game there may be renegotiations under some parameter combinations.  $\mu_H$  always imitates  $\mu_L$  if  $\mu_L$  successfully renegotiates. This rules out the existence of a separating equilibrium. A pooling equilibrium with renegotiation in which the IOC accepts the country's offer could exist. At an oil price where neither  $\mu_L$  nor  $\mu_H$  wants to expropriate, no expropriation threat can be credible, and there is no renegotiation. By Proposition 2, the optimal contract avoids situations where both  $\mu_L$  and  $\mu_H$  want to expropriate. It remains to consider an oil price at which  $\mu_L$  wants to expropriate, but  $\mu_H$  does not. The minimum amount the IOC would accept,  $e$ , is the expected value of the payment it would get if it rejected the offer. This is equal to  $e = \pi_L \cdot 0 + \pi_H(p - y(p))$ . If it got offered less, it would be optimal to reject and hope that the country turns out to be a  $\mu_H$  country trying to imitate a  $\mu_L$  country. Whether it is optimal for  $\mu_L$  to offer  $e$ , rather than to expropriate directly, depends on the relative size of  $\mu_L$ ,  $\delta$ ,  $\eta$ ,  $\phi(\mu)$  and  $\pi_H$ .

<sup>10</sup>Under the strong assumption of risk-neutrality of the IOC, we can say more about the shape of the optimal contract for a continuous price distribution  $f(p)$ . In that case, there exists a  $p'$  such that the optimal contract involves constant tax payments at prices  $p \leq p'$ . There may also exist a lowest  $p''$  such that  $IC(\mu_H)$  binds. For  $p' \leq p < p''$ ,  $IC(\mu_L)$  binds, the optimal contract is increasing in  $p$ , and no expropriations occur. For some  $p \geq p''$ , expropriations occur when  $\mu = \mu_L$ . Proof available from the authors.

price to low price states by reducing  $y(p_H)$  and increasing  $y(p_L)$ . However, such redistribution from high price states increases the incentives to expropriate. At the same time, the decrease in  $y(p_H)$  increases the IOC's profit if  $\mu_H$  occurs. Hence, the contract accepts expropriations at  $\mu_L$  in exchange for higher profits at  $\mu_H$ , which allows for more insurance.

To formalize this intuition, we derive a condition under which expropriations occur in the optimal contract with a continuous oil price distribution as in [A2]. First, consider the contract in which  $IC(p, \mu_L)$  binds  $\forall p \in P$ , where  $P$  is some compact set of oil prices. Under this contract, expropriations are avoided  $\forall p \in P$ . Now consider the following change to the contract: for a price region  $[\hat{p}, \hat{p} + \varepsilon] \subset P$ , reduce contract payments such that  $IC(p, \mu_H)$  binds. Such a change will increase the IOC's revenue when  $\mu_H$  is realized, but in the case of  $\mu_L$  the IOC will be expropriated and receive nothing. Formally, the change  $\Delta$  in the IOC's expected revenue is:

$$\Delta = \pi_{\mu_H} \int_{\hat{p}}^{\hat{p}+\varepsilon} \underbrace{(u^{-1}(u(p) - \mu_H) - u^{-1}(u(p) - \mu_L))}_{\text{Increased IOC revenues at } \mu_H} f(p) dp - \pi_{\mu_L} \int_{\hat{p}}^{\hat{p}+\varepsilon} \underbrace{(p - u^{-1}(u(p) - \mu_L))}_{\text{Lost IOC revenues at } \mu_L} f(p) dp \quad (9)$$

If the IOC's expected revenues increase ( $\Delta > 0$ ), this allows an increase in the contractual payments from  $y(p)$  to  $y'(p)$ , for  $p \in P'$ , where  $P'$  is a region such that  $y(p|p \in P') \leq y(p|p \notin P')$ . The new contractual payments  $\forall p \in P'$  are

$$y'(p) = y(p) + \frac{\Delta}{\int_{\tilde{p} \in P'} f(\tilde{p}) d\tilde{p}} \quad (10)$$

The redistribution will generate a welfare increase for the country if:

$$\begin{aligned} \int_{p \in P'} [u(y'(p)) - u(y(p))] f(p) dp &> \int_{\hat{p}}^{\hat{p}+\varepsilon} [ \underbrace{u(p) - \mu_L}_{\text{Pre-change payment}} - \underbrace{(\pi_{\mu_H}(u(p) - \mu_H) + \pi_{\mu_L}(u(p) - \mu_L))}_{\text{Post-change payment}} ] f(p) dp \\ &= \int_{\hat{p}}^{\hat{p}+\varepsilon} \pi_{\mu_H} (\mu_H - \mu_L) f(p) dp \end{aligned} \quad (11)$$

Whether condition (11) holds depends on the specific parameterization. It is more likely to hold for smaller values of  $\pi_{\mu_L}$ . In that case the shift to  $IC(p, \mu_H)$  causes few expropriations and thus allows for a larger reduction in revenue volatility.

### 4.3 The Linear Contract

Since real-world contracts exhibit a high degree of linearity, in this section we restrict ourselves to linear contracts. This parametric restriction allows us to obtain a number of additional predictions about the determinants of contract structure. We analyze (1) the solution of the optimal linear hydrocarbon contract, (2) what determines the probability of expropriation and (3) how the optimal linear contract structure varies with the cost of expropriation, the IOC's efficiency advantage, hydrocarbon production and GDP. The country's expropriation choice as well as the IOC's participation constraint remain unaffected by the focus on linear contracts. The optimal linear contract remains renegotiation-proof. [A7] is changed to:

[A7'] The only allowable per barrel contracts between the host country and IOC are linear in the following way:

$$y(p) = \alpha + \gamma(p - \bar{p}) \quad \gamma \in [0, 1], \alpha > 0 \quad (12)$$

$$\alpha + \gamma(p - \bar{p}) \quad \forall p \in [0, \infty) \quad (13)$$

$y(p)$  consists of a fixed positive payment  $\alpha$  and a variable part that is linear in the oil price. Note that autarky corresponds to  $\alpha = \bar{p}$  and  $\gamma = 1$ , while a contract that eliminates all risk for the country has  $\gamma = 0$ . The second condition ensures that the government's receipts are never negative. Under these assumptions, the optimal contract can be described as follows.

**Proposition 3.** *If there exists a  $p$  in the domain for which  $V_e(p, \mu_H) > V_h(p)$ , the domain of  $p$  can be divided into three regions.  $\exists p^*, p^{**}$  such that (i) for  $p \leq p^*$ , expropriation will never take place, independent of the realization of  $\mu$ :  $\forall p \leq p^*, \forall \mu : V_h(p) \geq V_e(p, \mu)$ ; (ii) for  $p^* < p \leq p^{**}$ , we only see expropriation when  $\mu_L$  is realized:  $\forall p \in [p^*, p^{**}], V_h(p) \geq V_e(p, \mu_H)$  and  $V_h(p) < V_e(p, \mu_L)$ ; and (iii) for  $p > p^{**}$ , we will see expropriation occurring independently of the realization of  $\mu$ :  $\forall p > p^{**}, \forall \mu : V_h(p) < V_e(p, \mu)$ .*

**Proof.** See Appendix B. ■

In words, there exists an oil price  $p^*$  below which expropriation is never optimal. There may also exist an oil price  $p^{**}$  above which expropriation is always optimal. In between  $p^*$  and  $p^{**}$ , expropriation occurs only if the country's cost of expropriation is low. Since we assume i.i.d. oil prices, each period expropriation will take place with the same ex-ante probability  $\pi_{\mu L}(F(p^{**}) - F(p^*)) + (1 - F(p^{**}))$ .

The cut-off prices  $p^*$  and  $p^{**}$  are functions of  $\mu_H, \mu_L, g_0$  and  $q$ , as well as the contract parameters  $\alpha$  and  $\gamma$ , and can be obtained by solving the following two equations

$$V_h(p^*) = V_e(p^*, \mu_L) \quad (14)$$

$$V_h(p^{**}) = V_e(p^{**}, \mu_H) \quad (15)$$

By restricting ourselves to linear contracts, we can solve for the optimal contract parameters  $(\alpha, \gamma)$  that solve the host country's optimization problem:

$$\begin{aligned} U^* = \max_{\alpha, \gamma} & \int_0^{p^*(\alpha, \gamma)} [u(g_0 + (\alpha + \gamma(p - \bar{p}))q) + \beta V_c] f(p) dp \\ & + \int_{p^*(\alpha, \gamma)}^{p^{**}(\alpha, \gamma)} (\pi_{\mu, L} [u(g_0 + pq) - \mu_L + \beta V_{aut}] + \pi_{\mu, H} [u(g_0 + (\alpha + \gamma(p - \bar{p}))q) + \beta V_c]) f(p) dp \\ & + \int_{p^{**}(\alpha, \gamma)}^{\infty} (u(g_0 + pq) + \beta V_{aut} - \mu_H \pi_{\mu, H} - \mu_L \pi_{\mu, L}) f(p) dp \end{aligned} \quad (16)$$

subject to the company's participation constraint (8) and with  $V_c$  defined in (7). The country's incentive compatibility constraints are implicit, since  $p^*(\alpha, \gamma)$  and  $p^{**}(\alpha, \gamma)$  are defined in (14) and (15) such that the country always makes an optimal choice.

We are now ready to provide a full answer to the first main question: why do expropriations occur? There are two reasons why we observe expropriations. First, as shown in the first part of this section, expropriations will occur as part of an optimal contract, if there is incomplete information about the country's willingness to expropriate. Proposition 3 shows that incomplete information remains a reason for expropriation under the overwhelmingly-used linear contracts. The proposition also shows that there may exist an oil price range for which expropriation is always preferred. Hence, linear contracts constitute a second reason for expropriations.

#### 4.4 Comparative Statics of the Linear Contract

This section presents (numerical) comparative statics of the optimal linear contract. The key comparative statics of interest are how the contract insurance parameter  $\gamma$  varies with the cost of expropriation  $\mu$  and the efficiency advantage of the IOC  $\delta$ . We also discuss comparative statics for GDP and oil production  $q$ . All comparative statics are qualitatively similar to those from the unconstrained contract. The results in this section, and therefore the answer to our second main question, do not rely on contract linearity.

To conduct simulations, we assume a lognormal oil price distribution (Gibson and Schwartz, 1990), parameterized to the period 1999-2009. In addition, we assume that the country's

one-period utility is  $u(g) = \sqrt{g}$ . We choose a discount factor of  $\beta = 0.9$ . Furthermore, we assume that  $\mu_L = 0.5\mu_H$ , and that  $\pi_{\mu H} = 0.9$  and  $\pi_{\mu L} = 0.1$ . The predictions regarding the determinants of contract structure obtained in this section will be tested empirically in Section 6.

#### 4.4.1 Vary Expropriation Costs and Production Efficiency Loss ( $\mu$ and $\delta$ )

Figure 2 (left panel) shows the comparative statics of the contract parameters with respect to the cost of expropriation,  $\mu$ , keeping  $\delta$ , GDP and  $q$  fixed (at 0, 100 and 1 respectively). Varying the expropriation cost has two main consequences. First, the slope of the linear contract  $\gamma$  (inversely related to insurance) is decreasing in  $\mu$ . A higher  $\mu$  increases a country's ability to commit, which allows contracts with more insurance. Second, the critical oil price values  $p^*$  and  $p^{**}$  beyond which expropriation takes place are increasing in  $\mu$ . The more costly it is for a country to expropriate the IOC, the higher the oil price needs to be before it is worthwhile to do so. Correspondingly, the probability of expropriation decreases in  $\mu$ .

The comparative statics of increasing  $\mu$  are similar to the comparative statics of increasing the production efficiency loss  $\delta$ . Both make reneging on the contract more costly to the host country. A higher efficiency loss  $\delta$  increases the cost of autarky. Hence, Figure 2 (right panel) shows that contract insurance is increasing in  $\delta$ .

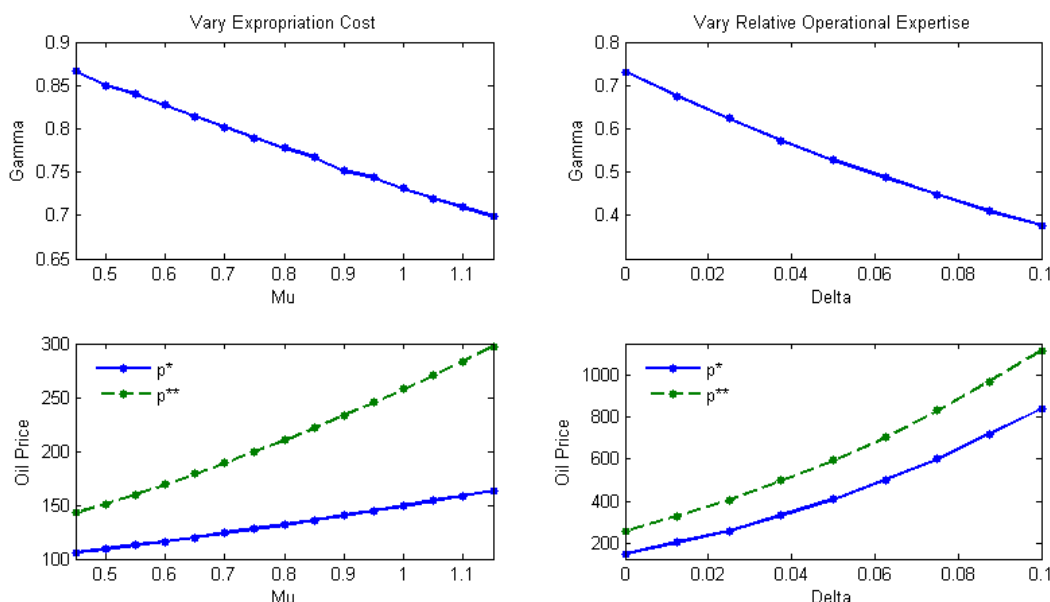


Figure 2: Numerical Comparative Statics with Respect to Expropriation Costs (Left) and Production Efficiency (Right)

#### 4.4.2 Vary Oil Production and Total GDP

While the comparative statics with respect to  $\mu$  and  $\delta$  give unambiguous predictions on the contract slope  $\gamma$ , the effects of changing hydrocarbon production and GDP are more subtle because of the interaction of two countervailing forces. Increasing a country's hydrocarbon production (keeping total GDP fixed) has the effect that at any given oil price the financial gain from expropriation is larger. This makes expropriation more attractive, and reduces the insurance provided by the optimal contract. A countervailing effect is that a country with more hydrocarbon production suffers more from losing insurance and operational expertise in autarky, which makes expropriation less attractive and increases contract insurance. The effect of increasing GDP is similarly ambiguous.

Which effect dominates depends on current levels of production, GDP, risk aversion and most notably the government's time discount factor. Numerical simulation confirms that the former effect dominates for low discount factors, while the latter effect dominates for high discount factors. We will empirically test which effect dominates in our data set in Section 6.

### 4.5 Possible Reasons for the Linearity of Real-World Contracts

We observed in Section 3 that real-world hydrocarbon extraction contracts are overwhelmingly linear. Section 4 used this empirical observation to motivate our focus on analyzing the optimal linear contract. Furthermore, this paper concentrates less on determining the shape of the optimal contract, but rather on explaining why the contracts that we do observe in practice give rise to expropriations and different degrees of oil price insurance of host countries. To do this, it is important that comparative statics are derived for contracts that resemble real-world contracts reasonably well.

The observed linearity of real-world contracts could be due to at least two reasons. First, it is possible that the optimal contract can be closely approximated by a linear contract. In other words, welfare gains from explicitly conditioning the contract on the oil price may be small.

Second, there may be complementary explanations for the linear taxation structures, which could help to explain the observed contracts. We discuss three of these explanations.

One potential reason for linear contracting falls under the broad heading of cognitive costs. Countries have a habit of using an existing "menu" of taxes, almost all of which rise linearly with the oil price. Given the pre-existing framework of fixed fees, production, revenue and profit taxes, the design of a completely different tax system that explicitly conditions on the

oil price may be deemed too cumbersome. Thinking about different contract designs and seeing through their implications is costly (Tirole, 2009). This argument is especially strong for inexperienced governments (Amadi et al., 2006; Waelde, 2008).

Another possible explanation for linear contracts relates to incentives in the negotiation process. It may be uncomfortable and risky for an IOC to directly discuss the issue of potential future expropriation with a foreign government. This may signal a lack of trust: "The government [...] will send out only positive signals so that excessive attention to the political risk at the tail-end of the investment cycle may appear inappropriate and likely to poison the relationship" (Waelde, 2008). Similarly, under asymmetric information a government may not want to address the risk of future unfavorable regime changes. Such a dynamic is captured in Spier's (1992) explanation of contractual incompleteness, in which an agent may refrain from including a particular clause in a contract in order to signal his type. Similarly, a country that suggests the need for a progressive taxation scheme might be signaling a higher willingness to expropriate. Therefore negotiators may shy away from suggesting a move towards non-linear taxation. In addition, the IOC negotiators are likely to have a strong interest in closing a deal quickly, and may discourage them from deviating significantly from pre-existing tax frameworks.

A further possible explanation is that high marginal tax rates in a progressive taxation system encourage the abuse of transfer pricing (Engel and Fischer, 2010). When marginal tax rates differ across countries, transfer pricing allows a company to shift profits between tax jurisdictions to minimize the overall tax burden. A typical method for a company is to overstate its costs, claim excessive management fees or to provide capital equipment at above market leasing costs (Lund, 2009). Therefore, it may be difficult to design a unilateral welfare-improving deviations from linear taxes towards high marginal tax rates.

In summary, we suggest two possible explanations for the linearity of observed hydrocarbon tax contracts. First, linear contracts may not deviate strongly from the optimal contract. Second, cognitive costs, incentives in the negotiation process and transfer pricing make it difficult for a country to move to alternative taxation structures.<sup>11</sup>

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<sup>11</sup>Communication with academic energy economists and industry experts from BP and WoodMackenzie support this conclusion. Simple fixed revenue-sharing dominates "because it minimizes the potential for accounting manipulation". For inexperienced governments, "it takes time [...] to change an existing system, which is why [...] most systems do not include these more progressive elements". The heuristic linear contracts approach did not fully consider "implications for division of rents in such unprecedented circumstances [the 2008 oil price spike]".

## 5 Data

The unit of observation in our data set is a specific tax contract agreed between a company and a country, pertaining to an individual field. Table C3 in Appendix C provides summary statistics for the year 2007. We match these fiscal terms with country characteristics at the time of signing the contract. For each contract, we take the year in which the company's stake in the field is first recorded by WoodMackenzie.

**Government tax revenue:** This is obtained from WoodMackenzie as described in Section 3.  $\gamma$  is directly calculated from this data using (1).

**Total remaining reserves and current production:** Total remaining reserves are defined as the sum of all oil and gas - both expressed in millions of barrels of oil equivalent - that is expected to be produced from the start of 2010 until the field shuts down. Annual production is available for each year since production started. These numbers are taken from WoodMackenzie.

**Company classification:** We classified companies into four categories (1 – IOC, 2 – likely IOC, 3 – National Oil Company (NOC), 4 – partial NOC). To do this, we looked at the shareholder structure of each of the 445 companies in our sample in Bloomberg (extended with internet search). Whenever we could confirm that the government had no shares in the company, it was classified as an IOC. If we could not confirm this, but found no evidence of a government share, the company was classified as "likely IOC". NOCs are defined as companies in which the combined local and federal government share exceeds 50%, while this share is below 50% for the "partial NOC" category.

**GDP and population:** Gross Domestic Product is taken from the United Nations UNdata database. This covers the period from 1970 onwards. Population numbers are from the United Nations Population Program.

**Expropriations:** This is a binary variable that is equal to 1 if an expropriation occurred in a country-year observation. Coding expropriations requires a certain element of judgment. To be consistent with past literature, we use the publicly available expropriations dataset compiled by Guriev et al. (2010), complemented with recent expropriations from the World Investment Report 2007.

Section 4 discussed factors that contribute to a government's cost of expropriation and production efficiency loss. We measure expropriation costs by its domestic institutional quality and the amount of foreign direct investment (FDI). In addition, we measure a country's hydrocarbon production efficiency by its cumulative hydrocarbon extraction.

**Institutional quality:** We use an index that reflects the quality of a country's domestic legal institutions as one measure of the cost of expropriation to the government. Since institutional

quality varies over time as governments change, it is critical to use a time series with a long history. The only available database that goes back to at least 1965 is the Constraint on the Executive (CoE) Index from the Polity IV database, which has been commonly used by economists to measure institutional quality (see, e.g., Acemoglu et al., 2001). This index captures the extent of institutionalized constraints on the decision-making powers of the executive branch of government. A seven-category scale is used with a "1" signaling that there are no regular limitations on the executive's actions, and formal restrictions on the authority are regularly ignored. A "7" represents a regime where accountability groups have effective authority equal to or greater than the executive in most areas of activity. A low CoE means little opportunity for legal action against the government's decision and hence a lower cost of expropriation.

**FDI:** We take inward FDI data from the United Nation's World Investment Report 2008.

**Hydrocarbon production expertise:** Production efficiency and technological expertise are not easily measured. Education indices, such as school enrollment, are too broad. An effective way of capturing reliance on foreign expertise is by measuring the country's own expertise in conducting hydrocarbon projects. More previous engagement in hydrocarbon extraction enhances both local technical knowledge and operational experience, and increases exposure to international best practice. Hence, countries which have developed more hydrocarbon projects will have acquired more technical expertise (Bain, 2009). In addition, learning-by-doing suggests that operational experience reduces the NOC's production cost, independent of technology spillovers from IOCs. The learning-by-doing literature models production costs as a function of cumulative output (Arrow, 1962; Clark and Weyant, 2002). We thus employ the cumulative hydrocarbon extraction of the country up to the point of contract negotiation as a proxy for a country's efficiency in producing hydrocarbons.

## 6 Empirical Analysis

This section empirically tests the main model implications: (1) insurance in hydrocarbon contracts is increasing in direct expropriation costs (in particular, those generated by domestic institutions and dependence on FDI) and (2) increasing in the dependence on foreign expertise. In addition, we test how GDP and oil production affect contract insurance. We also test the model's predictions on the factors affecting the probability of expropriation.

## 6.1 Regression Analysis - Explaining Contract Structure

We conduct a regression analysis to test the main model predictions listed above. The unit of observation is a company-field contract within a country, signed in a specific year. There are a total of 2,466 such combinations in our data set. The dependent variable in all regressions is the slope parameter  $\gamma$  at an oil price of \$60 ( $\gamma_i(60)$ ).<sup>12</sup> The main explanatory variables correspond to the comparative statics from the model. These are the Constraint on Executive Index and reliance on FDI, which capture expropriation cost  $\mu$ , and cumulative hydrocarbon production, which is a measure of reliance on foreign production expertise  $\delta$ . We find results consistent with our model.

Table 2: Contract Structure Regressions - Dependent Variable:  $\gamma(60)$

	(1)	(2)	(3)	(4)
	OLS	WLS	OLS	WLS
Constraint on Executive	-0.0169*** (0.00263) [0.00586]	-0.0170*** (0.00263)	-0.0202*** (0.00286) [0.00547]	-0.0205*** (0.00286)
Per Capita FDI Inflow	-0.0342*** (0.00459) [0.00842]	-0.0342*** (0.00458)	-0.0301*** (0.00474) [0.00825]	-0.0302*** (0.00473)
Cumulative Hydrocarbon Production	2.371*** (1.160) [1.160]	2.381*** (0.466)	2.116*** (0.489) [1.040]	2.126*** (0.488)
R-squared	0.051	0.051	0.060	0.062
N	2466	2466	2033	2033

Standard errors in parentheses, SEs clustered at the country-year level (used for stars) in [ ]

WLS weighting by remaining barrels of oil equivalent, \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Columns (1) and (2) full sample, Columns (3) and (4) IOC only

Column (1) of Table 2 estimates the relationship suggested by our comparative statics. Higher institutional stability is associated with a smaller  $\gamma$ , and hence with better insurance. In addition, higher reliance on FDI also increases the insurance obtained. Furthermore, a country with more experience in hydrocarbon production obtains less insurance. Column (2) shows the same regression using weighted least squares. We weight each observation by the size of the remaining reserves of the relevant field. This is to rule out that the results in column (1) are primarily driven by a large number of contracts that only represent a small fraction of overall production. Columns (3) and (4) report similar results for IOCs only. This specification is preferred, because NOCs are (at least to a large degree) owned by the

<sup>12</sup>Due to the near-linearity of contracts illustrated in Section 3, results remain robust when analyzing the slope parameter at different oil prices.

government. Thus, the government is the claimant to all NOC profits. Consequently, our model has no clear predictions for tax contracts between host governments and NOCs.

All results are highly statistically significant, both with normal OLS standard errors, and with standard errors clustered at the country-year level, the highest level at which the explanatory variables vary. The coefficients on the regressors are also economically significant. For IOCs only, a one standard deviation increase in the CoE index is associated with a decline in  $\gamma$  of 0.05.<sup>13</sup> Similarly, a one standard deviation increase in the FDI per capita leads to a fall in  $\gamma$  of 0.03. A one standard deviation increase in cumulative production leads to an increase in  $\gamma$  of 0.02. We hence conclude that the structure of hydrocarbon contracts varies with our model parameters in a consistent way.

Table 3 includes per capita hydrocarbon production and per capita real GDP as additional regressors. This is both to ensure that our expropriation cost variables (especially cumulative production) do not just pick up the effect of higher current production and GDP, and because the coefficients on these variables are of intrinsic interest. Section 4 argues that the theoretical effects of GDP and oil production on contract insurance are ambiguous. For instance, if countries heavily discount the future, the relative importance of direct costs and benefits from expropriations implies that countries with higher GDP and lower oil production should obtain more insurance. Since the future costs of autarky also decrease, this conclusion may reverse when countries discount the future less.

The results in Table 3 show that the inclusion of the additional regressors leaves the magnitude and statistical significance of the expropriation cost variables unaffected. Using column (3) we find that a one standard deviation increase in real per capita GDP is associated with a decline in  $\gamma$  of 0.02. Likewise, a one standard deviation increase in per capita hydrocarbon production is associated with an increase in  $\gamma$  of 0.07. These results are consistent with the view that (for the countries in our sample), as oil production becomes more important, the immediate gains from expropriation outweigh the losses these countries suffer in autarky. A possible explanation is that these countries face a relatively high discount factor.

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<sup>13</sup>There is a literature discussing the effects of endogenous matching on estimates of contract determinants (Akerberg and Botticini, 2002). In our case, if companies were not perfectly risk-neutral, we would expect the least risk-averse companies to operate in the most risky (low  $\mu$ ) countries. This would lead to a smaller coefficient on  $\mu$  than when allocating IOCs randomly to countries.

Table 3: Contract Structure Regressions - Dependent Variable:  $\gamma(60)$ 

	(1)	(2)	(3)	(4)
	OLS	WLS	OLS	WLS
Constraint on Executive	-0.0242*** (0.00306) [0.00502]	-0.0244*** (0.00306)	-0.0235*** (0.00339) [0.00529]	-0.0237*** (0.00339)
Per Capita FDI Inflow	-0.0242*** (0.00466) [0.00765]	-0.0242*** (0.00465)	-0.0222*** (0.00496) [0.00783]	-0.0221*** (0.00494)
Cumulative Hydrocarbon Production	2.723*** (0.438) [0.850]	2.745*** (0.437)	2.385*** (0.464) [0.845]	2.405*** (0.463)
Real per Capita GDP	-1.197 (0.504) [0.893]	-1.214** (0.503)	-1.159 (0.545) [0.900]	-1.181** (0.544)
Per Capita Hydrocarbon Production	1.078*** (0.0605) [0.119]	1.081*** (0.0604)	1.005*** (0.0673) [0.113]	1.008*** (0.0672)
R-squared	0.211	0.213	0.191	0.193
N	2466	2466	2033	2033

Standard errors in parentheses, SEs clustered at the country-year level (used for stars) in [ ]

WLS weighting by remaining barrels of oil equivalent, \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Columns (1) and (2) full sample, Columns (3) and (4) IOCs only

In summary, the empirical results show that the observed structure of hydrocarbon contracts is strikingly consistent with our main model predictions. The results are robust to various econometric specifications. While there will be other factors that determine contract structure, the regressions provide suggestive evidence that a country's quality of legal institutions, its local technical expertise and FDI, as well as its GDP and dependence on hydrocarbons are important drivers of the structure of hydrocarbon contracts.

## 6.2 Regression Analysis - Explaining Expropriation Probability

As a robustness check for our linear contract model, we also test a number of its predictions for the probability of expropriation: expropriations are more likely when oil prices are high, the efficiency loss in autarky is low, and the cost of expropriation is low. In addition, the signs on GDP and hydrocarbon production in Table 3 suggest that the relevant parameter region of the model is the one where the expropriation probability increases with current oil production and decreases with per capita GDP. The expected magnitude of these effects is not

obvious. This is because (as shown in the previous section) contract structure reacts to these variables in a way to reduce the probability of expropriation. Guriev et al. (2010) analyzed the effect of a number of these factors. However, in their analysis of expropriations in the oil and gas sector, they included a large number of countries without hydrocarbon production, and thus no scope for expropriation by definition. In fact, the expropriations data set used by Guriev et al. (2010) includes some expropriations in the oil sector in country-years with zero hydrocarbon production, possibly in the downstream sector. We expand upon their work by analyzing observations with positive hydrocarbon production only, and by adding hydrocarbon production and cumulative production as additional regressors (as suggested by our model).<sup>14</sup> Table 4 shows the results of a probit regression using both the full sample with all countries, as well as the subsample with positive production observations only.

Table 4: Probit Regressions - Dependent Variable: Probability of Expropriation

	(1)	(2)	(3)	(4)
Real Oil Price	0.00321 (0.00228)	0.00751*** (0.00252)	0.00275 (0.00249)	0.00828*** (0.00276)
Constraint on Executive	-0.123*** (0.0214)	-0.0552** (0.0242)	-0.117*** (0.0224)	-0.0357 (0.0257)
Per Capita FDI Inflow	-0.0943 (0.117)	0.0603 (0.161)	-0.0910 (0.121)	0.0663 (0.165)
Cumulative Hydrocarbon Production	0.0417*** (0.0129)	0.0692*** (0.0162)	0.0298** (0.0137)	0.0595*** (0.0169)
Real per Capita GDP		-0.0401*** (0.00910)		-0.0423*** (0.00905)
Per Capita Hydrocarbon Production		0.0237*** (0.00292)		0.0234*** (0.00293)
N	3857	3790	2662	2662

Standard errors in parentheses, \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Columns (1) and (2) full sample, Columns (3) and (4) positive production only

Table 4 shows that the model predictions generally hold in the data. A higher oil price is associated with an increased probability of expropriation. Using the results from column (4), a one standard deviation increase in the real oil price is associated with an increase in the annual probability of expropriation of 0.63 percentage points. A one standard deviation increase in cumulative hydrocarbon production is associated with a 0.57 percentage point

<sup>14</sup>To only use publicly available data for this part of the analysis, we took production figures from the International Energy Agency's Extended Energy Balances.

increase in the annual expropriation probability. The CoE index is only statistically significant in the full sample, and per capita FDI is not significant in either sample. Per capita GDP and hydrocarbon production are both significant and have the sign expected given our results in the previous section. Despite the difficulties with precisely defining expropriations, it is reassuring that these empirical results are consistent with our model.

## 7 Conclusions

This paper uses a large data set of real-world hydrocarbon contracts between IOCs and resource-holding governments to address two main questions. The first question is why expropriations occur. We show that, if there is incomplete information about a country's expropriation cost, expropriations are an element of the optimal contract. We use our data to show that most real-world fiscal contracts are linear with respect to the oil price. Although these contracts may closely resemble the optimal contract, this linearity can provide a second reason for the occurrence of expropriations, especially at high oil prices. The second question considered by this paper is what determines how much oil price insurance a country can obtain from these contracts. Our model predicts that countries with a high cost of expropriation and limited hydrocarbon expertise can obtain better insurance. We demonstrate that these predictions hold empirically.

We conclude that not all expropriations can and should be avoided in the optimal contract. Nevertheless, the empirical linearity of contracts poses the question of why parties do not exploit their proven ability to use non-linear provisions. Angola's tax code shows that progressive rate-of-return taxes can be implemented. Section 4 provides a discussion of possible reasons. First, linear contracts may closely resemble the optimal contract, especially if the IOC is risk-averse. Second, cognitive costs, incentives in the negotiation process and transfer pricing could make a deviation from the linear structure costly to the host country. Several authors have commented on a recent shift towards progressive hydrocarbon taxation (Johnston, 2008; Lovas and Osmundsen, 2009). This suggests that in recent years the benefits of introducing non-linear elements have increased, possibly due to the recurrence of high oil prices and expropriations.

We show that the ability to commit to contracts improves a country's welfare. Therefore we recommend that resource rich countries improve their commitment technologies in order to reduce expropriation risk. Resource holding countries can benefit from providing more recourse to foreign investors, for example by joining bilateral investment treaties. Such treaties usually include a clear description of what is considered an unlawful expropriation. Violations of contractual agreements with the IOC become a breach of the investment treaty with

the IOC's country of incorporation. This facilitates the seizure of certain assets held abroad by the expropriating country. Commitment through the treaty can be strengthened by including provisions that broaden the asset base subject to seizure following an expropriation. Hence expropriation costs increase, allowing for more insurance to be provided.

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## Appendix A - Alternative Insurance Mechanisms

An important question is to what degree other mechanisms can insure countries against fluctuations in oil prices. Potential mechanisms are oil stabilization funds, explicit fiscal rules and futures markets. These mechanisms are likely to be less effective than insurance through IOCs, particularly for countries with limited ability to commit to contracts. The reason is that the costs of renegeing on agreements, either with future regimes (as in the case of oil funds and fiscal rules) or with financial intermediaries (as in the case of futures markets) are lower than the costs of renegeing on contracts with IOCs. Oil funds and explicit fiscal rules require self-commitment, and countries unable to commit to IOCs are likely to be unable to commit to saving for future administrations. In many cases, they fail to deposit the budget surplus in the oil account when oil prices are high. Oil futures contracts could also potentially provide insurance. However, a similar inability to commit also applies to futures

contracts: should prices move against the country, it could renege on its side of the deal. As discussed, IOCs on the other hand possess significant operational or technical knowledge that allows them to extract oil at lower cost than the host country. This efficiency gain would be lost after expropriation, in addition to the other expropriation costs faced when renegeing on contracts with financial intermediaries. This makes contracts with IOCs more stable, and strengthens their role in providing price insurance to host governments. Below we provide more details on problems with alternative insurance mechanisms.

**Oil funds:** Countries could use oil funds to smooth out fluctuating oil prices. The prime example of such a fund is the Government Pension Fund of Norway ("Statens Pensjonsfond"), the largest stockholder in Europe in 2008. This is formally a government account at the central bank into which the government pays the net revenue from hydrocarbon activities. It was set up to counter the effects of the forthcoming decline in income and to smooth out the disrupting effects of highly fluctuating oil prices.

While there has been a recent increase in the number of oil funds, many countries have proven to be unable to commit to this form of saving for future generations. Furthermore, government expenditure is not effectively stabilized by oil funds unless accompanied by expenditure restraints, since resources are fungible (Daniel, 2001). For example, in 2000, Mexico established an Oil Revenue Stabilization Fund, to lessen the impact of oil price volatility that had led to unplanned budget cuts in the late 1990s. However, congress decided to appropriate the Stabilization Fund and included it in its 2002 budget, a decision that disregarded the rules regarding proper spending of fund resources (IMF, 2007). Gabon, Kazakhstan, Russia, Trinidad and Tobago and Venezuela also changed their funds' deposit and withdrawal rules. Chad and Papua New Guinea abolished their oil funds (IMF, 2007). Therefore, while oil funds may be very effective tools to insure against low oil prices for countries with high institutional stability, it is precisely the countries in which expropriations are a relevant concern that lack the commitment technology to effectively manage them.

**Explicit fiscal rules:** Explicit fiscal rules for the spending of oil revenues suffer from similar commitment problems as the establishment of oil funds. Such rules usually put constraints on the size of the non-oil balance, which prevent large increases in expenditure when oil prices are temporarily high. However, actual adherence to such rules during times of high oil prices is rare. For example, in 2002 Ecuador adopted three fiscal rules focused on the non-oil balance, expenditure growth, and the public debt ratio to GDP. These deficit and spending rules were breached repeatedly. Growing political and social pressures led to a relaxation of the constraints in 2005. Other examples of countries that breached their fiscal rules are Azerbaijan, Equatorial Guinea and Venezuela (IMF, 2007).

**Futures trading:** A possible tool for oil-dependent countries to smooth the impact of oil

price shocks is participation in the oil futures markets (UNCTAD, 2005). However, futures contracts involve counterparty risk that may discourage a trader from entering into contracts with oil-dependent nations. To illustrate this, assume that a country agrees to deliver one million barrels of oil on December 31, 2010, at \$60 a barrel. This insures the country against price drops below that amount. However, should the oil price rise above \$60, the country has an incentive to renege on the futures contract, and sell the output on the spot market.

## Appendix B - Proofs

This appendix contains the proofs for the propositions in the main text. Without loss of generality, we set  $q = 1$ ,  $g_0 = 0$  to simplify notation.

**Lemma 1** *Due to the risk-aversion of the host country,  $y(p_L) > p_L$ .*

**Proof.** Suppose this were not the case, i.e.  $y(p_L) < p_L$ . The country would then receive  $y(p_H) > p_H$  and would never expropriate at high oil prices. But for a risk-averse country, autarky ( $y(p) = p$ ) would dominate this contract. We can improve upon this autarky contract by having  $y(p_L) = p_L + \varepsilon$  and  $y(p_H) = p_H - \varepsilon$  for small  $\varepsilon$ . ■

**Lemma 2** *A contract that generates expropriation at  $\mu_H$  will be suboptimal.*

**Proof.** If expropriation is optimal at  $\mu_H$  it is also optimal at  $\mu_L$ . Consequently the country gets  $y(p_L) = p_L$ . It would be possible to improve upon such a contract by paying the country  $y(p_H) = p_H - \varepsilon$ , avoiding expropriation for all  $\mu > \varepsilon$ . This would allow the IOC to pay  $y(p_L) > p_L$ . Due to the country's risk aversion, this contract would be superior. ■

**Lemma 3** *If renegotiation were to occur, there are only two undominated counteroffers  $x_i(p_H)$  for the IOC, defined by  $u(x_i(p_H) - \eta) - \varphi(\mu_i) = u(p_H - \eta) - \mu_i$  for  $i = L, H$ .*

**Proof.** First, it will never be optimal to offer more than what the country would just accept at  $\mu_L$ . Any higher amount would also be accepted but would leave less money at the lower oil price, reducing insurance. Second, the IOC would never offer less than the amount that the country would just accept at  $\mu_H$ . If it offered less, expropriation would always occur and the IOC would get nothing with certainty. This is clearly not optimal. Third, the IOC would never offer anything "in between" the counteroffers that make the country just indifferent between accepting or rejecting the counteroffer at a specific value of  $\mu$ . The reason is that bidding slightly less would not change the country's actions, but increase the IOC's pay-off (and its ability to provide insurance). ■

**Proposition 1.** *There will never be renegotiation in equilibrium.*

**Proof.** Suppose  $\mu_L$  is realized. By Lemma 3 the IOC will never offer more than the  $x_L(p_H)$  that generates payoff  $u(p_H - \eta) - \mu_L$ . Hence the country would be better off by expropriating

immediately, without paying time cost  $\eta$  for entering into renegotiation. Knowing this, the IOC would infer that expressing an intent to renegotiate means that  $\mu_H$  is realized. Hence, it would offer  $x_H(p_H)$ . But then, the country should deviate by choosing contract adherence, again avoiding the time cost of renegotiation. ■

**Proposition 2.**  $y(p_L) > p_L$ . There are two possible optimal values for  $y(p_H)$ , defined by binding incentive compatibility constraints  $IC(p, \mu_L)$  and  $IC(p, \mu_H)$ : (1)  $y(p_H)$  is such that expropriations never happen; (2)  $y(p_H)$  is such that expropriations will only happen at  $\mu_L$ .

**Proof.**  $y(p_L) > p_L$  by Lemma 1. By Proposition 1, we discard the possibility of renegotiation and only consider adherence versus expropriation. By Lemma 3, we know that  $u(y(p_H)) \geq u(p_H) - \mu_H$ . A contract that always avoids expropriations must make sure that  $u(y(p_H)) \geq u(p_H) - \mu_L$ . This would never hold with strict inequality, since reducing  $y(p_H)$  by  $\varepsilon$  and increasing  $y(p_L)$  by  $\varepsilon$  would be welfare-improving for a risk-averse country. Hence, the optimal no-expropriation contract specifies  $u(y(p_H)) = u(p_H) - \mu_L$ . The other option is a contract at which  $u(p_H) - \mu_H \leq u(y(p_H)) < u(p_H) - \mu_L$ . The first inequality will not be strict. If  $y(p_H)$  was set any higher, it would be better to decrease  $y(p_H)$  by  $\varepsilon$ , and increase  $y(p_L)$  by  $\varepsilon \frac{\pi_{pH}}{\pi_{pL}} \pi_{\mu H}$ , which still satisfies the IOC's participation constraint. The country would be better off, since  $\pi_{pL}(u'(y(p_L)) \frac{\pi_{pH}}{\pi_{pL}} \pi_{\mu H}) = u'(y(p_L)) \pi_{pH} \pi_{\mu H} > \pi_{pH} \pi_{\mu H} u'(y(p_L))$ . ■

Instead of only two possible values for the cost of expropriation,  $\mu_L$  and  $\mu_H$ , now consider a discrete probability distribution over a finite number of realizations of  $\mu$ :  $Pr(\mu = \mu_i) = \pi_{\mu i}$  for  $i = 1, \dots, N$ . There are only two oil prices  $p_L$  and  $p_H$ .

**Lemma 4** *Again, the country will never renegotiate in equilibrium.*

**Proof.** By the same logic as Proposition 1, there will be a highest undominated counteroffer. Even if the company offered its highest counteroffer  $x_1(p_H)$ , the country will never choose to renegotiate if  $\mu_1$  is realized. It is better off expropriating immediately, and avoiding the time cost of renegotiation  $\eta$ . The IOC knows this, and infers that any country that expresses intent to renegotiate must have  $\mu \geq \mu_2$ , and will never offer more than  $x_2(p_H)$ . Hence, we see unraveling with the result that no renegotiation can be sustained in equilibrium, except if  $\mu \geq \mu_N$ , but in that case the country would be better off adhering to the contract. ■

**Proposition 3.** *If there exists a  $p$  in the domain for which  $V_e(p, \mu_H) > V_h(p)$ , the domain of  $p$  can be divided into three regions.  $\exists p^*, p^{**}$  such that (i) for  $p \leq p^*$ , expropriation will never take place, independent of the realization of  $\mu$ :  $\forall p \leq p^*, \forall \mu : V_h(p) \geq V_e(p, \mu)$ ; (ii) for  $p^* < p \leq p^{**}$ , we only see expropriation when  $\mu_L$  is realized:  $\forall p \in [p^*, p^{**}], V_h(p) \geq V_e(p, \mu_H)$  and  $V_h(p) < V_e(p, \mu_L)$ ; and (iii) for  $p > p^{**}$ , we will see expropriation occurring independently of the realization of  $\mu$ :  $\forall p > p^{**}, \forall \mu : V_h(p) < V_e(p, \mu)$ .*

**Proof.** First, we need to establish that  $V_e(p, \mu) - V_h(p)$  is weakly increasing in  $p$ . The

condition is equivalent to  $\frac{\partial u(g_0+pq)}{\partial p} - \gamma \frac{\partial u(g_0+\gamma pq+k)}{\partial p} > 0$  for  $k \geq 0$ , since  $\alpha - \gamma\bar{p} \geq 0$  by [A7']. By the concavity of  $u(\cdot)$ , the condition is satisfied if  $\frac{\partial u(p)}{\partial p} - \gamma \frac{\partial u(\gamma p)}{\partial p} > 0$ . This condition holds for the utility function in [A1], since  $u'(g) - \gamma u'(\gamma g) = (g)^{-\eta} - \gamma(\gamma g)^{-\eta} = g^{-\eta} - \gamma^{1-\eta} g^{-\eta} > 0$  iff  $\eta \in [0, 1]$ . Second, note that at the lowest possible price,  $p = 0$ , we find that

$$\begin{aligned} V_e(0, \mu) &= u(g_0) + \beta V_{aut} - \mu \\ V_h(0) &= u(g_0 + (\alpha - \gamma\bar{p})q) + \beta E_{p,\mu}[\max(V_e(p, \mu), V_h(p))] \end{aligned}$$

Hence,  $V_h(0) > V_e(0, \mu)$ , which means that the country will never expropriate the IOC at  $p = 0$ . The result then follows from the fact that  $V_e(p, \mu) - V_h(p)$  is weakly increasing in  $p$ . ■

## Appendix C - Data Summary

We use WoodMackenzie's Global Economic Model as the underlying data source for historical hydrocarbon production, remaining reserves, contract signing year and government take. A typical summary report for a field-company-country consists of annual historical and projected future production rates, gross revenue, operating and capital costs, various tax payments, total government take and company cash flow. The model also calculates the value of total remaining government take. These calculations are performed by a detailed underlying model that contains all country-field-company specific fiscal terms. The model acts as a tax simulator through its ability to change hydrocarbon prices - keeping all other variables fixed - and recompute total government take. Table C1 provides a fictitious sample summary report.

Table C1 simulates government take at an assumed oil price of \$50/bbl for 2009 onwards. This can be repeated for different oil price profiles, for each field-company-country observation in our sample.

Country Name: [Country]  
 Field Name: [Field]  
 Company Name: [Company]

Year	Production Liquids 000b/d	Gross Revenue \$M	Op Costs \$M	Capital Costs \$M	Royalty \$M	Cost Oil \$M	Profit Oil \$M	Government Profit Oil \$M	Windfall Tax \$M	State Equity Cash Flow \$M	Company Cash Flow \$M	Total Field Cash flow \$M	Company Interest %	Nominal Prices Brent US\$/bbl
1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.00%	18.20
2000	20.3	203.2	23.7	19.1	26.4	181.0	0.0	82.5	0.0	0.0	63.7	63.9	30.00%	28.90
2001	27.1	248.5	32.3	6.4	32.6	188.4	38.9	96.8	0.0	0.0	86.8	88.6	30.00%	24.69
2002	28.3	257.9	32.2	32.6	31.9	69.2	164.8	99.7	0.0	0.0	63.8	64.8	30.00%	25.15
2003	21.3	240.6	27.1	35.5	28.9	51.4	152.1	93.4	0.0	0.0	50.6	51.6	30.00%	28.76
2004	19.4	277.4	24.3	43.4	34.7	51.3	184.9	106.3	0.0	0.0	61.9	64.1	30.00%	38.22
2005	17.2	339.7	22.6	6.0	45.7	50.7	255.6	139.2	0.0	0.0	143.3	138.7	30.00%	54.80
2006	16.0	397.8	27.3	6.1	49.0	48.2	294.7	152.0	11.0	0.0	136.5	137.9	30.00%	66.32
2007	14.1	384.4	27.0	6.5	49.1	40.5	296.7	147.7	30.1	0.0	137.0	126.6	30.00%	72.63
2008	13.5	517.5	26.1	6.3	64.4	31.1	380.3	219.1	58.9	0.0	136.0	136.6	30.00%	97.27
2009	13.0	241.8	24.5	0.0	28.7	27.7	169.2	124.1	5.0	0.0	52.2	53.1	30.00%	50.00
2010	11.2	222.0	23.9	0.0	25.9	25.2	158.5	112.8	5.0	0.0	47.0	45.1	30.00%	50.00
2011	10.9	186.3	22.7	8.1	23.8	24.8	143.6	104.6	4.5	0.0	34.4	35.3	30.00%	50.00
2012	9.8	174.6	20.5	0.0	22.9	24.3	128.1	92.6	4.1	0.0	38.1	37.7	30.00%	50.00
2013	8.5	162.1	21.2	0.0	20.4	23.2	122.3	87.0	3.7	0.0	34.5	32.8	30.00%	50.00
2014	8.2	152.8	20.1	8.0	17.7	24.8	108.8	77.1	3.0	0.0	22.9	24.7	30.00%	50.00
2015	7.1	130.0	19.4	0.0	17.3	20.6	94.8	70.0	2.8	0.0	26.8	26.8	30.00%	50.00
2016	6.0	106.8	18.1	8.2	14.3	21.8	73.6	51.0	2.2	0.0	16.2	16.5	30.00%	50.00
2017	5.5	96.7	18.2	0.0	12.7	20.6	66.9	47.2	2.0	0.0	20.6	21.1	30.00%	50.00
2018	4.8	95.8	17.4	0.0	12.0	19.3	60.6	42.6	1.9	0.0	18.4	18.1	30.00%	50.00
2019	4.2	74.0	16.8	32.2	9.1	16.4	50.1	36.2	1.5	0.0	-18.6	-17.7	30.00%	50.00
2020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.00%	50.00
<b>Totals:</b>	<b>97.3</b>	<b>4511.8</b>	<b>465.4</b>	<b>218.6</b>	<b>567.5</b>	<b>960.4</b>	<b>2954.3</b>	<b>1981.0</b>	<b>135.6</b>	<b>0.0</b>	<b>1172.3</b>	<b>1166.2</b>		

Table C1: Sample Field-Company Summary Report

Table C2 below summarizes the results for total undiscounted future revenues (in millions of USD; no inflation), where we aggregate over all field-company observations within a country. Table C3 provides summary statistics for the data discussed in Section 5 for the year 2007. Remaining reserves and production are aggregated across all fields and companies within a country. Note that remaining reserves and production are also available on the field-company level. Reserves and production are expressed in millions of barrels of oil equivalent (mmboc).

Country	Oil Price (USD per Barrel)				
	20	40	60	80	100
Algeria	37,171	85,619	139,720	195,325	279,830
Angola	64,689	162,004	271,550	407,753	633,103
Azerbaijan	31,176	112,216	199,619	290,168	425,514
Brunei	6,261	15,136	24,025	32,913	46,246
Bulgaria	1	4	9	14	28
Cameroon	245	2,309	4,989	7,854	12,068
Chad	628	6,190	12,159	18,157	27,114
China	4,241	10,857	19,317	28,858	43,264
Croatia	4	70	154	240	368
Democratic Republic of Congo	131	559	1,022	1,487	2,186
Denmark	2,996	16,171	30,387	45,052	67,126
Egypt	35,103	86,955	145,804	205,727	295,906
Equatorial Guinea	4,639	11,885	20,053	28,343	40,807
France	147	197	481	819	1,330
Gabon	5,000	14,833	25,468	36,454	53,055
Georgia	10	21	31	42	57
Germany	6,674	17,142	28,256	39,385	56,079
Hungary	470	1,256	2,044	2,832	4,015
Indonesia	35,747	129,990	231,174	332,005	483,222
Ireland	11	25	427	873	1,553
Kazakhstan	55,161	205,858	400,211	641,006	1,016,960
Kirgizstan	22	53	84	115	161
Libya	22,567	62,818	106,248	148,730	212,933
Malaysia	23,322	66,635	113,237	162,238	237,421
Myanmar	13,040	27,215	41,652	55,916	77,169
Netherlands	-64	2,441	5,526	8,692	13,469
Norway	-6,948	77,461	169,966	262,601	401,892
Philippines	1,634	4,546	7,492	10,440	14,862
Poland	5	15	25	36	52
Republic of Congo	7,025	18,816	31,188	43,630	62,318
Romania	115	303	488	674	952
Thailand	5,460	18,744	32,494	46,342	67,210
Tunisia	743	2,768	5,006	7,289	10,863
Turkmenistan	7,490	38,749	76,282	116,042	173,116
Ukraine	2,873	4,210	5,772	7,430	9,918
United Kingdom	-1,117	61,617	126,278	191,241	288,888
Uzbekistan	9,062	25,196	43,784	66,828	97,944
Vietnam	8,658	21,890	37,157	53,023	76,990

Table C2: Simulation of Remaining Government Take at Various Oil Prices

Country	Constraint on Executive	FDI	Production	Cumulative Production	Remaining Reserves	GDP
		<i>millions of 2005 USD</i>	<i>mmbae</i>	<i>mmbae</i>	<i>mmbae</i>	<i>billions of 2005 USD</i>
Algeria	5	1568.1	1341.6	30751.4	21662.0	125
Angola	3	-1412.9	631.3	6608.0	13800.1	49
Azerbaijan	2	-4537.6	277.5	858.4	8262.4	29
Brunei		173.2	145.5	4574.1	1963.3	12
Bulgaria	7	7940.1	2.0	96.8	7.0	37
Cameroon	2	267.8	29.6	1234.0	367.7	19
Chad	2	567.8	52.5	242.4	633.1	7
China	3	78676.8	1739.0	12488.1	35726.3	3202
Croatia	7	4639.5	25.6	1102.6	323.7	48
Democratic Republic of Congo	5	678.2	8.9	299.8	53.1	9
Denmark	7	10573.0	166.7	2787.2	1660.7	293
Egypt	3	10906.6	575.8	10965.8	9025.6	126
Equatorial Guinea	2	1626.4	157.1	984.4	2242.2	10
France	6	148807.9	17.2	2683.5	113.6	2326
Gabon	2	253.7	89.1	3210.6	1054.0	11
Georgia	5	1562.8	0.3	5.7	13.9	10
Germany	7	47971.8	136.9	1535.7	1678.4	3123
Hungary	7	5248.3	25.7	1994.7	213.8	130
Indonesia	6	6526.2	748.5	26727.1	12024.7	407
Ireland	7	28816.8	3.1	302.7	160.7	241
Kazakhstan	2	9664.4	590.3	4164.5	29561.3	98
Kirgizstan	4	195.9	0.1	0.2	3.5	4
Libya	1	2393.6	278.0	2174.8	5603.3	58
Malaysia	4	7915.7	604.3	11072.7	10798.1	176
Myanmar	2	402.9	80.2	462.3	2193.6	17
Netherlands	7	93670.4	442.4	19566.4	8678.1	721
Norway	7	567.4	1491.7	30111.2	25023.7	365
Philippines	6	2758.2	25.5	162.4	489.0	136
Poland	7	16560.4	41.1	314.6	822.0	395
Republic of Congo	2	331.3	82.7	2807.0	1323.9	7
Romania	7	9206.8	107.7	971.9	1912.2	152
Thailand	4	9020.0	217.6	2695.7	3691.5	231
Tunisia	2	1524.1	46.6	1431.8	504.3	33
Turkmenistan	1	757.4	196.2	1097.5	14244.4	7
Ukraine	6	9317.3	5.7	25.7	488.6	133
United Kingdom	7	210976.1	1029.4	37942.5	9311.0	2607
Uzbekistan	1	246.8	11.9	16.6	2277.9	18
Vietnam	3	6348.1	149.9	1585.9	2661.4	67

Table C3: Summary Statistics by Country in 2007