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RESOURCE EXTRACTION CONTRACTS UNDER THREAT OF EXPROPRIATION: THEORY AND EVIDENCE

Johannes Stroebel and Arthur van Benthem*

Abstract—We use fiscal data on 2,468 oil extraction agreements in 38 countries to study tax 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 tax 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.

I. 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. Countries with recent expropriations include Algeria (2006), Bolivia (2006), China (2006), Ecuador (2007), Russia (2006, 2007), and Venezuela (2001, 2006, 2007). The subsequent collapse of the oil price emphasized how exposed many producing 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%. 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.[1] 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.

With full commitment on part of the country, a risk-neutral IOC would optimally assume all the oil price risk. However, if commitment is limited, this full-insurance contract generates large incentives for the country to expropriate at high oil prices.[2] With complete information about the country's cost of reneging, the optimal contract will avoid all expropriations (Kocherlakota, 1996; Ljungqvist & Sargent, 2004). The lower the costs of expropriation, the less price insurance can be provided by the IOC: 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 tax 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, if optimal contracts respond to expropriation incentives, why do expropriations occur in practice? Second, what determines how much price insurance a country can obtain by contracting with a foreign company?

These are important questions for at least two reasons. First, expropriations entail significant economic losses, including those from reduced foreign investment and reduced production efficiency, as well as time and legal costs from arbitration procedures. Second, exposure to oil price volatility can greatly disrupt a government's operations and planning ability.[3] Understanding why expropriations occur and what determines the degree of price insurance in hydrocarbon tax contracts can shed light on how to possibly avoid these costs in the future.

We address our two main questions using a highly detailed 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

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[1] 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).

[2] 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.

[3] 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 & Keen, 2009). Had the oil price in 2005 been 1 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 (International Monetary Fund, 2007).

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 nonlinear taxes are present, they usually play a minor role in practice.

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. We then show that unlike in the complete information model discussed above, incomplete information about a country's expropriation cost leads to an optimal contract in which expropriations may occur with positive probability. If true expropriation costs cannot be verified, it may be optimal to accept expropriations for low realizations of the expropriation cost, if this allows the provision of more insurance at other realizations of this cost. The optimal contract now trades off the benefits of insurance against the cost of expropriation. Expropriations are endogenous and occur whenever the country's direct benefits from reneging on the contract exceed the cost of expropriation. This happens at high oil prices or when expropriation costs are low. We then restrict our attention to the linear tax contracts that we observe in practice. This allows us to derive a number of further predictions: the model shows that the empirical reality of linear contracts can lead to additional expropriations at high oil prices. This completes the answer to the first main question: expropriations may be inevitable in an optimal contract, but also can occur at high oil prices due to the near 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 at 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 2,468 contracts in 38 countries to run regressions analyzing the degree of contract insurance. We find that the observed structure of hydrocarbon contracts is highly 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 empirical evidence that the immediate effect dominates for the countries in our sample. The results thus provide suggestive evidence that proxies for the cost of expropriation (the strength of domestic legal institutions, reliance on foreign direct investment and hydrocarbon production expertise), dependence on hydrocarbons, and per capita GDP are important drivers of insurance in hydrocarbon contracts.

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

II. Literature Review

The first main question of this paper is: Why do expropriations occur in practice? Earlier literature has shown that with optimal contracts and complete information, costly expropriations will never happen in equilibrium (Thomas & Worrall, 1994; Ljungqvist & Sargent, 2004). The contract structure in these models responds to parties' incentives to renege and eliminates expropriations in all states of the world. We build on these seminal models and show how the introduction of asymmetric information about the cost of expropriations can lead to expropriations on the equilibrium path. Other models assume an exogenous probability of expropriation, which is not directly derived from a country's utility maximization problem. 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.

Rather than assuming expropriations, to understand their occurrence it helps to endogenize such events so that they result from rational economic behavior. Guriev, Kolotilin, and Sonin (2011) provide a model with risk-neutral agents in which expropriations occur in equilibrium, resulting from the assumption that both the government and the IOC can renege, the latter by choosing to retain all revenues in a given period without paying taxes. Therefore, taxes cannot be too high, which generates expropriations at high oil prices. In reality, however, IOCs do not typically renege on fiscal agreements. 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.

Another large literature has focused on the effect of taxation on investment incentives, abstracting from the possibility of expropriation. Taxes may affect the decision to invest in exploration, development, and extraction of hydrocarbon resources, as well as the incentives for enhanced recovery and shutdown. Deacon (1994) shows that corporate income taxes barely distort drilling and production, while production and property taxes decrease lifetime production by a limited amount (4.8% to 6.5% in his simulations). Kunce et al. (2003) find that oil production is highly inelastic with respect to changes in production taxation. Blake and Roberts (2006) find slightly higher distortionary effects of taxation on investment, although the results are sensitive to parameterization. Moreover, they find that progressive taxation leads to larger distortions. This paper follows Rigobon (2010) and others by abstracting from investment incentives as a first step toward understanding the optimal contract. We solve for the optimal contract conditional on a field being operational and focus on the effect of oil price risk on contract structure. A theoretical literature has begun to address this question, but we are not aware of any existing empirical work.

Rigobon (2010) concludes that the optimal contract choice will involve partial insurance for a risk-averse government. In his model, a government chooses between nondistortionary 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. 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.

Engel and Fischer (2010) argue that (exogenous) expropriations involve a social cost (for example, 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. Again, the risk neutrality of the government makes insurance irrelevant in this model.

Previous papers' common assumption of a risk-neutral government removes the value of oil price insurance to the host country. However, there exists extensive evidence that governments have an incentive to reduce revenue volatility. Rigobon does analyze risk sharing in optimal contracts. His approach, in line with the existing literature, is theoretical or simulation based, 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). This paper provides a first step toward closing this empirical gap by analyzing the degree of risk sharing in real-world contracts. Existing papers have also not addressed the question of why contract structure varies so widely by country. This paper builds on Rigobon's work by making explicit how the risk transfer in an optimal contract is determined by various country-specific factors. We then empirically estimate the magnitude of each factor's impact using detailed real-world contract data. To the best of our knowledge, this is the first empirical test of an optimal resource taxation model.

III. Real-World Hydrocarbon Contracts

Real-world hydrocarbon contracts are complicated combinations of taxes on production (often in the form of production sharing agreements), revenue, profits, and "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).

A. *The Tax Simulator*

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 (2,468 contracts) in 38 non-OPEC countries in Europe, Africa, Central Asia, and Far East Asia.[4] 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 payoffs (their marginal tax rates) vary with the oil price, keeping other parameters such as output fixed. More details on the tax simulator are provided in the online appendix.

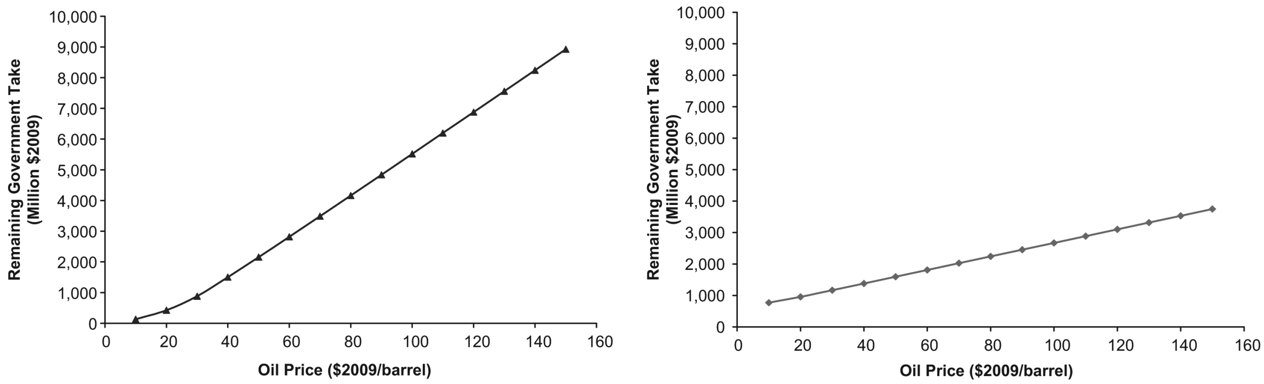
Figure 1 shows example outputs from the tax simulator for fields in Algeria (Adrar Project) and France (Cazaux Project). The simulator takes account of the plethora of taxes and fees described above to show how the tax revenue profile varies with the oil price. Table C2 in the online appendix provides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

B. *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

[4] This commercially available data set was built to guide business decisions for hydrocarbon companies and has been widely used in industry and government. We could obtain a subsample of 38 countries. Researchers have previously used these data in other contexts; see Kretzschmar, Kirchner, and Reusch (2008).

FIGURE 1.—HYDROCARBON CONTRACT STRUCTURE



This figure shows the development of remaining government take as the oil price varies for the Adrar field, Algeria (left), and the Cazaux field, France (right).

explicitly condition on the oil price. Instead, they comprise 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).

The tax simulator neither ignores tax terms that are nonlinear in the oil price nor imposes linearity. A few countries do apply taxes that explicitly condition on the oil price in a non linear fashion (see the online appendix for details). First, windfall profits taxes (for example, in Algeria and China) introduce nonlinearities at low and medium oil prices, although tax payments become linear again at higher prices. Second, a few countries employ elements of rate-of-return taxes. A different source of nonlinearities is imperfect loss offsets at persistent low oil prices (Mackie-Mason, 1990). At these prices, there may not be enough future profits to offset any initial losses. By considering all (both linear and nonlinear) taxes, the tax simulator generates payment profiles for all fields and companies. This allows us to investigate the overall importance of any nonlinear 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.

Linearity measure 1: Comparing slopes. The first measure to assess linearity is a comparison of slopes. A perfectly linear contract's payment profile has a constant slope 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 Δp as

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

where $TGR(p)$ is the total undiscounted government revenue over the remaining lifetime 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 γ 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.

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 indicate a progressive tax scheme or just variance around a constant slope:

$$\sigma(\gamma_i(p)) = \sqrt{\sum_{j=1}^{n} \left(\gamma_i(p_j) - \overline{\gamma_i}\right)^2 / (n-1)}. \tag{2}$$

Table 1 presents $\gamma_i(60)$, $\gamma_i(100)$, and the difference in slope (measure 1). We chose these values since the average oil price in 2009 was approximately \$60 per barrel, and in 2008 it was \$100 per barrel. We also show the standard deviation of the slope (measure 2) for all countries in our sample.[5] The standard deviation is computed using values of $\gamma_i(p)$ computed at oil prices from \$20 to \$100, in \$10 increments.

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 most countries in our sample, this linear relationship holds for much lower oil prices. The vast majority of countries have a taxation structure that results in a tax schedule that is almost linear in the oil price. Nonlinear elements in the tax code may be present but play a minor role. Angola is the only clear exception with progressive tax rates at high oil prices. Besides a number of linear taxes,

[5] As a third measure of linearity, one could calculate the R^2 of the regression of government take per barrel on a constant ϕ_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.

Table 1.—Measures of Linearity of Contracts between Countries and IOCs

Country	Slope at \$60	Slope at \$100	Difference in Slope	SD 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
Kyrgyzstan	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

Angola employs a rate-of-return tax.[6] IOCs' profit share typically decreases from 75% to 10% when the rate of return increases from 0% to 40% (WoodMackenzie, 2009). Some fields, like Adrar in figure 2, exhibit nonlinearities due to imperfect loss offsets in the tax payments at low oil prices, as well as the presence of windfall profit taxes, as described in the online appendix.[7] 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. The observation of nearlinearity is as strong as it may be surprising and is discussed section IV.E.[8]

IV. The Optimal Contract

In this section, we determine theoretical properties of the optimal contract between an IOC and a host country. We show that introducing incomplete information about a country's expropriation cost into models similar to those of Thomas and Worrall (1994) 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 at high oil prices. We also find that insurance is increasing in a country's cost of expropriation and decreasing in

[6] 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. Bulgaria and Kazakhstan have slightly increasing slopes, while Turkmenistan and Uzbekistan have slightly decreasing slopes between \$60 and \$100. However, these differences are small. Also, the slope becomes constant at oil prices above \$80.

[7] Since we use undiscounted revenues and a constant oil price to facilitate the interpretation of gamma, our calculations do not reflect any imperfect loss offsets due to time discounting. We acknowledge this but emphasize that this issue is less of a concern for low and high oil prices. At low prices, losses are never recovered, independent of time discounting. At high oil prices, the relevant range to study expropriations, losses are recovered quickly.

[8] 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 & Osmundsen, 2009).

its relative production efficiency. In section VI, we test for these predictions in the data and find them to hold for the countries in our sample.

A. Model Setup

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 the assumption of risk aversion with respect to revenues, especially for low-income countries (Daniel, 2001; Boadway & Keen, 2009). In our model, we assume the IOC to be risk neutral for simplicity. 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 0 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 time.

Consider in addition the following assumptions:

Assumption 1. 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 nonoil 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.

Assumption 2. The oil price p is identical and independently distributed (i.i.d.) over time with mean $\bar{p}$ and domain $[0, \infty)$. $f(.)$ represents the probability density function of the oil price.

We follow Guriev et al. (2011) and assume an i.i.d. price process for tractability. This contrasts with the geometric Brownian motion traditionally assumed in the finance literature (Pindyck, 1981; Gibson & Schwartz, 1990). Stochastic processes with weaker or no mean reversion would complicate the analysis but strengthen our results since oil price persistence reinforces the incentives for expropriation at high oil prices.

Assumption 3. 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 (International Energy Agency, 2009). The geological properties of oil and gas fields are such that the lifetime production profile can be adjusted only 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 & 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 with significant on-site storage or fields that can be shut down temporarily. Hence, fixing production is a reasonable assumption.[9] Note that the fixed oil production assumption is a convenient but not material simplification. If production could be adjusted upward in response to a higher oil price, it would make expropriation more attractive at high oil prices. The comparative statics of the model would be unaffected.

Assumption 4. The country faces utility cost (or benefit) $\mu > 0$ on expropriation. In each period there are two potential values, $\mu_L < \mu_H$, drawn from an i.i.d. Bernoulli distribution with probabilities π_{μ_L} and π_{μ_H} known to both parties. The realization of this parameter is unobservable to the IOC, but known to the country after μ and p are simultaneously determined.

In practice, a number of factors contribute to this cost. First, μ reflects the cost of domestic legal challenges to expropriation (Engel & Fischer, 2010). Second, the company might recover some of its loss through international arbitration, imposing costs on the expropriating country. Third, μ includes the loss of a country's international reputation following an expropriation. This reputation loss has been shown to depress foreign direct investment (Eaton & Gersovitz, 1984; Bohn & Deacon, 2000; Azzimonti & Sarte, 2007; Stroebel & van Benthem, 2013) and to lead to less favorable terms in the international credit market (Cole, Dow, & English, 1995). Finally, μ also contains possible benefits or costs of expropriation in light of domestic political motives. It is especially this last component of μ that is primarily observable to governments. The other components are (partially) observable to both parties. For the remainder of this section, the key assumption is that there is asymmetric information about at least one of the components of μ.

Assumption 5. After expropriation, the host country will revert to autarky: it will produce oil and sell at the world oil

[9] As discussed in section II, we abstract from investment incentives as a function of the oil price (and thus tax).

price forever. Moreover, it will incur a relative efficiency loss of δ.

This assumption is a stylized version of what happens in practice. Often, 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 δ reflects that IOCs possess specific operational or technical knowledge that allows them to extract oil at a lower cost than the host country can (Opp, 2008; Wolf, 2009). The larger the efficiency advantage δ of the IOC, the more costly it is for the host country to expropriate.

Assumption 6. The contract can be conditioned only on the observed oil price, p, not on the realization of the unobserved value μ. The contract is fully described by the function $y(p)$, which captures the contractual government revenues at each price.

Assumption 7. The IOC makes zero profits in expectation: $E_{p,\mu}[p - y(p)] = 0$.

Note that for notational simplicity, we normalize annual production costs to 0. Introducing nonzero production costs would be a straightforward extension that does not change the model structure or implications. Similarly, we normalize upfront investment cost to 0. 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 assumption 7. This does not have a qualitative impact on the comparative statics of contract structure.

The Country's Expropriation Decision. At each point in time, on realizing the current oil price p and its expropriation cost μ, a country has two options. It can expropriate the IOC, thereby receiving revenues pq while facing a utility cost μ. After expropriation, the country will remain in autarky forever. Given assumptions 4 and 5, the value function for the country when expropriating is given by

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

where β is the time discount factor and the value of autarky, V_{aut}, is defined as

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

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 payoff $y(p)$ today, while facing the same option to expropriate in the next period. The value of honoring the contract is given by

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

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

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. Π is the set of (p, μ) 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

$$\iint_{(p,\mu)\in\Pi} (p - y(p))f(p)f(\mu)dpd\mu \geq 0. \tag{8}$$

B. *Benchmark Model with No Asymmetric Information*

Under the benchmark case with complete information about the realization of μ, the optimal contract will involve payments that are conditioned on both p and μ and avoid all expropriations.[10] To simplify the intuition, assume in this section and the next 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 π_{p_L} and π_{p_H}. Any contract that improves on autarky will reduce the revenue volatility for the host country and require $y(p_L) > p_L$. For the IOC to break even in expectation, it also requires $y(p_H) < p_H$. This means that expropriations would occur only at p_H, when per barrel contractual payments to the country are less than the world market price. Now consider a contract that did involve expropriations at (p_H, μ_L), that is, where $V_e(p_H, \mu_L) > V_h(p_H)$. This contract cannot be optimal: it is possible to raise $y(p_H, \mu_L)$ to a value below p_H such that the country is indifferent between expropriating and honoring the contract. The IOC now receives a positive revenue at (p_H, μ_L), which it can redistribute to the country in other states of the world. By an analogous argument, a contract that involves expropriation at (p_H, μ_H) is also suboptimal. Consequently, if contracts can be conditioned on the realization of μ, the optimal contract's payoff at p_H is as low as possible without violating the country's incentive compatibility constraint. This generates the maximum possible insurance at low oil prices.

[10] See Ljungqvist and Sargent (2004) for a full exposition. This relaxes assumption 6. Instead of assumption 4, we now assume that the realization of μ is still stochastic but observable to both parties in every period. We thank an anonymous referee for suggesting we include a discussion of this benchmark case.

C. *Expropriation under the Optimal Contract*

In this section, we show that in the presence of asymmetric information about a country's μ, expropriations cannot always be avoided, even under the optimal contract. Following assumption 6, 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 on.
2. Each period, the oil price p and the cost of expropriation μ are simultaneously realized.
3. The country has three choices: expropriate immediately at cost μ, take the contractual payment $y(p)$, or enter into renegotiation at time cost η (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 μ. Successful renegotiation incurs a cost of $\phi(\mu)$, where $\mu > \phi(\mu) > 0$, since reputational costs will still be incurred even if legal procedures can be avoided.

Note that this multiperiod problem is stationary. Since p and μ are i.i.d., the game repeats itself each period. Therefore, in the discussion, 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 μ in equilibrium (by choosing the same action at μ_L and μ_H), the company's beliefs follow Bayes' rule and are π_{μ_L} and π_{μ_H}.

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

Proof. See appendix B.

Proposition 1 argues that the optimal contract will never lead to renegotiation.[11] This means that we can focus on finding the tax contract that optimizes the country's utility under the allocation determined by the contract, not the allocation that results from renegotiation.

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

Proof. See appendix B.

Proposition 2 states that the optimal contract may involve expropriation at μ_L. Note that there are two possible equilibria at p_H: a no-expropriation contract and a contract with expropriation at μ_L only, both subject to the company's participation constraint $\pi_{p_L}(p_L - y(p_L)) + \pi_{p_H}(p_H - y(p_H))\left(1 - \pi_{\text{exp}}\right)$, 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 μ.[12] In appendix B, we relax the assumption of only two values for μ.

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 that 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-price to low-price states by reducing $y(p_H)$ and

[11] 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 μ_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. μ_H always imitates μ_L if μ_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 μ_L nor μ_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 μ_L and μ_H want to expropriate. It remains to consider an oil price at which μ_L wants to expropriate but μ_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 were offered less, it would be optimal to reject and hope that the country turns out to be a μ_H country trying to imitate a μ_L country. Whether it is optimal for μ_L to offer e rather than to expropriate directly depends on the relative size of $\mu_L, \delta, \eta, \phi(\mu)$, and π_H.

[12] 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 $\mu = \mu_L$. A proof is available from the authors.

We also considered whether there exists a set of contracts with payments conditional on both the oil price and an announced cost of expropriation by the government, $\hat{\mu} \in \{\hat{\mu}_L, \hat{\mu}_H\}$, that would induce governments to truthfully announce their realization of μ. If announcing $\hat{\mu}_L$ was costly and was sufficiently more costly for a μ_H country than for a μ_L country, then there exists a set of incentive-compatible contracts contingent on $(p, \hat{\mu})$ that do not feature expropriations on the equilibrium path (the contractual payments would mirror those described in section IVB, which assumed perfect information about μ). This might be the case, for example, if the IOC could enforce a punishment for announcing $\hat{\mu}_L$ that would impose larger costs on a μ_H country than on a μ_L country. We thank a referee for bringing this set of contracts to our attention.

increasing $y(p_L)$. However, this 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 μ_H occurs. Hence, the contract accepts expropriations at μ_L in exchange for higher profits at μ_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 assumption 2. First, consider the contract in which $IC(p, \mu_L)$ binds $\forall p \in P$, where P is some compact set of oil prices: expropriations are avoided $\forall p \in P$. Now consider the following change to the contract: for a price region $[\widehat{p}, \widehat{p}+\varepsilon] \subset P$, reduce contract payments such that $IC(p, \mu_H)$ binds. This will increase the IOC's revenue when μ_H is realized, but in the case of μ_L, the IOC will be expropriated and receive nothing. Formally, the change Δ in the IOC's expected revenue is

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

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

$$y'(p) = y(p) + \frac{\Delta}{\int_{\widetilde{p} \in P'} f(\widetilde{p}) d\widetilde{p}}. \tag{10}$$

The redistribution will generate a welfare increase for the country if

$$\int_{p \in P'} [u(y'(p)) - u(y(p))] f(p)dp > \int_{\widehat{p}}^{\widehat{p}+\varepsilon} [\underbrace{u(p) - \mu_L}_{\text{Utility from pre-change payment}} - \underbrace{(\pi_{\mu_H}(u(p) - \mu_H) + \pi_{\mu_L}(u(p) - \mu_L))}_{\text{Expected utility from post-change payment}}] f(p)dp \tag{11}$$
$$= \int_{\widehat{p}}^{\widehat{p}+\varepsilon} \pi_{\mu_H}(\mu_H - \mu_L) f(p)dp.$$

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

D. *The Linear Contract*

Since real-world tax 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 (a) the solution of the optimal linear hydrocarbon contract, (b) what determines the probability of expropriation, and (c) 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. Assumption 6 is changed to:

Assumption 8. The only allowable per barrel contracts between the host country and IOC are linear in the following way:

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

$$\alpha + \gamma(p - \bar{p}) \geq 0 \qquad \forall p \in [0, \infty). \tag{13}$$

$y(p)$ consists of a fixed positive payment α 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 μ_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 occuring independently of the realization of $\mu : \forall p > p^{**}, \forall \mu : V_h(p) < V_e(p, \mu)$.*

Proof. See appendix B.

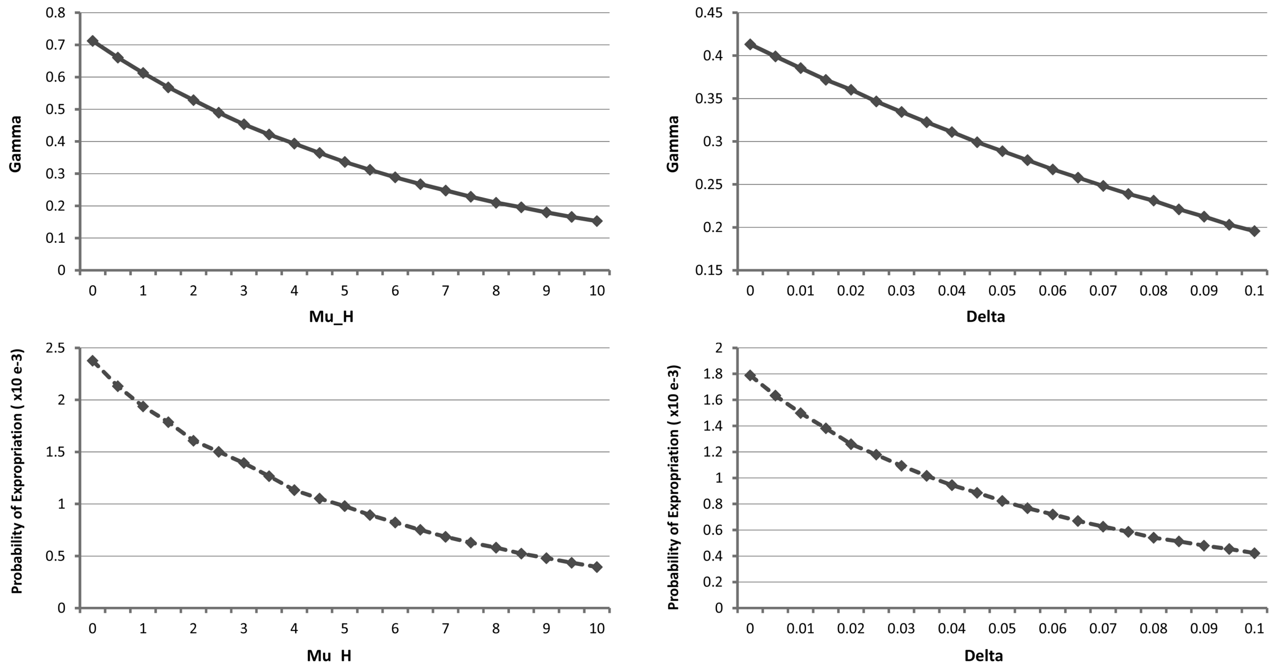
In words, there exists an oil price p^* below which expropriation is never optimal. There may also exist an oil price p^{**} above which expropriation is always optimal. In between p^* and p^{**}, expropriation occurs only if the country's cost of expropriation is low. Since we assume i.i.d. oil prices, 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 μ_H, μ_L, g_0, and q, as well as the contract parameters α and γ, and can be obtained by solving the following two equations:

$$V_h(p^*) = V_e(p^*, \mu_L), \tag{14}$$

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

FIGURE 2.—COMPARATIVE STATICS, VARYING μ_H AND δ, AND LOW NONOIL GDP



This figure shows the comparative statics of contract slope γ (top row) and the probability of expropriation (bottom row) with respect to the cost of expropriation μ_H (left column) and the efficiency advantage of the IOC δ (right column). Other parameters are $\eta = \frac{1}{2}, q = 1, g_0 = 50$, and $\pi_{\mu_H} = 0.9$. When varying $\mu_H, \delta = 0.05$. When varying $\delta, \mu_H = 6$.

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

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

subject to the company's participation constraint, equation (8), and with V_c defined in equation (7). The country's incentive compatibility constraints are implicit, since $p^*(\alpha, \gamma)$ and $p^{**}(\alpha, \gamma)$ are defined in equations (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. First, as shown in section IVB, expropriations may 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 commonly used linear tax 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 at high oil prices.

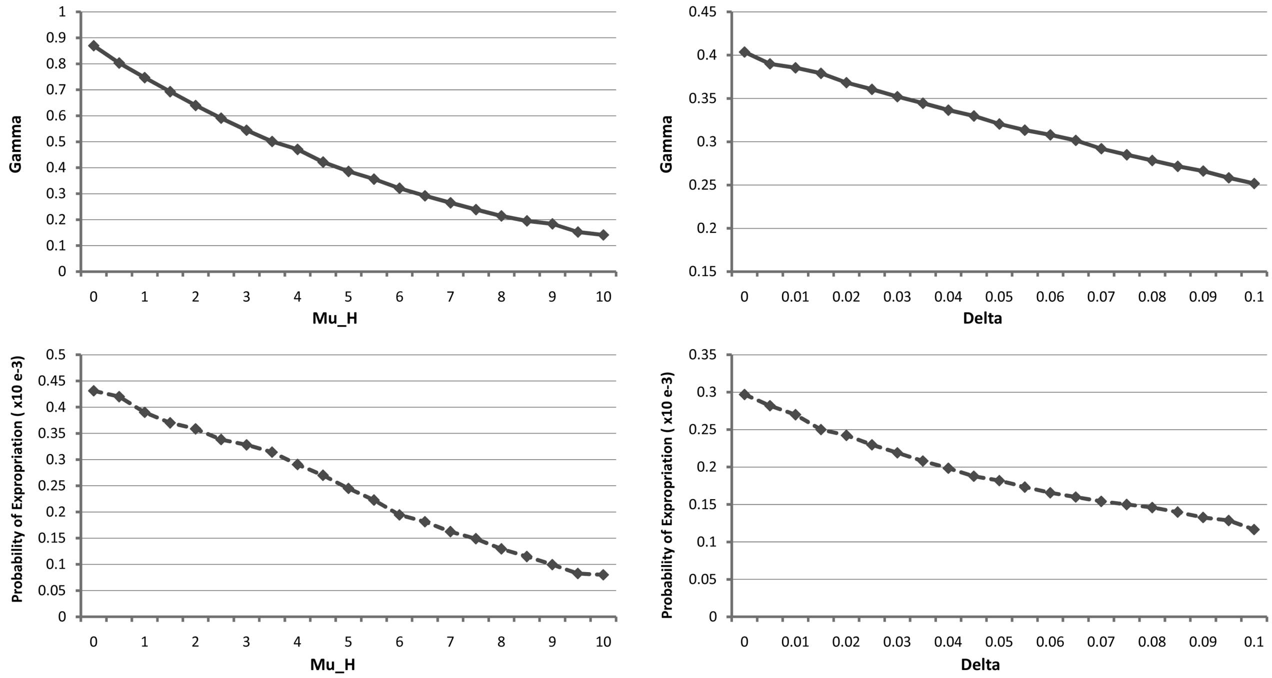
E. *Comparative Statics of the Linear Contract*

This section presents (numerical) comparative statics of the optimal linear contract. The key comparative statics of interest are how the contract insurance parameter γ varies with the cost of expropriation, μ, and the efficiency advantage of the IOC, δ. We also discuss comparative statics for GDP g 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 follow Gibson and Schwartz (1990) and specify an instantaneous log-normal oil price distribution, parameterized to the period 1999 to 2009, with a mean oil price of approximately \$46. As discussed in assumption 2, we assume an i.i.d. oil price process. We set nonoil GDP g_0 equal to 50. We keep oil production q at a value of 1. At the mean oil price, this parameterization implies that about 50% of the country's GDP is hydrocarbon related. As discussed in note 3, this fraction reflects the high hydrocarbon intensity of the economies of many countries in our sample. 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 are tested empirically in section VI.

Vary expropriation costs and production efficiency loss (μ_H and δ). Figure 2 (left column) shows the comparative statics of the contract parameters with respect to the cost of

FIGURE 3.—COMPARATIVE STATICS, VARYING μ_H AND δ, AND HIGH NONOIL GDP



This figure shows the comparative statics of contract slope γ (top row) and the probability of expropriation (bottom row) with respect to the cost of expropriation μ_H (left column) and the efficiency advantage of the IOC δ (right column). Other parameters are $\eta = \frac{1}{2}, q = 1, g_0 = 500, \pi_{\mu_H} = 0.9$. When varying $\mu_H, \delta = 0.05$. When varying $\delta, \mu_H = 6$.

expropriation, μ_H, while keeping δ, g_0, and q fixed (at 0.05, 50, and 1, respectively). Varying the expropriation cost has two main consequences. First, the slope of the linear contract γ (inversely related to insurance) is decreasing in μ_H. A higher μ_H increases a country's ability to commit, which allows contracts with more insurance. Second, the probability of expropriation is decreasing in μ_H despite the fact that the contract adjusts to provide the host country with more insurance.

The comparative statics of increasing μ_H are similar to the comparative statics of increasing the production efficiency loss δ. Both make reneging on the contract more costly to the host country. A higher efficiency loss δ increases the cost of autarky. Hence, figure 2 (right column) shows that contract insurance is increasing in δ, and the probability of expropriation is decreasing in δ.[13]

Figure 3 shows the comparative statics for a richer country in which oil production contributes only approximately 10% to GDP. To do this, we set $g_0 = 500$ while keeping all other parameter values the same. The comparative statics do not change qualitatively: insurance is still increasing in μ and δ, and the probability of expropriation is decreasing. The probability of expropriation is lower, since for richer countries, the same utility cost of expropriation translates into a higher dollar cost.[14]

Vary oil production and total GDP. While the comparative statics with respect to μ_H and δ give unambiguous predictions on the contract slope γ, the effects of changing hydrocarbon production and GDP are more subtle because 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 the current level of production, GDP, risk aversion, and, most notably, the government's time discount factor. The former effect dominates for low discount factors, while the latter effect dominates

[13] We choose $0 \leq \delta \leq 0.1$ as the relevant range, based on the (sparse) literature on relative production efficiency of NOCs and estimates of production costs. Eller, Hartley, and Medlock (2007) and Wolf (2009) estimate that NOC production efficiency is 21% to 48% lower than IOC efficiency. There is little public information on the production cost of oil, but even unconventional oil can be produced at costs as low as \$5 to \$10 (International Energy Authority, 2010). Using the upper ends of both ranges, the NOC's additional production cost would be about \$5. Using our average oil price, this implies an upper estimate of δ of about 0.1. For μ_H, we consider values between 0 and 10. At the mean oil price, total GDP is about 100, and period utility is about 10. This means that the upper limit of the range for μ_H corresponds to a loss of a full period's GDP.

[14] The comparative statics are robust to a wide range of parameter values. Results available from the authors on request.

for high discount factors. We empirically test which effect dominates in our data set in section VI.

F. *Possible Reasons for the Linearity of Real-World Contracts*

We observed in section III that real-world hydrocarbon extraction contracts are overwhelmingly linear. Section IV uses this empirical observation to motivate our focus on analyzing the optimal linear contract, since this paper concentrates on explaining why the contracts that we observe in practice give rise to expropriations and different degrees of oil price insurance for host countries.

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 preexisting 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, Germiso, & Henriksen, 2006).

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 not to signal his type. Here, 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 toward nonlinear taxation. In addition, the IOC negotiators are likely to have a strong personal interest in closing a deal quickly, which may discourage them from deviating significantly from preexisting tax frameworks.

A further possible explanation is that high marginal tax rates in a progressive taxation system distort investment incentives (Blake & Roberts, 2006) or encourage the abuse of transfer pricing (Engel & 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 provide capital equipment at above market leasing costs (Lund, 2009). Therefore, it may be difficult to design a unilateral welfare-improving deviation from linear taxes toward 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.[15]

V. Data

The unit of observation in our empirical analysis is a set of tax terms agreed between a company and a country, pertaining to an individual field. Table C3 in the online appendix 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 III. γ is directly calculated from these data using equation (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: IOC, likely IOC, national oil company (NOC), and partial NOC. To do this, we analyzed 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.

[15] Communication with academic energy economists and industry experts from BP and WoodMackenzie supports 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]."

GDP and population: Gross domestic product is taken from the United Nations UNdata database. This covers the period from 1970 onward. Population numbers are from the United Nations Population Program.

Expropriations: This is a binary variable 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 data set compiled by Guriev et al. (2011), complemented with recent expropriations from the World Investment Report (2007).

Section IV discussed factors that contribute to a government's cost of expropriation and production efficiency loss. We measure a country's expropriation costs by its domestic institutional quality and the amount of foreign direct investment (FDI). In addition, we measure its 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 comprehensive 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 (Acemoglu, Johnson, & Robinson, 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 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. In addition, we tested the robustness of our empirical results using an alternative proxy for expropriation costs: the Investment Profile Score provided by the PRS Group. This score is "an assessment of factors affecting the risk to investment that are not covered by other political, economic and financial risk components" and includes contract viability/expropriation as one of its subcomponents. It is scored between 1 and 12, with a higher score representing a lower investment risk. Unfortunately the coverage is somewhat more limited than that of the Constraint on the Executive measure (it excludes Turkmenistan, Uzbekistan, Chad, and Kyrgyzstan and starts only in 1984).

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 to measure 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 that 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 & 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.

VI. Empirical Analysis

This section empirically tests the main model implications: (a) insurance in hydrocarbon contracts is increasing in direct expropriation costs (in particular, those generated by domestic institutions and dependence on FDI) and (b) increasing in the dependence on foreign expertise. In addition, we test how GDP and oil production affect contract insurance.[16] We also test the model's predictions on the factors affecting the probability of expropriation.

A. *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 2,468 such combinations in our data set. The dependent variable in all regressions is the slope parameter γ at an oil price of \$60 ($\gamma_i(60)$).[17] The main explanatory variables correspond to the comparative statics from the model. In columns 1 to 4 of Table 2, we use the Constraint on Executive Index as our proxy for μ. In columns 5 and 6, we show that our results are robust to using the Investment Profile Score. We also include reliance on FDI to capture expropriation cost μ and cumulative hydrocarbon production, which is a measure of reliance on foreign production expertise δ.

In this section, we present OLS and WLS results and conclude that these are consistent with our model. A causal interpretation would require stronger assumptions (or exogenous variation in the regressors). While it is not obvious that γ and the regressors are driven by the same unobserved variables, endogeneity is a potential problem for a causal interpretation. For instance, it is possible that variation in unobservable or omitted institutional quality is correlated with both γ and FDI. We acknowledge this possibility but

[16] We measure insurance using γ, the marginal tax rate with respect to the oil price. The model in section III assumes that α in equation (12) adjusts to satisfy equation (8). If this were not the case, γ could still be interpreted as measuring insurance, although it would not necessarily be actuarially fair.

[17] Due to the near linearity of contracts illustrated in section III, results remain robust when analyzing the slope parameter at different oil prices.

TABLE 2.—CONTRACT STRUCTURE REGRESSIONS
DEPENDENT VARIABLE: $\gamma(60)$

	Constraint on Executive				Investment Profile Score	
	OLS (1)	WLS (2)	OLS (3)	WLS (4)	OLS (5)	WLS (6)
Institutional quality	−0.0170***	−0.0173***	−0.0204***	−0.0209***	−0.0188***	−0.0188***
	(0.0026)	(0.0026)	(0.0029)	(0.0029)	(0.0024)	(0.0024)
	[0.0058]		[0.0055]		[0.0068]	
Per capita FDI inflow	−0.0341***	−0.0341***	−0.0300***	−0.0301***	−0.0230**	−0.0232***
	(0.0046)	(0.0046)	(0.0047)	(0.0047)	(0.0051)	(0.0051)
	[0.0084]		[0.0083]		[0.0097]	
Cumulative hydrocarbon production	2.399**	2.417***	2.149**	2.165***	1.661*	1.634***
	(0.465)	(0.465)	(0.488)	(0.486)	(0.480)	(0.480)
	[1.158]		[1.030]		[0.849]	
R^2	0.051	0.052	0.061	0.063	0.071	0.072
N	2,468	2,468	2,035	2,035	1,881	1,881

Columns 1–4 use the Constraint on the Executive as the proxy for μ; columns 5 and 6 use the Investment Profile Score. Standard errors in parentheses and clustered at the country-year level (used for asterisks) in brackets. WLS weighting by remaining barrels of oil equivalent. * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$. Columns 1 and 2 include the full sample; columns 3 to 6 include IOCs only.

note that using and identifying (enough) instrumental variables is likely to be challenging and subject to a range of other criticisms. Therefore, we choose to present OLS regressions and interpret the results in table 2 as suggestive evidence consistent with our model.

Column 1 of table 2 estimates the relationship suggested by our comparative statics. Higher institutional stability is associated with a smaller γ, and hence with better insurance. In addition, higher reliance on FDI 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 represent only 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 government. Thus, the government is the claimant to all NOC profits. Consequently, our model has less clear predictions for tax contracts between host governments and NOCs.

All results are highly statistically significant 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 1 standard deviation increase in the CoE index is associated with a decline in γ of 0.05.[18] Similarly, a 1 standard deviation increase in the FDI per capita leads to a fall in γ of 0.03. A 1 standard deviation increase in cumulative production leads to an increase in γ of 0.02. We hence conclude that the structure of hydrocarbon contracts varies with our model parameters in a consistent way.

[18] There is a literature discussing the effects of endogenous matching on estimates of contract determinants (Ackerberg & Botticini, 2002). In our case, if companies were not perfectly risk-neutral, we would expect the least risk averse companies to operate in the riskiesf (low μ) countries. This would lead to a smaller coefficient on μ than when allocating IOCs randomly to countries.

In columns 5 and 6, we repeat the regressions from columns 3 and 4 using the Investment Profile Score as the proxy for μ. A 1 standard deviation increase in this measure is associated with a decline in γ of about 0.05. The effect of changes in per capita FDI and cumulative production is of similar magnitude as before.

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 IV 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 1 standard deviation increase in real per capita GDP is associated with a decline in γ of 0.02. Likewise, a 1 standard deviation increase in per capita hydrocarbon production is associated with an increase in γ 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 rate.

In columns 5 and 6, we again present a robustness check of the key empirical results with respect to the proxy for μ. While the variable capturing reliance on FDI is no longer statistically significant, the coefficient on the Investment Profile Score suggests that a 1 standard deviation increase in value is associated with a decline in γ of 0.04. In summary, the

TABLE 3.—CONTRACT STRUCTURE REGRESSIONS
DEPENDENT VARIABLE: $\gamma(60)$

	Constraint on Executive				Investment Profile Score	
	OLS (1)	WLS (2)	OLS (3)	WLS (4)	OLS (5)	WLS (6)
Institutional quality	−0.0243***	−0.0247***	−0.0236***	−0.0240***	−0.0162***	−0.0161***
	(0.0031)	(0.0031)	(0.0034)	(0.0034)	(0.0025)	(0.0025)
	[0.0050]		[0.0052]		[0.0060]	
Per capita FDI inflow	−0.0242***	−0.0240***	−0.0221***	−0.0220***	−0.0054	−0.0054
	(0.0047)	(0.0046)	(0.0050)	(0.0049)	(0.0051)	(0.0051)
	[0.0076]		[0.0078]		[0.0073]	
Cumulative hydrocarbon production	2.738***	2.779***	2.406***	2.441***	1.982**	1.983***
	(0.437)	(0.436)	(0.463)	(0.461)	(0.467)	(0.466)
	[0.849]		[0.843]		[0.783]	
Real per capita GDP	−1.195	−1.232**	−1.156	−1.204**	−2.684***	−2.758***
	(0.504)	(0.502)	(0.545)	(0.543)	(0.502)	(0.501)
	[0.893]		[0.899]		[0.750]	
Per capita hydrocarbon production	1.079***	1.085***	1.005***	1.012***	1.168***	1.175***
	(0.061)	(0.060)	(0.067)	(0.067)	(0.0693)	(0.0691)
	[0.119]		[0.113]		[0.102]	
R^2	0.211	0.215	0.191	0.195	0.218	0.221
N	2,468	2,468	2,035	2,035	1,881	1,881

Columns 1–4 use the Constraint on the Executive as the proxy for μ; columns 5 and 6 use the Investment Profile Score. Standard errors in parentheses and clustered at the country-year level (used for asterisks) in brackets. WLS weighting by remaining barrels of oil equivalent. $^*p < 0.10$, $^{**}p < 0.05$, and $^{***}p < 0.01$. Columns 1 and 2 include the full sample; columns 3 to 6 include IOCs only.

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 influence 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.

B. *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. The most direct implication is that expropriations are more likely when oil prices are high. The second implication is that the probability of expropriation is declining in the efficiency loss in autarky and the cost of expropriation (figure 2). Finally, 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 section VIA) contract structure responds to expropriation incentives. Keeping contract structure fixed, the probability of expropriation increases as μ and δ decrease. However, the new optimal contract will offer less insurance, which provides a countervailing force. Therefore, the resulting increase in the probability of expropriation may be quantitatively small.

Guriev et al. (2011) 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 that Guriev et al. (2011) used includes some expropriations in the oil sector in country-years with zero hydrocarbon production, possibly in the downstream sector. We expand on 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).[19] Table 4 shows the results of a probit regression using both the full sample with all countries and the subsample with positive production observations 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 1 standard deviation increase in the real oil price is associated with an increase in the annual probability of expropriation of 0.84 percentage points. A 1 standard deviation increase in cumulative hydrocarbon production is associated with a 0.79 percentage point increase in the annual expropriation probability. The statistical significance of the CoE index depends on the specification, with the (statistically insignificant) effect in column 4 being −0.45 percentage points for a 1 standard deviation increase in the CoE index. 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. In Columns 5 and 6, we use the Investment Profile Score as our proxy for μ. This proxy is statistically significant: a 1 standard deviation increase in μ is associated with a 0.7 percentage point fall in the annual probability of expropriation. Despite the difficulties with precisely defining expropriations, it is

[19] To use only publicly available data for this part of the analysis, we took production figures from the International Energy Agency's Extended Energy Balances.

TABLE 4.—PROBIT REGRESSIONS
DEPENDENT VARIABLE: PROBABILITY OF EXPROPRIATION

	Constraint on Executive				Investment Profile Score	
	(1)	(2)	(3)	(4)	(5)	(6)
Real oil price	0.0001	0.0003***	0.0001	0.0004***	0.0006***	0.0006***
	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Institutional quality	−0.0062***	−0.0023**	−0.0076***	−0.0019	−0.0027**	−0.0023**
	(0.0012)	(0.0011)	(0.0016)	(0.0014)	(0.0011)	(0.0011)
Per capita FDI inflow	−0.0049	0.0025	−0.0061	0.0034	−0.0040	−0.0108
	(0.0059)	(0.0072)	(0.0079)	(0.0093)	(0.0034)	(0.0171)
Cumulative hydrocarbon production	0.0021***	0.0030***	0.0019**	0.0033***	0.0014***	0.0034***
	(0.0007)	(0.0008)	(0.0009)	(0.0010)	(0.0004)	(0.0008)
Real per capita GDP		−0.0018***		−0.0024***		−0.0022***
		(0.0004)		(0.0005)		(0.0007)
Per capita hydrocarbon production		0.0010***		0.0013***		0.0005
		(0.0001)		(0.0002)		(0.0004)
N	3,836	3,769	2,641	2,641	1,709	1,709

Table reports average probit marginal effects. Columns 1–4 use the Constraint on the Executive as the proxy for μ; columns 5 and 6 use the Investment Profile Score. Standard errors in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, and $^{***}p < 0.01$. Columns 1 and 2 include the full sample; columns 3 to 6 include observations with positive hydrocarbon production only.

reassuring that these empirical results are consistent with our model.

VII. Conclusion

This paper uses a large data set of real-world hydrocarbon tax 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 nearly 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 we considered 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 nonlinear provisions. Section IV provides a discussion of possible reasons. Several authors have commented on a recent shift toward progressive hydrocarbon taxation (Johnston, 2008; Lovas & Osmundsen, 2009). This suggests that in recent years, the benefits of introducing nonlinear 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 signing 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 reneging on agreements, with either future regimes (as in the case of oil funds and fiscal rules) or financial intermediaries (as in the case of futures markets) are lower than the costs of reneging 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 applies to futures contracts: should prices move against the country, it could renege on its side of the deal. As discussed, IOCs possess significant operational or technical knowledge that allows them to extract oil at a lower cost than the host country can. This efficiency gain would be lost after expropriation, in addition to the other expropriation costs faced when reneging 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 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 the Oil Revenue Stabilization Fund to lessen the impact of oil price volatility that had led to unplanned budget cuts in the late 1990s. However, its 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 (International Monetary Fund, 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 (International Monetary Fund, 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 nonoil balance, which prevent large increases in expenditure when oil prices are temporarily high. However, adherence to such rules during times of high oil prices is rare. For example, in 2002 Ecuador adopted three fiscal rules focused on the nonoil balance, expenditure growth, and the ratio of public debt 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 countries that breached their fiscal rules are Azerbaijan, Equatorial Guinea, and Venezuela (International Monetary Fund, 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 1 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: $y(p_L) < p_L$. 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 on this autarky contract by having $y(p_L) = p_L + \varepsilon$ and $y(p_H) = p_H - \varepsilon$ for small ε.

Lemma 2: *A contract that generates expropriation at μ_H will be suboptimal.*

Proof. If expropriation is optimal at μ_H, it is also optimal at μ_L. Consequently the country gets $y(p_L) = p_L$. It would be possible to improve on 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 $u(x_i(p_H) - \eta) - \phi(\mu_i) = u(p_H - \eta) - \mu_i$ for $i = L, H$.*

Proof. First, it will never be optimal to offer more than what the country would just accept at μ_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 μ_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 indifferent between accepting or rejecting the counteroffer at a specific value of μ. The reason is that bidding slightly less would not change the country's actions but world increase the IOC's payoff (and its ability to provide insurance).

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

Proof. Suppose μ_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 η for entering into renegotiation. Knowing this, the IOC would infer that expressing an intent to renegotiate means that μ_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 $IC(p, \mu_H)$: (a) $y(p_H)$ is such that expropriations never happen; (b) $y(p_H)$ is such that expropriations will happen only at μ_L.*

Proof. $y(p_L) > p_L$ by lemma 1. By proposition 1, we discard the possibility of renegotiation and consider only 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 ε and increasing $y(p_L)$ by ε 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 ε and increase $y(p_L)$ by $\varepsilon \frac{\pi_{p_H}}{\pi_{p_L}} \pi_{\mu_H}$, which still satisfies the IOC's participation constraint. The country would be better off, since $\pi_{p_L}(u'(y(p_L)) \frac{\pi_{p_H}}{\pi_{p_L}} \pi_{\mu_H}) = u'(y(p_L))\pi_{p_H}\pi_{\mu_H} > \pi_{p_H}\pi_{\mu_H}u'(y(p_L))$.

Instead of only two possible values for the cost of expropriation, μ_L and μ_H, now consider a discrete probability distribution over a finite number of realizations of μ: $Pr(\mu = \mu_i) = \pi_{\mu_i}$ for $i = 1, \ldots, N$. 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 μ_1 is realized. It is better off expropriating immediately and avoiding the time cost of renegotiation η. 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 see expropriation only when μ_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 occuring 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 $\alpha - \gamma\overline{p} \geq 0$ by assumption 6'. By the concavity of $u(.)$, 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 assumption 1, 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

$$V_e(0, \mu) = u(g_0) + \beta V_{aut} - \mu,$$
$$V_h(0) = u\,(g_0 + (\alpha - \gamma\overline{p})q) + \beta E_{p,\mu}[\max(V_e(p, \mu), V_h(p))].$$

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.