Pushing one’s luck: Petroleum ownership and discoveries

Christa N. Brunnschweiler a,b,c, Steven Poelhekke d,e,f,g,*

a University of East Anglia, Norwich NR4 7TJ, United Kingdom
b CBESS, University of East Anglia, United Kingdom
c OxCarre, University of Oxford, United Kingdom
d University of Auckland, Owen G. Glenn Building, 12 Grafton Rd., Auckland 1010, New Zealand
e Vrije Universiteit Amsterdam, Netherlands
f CESifo, Munich, Germany
g CEPR, United Kingdom

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ABSTRACT

We present a new dataset that tracks changes in legal ownership regimes in the petroleum sector between 1867 and 2008 for a panel of countries. We document that foreign ownership has been taken over by partnerships as the leading ownership regime, while domestic ownership is on the rise again in recent years. We use this dataset to examine whether institutional change in the petroleum sector leads to more oil and gas exploration and discoveries. On average, switching to majority foreign ownership is related to up to a quarter of a standard deviation more discoveries than under majority domestic ownership. Switching to partnership is positively related to drilling activity, but is less likely to be linked to many more discoveries. Petroleum exploration and discoveries may thus be endogenous to industry-specific institutional change.

1. Introduction

Proven world oil reserves have increased from 680 billion barrels in 1980 to more than 1700 billion barrels in 2019. Despite oil being an exhaustible resource in principle, we appear to be finding ever more of it. Although the existence of natural resource endowments is determined by local geology and is therefore exogenous, finding these resources often relies on foreign firms to provide capital and expertise, because many countries do not have the capital or technology available to engage in exploration themselves. Yet, it is often argued that known resource endowments are exogenous; that they are due to chance rather than to the political and economic environment of the host country; and that they therefore provide good measures of exogenous variation in resource wealth in the analysis of economic development (see e.g., Brunnschweiler and Bulte, 2008; Ploeg and Poelhekke, 2010; Cotet and Tsui, 2013).

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New seismic survey methods and new extraction technologies – and high oil prices that make them competitive – also play a large role, as exemplified by the recent shale boom. See, for example, Alcott and Keniston (2018).

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This paper presents a new database that tracks the institutions that govern the petroleum sector, covering over a century of data for up to 68 oil-producing countries, and relates these institutional setups to petroleum exploration intensity and discoveries. Hydrocarbons continue to be a vital resource as a fuel, a source of electricity, or a source of foreign exchange, so understanding whether and how the institutional framework has any bearing on oil and gas discoveries is an important issue. Our dataset captures legal restrictions on control rights over petroleum exploration and production decisions, distinguishing between those that allow Domestic, Foreign, and mixed, or ‘Partnership’ ownership regimes. In addition, we show that the nationality of ownership is more important than the conventional distinction between public and private ownership (Bohn and Deacon, 2000; Wolf, 2009).

We document that Foreign ownership (typically in the form of concessions with long maturities in exchange for a royalty) has gradually been replaced by a bigger role for domestic firms as host countries’ nationalism and own-industry know-how have increased, to the point where Partnerships are the norm today. Domestic ownership has been on the rise again in recent years with partial or full nationalizations taking place in Russia (2005), Bolivia (2006), Ecuador, and Venezuela (both 2007).

We describe the evolution of ownership regimes over time, and regress measures of discoveries and drilling activity on ownership regimes. These results show that both switching to Foreign and Partnership regimes is positively related to drilling, but only Foreign ownership is significantly positively correlated with discoveries. We also show that the relationships between oil-sector-specific institutions and exploration and discovery are robust to controlling for broader national-level institutions and cumulative previous discoveries. These findings suggest that foreign petroleum firms are better able than domestic firms to gauge the risks involved in oil and gas exploration, and likely invest more in new technology and in geological and seismic knowledge. This gives them an edge over domestic firms that often operate in a protected home market.3

In the online appendix we take a first step towards fixed-effects two-stage least squares (2SLS) estimations, which strengthen the result that adopting Domestic ownership is followed by a drop in discoveries. Our contribution is to improve our understanding of the specific institutions that may be adopted by countries, although in the absence of strong instruments, we do not claim that the link is causal, nor do we claim that the institutions that raise the probability of finding petroleum also lead to long-term economic development.

We extend the recent literature on the endogeneity of natural resource endowments (Arezki et al., 2019; Cust and Harding, 2020) by focusing on industry-specific institutions, rather than the more general institutional framework. In addition, we add to the literature that uses discoveries as exogenous variation for a range of outcomes (Lei and Michaels, 2014; Smith, 2015; Arezki et al., 2017). Our results suggest that the use of (the timing of) oil and gas discoveries as exogenous variation may be improved by controlling for the specific ownership regime under which those discoveries were made.

2. A new database on petroleum ownership regimes

We introduce a unique annual dataset on petroleum ownership regimes spanning more than a century, from 1867 to 2008. Our dataset includes information on 68 oil-producing countries from all regions of the world.4 The main criteria for inclusion in the dataset are that the country had a minimum of 0.2 billion barrels in (proved) oil reserves between 1980–2008, and that it produced an average of at least 20,000 barrels of crude oil per day during at least one year over the same period. The principal source for this information was the U.S. Energy Information Administration (EIA), which we cross-checked with the BP Statistical Review of World Energy (covering fewer countries in detail, but over a longer time period). Our sample includes 96.6 percent of known worldwide proved crude oil reserves in 1980, while in 2008 the share goes up to 99.9 percent. In practice, we include all but the very smallest and most recent oil producers of the past century. A country first enters our dataset when it is independent and passes a petroleum sector-specific law, rule or regulation that determines what we call the petroleum ownership regime.5

We distinguish between three main ownership regimes: Domestic, Foreign, and mixed domestic-foreign, which we label Partnership:

**Domestic:** The maximum legally allowed degree of involvement of foreign petroleum exploration and production firms is less than 50%, and foreign involvement – if present – is limited to roles with little or no operational and managerial control, e.g., through service contracts. The managerial power lies in domestic hands. Domestic (private or state-owned) firm(s) hold(s) the rights to develop the majority of petroleum deposits and own(s) a controlling share (over 50%) in the oil and gas sector.

**Partnership:** The maximum legally allowed degree of involvement of foreign petroleum exploration and production firms is less than 50%, but foreign firms are allowed to have substantial involvement such that both domestic and foreign oil firms have operational and managerial competencies, e.g., through Production Sharing Agreements (PSAs) or joint ventures. The state, state firm(s), or private domestic firm(s) hold(s) the rights to develop the majority of petroleum deposits and own(s) a controlling share (over 50%) in the oil and gas sector.

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3 See Nolan and Thurber (2012) for similar arguments.

4 A list of countries and years of coverage is shown in Online Appendix OA1.

5 The only exception is Canada, where petroleum-specific legislation is passed by provincial governments. The national government instead sets out laws for the mining sector in general. The first mining sector law was passed in 1867, the year of Canada's independence from Great Britain. Given that oil refining (for kerosene production) was originally invented in Canada in the 1840s, and that the Canadian petroleum industry developed in parallel with that of the United States in the second half of the nineteenth century, we argue that the 1867 law fully applies to the petroleum sector. Canada therefore enters our dataset in 1867.
Fig. 1. PETROLEUM OWNERSHIP REGIMES SINCE 1867. NOTE: COUNTRIES ARE INCLUDED IN OUR DATASET FROM THE YEAR THAT THEY INTRODUCE THE FIRST PETROLEUM-SPECIFIC LAW, RULE OR REGULATION AS AN INDEPENDENT NATION. THE X-AXIS SHOWS THE TIMELINE AND THE Y-AXIS SHOWS THE SHARE OF COUNTRIES IN OUR SAMPLE WITH THE RESPECTIVE PETROLEUM OWNERSHIP REGIME. FOR AN ANALOGOUS FIGURE WITH THE NUMBER OF COUNTRIES, SEE THE ONLINE APPENDIX.

**FOREIGN**: The maximum legally allowed degree of involvement of foreign petroleum exploration and production firms is more than 50%. The operational and managerial power lies in foreign hands, e.g., via concessions. Foreign (private or state-owned) firms hold the rights to develop the majority of petroleum deposits and own(s) a controlling share (over 50%) in the oil sector.

We establish **de jure** ownership by tracking the degree of operational and managerial roles that domestic and foreign firms can have in a country’s laws, rules and regulations. We rely primarily on countries’ constitutions, and official laws and regulations governing the petroleum sector; sample petroleum contracts and many secondary sources were also consulted. To distinguish between Domestic Control and Partnership in particular, we first determine whether the petroleum sector is controlled by domestic firms in the relevant laws, rules and regulations. If foreign firms can have little or no operational and managerial influence (and thus hold at best service contracts), we code the country’s ownership regime as Domestic Control. In typical service contracts, foreign firms develop a field in exchange for a fixed fee, but do not control the extracted oil. If foreign firms can have substantial operational and managerial influence (such as through PSAs) and thus more co-equal roles with domestic firms, we code the country’s ownership regime as Partnership. In PSAs, foreign firms do not process or sell all extracted oil; a share of oil extracted is processed and sold by the domestic firm. To illustrate the process of classification in more detail, in Online Appendix OA2 we describe the evolution of petroleum ownership regimes in two prominent oil producers: Saudi Arabia and Norway.

### 2.1. The diffusion of ownership regimes

We gathered information on ownership regimes for 3874 country–year observations, with an average coverage of nearly 57 years per country. The figure tracks 65 switches between the three regime types, as well as the entry of new countries over time. More than half of the countries (35 out of 68) switch regimes at least once. The most common regime in our dataset is Foreign (1557 out of 3874 country-years, or 41.8%), followed by Partnership (1191 or 32% of country-years), and finally Domestic (975 or 26.2% of country-years). Although Foreign is the most frequently found regime among the countries that never change ownership structure (19 out of the 33 ‘never-changers’), it is also the one most frequently abandoned: 27 countries change from Foreign to another regime, followed by Domestic and Partnership with 23 and 14 changes to another regime, respectively. The most common switch from Foreign is towards Domestic ownership (15 out of...
Fig. 2. Ownership regimes split by public–private. Note: Countries are included in our dataset from the year that they introduce the first petroleum-specific law, rule or regulation as an independent nation. The x-axis shows the timeline and the y-axis shows the share of countries in our sample with the respective petroleum ownership regime. Foreign, Domestic and Partnership regimes as described in the article. Private and public ownership are coded by the authors, adapting and extending the dataset in Jones Luong and Weinthal (2010).

27 switches); for Domestic, the most common switch is to Partnership (18 out of 23 switches); and for Partnership it is Domestic ownership (8 out of 14 switches).

The new database also tracks public versus private ownership. Fig. 2 illustrates the differences between our novel ownership classification based on nationality and the more conventional distinction between public and private ownership in the petroleum sector. Countries that have a Foreign ownership regime also do not restrict private ownership (top graph). Countries under a Domestic regime have historically primarily been dominated by public oil companies (middle graph), with some exceptions where private extraction firms were shielded from foreign competition for some years: Guatemala until 1983; Brazil until 1938; (Imperial) Russia until 1918; and Venezuela until 1907. Most Partnership countries see foreign companies working with a public oil company (bottom graph).

Our focus on Domestic, Foreign, and mixed ownership is based on three additional observations that make ownership nationality most important for exploration and discoveries. First, the petroleum management literature suggests that international oil companies (i.e. those that are foreign from the perspective of the host country) are exposed to competitive global market pressures and have strong incentives to invest in technology — pressures which domestic or national oil companies typically do not face in their home markets (Victor et al., 2012). Second, foreign affiliates tend to be more productive (Arnold and Javorcik, 2009; Guadalupe et al., 2012; Javorcik and Poelhekke, 2017). Third, the distinction between public and private petroleum companies becomes irrelevant
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when it comes to cross-border investment in exploration and production where competition is most intense: petroleum firms that invest beyond their home-country borders can be private or public.

The big picture that emerges is a shift between the extremes – Foreign and Domestic ownership – as evidence of shifting balances of power between foreign oil companies and the host country governments, while the number of countries adopting Partnership steadily increases. Fig. 3 focuses on the period since 1960 and splits countries into OPEC members and non-OPEC members that are open or closed to trade. This shows that (partial) nationalizations by OPEC members during the 1970s seem to have been followed by a sharp increase in Foreign ownership and Partnerships in other countries that were open to trade.\footnote{We describe these periods in more detail in Online Appendix OA3.} This trend is consistent with the literature that describes foreign oil companies as seeking to counter the seizure of control over oil deposits by the host country governments by exploring for and developing new reserves elsewhere (Skeet, 1988). They are driven by a fundamental characteristic of the petroleum industry: company survival hinges on “successful discovery, development, and production of oil and gas reserves”, because “reserves represent the main source of future cash flow for an [exploration and production] company and affect virtually every aspect of financial accounting and reporting” (Wright, 2017, p77). In particular, petroleum companies try to maintain their reserve replacement ratio, a key performance indicator which reflects their ability to operate in the future. A company can add or ‘book’ proven reserves by new discoveries or extensions; by purchasing existing reserves — usually more expensive than new discoveries; or by revising previous estimates — often treated with suspicion in the industry. Ownership regimes may thus influence exploration, because ‘bookable reserves’ are largest under majority Foreign ownership; lower under a Partnership contract; and very low or zero under majority Domestic ownership (Wright, 2017).

3. Ownership regimes, exploration and discoveries

We use the new dataset to test whether oil and gas exploration and discovery are linked to petroleum-sector ownership regime, specifying a dummy for each ownership category and excluding Domestic ownership as the base category. We use pooled OLS to estimate the equation:

\[ Y_{ct} = \beta_1 \text{Partnership}_{ct} + \beta_2 \text{Foreign}_{ct} + \beta_3 X_{ct} + \alpha_c + \delta_t + \epsilon_{ct}, \]

\[ ct \]

where \( Y_{ct} \) is either discoveries or exploration in country \( c \) in year \( t \). Discoveries are measured by the number of giant oil and gas discoveries since 1868 from Horn (2014), defined as fields that contain at least 500 million barrels of ultimately recoverable oil equivalent (i.e., the amount that is technically recoverable given existing technology). Exploration is measured by the (inverse
hyperbolic sine of) number of exploratory boreholes, known as ‘wildcats’, from the Association for the Study of Peak Oil (ASPO, from Cotet and Tsui, 2013); it is available for the period between 1930–2003. It is the oil equivalent sum of the size of all discoveries made in a year in billions of barrels, transformed by the inverse hyperbolic sine which approximates a log transformation but still includes zeros. Robust standard errors (clustered by country and year) in parenthesis: Table OA1 contains summary statistics. See Section 2 for variable definitions and sources.

### Table 1: Discoveries, drilling, and petroleum ownership: OLS estimations.

<table>
<thead>
<tr>
<th>Ownership regime</th>
<th>Discoveries</th>
<th>Discoveries (t + 1)</th>
<th>Wildcats</th>
<th>Wildcats t + 1</th>
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<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>Countries with first discovery after first ownership regime</td>
<td>Same as (3)</td>
<td>Same as (3)</td>
<td></td>
<td></td>
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<tr>
<td>Partnership</td>
<td>0.094*</td>
<td>0.098*</td>
<td>0.110</td>
<td>0.127</td>
</tr>
<tr>
<td></td>
<td>(0.072)</td>
<td>(0.068)</td>
<td>(0.086)</td>
<td>(0.092)</td>
</tr>
<tr>
<td>Foreign</td>
<td>0.105**</td>
<td>0.094**</td>
<td>0.089</td>
<td>0.119**</td>
</tr>
<tr>
<td></td>
<td>(0.047)</td>
<td>(0.048)</td>
<td>(0.059)</td>
<td>(0.064)</td>
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<tr>
<td>BITs signed</td>
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<td>−0.018</td>
</tr>
<tr>
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<td>0.002</td>
</tr>
<tr>
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<td>0.069*</td>
<td>0.060</td>
<td>0.056</td>
</tr>
<tr>
<td></td>
<td>(0.054)</td>
<td>(0.054)</td>
<td>(0.046)</td>
<td>(0.046)</td>
</tr>
<tr>
<td>Cumul. oil eq. discovered, t − 1</td>
<td>0.015**</td>
<td>0.009</td>
<td>−0.007</td>
<td>0.013**</td>
</tr>
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<td>(barrels, arcsinh bn)</td>
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<td>(0.006)</td>
<td>(0.005)</td>
<td>(0.005)</td>
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<tr>
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<td></td>
<td>(0.210)</td>
<td>(0.198)</td>
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<tr>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Clusters</td>
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<td>63</td>
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<td>62</td>
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<tr>
<td>Observations</td>
<td>3722</td>
<td>3609</td>
<td>2400</td>
<td>2400</td>
</tr>
</tbody>
</table>

Note: This table shows panel regressions of the effect of petroleum ownership regimes on discoveries and drilling activity using OLS. The base petroleum ownership regime is Domestic ownership. Discoveries is the sum of giant oil and gas discoveries made in each country and year. Wildcats is the inverse hyperbolic sine of the sum of wildcat wells drilled in each country and year. Cumulative oil eq. discovered (barrels, arcsinh bn) is the oil equivalent sum of the size of all discoveries made in a year in billions of barrels, transformed by the inverse hyperbolic sine which approximates a log transformation but still includes zeros. Robust standard errors (clustered by country and year) in parenthesis: Table OA1 contains summary statistics. See Section 2 for variable definitions and sources.

Our exploratory 2SLS estimations shown in Table OA2 confirm these results particularly for discoveries.

Taking logs would drop the many zeros, while the inverse hyperbolic sine (or arcsinh(y), equal to ln(y + √(y^2 + 1))) transformation is defined at zero and approximates the natural logarithm of that variable. See Bellemare and Wichman (2020).


Our exploratory 2SLS estimations shown in Table OA2 confirm these results particularly for discoveries.

### 3.1. Results

Fig. 4 shows the evolution of total annual discoveries (first column of graphs) and drilling (second column of graphs) by ownership regime. Countries with Foreign ownership appear to explore and discover the most. The number of discoveries under Partnership regimes increases markedly towards the end of the period, along with the frequency of that regime type (as per Fig. 1), though there is comparatively less drilling activity. With the exception of the 1970s, countries under Domestic ownership seem to explore and discover relatively less.

Table 1 shows the result of estimating equation (1) for the effect of ownership regimes on discoveries (columns 1 to 5) and wildcat drilling (columns 6 to 10). Progressively, we first lag all explanatory variables (2–5 and 7–10), then add measures of trade agreements (2 and 7) and openness which limits the sample to post-1960 (3 and 8), estimate a more parsimonious model for the same limited period (4 and 9), and drop countries where the first giant discoveries preceded the first ownership legislation (5 and 10). Overall, the results suggest that Foreign ownership is conducive to discoveries, and more so than Domestic or Partnership ownership. Switching to Foreign ownership is linked to up to 0.134 (or nearly a quarter of a s.d.) more discoveries in the next period than under Domestic ownership. Moreover, both Foreign and Partnership are related to significantly more exploration. Combined, this suggests that exploration effort under Foreign ownership has a higher chance of success.
Fig. 4. Discoveries and drilling by ownership regime. Note: Countries are included in our dataset from the year that they introduce the first petroleum-specific law, rule or regulation as an independent nation. The x-axis shows the timeline and the y-axis shows the count of oil&gas discoveries or wildcat drilling.

4. Conclusions

Can countries shape their own luck when it comes to discovering petroleum? We introduce a new dataset on petroleum ownership regimes for up to 68 countries and spanning over a century, from 1867 to 2008. We show major changes over time in the way that countries govern ownership in their petroleum sectors, with Domestic ownership replacing Foreign ownership since the 1930s, and
both losing ground to Partnerships from the 1960s. Using this data, we show that the laws governing the ownership of key natural resources such as oil and gas are related to exploration activity and the number of new petroleum discoveries made. Adopting a Foreign ownership regime results in more discoveries of oil and gas than under Domestic ownership. Switching to Partnership is linked to more exploration drilling, but this is less successful under Partnership regimes as it is not linked to significantly more discoveries.

We conclude that exploration for and discovery of petroleum is likely endogenous to industry-specific institutional change. This suggests that the literature that uses (the timing of) oil and gas discoveries as exogenous variation may be improved by controlling for the specific ownership regime under which those discoveries were made. Of course, these findings are limited to the exploration and discovery stage; we do not make any predictions regarding petroleum production or the contribution to the wider domestic economy. Our results are also limited to the petroleum sector; whether similar outcomes would apply in other sectors is left to future research.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jeem.2021.102506.

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