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**Working Paper**

## Pushing One's Luck: Petroleum Ownership and Discoveries

CESifo Working Paper, No. 9169

**Provided in Cooperation with:**

Ifo Institute – Leibniz Institute for Economic Research at the University of Munich

*Suggested Citation:* Brunnschweiler, Christa N.; Poelhekke, Steven (2021) : Pushing One's Luck: Petroleum Ownership and Discoveries, CESifo Working Paper, No. 9169, Center for Economic Studies and Ifo Institute (CESifo), Munich

This Version is available at:

<https://hdl.handle.net/10419/245350>

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## **Impressum:**

CESifo Working Papers

ISSN 2364-1428 (electronic version)

Publisher and distributor: Munich Society for the Promotion of Economic Research - CESifo GmbH

The international platform of Ludwigs-Maximilians University's Center for Economic Studies and the ifo Institute

Poschingerstr. 5, 81679 Munich, Germany

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Editor: Clemens Fuest

<https://www.cesifo.org/en/wp>

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- from the SSRN website: [www.SSRN.com](http://www.SSRN.com)
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# Pushing One's Luck: Petroleum Ownership and Discoveries

## 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.

JEL-Codes: E020, O430, Q300.

Keywords: discoveries, oil and gas, natural resources, institutions.

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May 14, 2021

We thank the editor and three anonymous referees, and Lassi Ahlvik, Alexandra Brausmann, James Fenske, Lutz Kilian, and participants at the Macroeconomic Stability and Diversification in Oil-based Economies workshop at KAPSARC in Riyadh, at the Statoil Oil Project workshop at BI Norwegian Business School, Oslo, the 24th annual EAERE conference in Manchester, the International Association for Energy Economics Conference 2020, and the 2020 conference on Environmental Economics: A Focus on Natural Resources for helpful comments. All remaining errors are our own.

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# 1 Introduction

Proven world oil reserves have increased from 680 billion barrels in 1980 to more than 1,700 billion barrels in 2019. Despite oil being an exhaustible resource in principle, we appear to be finding ever more of it.<sup>1</sup> 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.<sup>2</sup> 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; Van der Ploeg and Poelhekke, 2010; Cotet and Tsui, 2013).

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

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<sup>1</sup>See the BP Statistical Review of World Energy of June 2020, <https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html> Natural gas reserves have also soared from 71 trillion cubic metres to almost 200 trillion over the same period.

<sup>2</sup>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, Allcott and Keniston (2018).

(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.<sup>3</sup>

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.<sup>4</sup> The main criteria for inclusion in the dataset are

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<sup>3</sup>See Nolan and Thurber (2012) for similar arguments.

<sup>4</sup>A list of countries and years of coverage is shown in Online Appendix [OA1](#).

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.<sup>5</sup>

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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<sup>5</sup>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.

*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.<sup>6</sup> 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.<sup>7</sup> 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 3,874 country-year observations, with an average coverage of nearly 57 years per country.<sup>8</sup> Figure 1 shows the evolution of

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<sup>6</sup>Note that in practice, the distinction between *de jure* and *de facto* ownership rarely becomes salient. There are two exceptions in our sample: the United States and the United Kingdom, both of whose ownership regimes do not change over time. Foreign oil companies have been granted legal access to the respective oil sectors since the countries first enter our dataset, and we have therefore coded them as Foreign ownership regimes throughout the period of analysis. However, domestic companies have dominated the respective sectors in terms of ownership shares.

<sup>7</sup>See Ghandi and Lin (2014) for more details on the distinctions between common contracts between foreign and domestic oil companies.

<sup>8</sup>This ranges from a maximum of 141 years of ownership information for Canada, to a minimum of 6 years for East Timor.



the share of each ownership regime.<sup>9</sup> 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.<sup>10</sup> The most common regime in our dataset is Foreign (1,557 out of 3,874 country-years, or 41.8%), followed by Partnership (1,191 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 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. Figure 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 when it

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<sup>9</sup>A corresponding figure with the number of countries with a given ownership regime can be found in Online Appendix [OA6](#).

<sup>10</sup>Few countries change more than twice; Bolivia is the outlier with 6 regime switches from the time it enters the dataset in 1906.

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. Figure 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.<sup>11</sup> 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

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<sup>11</sup>We describe these periods in more detail in Online Appendix OA3.

the equation:

$$Y_{ct} = \beta_1 Partnership_{ct} + \beta_2 Foreign_{ct} + \beta_3 X_{ct} + \alpha_c + \delta_t + \epsilon_{ct}, \quad (1)$$

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.<sup>12</sup>

$\beta_1$  and  $\beta_2$  capture the effect of switching from the base regime of *Domestic* ownership to a *Partnership* or *Foreign* ownership, respectively.  $X$  is a vector of control variables,  $\alpha_c$  and  $\delta_t$  are country and year fixed effects, respectively, and  $\epsilon_{ct}$  denotes the error term. We cluster standard errors at the country level.

Our control variables include *openness* to trade, a dummy variable proxying for general change in economic institutions since 1960. We extend the dataset by Wacziarg and Welch (2008) and use the same criteria to include Middle Eastern countries and recent years up to 2008. We include a dummy for OPEC membership (own construction) and cumulative past discoveries in ultimate recoverable barrels of oil equivalent (based on Horn 2014). We also control for agreements on foreign investment – measured by the number of bilateral investment treaties (BITs) that were signed or came into force in the preceding year (based on World Bank ICSID data<sup>13</sup>) – that might affect the choice of ownership regime.

We cannot rule out that the choice of oil sector ownership regime is endogenous to discoveries made. In Online Appendix OA5, we therefore apply a two-stage least squares (2SLS) approach. We show test statistics for weak-instrument-robust inference that broadly support the OLS analysis, but these results should be considered exploratory.

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<sup>12</sup>Taking logs would drop the many zeros, while the inverse hyperbolic sine (or  $\operatorname{arcsinh}(y)$ , equal to  $\ln(y + \sqrt{y^2 + 1})$ ) transformation is defined at zero and approximates the natural logarithm of that variable. See Bellemare and Wichman (2020).

<sup>13</sup>International Centre for Settlement of Investment Disputes. Retrieved from <https://icsid.worldbank.org/resources/databases/bilateral-investment-treaties>

### 3.1 Results

Figure 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 Figure 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.<sup>14</sup>

## 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

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<sup>14</sup>Our exploratory 2SLS estimations shown in Table OA2 confirm these results particularly for discoveries.

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.

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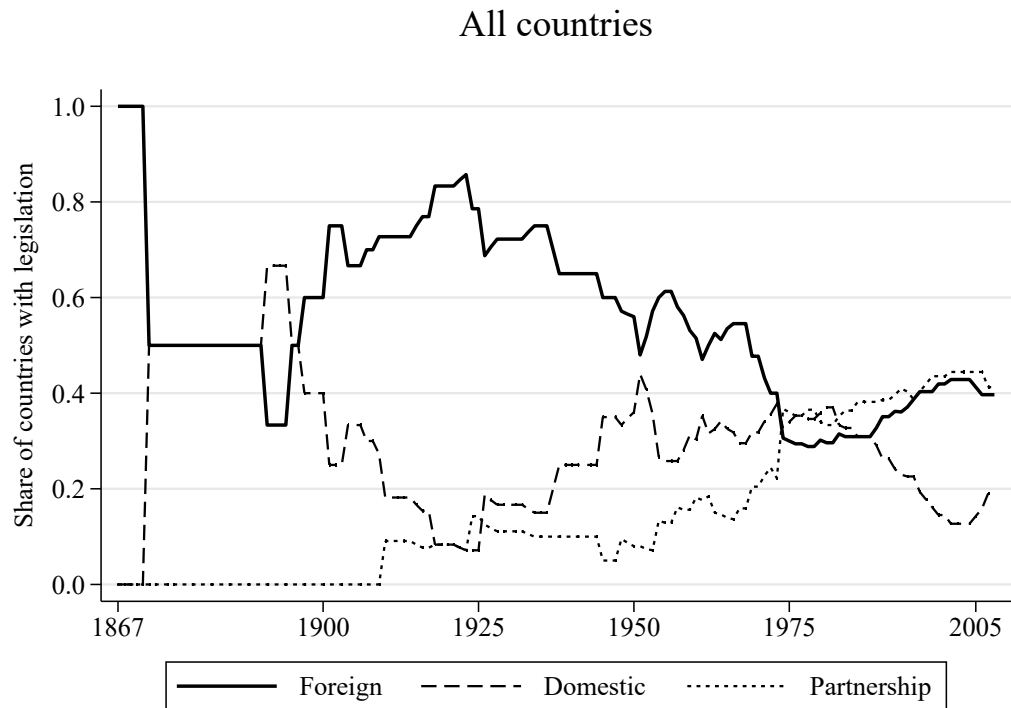
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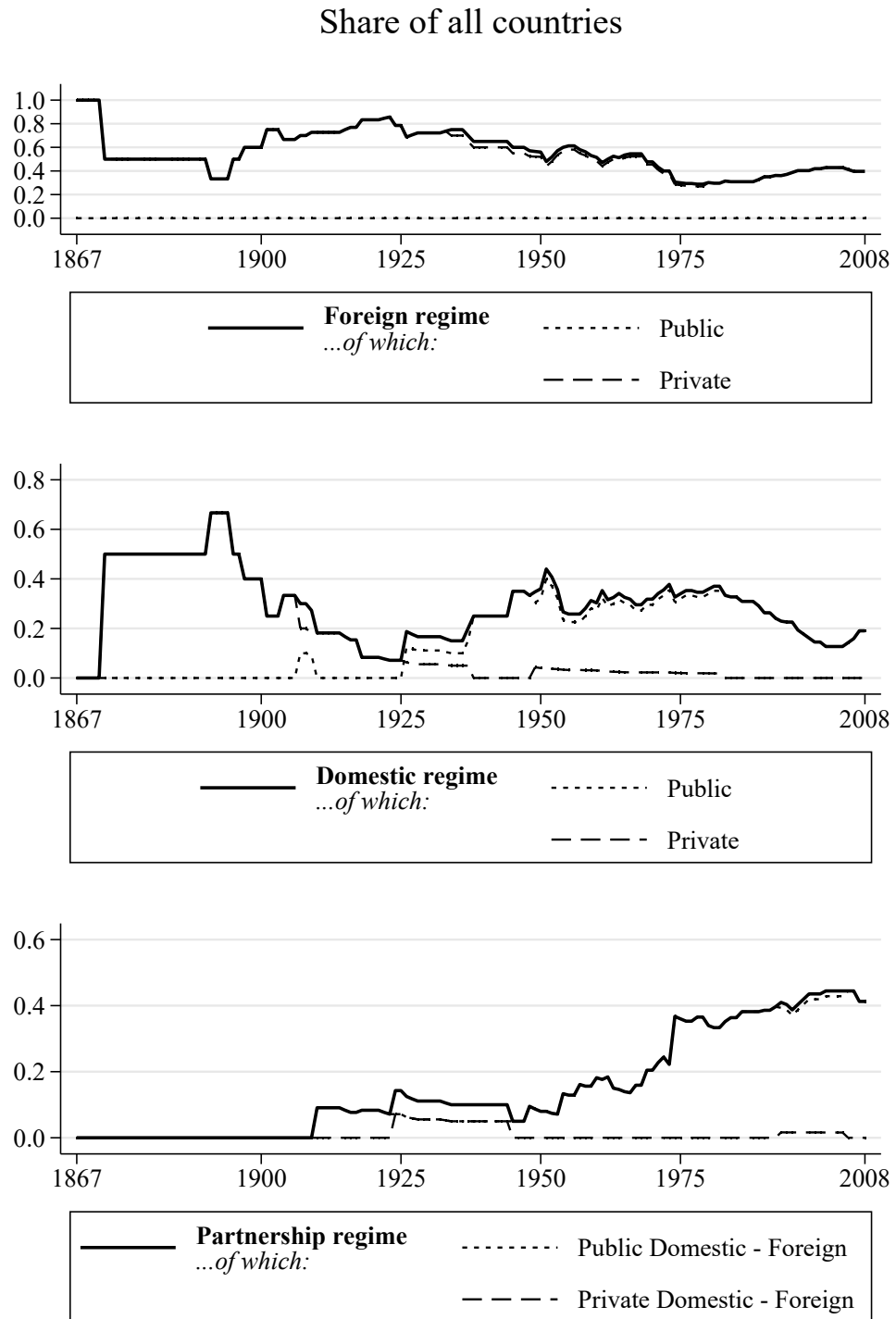
# Figures

Figure 1: Petroleum ownership regimes since 1867



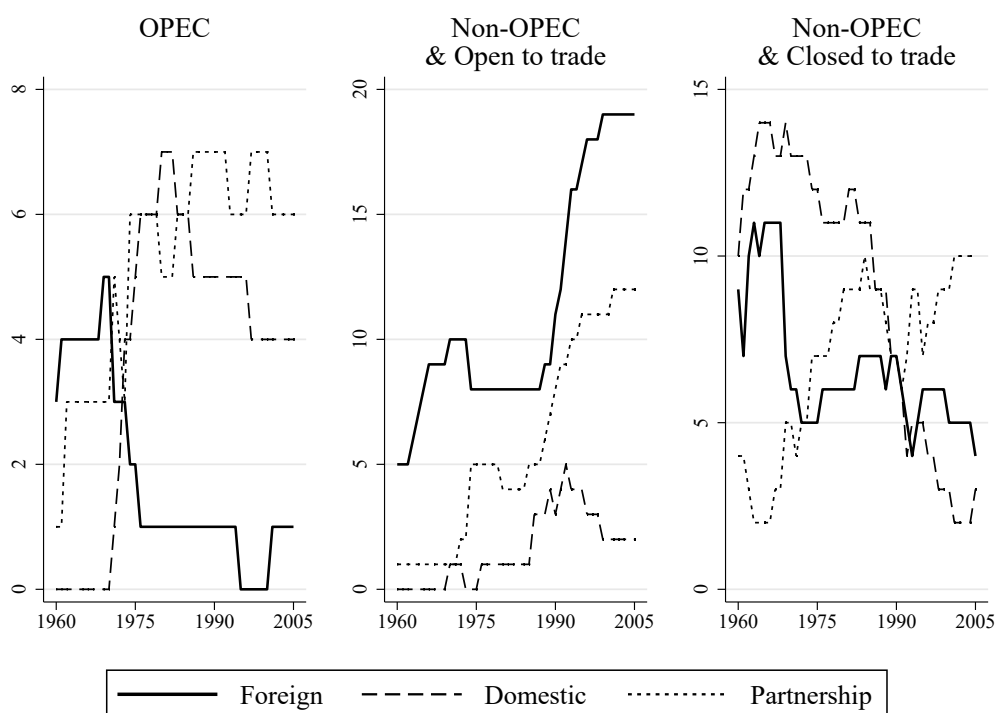
Note: Countries are included in our dataset from the year that they introduce the first petroleum-specific law, rule or regulation as an independent nation. The x-axis shows the timeline and the y-axis shows the share of countries in our sample with the respective petroleum ownership regime. For an analogous figure with the number of countries, see the Online Appendix.

Figure 2: Ownership regimes split by public-private



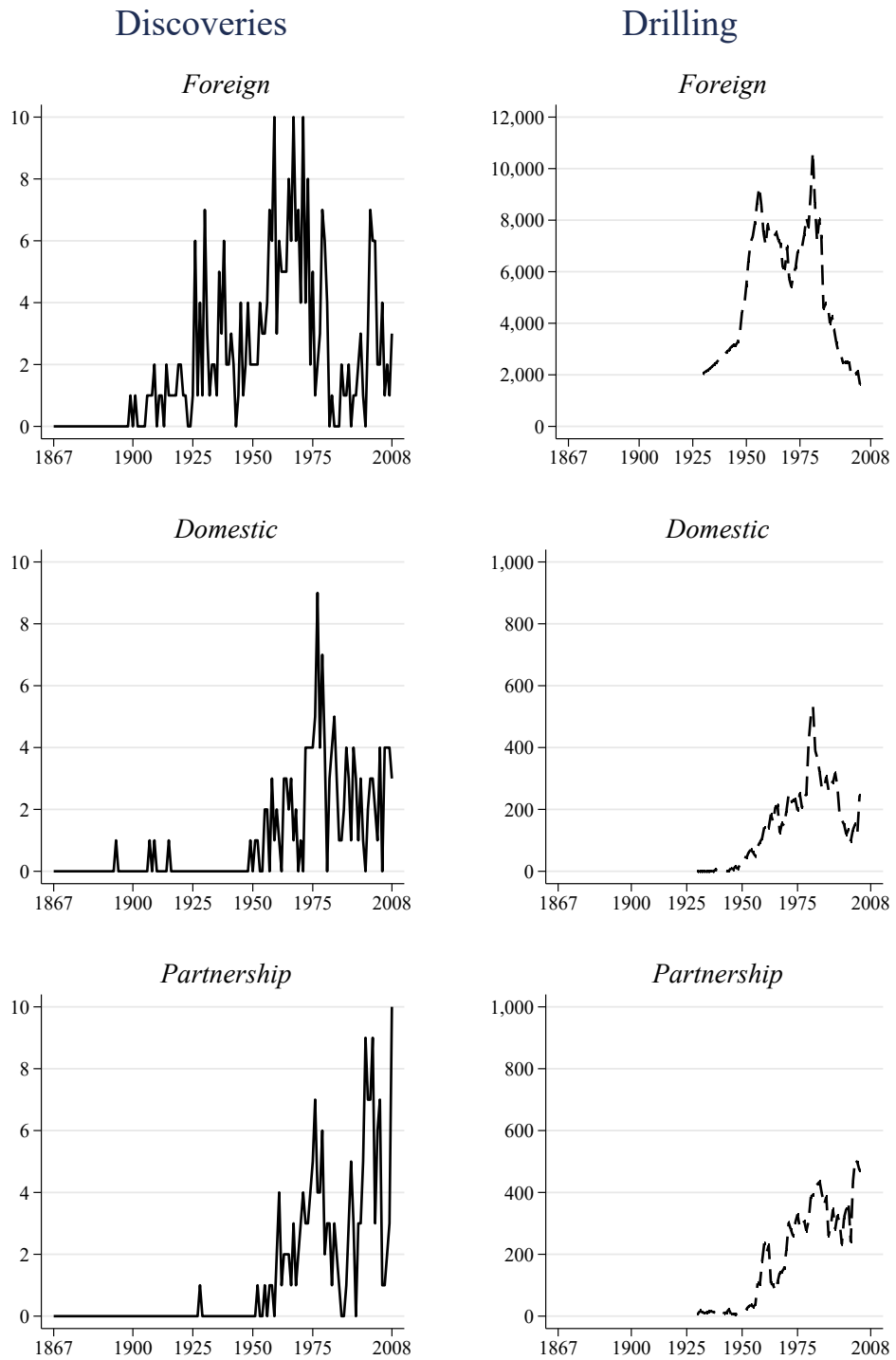
Note: Countries are included in our dataset from the year that they introduce the first petroleum-specific law, rule or regulation as an independent nation. The x-axis shows the timeline and the y-axis shows the share of countries in our sample with the respective petroleum ownership regime. Foreign, 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).

Figure 3: Petroleum ownership regimes since the inception of OPEC



Note: The x-axis shows the timeline and the y-axis shows the number of countries in our sample with the respective petroleum ownership regime. For an analogous figure with the share of countries, see the Online Appendix.

Figure 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.

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

Dependent variable →	Discoveries			Discoveries (t+1)			Wildcats			Wildcats t+1		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)		
Sample →				same as (3)	countries with first discovery after first ownership regime				same as (3)	countries with first discovery after first ownership regime		
Ownership regime												
Partnership	0.094 (0.072)	0.098 (0.068)	0.110 (0.086)	0.127 (0.092)	0.135 (0.098)	0.602*** (0.139)	0.579*** (0.139)	0.558*** (0.185)	0.503*** (0.182)	0.586*** (0.164)		
Foreign	0.105*** (0.047)	0.094** (0.048)	0.089 (0.059)	0.119* (0.064)	0.134*** (0.052)	0.635*** (0.183)	0.617*** (0.183)	0.599*** (0.227)	0.509*** (0.197)	0.711*** (0.196)		
BITs signed		-0.010 (0.007)					0.026 (0.018)					
BITs that came into force		0.002 (0.008)					-0.018 (0.026)					
Openness dummy			0.069 (0.054)					-0.210 (0.157)				
Cumul. oil eq. discovered (barrels, arcsinh bn), t-1	0.015** (0.006)	0.009 (0.006)	-0.007 (0.005)	-0.006 (0.005)	0.013** (0.006)	0.072*** (0.025)	0.061** (0.024)	0.027 (0.025)	0.027 (0.026)	0.083*** (0.026)		
OPEC dummy	0.035 (0.210)	0.037 (0.198)	-0.162 (0.146)	-0.161 (0.146)	0.060 (0.239)	-0.677 (0.412)	-0.742* (0.415)	-0.278 (0.218)	-0.288 (0.218)	-0.748 (0.483)		
Country and year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		
Clusters	63	63	62	62	36	56	56	56	56	30		
Observations	3,722	3,659	2,400	2,400	2,490	2,578	2,539	1,945	1,945	1,637		

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: \*\*\* p < 0.01, \*\* p < 0.05, \* p < 0.10. Table OAI contains summary statistics. See Section 2 for variable definitions and sources.

# Online Appendix

**Pushing One's Luck: Petroleum ownership and discoveries**

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May 14, 2021

## OA1 The petroleum ownership dataset: country list

The following countries are included in the petroleum ownership dataset, listed in alphabetical order with years of coverage in parentheses:

Albania (1928-2008), Algeria (1963-2008), Angola (1978-2008), Argentina (1907-2008), Australia (1901-2008), Azerbaijan (1993-2008), Bahrain (1974-2008), Bolivia (1916-2008), Brazil (1891-2008), Brunei (1984-2008), Cameroon (1964-2008), Canada (1867-2008), Chad (1962-2008), Chile (1926-2008), China (1950-2008), Colombia (1915-2008), Congo Brazzaville (1965-2008), Cuba (1954-2008), Denmark (1950-2008), East Timor (2005-2008), Ecuador (1909-2008), Egypt (1952-2008), Equatorial Guinea (1980-2008), France (1923-2008), Gabon (1962-2008), Germany (1990-2008), West Germany (153-1989), Guatemala (1949-2008), India (1953-2008), Indonesia (1960-2008), Iran (1901-2008), Iraq (1952-2008), Italy (1927-2008), Kazakhstan (1994-2008), Kuwait (1961-2008), Libya (1955-2008), Malaysia (1966-2008), Mexico (1901-2008), Netherlands (1965-2008), Nigeria (1962-2008), North Yemen (1974-1990), Norway (1963-2008), Oman (1974-2008), Pakistan (1948-2008), Papua New Guinea (1976-2008), Peru (1922-2008), Philippines (1949-2008), Qatar (1974-2008), Romania (1895-2008), Imperial Russia/Russian Federation (1872-1917; 1993-2008), Saudi Arabia (1933-2008), South Yemen (1976-1990), Sudan (1975-2008), Syria (1954-2008), Thailand (1972-2008), Trinidad and Tobago (1962-2008), Tunisia (1958-2008), Turkey (1926-2008), Turkmenistan (1992-2008), United Arab Emirates (1974-2008), Ukraine (2001-2008), United Kingdom (1934-2008), United States (1897-2008), USSR (1917-1991), Uzbekistan (1993-2008), Venezuela (1904-2008), Vietnam (1981-2008), Yemen (1990-2008).

## OA2 Sample classifications

To illustrate our classification of petroleum ownership regimes, we describe two examples: Saudi Arabia and Norway.

### Saudi Arabia

We code Saudi Arabia's ownership regime as: Foreign from 1933 up to and including 1973; Partnership during 1974-1979; Domestic during 1980-2008. The two switches thus took place in 1974 and in 1980.

The period under Foreign ownership from 1933-1973 covers the heyday of the concession system. Concessions were the norm during this period, and countries that adopted concessions are generally classified as Foreign ownership. The biggest early concession occurred in Saudi Arabia: in 1933, the independent Kingdom of Saudi Arabia granted the first concession to Standard Oil Company of California (Stancal), which founded the California Arabian Standard Oil Company (Casoc) to explore and exploit any petroleum found in the huge area under concession. Casoc was required to pay a fixed royalty in British shillings, with a gold guarantee. From 1933 until 1973, the ownership regime formally remains as majority Foreign, though there were important underlying, mainly political, shifts going on during this period, which we discuss in Section 2.1 of our article. The 1972 General Agreement between the Saudi government and what was now Aramco, the crude oil producer in Saudi Arabia, envisaged future changes to the concession system: a 25% government share of Aramco to be acquired in 1973 with annual increments of 5% participation, to culminate in 51% Saudi state ownership in 1983. The Saudi government would pay for the acquired shares, and get the right to crude oil shares equal to its participation.

However, in 1974 the situation changed rapidly. In June 1974, Saudi Arabia through its new national oil company Petromin acquired 60% of Aramco after more negotiations, which changes the ownership regime status in our dataset to Partnership, because the public share is above the threshold of 50%, but foreign oil companies retained substantial managerial and operational control. In 1976, the parties reached an agreement on full transfer of ownership and nationalization of management, but as yet specified no date.

The complete purchase of 100% of Aramco (soon-to-be Saudi Aramco) assets in fact happened in 1980: this is when the ownership regime changes to Domestic in our dataset,



and remains so until the end of our period of analysis.

The sources for this information were:

Office of International Energy Affairs (1975). *The Relationship of oil companies and foreign governments*, Washington D.C.: Federal Energy Administration.

Myers Jaffe, A. and J. Elass (2007). *Saudi Aramco: National flagship with global responsibilities*, Baker Institute, Rice University.

Philip, G. (1994). *The political economy of international oil*, Edinburgh: Edinburgh University Press.

## **Norway**

We code the ownership regime as: Foreign from 1963 up to and including 1973; Partnership during 1974-2008.

Like Saudi Arabia, Norway initially lacked the technology and experience to develop the (potential) offshore petroleum deposits itself, and started with a concession system in 1963. We therefore classify it as Foreign ownership in the early years. However, the Norwegian government was increasingly dissatisfied with the minimal control over exploration and production through taxes and lease distribution, and in 1972 founded the wholly state-owned oil company Statoil.

Minimum 50% government (i.e. Statoil) participation in oil exploration and production became mandatory in 1974, but foreign technology was retained through cooperative production arrangements, in which foreign companies still had a lot of operational and managerial control. From 1974 onwards, we therefore classify Norway as Partnership ownership until the end of our period of analysis. The partial privatization of Statoil in 2001 did not alter this classification, as the Norwegian state still owned 70% of Statoil, and the States Direct Financial Interest was devolved to state-owned Petoro.

Note that Norway's membership of the European Economic Association (EEA) in 1994 did not affect the classification of Norway. EEA legislation does not allow discrimination of domestic private companies versus foreign private companies, but Norway can still enforce a partnership with its state-owned company, as long as it treats all EEA companies in the same way within that partnership. Adaptation to EU legislation weakened the preferential treatment and government control of the state-owned oil company Statoil.

Yet, after an extensive analysis of the consequences of EEA entry on the Norwegian oil gas sector, Austvik (2009) concludes that through regulatory innovation, increased direct state participation and ownership dominance, the Norwegian government managed to defend national interests. This confirms the earlier findings of Claes (2003, p.54) “The state’s role as sovereign owner of the resources, the amount of state ownership in the Norwegian companies, and the government’s role as granter of concessions have not been undermined by the EU.” Furthermore, “the core of the Norwegian state-dominated model has been sustained. The company [Statoil] has a dominant ownership position on the Norwegian Continental Shelf, and it is still a state-owned enterprise. For the foreseeable future, it will be the key company in most licenses on the Norwegian shelf. Through Petoro the state will have a substantial direct participation in most fields on the shelf.” (ibid., p.58).

The sources for this information were:

Austvik, O.G. (2009). *The Norwegian State as Oil and Gas Entrepreneur: The Impact of the EEA Agreement and EU Gas Market Liberalization*, Saarbrücken: VDM Verlag.

Dam, K.W. (1976). *Oil Resources: Who gets what how?* Chicago: University of Chicago Press.

Claes, D.H. (2003). Globalization and state oil companies: The case of Statoil, *The Journal of Energy and Development* 29 (1).

Klapp, M.G. (1987). *The Sovereign Entrepreneur: Oil policies in advanced and less developed capitalist countries*, Ithaca, NY: Cornell University Press.

Norwegian government website [www.regjeringen.no](http://www.regjeringen.no)

Taverne, B. (1994). *An Introduction to the Regulation of the Petroleum Industry: Laws, Contracts and Conventions*, London: Graham Trotman Ltd.

Thurber, M., Istad, B. (2011). Norway’s evolving champion: Statoil and the politics of state enterprise. In D. Victor, D. Hults, M. Thurber (Eds.), *Oil and Governance: State-Owned Enterprises and the World Energy Supply* (pp. 599-654). Cambridge: Cambridge University Press.

## **OA3 Three major periods in the diffusion of ownership regimes**

### **1900-1960: Foreign ownership and nationalizations**

The era starts with the rise of Foreign ownership: this is the big era of concessions to (foreign) ‘majors’, the small number of large oil companies that dominated world oil production and marketing.<sup>15</sup> From the late 1930s, oil sector nationalizations in Bolivia in 1937 and Mexico in 1938 sent a shock-wave through the industry (Yergin, 2008) and marked the beginning of the first rise in Domestic ownership, which culminates in the 1951 expropriation of Anglo-Iranian in Iran. During the 1950s, Domestic ownership started to decline. This was likely due to a negative demonstration effect: Myers Jaffe (2007) argues that the failed nationalization in Iran between 1951-54 affected policy in neighboring Iraq, discouraging the Iraqi government from pursuing a similar nationalist approach in its oil sector (Kobrin, 1985). During the 1950s, foreign oil companies find new producing countries, primarily in Northern Africa (e.g., Algeria, Libya), where they are able to agree favorable terms (i.e. Foreign ownership), at least for a while.

### **1960 to 1980: The formation of OPEC and the widening search for new oil deposits**

The Organization of Petroleum Exporting Countries (OPEC) is formed in 1960 and marks a major change, though one that is slow to show its full effect. In Figure 3 and Figure OA2 we zoom in on the period since 1960 and split countries into OPEC members, and non-OPEC members that are open or relatively closed to trade.<sup>16</sup> The aggregate drop in the countries that allowed foreign ownership is clear among OPEC members. The increase in Domestic ownership loses momentum during the late 1960s, when Arab nationalism stalls. The literature suggests that foreign companies again adapted to the challenge and seek different forms of cooperation with countries, e.g. through technical service contracts under Domestic ownership regimes. Another significant development is the introduction of the production-sharing agreement (PSA) in 1967 in Indonesia. This type of contract becomes typical of Partnership regimes, which start to replace Foreign ownership. This

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<sup>15</sup>Concessions were grants for petroleum exploration and production in large areas for very long periods. The host country received a share of any oil revenues, mainly in the form of royalties based on fixed oil prices. See Dam (1976), Klapp (1987) and Philip (1994) for a history of oil contracts.

<sup>16</sup>Open versus closed to trade follows the institutional definition of Wacziarg and Welch (2008), which we update to include all OPEC member countries.

happens most clearly outside OPEC among countries that were open to trade. Instead, countries that were closed to trade tended to favor Domestic ownership regimes until the late 1980s. Over time, foreign companies turned to areas that became economically viable thanks to higher oil prices in the 1970s (Skeet, 1988), particularly in Asia and Africa, which leads to an increase in the absolute number of countries with Foreign ownership regimes. This period also sees the start of offshore North Sea oil production in Europe.

By the end of this period, Partnership surpasses the other two regimes as the number one choice for oil-producing countries. The oil sectors in 18 out of our 54 countries are under joint control by 1980, against 19 under Domestic ownership – though the latter now include the biggest oil-producer of all, Saudi Arabia.

### **1980-2008: The end of the last great concession and the beginning of a new era of resource sovereignty**

In 1980 Saudi Arabia nationalises Aramco (now Saudi Aramco), which is also when the incidence of Domestic ownership reaches its apex – and provokes an increase in Foreign ownership among countries that are open to trade. This is shown most clearly in the middle graph of Figure 3 and Figure OA2. At the end of the period, Domestic ownership picks up again due to a renewed nationalism in Latin America and – in different guise – in Russia. However, Partnership remains as the regime of choice for 26 out of the 63 oil producing countries in our dataset in 2008. During this period in particular, ‘foreign’ oil companies include an increasing number of state-owned firms, as several oil producers that emerged in the second wave begin exporting their expertise (Jones Luong and Weinthal, 2010).

## OA4 Descriptive statistics

Table OA1: Descriptive statistics, 1960-2005

All country-periods	N	mean	s.d.	min	max
Ownership regime					
Partnership	2,604	0.35	0.48	0.00	1.00
Foreign	2,604	0.39	0.49	0.00	1.00
Domestic	2,604	0.26	0.44	0.00	1.00
Discoveries of oil & gas	3,087	0.20	0.59	0.00	7.00
Wildcats (arcsinh)	1,989	2.95	1.83	0.00	9.88
Cumul. oil eq. discovered (barrels, arcsinh, bn)	3,087	5.76	4.75	0.00	13.51
BITs signed	3,087	0.88	1.90	0.00	17.00
BITs that came into force	3,087	0.66	1.59	0.00	15.00
Openness dummy	2,362	0.41	0.49	0.00	1.00
OPEC dummy	2,604	0.20	0.40	0.00	1.00
Partnership ownership, regional average	3,071	0.33	0.19	0.00	1.00
Ownership regime, regional average					
Partnership	3,066	0.31	0.18	0.00	1.00
Foreign	3,071	0.41	0.26	0.00	1.00
Ownership regime, OPEC by open-to-trade regional average					
Partnership	3,066	0.31	0.18	0.00	1.00
Foreign	3,066	0.35	0.23	0.00	1.00
Openness, inverse distance weighted	2,604	0.28	0.18	0.00	0.67
Ownership regime, egion by 1960 oil status average					
Partnership	2,472	0.37	0.31	0.00	1.00
Foreign	2,472	0.39	0.35	0.00	1.00
Ownership regime, regional average excluding neighbour w. field <10km EEZ					
Partnership	2,604	0.07	0.07	0.00	0.29
Foreign	2,604	0.07	0.19	0.00	1.00

Note: This table shows descriptive statistics for the main estimation period 1960-2005. See Section 2 in the main paper for variable definitions and sources.

## OA5 2SLS estimation

We adapt equation 1 from the main paper and endogenize the ownership regimes and construct four sets of instrumental variables.<sup>17</sup> Our second-stage estimation equation becomes:

$$Y_{c,t+1} = \theta_1 \widehat{Partnership}_{ct} + \theta_2 \widehat{Foreign}_{ct} + \theta_3 X_{ct} + \alpha_c + \delta_t + \mu_{ct} \quad (2)$$

Our IV approach is based on predicting changes in petroleum ownership regimes using institutional changes that happen in other countries. We take inspiration from Buera et al. (2011) on the spread of institutions, Acemoglu et al. (2019) on democratization, and, in our context, Arezki et al. (2019) on the spread of trade openness, who all argue that policymakers update their beliefs on ‘good’ policy based (at least in part) on the experience of neighboring countries, resulting in the slow spread of institutional change across regions.

The common underlying assumption is that institutional change in a reference group of countries does not affect the outcome variable of interest in a country  $c$  directly. In our setting, it is very unlikely that a change in oil sector ownership regime in one country changes the probability and number of oil discoveries in another country directly, through other channels than institutional change, *ceteris paribus*. Cust and Harding (2020) show that institutions (as captured by the Freedom House index of democratic institutions) explain differences in drilling even within short distances of the border, where geology is more similar. We consider this threat to our exclusion restriction and adjust one set of instruments to exclude neighboring countries that discovered oil and gas close to their borders, as captured by land and maritime Exclusive Economic Zone (EEZ) borders.

However, we believe that in the case of petroleum sector regulation, neighboring countries are not the main source of influence on policymakers, because the oil industry is globally integrated rather than regionally focused. Oil ownership regime changes have happened in waves and trends that transcend regional borders, as described in the his-

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<sup>17</sup>We experimented with specifying a non-linear negative binomial count model. Deb and Trivedi (2006) extended this estimator to allow for multinomial endogenous treatment such as our ownership dummies. However, the estimator does not allow us to instrument additional variables, such as openness, and is not designed for fixed effects. The large number of instruments, year and country fixed effects in our model lead to convergence issues, which are compounded by the reliance on simulation-based estimation in each iteration. We thus adopt a linear model.

torical overview above. One example is the fact that OPEC draws members from four continents.<sup>18</sup> Host country governments may look at what is happening in other oil countries when deciding the oil sector ownership regime, and these broad institutional characteristics play a greater role than geographical proximity (though we do not exclude regional diffusion of regimes). In practice, we believe that petroleum ownership regime choice is influenced mainly by changes in regimes in OPEC countries, and by the ownership regimes in countries that are integrated into world markets, as measured by the trade openness dummy. We exploit these factors, along with geographical distance, to construct four sets of exogenous instruments.

We thus specify a first stage regression for each of the endogenous regressors, where as before we split the categorical variable *Ownership* into three ownership regime dummies such that  $Z_{ct} = \{Partnership_{ct}, Foreign_{ct}, \}$  (with *Domestic* the excluded category of *Ownership*). We then instrument these with lags of their average value in *other* countries, where other countries are defined within the geographical *region*, those *open to trade*, and those that are members of *OPEC*:

$$\begin{aligned}
Z_{ct} = & \gamma_1 E(Partnership_{j,t-1} | Region_{cj} = 1) + \gamma_2 E(Foreign_{j,t-1} | Region_{cj} = 1) \\
& + \gamma_3 E(Partnership_{j,t-1} | Openness \times OPEC_{j,t-1}) + \gamma_4 E(Foreign_{j,t-1} | Openness \times OPEC_{j,t-1}) \\
& + \gamma_5 \widetilde{Openness}_{j,t-1} + \gamma_6 X_{ct} + \alpha_c + \delta_t + \nu_{ct}.
\end{aligned} \tag{3}$$

We define *Region* in three alternative ways: a country's *geographic region* as defined by the World Bank, such as Latin America and Middle East & North Africa; *Geographic region by 1960 oil&gas-status*, which splits the geographic region further into those countries with and without discoveries by 1960; and *Geographic region excluding neighbour with field < 10km EEZ*, which drops from the geographic region a country's neighbor if that neighbor has made discoveries within 10km of the land or maritime EEZ border. Geographic region follows from the literature on the diffusion of institutions across countries (Buera et al. 2011, Acemoglu et al. 2019, Arezki et al. 2019). The second definition of region takes into account that past success may be an important reference for countries,

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<sup>18</sup>We always control for OPEC membership but we do not attempt to model membership. While membership may be endogenous to cumulative past discoveries (which add to market share), we believe that this is not the case for future new discoveries nor for exploration intensity and thus treat membership as predetermined.

i.e. they are more likely to adopt a successful ownership regime from other countries in their region; the third definition mitigates concerns that past discoveries near borders have a direct effect on exploration and discoveries on the other side of the border.  $Openness \times OPEC$  defines four regions depending on whether countries are open to trade and/or members of OPEC and aims to capture these four distinct sets of policy choices as reference regions.<sup>19</sup>  $\widetilde{Openness}_{j,t-1}$  is the inverse distance weighted sum of  $Openness$  in all countries  $j$  other than country  $c$ , using the great circle distance between the capital cities. We expect broad institutional changes to diffuse across regions as in Buera et al. (2011), leading to a positive relationship between openness in nearby countries and the likelihood of allowing foreign involvement in the petroleum industry (either through majority foreign or partnership arrangements). Finally,  $X_{ct}$  includes control variables such as OPEC membership and cumulative past discoveries.

Two mechanisms influence the relationship between the regional instruments and the ownership regimes. First, the literature on institutional diffusion posits that policy follows (successful) example, which implies that, for example, an increase in the prevalence of Foreign ownership regimes in a reference group of countries increases the likelihood of having foreign ownership in country  $c$ , if Foreign ownership is perceived as successful policy. Similarly, nationalizations leading to Domestic ownership within OPEC may lead other OPEC members to follow suit. However, as Figure 1 showed, most countries start out with a majority foreign ownership regime. In fact, 53 out of 63 countries adopt Foreign ownership as their first petroleum ownership regime, but many of these switch to another regime later on. There are three regimes to choose from such that it is less clear that countries necessarily follow and adopt *similar* ownership regimes. Over the several waves of nationalizations described above, 24 countries switched from an initial Foreign ownership regime to Domestic ownership or Partnership (this includes countries with multiple regime reversals). In equation 3, a reduction in Partnership ownership in the reference region, while keeping the prevalence of Foreign constant, implies a switch from Partnership to Domestic ownership in the region. The second mechanism is that this may then *increase* Partnership domestically if international oil companies negotiate similar contracts in other countries in the region after losing access to reserves in the face

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<sup>19</sup>Ideally, we would separate these into OPEC members and countries open to trade separately, but jackknifed regional means cannot be identified joint with country and year fixed effects when there are only two regions.



of nationalizations. Petroleum companies can use their access to capital, technology and skilled labor as bargaining chips in order to gain attractive investment conditions in new host countries, which in turn facilitate this to attract investment.<sup>20</sup> Both mechanisms may be at play simultaneously, which can yield positive or negative signs of coefficients  $\gamma_1 - \gamma_4$  in equation 3.

An example is given by events after the inception of OPEC. The oil embargo of 16 October 1973 initiated OPEC's tighter control over its own level of oil production, after years or creeping nationalization in the form of higher royalty and tax payments, and increasing rates of participation in concession equity negotiated between individual companies and countries. More and more host governments ceased granting new concessions, instead offering joint ventures (starting with Egypt and Iran in 1957) or production sharing agreements (PSAs), starting with Indonesia in 1967 (Terzian, 1985). Increased producing-country government participation was (sometimes grudgingly) accepted by companies because the alternative was feared to be full nationalization (Skeet, 1988),<sup>21</sup> and there was no immediate access to alternative sources of oil (Wilkins, 1976). By 1972, all concessionary companies operating in the Gulf region had already accepted a 20% government participation rate. The Iraqi nationalization of IPC in 1972 was soon followed by Saudi Arabia's phased nationalization of Aramco, which began in 1974 and was completed in 1980, and later by other OPEC members including Iran (Skeet 1988).<sup>22</sup> By 1982, the average government stake in the Gulf oil countries had reached 51% (Terzian, 1985). One of the first victims of this process was exploration in the countries where nationalization happened. For example, before the revolution in Libya in 1969, 55 drilling rigs were active, while only 7 were active by 1972. The reduction was

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<sup>20</sup>The reason for this is twofold: first, the sector has historically been dominated by vertically integrated international oil companies that explore for, extract, trade, process and market their oil products. With such a business model, access to own crude oil supplies becomes vital to ensure timely delivery to refineries – which are often tailored to the specific sulphur content and viscosity of a company's crude oil – and final outlets (Wilkins, 1976). Any upstream disruption can thus become a major threat to the company (Skeet, 1988). To ensure a secure and diverse supply of crude oil and take advantage of changing oil prices, companies constantly seek new investments (Wilkins, 1976; Skeet, 1988). Conversely, countries seeking investment in petroleum exploration and extraction are mindful of the companies' downstream industry's ability to market and sell crude, and therefore have an incentive to offer favorable terms. The second reason is that losing control over petroleum reserves is also a painful blow to a company's reserve replacement ratio and its balance sheet, as lost reserves can no longer be booked.

<sup>21</sup>Outright nationalizations were still a rare occurrence in the early 1970s, because the producing countries themselves depended on the international oil companies' distribution channels (Yergin, 2008).

<sup>22</sup>Partial or full nationalizations were not confined within OPEC: other oil producing countries also obtained a larger stake in their oil sectors, including Argentina in 1907, between 1949-1956, again between 1958-1993, and from 2012; Mexico from 1938; Egypt in 1956; Syria in 1963; Algeria between 1969-1971.

the result of Colonel Qaddafi demanding a higher price for Libyan oil under threat of production cuts and outright withdrawal of concessions from the oil companies (Terzian, 1985). Exploration efforts instead shifted to ‘non-vulnerable’ regions outside the control of OPEC, including the North Sea (Wilkins, 1976), but also China and Soviet Siberia, and high-cost unconventional sources such as tar sands and shales (Smart 1976).<sup>23</sup>

Identification relies on the exogeneity of our instruments, i.e. that they only affect our dependent variables through their influence on country  $i$ ’s petroleum ownership structure. We believe this to be the case. Petroleum exploration requires very high capital investments. An oil company is unlikely to commit to an investment of such magnitude unless its control rights in that particular country are secured and, once committed, will not readily pull out based on concerns on what is happening in other countries, especially if they are not direct neighbors.<sup>24</sup>

The results of our 2SLS estimations are reported in Table OA2, along with Sanderson and Windmeijer (2016) first stage conditional F-tests for underidentification of individual endogenous regressors. We also report Hansen overidentification test p-values for excluded instrument redundancy, and Anderson-Rubin Wald Chi2 statistics for weak-instrument robust inference for testing the joint significance of the endogenous regressors (Andrews et al., 2007). Full first stages of columns 1 to 3 of Table OA2 are reported in Table OA3.<sup>25</sup>

## Results

The test statistics show that the first stage instruments are relatively weak by common standards as the F-test statistics are below 10. This holds for three different sets of instruments as we progressively change the reference region for the diffusion of institutions. This implies that the instruments cannot well distinguish between the individual ownership

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<sup>23</sup>The process is not unique to the petroleum industry: Smart (1976) describes similar mechanisms for the global spread of rubber and coffee production.

<sup>24</sup>It is in theory possible that a country A is already attractive for foreign investment, such that an oil company shifts exploration to that country when another country B changes its institutions and becomes less attractive. This would lead to a direct effect of regional institutional change in B on exploration in A. However, this assumes that the same oil company is active in both countries *and* that it was thus far underinvesting in country A. It is not clear why that would be the case or why that would be a regular feature that confounds our results. Also, this mechanism would not work for country A that was not already open to investment. Another direct effect may be driven by out-migration of oil workers after nationalizations, as happened in Venezuela after 2007. However, workers are only one factor of production, while oil exploration and extraction is very capital and technology intensive such that (foreign) oil companies also need to be willing to invest, which we argue requires industry-specific, investment-friendly institutions.

<sup>25</sup>First stages for columns 4 to 6 of Table OA2 are very similar and omitted for brevity.

regimes. However, weak-instrument robust inference can be made nevertheless according to the Anderson-Rubin Wald Chi2 statistics that cannot reject *joint* significance of the ownership regimes in columns 2 to 6. In other words, we find evidence that the Domestic ownership regime (the excluded baseline regime) performs significantly worse compared to both the Foreign and the Partnership regimes in terms of discoveries made. The tests also suggest joint significance for wildcat drilling, but in the smaller drilling sample the instruments are also weaker and there is still some correlation between the error term and the instruments. We conclude that a switch to Domestic ownership is followed by a drop in discoveries; adopting Foreign ownership instead yields around a standard deviation more discoveries in the next period.

Looking at the instruments in Table OA3, we find that the simple geographic region performs best as a reference region, together with the OPEC by open-to-trade regions. Within geographic regions, we see some evidence for inverse institutional diffusion of Partnership regimes as suggested by the negotiation mechanism, where Foreign oil companies are forced to explore for oil in other countries after losing access to reserves when countries switch from Partnership to Domestic ownership. For Foreign ownership, this relation is too noisy to draw conclusions. Conversely, within the four regions defined by OPEC and open-to-trade status, there is more evidence of positive diffusion for the adoption (or abandonment) of Foreign ownership.

In sum, these exploratory IV estimations support the results from the OLS estimations shown in the main text that suggest a significant relationship between petroleum sector ownership regimes and exploration and discoveries. However, further research is needed to determine the robustness of this finding.

Table OA2: Discoveries, drilling, and petroleum ownership: 2SLS estimations

Dependent variable →	Discoveries (t+1)			Wildcats t+1		
	(1)	(2)	(3)	(4)	(5)	(6)
Ownership regime						
Partnership	0.271** (0.137)	0.136 (0.278)	0.236 (0.195)	0.927* (0.488)	0.149 (1.274)	0.487 (0.610)
Foreign	0.446** (0.204)	0.636** (0.298)	0.473** (0.224)	0.465 (0.911)	0.572 (1.387)	0.736 (0.990)
Cumul. oil eq. discovered (barrels, arcsinh, bn), t-1	-0.003 (0.005)	-0.004 (0.007)	-0.004 (0.005)	0.020 (0.025)	0.027 (0.029)	0.018 (0.028)
OPEC dummy	0.037 (0.098)	0.100 (0.116)	0.049 (0.107)	-0.322 (0.414)	-0.110 (0.623)	-0.163 (0.390)
Clusters	63	61	63	56	55	56
Observations	2,461	2,333	2,461	1,878	1,835	1,878
<i>Instrument strength:</i>						
SW F-test (Partnership)	3.539	1.499	2.853	1.958	0.620	1.858
SW F-test (Foreign)	2.427	1.258	1.853	1.788	0.555	1.314
<i>Weak IV robust inference:</i>						
Anderson-Rubin Wald Chi2	8.542	15.40***	13.08**	12.41**	16.42***	14.56**
p-value	0.129	0.009	0.023	0.030	0.006	0.012
Hansen J-stat p-value	0.807	0.204	0.442	0.073	0.076	0.043

Note: This table shows second-stage results of 2SLS panel regressions of the effect of petroleum ownership regimes on discoveries and drilling activity. Columns 1 and 4 instruments: Geographic regional mean of ownership regime, OPEC by open-to-trade regional mean of ownership regime, and inverse distance weighted openness to trade. First stages for column 1 are provided in columns 1a and 1b of Table OA3. Columns 2 and 5 instruments: Geographic-region by 1960 oil&gas status mean of ownership regime, OPEC by open-to-trade regional mean of ownership regime, and inverse distance weighted openness to trade. First stages for column 2 are provided in columns 2a and 2b of Table OA3. Columns 3 and 6 instruments: Geographic region excluding neighbours with fields within 10km of the Exclusive Economic Zone mean of ownership regime, OPEC by open-to-trade regional mean of ownership regime, and inverse distance weighted openness to trade. First stages for column 3 are provided in columns 3a and 3b of Table OA3. 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) in parentheses: \*\*\* p < 0.01, \*\* p < 0.05, \* p < 0.10. The *SW F-test* is the Sanderson and Windmeijer (2016) first stage conditional F-tests for weak identification of individual endogenous regressors. The *Anderson-Rubin Wald Chi2* test statistics provides weak-instrument robust inference for testing the joint significance of the endogenous regressors (H0: both are equal to zero). Table OA1 contains summary statistics.

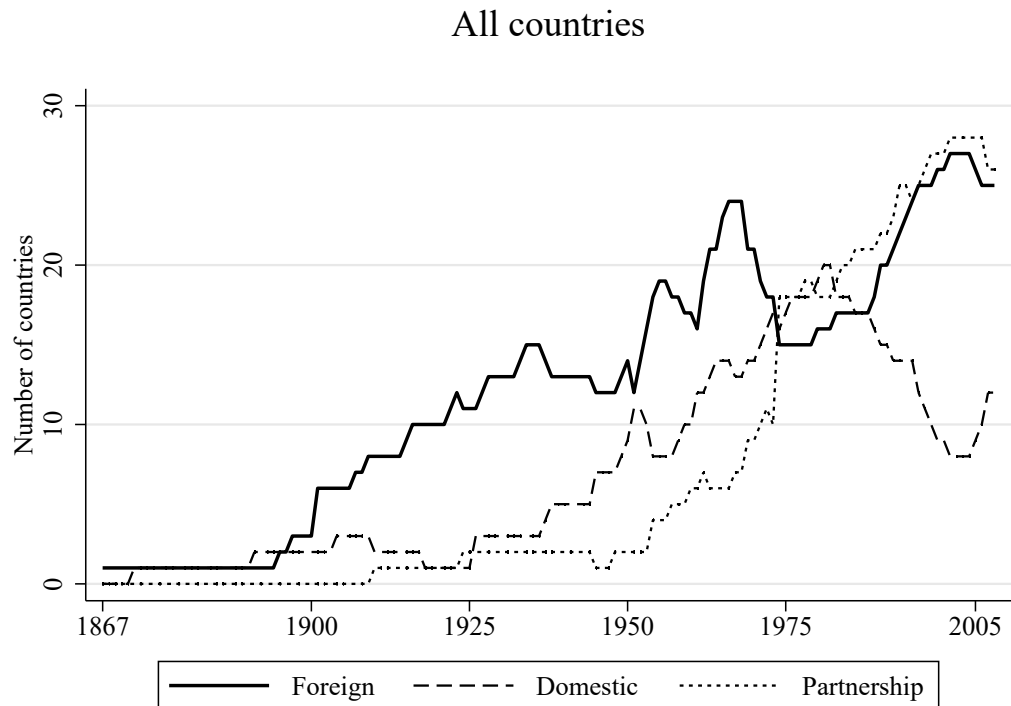
Table OA3: Predicting the adoption of petroleum ownership regimes: First-stage results

Dependent variable →	Partnership	Foreign	Partnership	Foreign	Partnership	Foreign
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
Geographic regional						
mean of Partnership (t-1)	-0.963**	0.276				
	(0.420)	(0.244)				
mean of Foreign (t-1)	-0.265	0.093				
	(0.359)	(0.232)				
OPEC by open-to-trade						
mean of Partnership (t-1)	-0.125	0.358***	-0.036	0.334***	-0.112	0.348**
	(0.221)	(0.134)	(0.236)	(0.128)	(0.206)	(0.137)
mean of Foreign (t-1)	0.288	0.322*	0.347*	0.265	0.261	0.322*
	(0.181)	(0.179)	(0.192)	(0.178)	(0.175)	(0.177)
Openness, inv. dist. weighted (t-1)	-0.148	1.097*	-0.180	0.984	0.103	1.063*
	(0.618)	(0.620)	(0.701)	(0.631)	(0.688)	(0.607)
Geographic-region by 1960-oil&gas-status						
mean of Partnership (t-1)			-0.132	0.023		
			(0.110)	(0.115)		
mean of Foreign (t-1)			0.036	0.070		
			(0.183)	(0.119)		
Geographic region excluding neighbour w. field <10km EEZ						
mean of Partnership (t-1)					-1.997***	0.247
					(0.696)	(0.608)
mean of Foreign (t-1)					-0.131	-0.119
					(0.929)	(0.781)
Cumul. oil eq. discovered (barrels, arcsinh, bn in (t-1))	-0.007	-0.001	-0.007	0.001	-0.010	-0.001
	(0.010)	(0.009)	(0.011)	(0.010)	(0.010)	(0.009)
OPEC dummy	0.229**	-0.267	0.210*	-0.260	0.192*	-0.260
	(0.106)	(0.168)	(0.122)	(0.167)	(0.105)	(0.171)
Country and year FE	Yes	Yes	Yes	Yes	Yes	Yes
Clusters	63	63	61	61	63	63
Observations	2,461	2,461	2,333	2,333	2,461	2,461
1st stage SW F-test	3.539	2.427	1.499	1.258	2.853	1.853

Note: This table shows first-stage regressions that aim to capture the spread of petroleum ownership regimes. They correspond to the first three second-stage regressions in Table OA2. The base petroleum ownership regime is Domestic ownership. Robust standard errors (clustered by country) in parentheses: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.10$ . Table OA1 contains summary statistics. See Section 2 of the main text for variable definitions and sources.

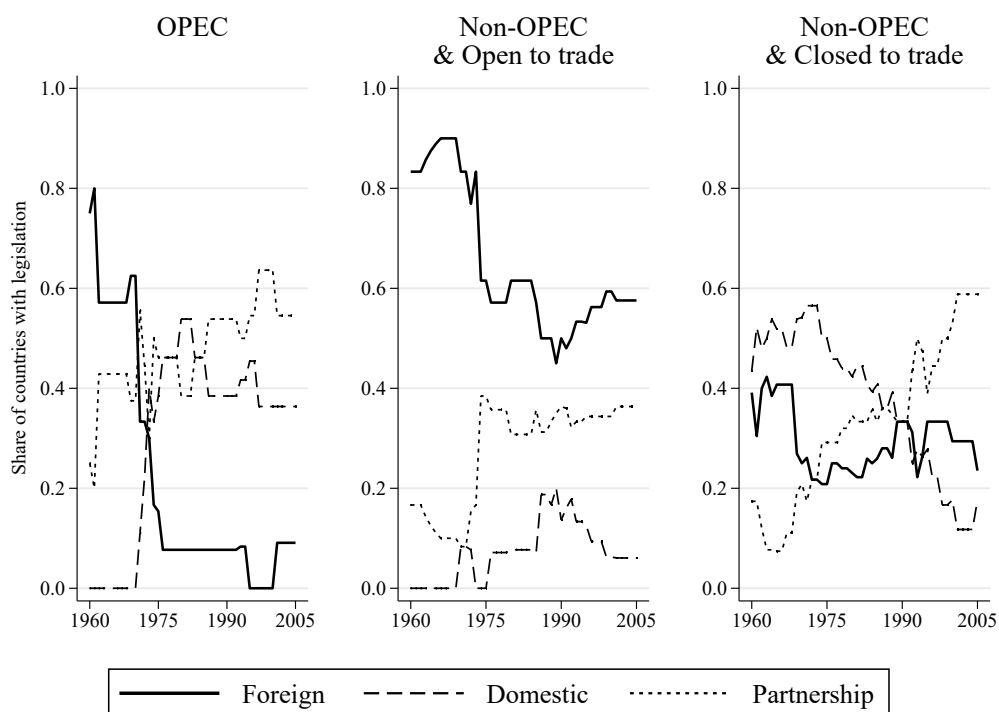
## OA6 Additional figures

Figure OA1: 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 number of countries in our sample with the respective petroleum ownership regime.

Figure OA2: Petroleum ownership regimes since the inception of OPEC



Note: The x-axis shows the timeline and the y-axis shows the share of countries in our sample with the respective petroleum ownership regime.

## OA7 References for Online Appendix

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