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Pushing One's Luck: Petroleum ownership and discoveries*

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Abstract

Does institutional change in the petroleum sector lead to more oil and gas exploration and discoveries? Foreign ownership and investment in the sector has traditionally been unrestricted. We document that this is no longer the case; foreign-domestic partnerships are the norm today. Tracking changes in legislation between 1867 and 2008 for a panel of countries, we show that switching to foreign ownership results in more drilling and more discoveries of petroleum than domestic ownership. Switching to partnership yields even more drilling, but yields fewer discoveries. Discoveries, and the intensity and quality of exploration drilling, are endogenous to industry-specific institutional change.

JEL codes: E02, O43, Q30

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1 Introduction

Proven World oil reserves have increased from 680 billion barrels in 1980 to 1,700 billion barrels in 2017.¹ Despite oil being an exhaustible resource in principle, we appear to be finding ever more of it.² 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.³ 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). An alternative view instead proposes that sound institutions and a good investment climate – including political stability, secure property rights, and strong market orientation – determine resource discoveries and endowments (see e.g., Bohn and Deacon, 2000; Arezki et al., 2019; Cust and Harding, forthcoming). Moreover, ‘good’ institutions are found to be important for overall economic development, further complicating the empirical relationships.⁴

In this paper, we focus on the institutions that govern the natural resource sector and use a new dataset on petroleum ownership regimes that spans over a century of data for up to 68 oil-producing countries, and uncover its impact on 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 influences oil and gas discoveries is an important issue. Our dataset captures who

¹See the BP Statistical Review of World Energy of June 2018, <https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html>

²Natural gas reserves have also soared from 72 trillion cubic metres to almost 200 over the same period. From a climate change perspective, we may paradoxically even need to find more, as an intermediate stage to replace CO₂-intensive coal before renewable sources become available in sufficient quantities (Van der Ploeg and Withagen, 2012).

³New 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).

⁴The empirical literature on institutions and economic performance builds on the seminal contribution by North (1990), and includes for example Hall and Jones (1999), and Acemoglu et al. (2002). It is less clear what the relative importance is of specific institutions. Some authors emphasize democracy (Acemoglu et al., 2019), while others corruption (Ades and Di Tella, 1999), or an unweighed average of rule of law, bureaucratic quality, corruption, risk of expropriation, and government repudiation of contracts (Mehlum et al., 2006). We focus on specific institutions governing one sector of the economy.

has control rights over petroleum exploration and production decisions, distinguishing between Domestic, Foreign, and mixed, or ‘Partnership’ regimes.⁵ While host countries have long been recognized as the legal owners of their subsoil wealth⁶, 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.

We describe the evolution of ownership regimes over time, and make use of the historical sequence of events in our empirical design. In a first step, we employ ordinary least squares (OLS) estimations to show a strong positive relationship between switching to Foreign and Partnership ownership regimes (where Domestic ownership is our base regime) and various measures of petroleum exploration activity and discoveries. Conversely, the implication is that nationalizations (which are a subset of switches to Domestic ownership) are followed by a drop in exploration and discoveries.⁷ In a second step, we propose a series of instruments based on oil sector institutional change in a reference group of other countries including those open to trade, OPEC member countries, and countries in the same geographical region. We empirically model the spread of different ownership regimes as a function of (political) events in these reference countries, in the spirit of the most recent literature on the gradual diffusion of institutions and democracy described by Buera et al. (2011) and Acemoglu et al. (2019), respectively.

In fixed-effects two-stage least squares (2SLS) estimations, we confirm that switching to substantial foreign involvement in the petroleum sector leads to more exploration activity and more discoveries of new petroleum deposits with respect to Domestic owner-

⁵The conventional distinction has been between public and private ownership (e.g., Bohn and Deacon 2000). However, in recent decades the petroleum industry has seen the rise of a number of internationally competitive, national oil companies, making a shift of the focus towards domestic versus foreign ownership appropriate. In practice, Domestic ownership almost always equates to Public ownership. There have been a few exceptions with private domestic ownership for some years: Guatemala until 1983; Brazil until 1938; (Imperial) Russia until 1918; and Venezuela until 1907.

⁶The United Nations General Assembly resolution 1803 (XVII) of 14 December, 1962 (on “Permanent sovereignty over natural resources”) grants “The right of peoples and nations to permanent sovereignty over their natural wealth and resources”.

⁷A related literature models cyclical changes in taxation of the resource sector (Jaakkola et al., 2019), while we focus on more discrete changes in who controls exploration and extraction. The prevalence of a mixture of ownership restrictions, corporate taxes, oil revenue taxes, bonuses, royalty rates, and production sharing arrangements that frequently change, make it difficult to precisely track taxation for our broad group of countries, although Stroebel and Van Benthem (2013) make progress on this topic for 38 non-OPEC countries. Such arrangements are not typically public knowledge, see also the Extractive Industries Transparency Initiative, <https://eiti.org/>.

ship. In particular, adopting majority Foreign ownership brings about more discoveries. Adopting a Partnership regime, on the other hand, results in much more drilling, but not more discoveries than under Domestic ownership. Moreover, we show that the effects are persistent within the first five years after a regime switch, and that the results are robust to controlling for other (national) institutional factors; using different proxies for petroleum discoveries and exploration effort (including cost); and altering our estimation specifications. 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.⁸

Our contribution is to uncover the oil sector-specific institutions that drive exploration and discovery, and show that these have more explanatory power than changing national-level institutions. We thereby contribute to our understanding of the effects of specific institutions that may be adopted by countries, although we do not claim that the institutions that raise the probability of finding natural resources also lead to long-term economic development.⁹ We also extend the recent literature on the endogeneity of natural resource endowments. For example, Cust and Harding (forthcoming) focus on general institutional quality and rely on differences in petroleum discoveries across national borders for causal identification in a regression discontinuity design. Looking at wells drilled close to national borders, they find that exploration takes place more frequently in the country with stronger institutions. Arezki et al. (2019) adopt a similar 2SLS approach to ours, but focus on the role of market orientation, measured by overall trade openness. They find that exploration and discovery of petroleum and other minerals are more likely in more market-oriented countries. In the present paper, we show that trade openness does not affect petroleum discoveries or drilling activity when we include our ownership measures. This suggests that the industry-specific institutions, rather than the more general institutional framework, play the biggest role in influencing oil and gas exploration and discoveries.

We also add to the literature that uses discoveries as exogenous variation for a range of outcomes. These include Harding et al. (2016) on real exchange rate appreciation;

⁸See Nolan and Thurber (2012) for arguments along these lines.

⁹See Brunnschweiler and Valente (2013) for the link between petroleum ownership regimes and income levels. A related literature explores the effect of general institutional quality on capital flows, e.g., Alfaro et al. (2008).

Brock (2015) on the positive effects of discoveries on GDP per capita; Arezki et al. (2017) on identifying macroeconomic news shocks; Perez-Sebastian and Raveh (2016) on fiscal decentralization; and Lei and Michaels (2014) on conflict. Our results suggest that the literature that uses (the timing of) oil and gas discoveries as exogenous variation should control for the specific ownership regime under which those discoveries were made. More promising is therefore the use of geographic variation in exploration and discoveries on outcomes within a country (such as in Caselli and Michaels, 2013, and Cavalcanti et al., 2019), because it is less likely that institutions vary systematically at the local level as well.

Our findings on the benefits of allowing foreign ownership in the oil sector also relate to the literature on the benefits of foreign direct investment more broadly, which have documented increased productivity of foreign affiliates, such as in Arnold and Javorcik (2009) for Indonesia and Guadalupe et al. (2012) for Spain, and that these benefits rely on the continued presence of foreign parents (Javorcik and Poelhekke, 2017). The superior performance of foreign affiliates is closely related to the fact that only the most productive firms are able to incur the fixed cost of undertaking foreign investment (see Helpman et al. 2004). In our context, multinational oil firms are thus likely to be more productive than purely domestic oil firms.¹⁰

The rest of the paper is organized as follows: Section 2 presents the petroleum data, including the novel dataset on oil and gas sector institutions, and traces the evolution of petroleum ownership structures since the beginnings of the industry; Section 3 describes the empirical approach; Section 4 discusses the results and robustness tests; and Section 5 concludes.

2 The petroleum data

2.1 Discoveries and exploration

Our main information on oil and gas discoveries stems from Horn (2014), who times the earliest discovery in 1868. This dataset records the discoveries of giant oil (including condensate) and gas fields, defined as a discovery of an oil and/or gas field that contains

¹⁰Others stress a positive spillovers channel from openness to foreign competition, such as in import-competing sectors, causing growth of domestic firms (Pavcnik, 2002).

at least 500 million barrels of ultimately recoverable oil equivalent (i.e., the amount that is technically recoverable given existing technology). We also use an alternative dataset on total barrels of oil equivalent discovered, which uses only 5,000 barrels as a minimum cut off, and is collected by the Association for the Study of Peak Oil (ASPO) and taken from the dataset of Cotet and Tsui (2013). We prefer the Horn (2014) database, because it is readily available online, more regularly maintained, and because of the large cut-off size less prone to measurement error.

In addition to discoveries data, we use three different measures of oil exploration efforts. The first gives the number of exploratory boreholes – known as ‘wildcats’ in the oil industry. This data was collected by the Association for the Study of Peak Oil (ASPO) and is taken from the dataset of Cotet and Tsui (2013); it is available for the period between 1930-2003. The second and third measures are both based on proprietary data compiled by Rystad Energy, a petroleum industry consulting and data company. Rystad Energy offers data on the number of wells drilled since the 19th century (with gaps) until 2017, and the total exploration cost per year and country, in nominal USD, which is split into expensed and capitalized costs. The former includes the initial exploration contract fees or ‘signature bonuses’, as well as the actual costs for the physical exploration for new reserves (i.e. geological surveys, drilling, wages, renting drilling rigs, etc.), while the latter is capital expenditure such as equipment.

At the median, a country’s first discovery follows one year after the instatement of the first oil & gas specific ownership regime. However, the standard deviation of the number of years between these events is 36 years for giant discoveries (of at least 500 million barrels, according to Horn, 2014) and 28 years for minor discoveries (of at least 5,000 barrels, according to ASPO, in Cotet and Tsui, 2013). The main reason for this is that several countries discovered oil before they became independent and set their own legislation. Also, there may be measurement error in the discoveries data. We do not model the timing of the first adoption of legislation. Instead, we focus on changes in ownership regimes within the group of independent countries with petroleum-specific legislation. We perform a robustness test in Section 4.3 where we exclude countries where discoveries precede legislation, and show that our main results are unaltered.

2.2 A new database on petroleum ownership regimes

We introduce a unique new yearly dataset on petroleum ownership structures spanning more than a century, from 1867 to 2008. Our dataset includes information on 68 oil-producing countries from all regions of the world.¹¹ 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). We cross-checked the entries from the EIA with the BP Statistical Review of World Energy, which covers 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 hundred-odd years.

We distinguish between Domestic, Foreign, and mixed domestic-foreign (i.e., Partnership) ownership regimes. Specifically, we code each (independent) country according to the following *de jure* criteria:

Domestic Control: The state, state firm(s), or private domestic firm(s) hold(s) the rights to develop the majority of petroleum deposits and owns the majority of shares (over 50%) in the oil and gas sector. The managerial power lies mainly in domestic hands, with foreign (private or state-owned) involvement – if present – being limited to roles with little or no operational and managerial control (e.g., service contracts).

Partnership: The rights to develop the majority of petroleum deposits and the majority of shares (over 50%) in the oil sector lie in domestic hands, but there is substantial involvement by foreign firms. Both domestic and foreign (private or state-owned) oil firms have operational and managerial competencies, e.g., through Production Sharing Agreements (PSAs).

Foreign Control: Foreign (private or state-owned) firms hold the rights to develop the majority of petroleum deposits and own the majority of shares (over 50%) in the domestic oil sector. The managerial power lies mainly in foreign hands, e.g., via concessions.

¹¹A list of countries and years of coverage is shown in the Appendix.

Figure 1 gives an overview of the countries included in the sample at the end of the period, in 2008, distinguishing by their ownership regime.

[Figure 1 about here]

As these criteria imply, host country legislation often does not assign domestic or foreign firms the exclusive right to all exploration and extraction of petroleum. For practical purposes, the essential point for us is who is allowed to hold the *majority* rights to exploit petroleum deposits according to domestic, host-country legislation. For the coding, we rely on the countries' constitutions, official laws and regulations governing the petroleum sector, sample petroleum contracts, and secondary sources. The initial (post-independence) year of inclusion of each country is based on the date of the first national law, rule or regulation pertaining explicitly to the petroleum sector.¹² This approach allowed us to gather information on control regimes for a total of 68 countries and 3,874 country-year observations, giving an average time coverage of nearly 57 years for each country.¹³

In total, we have 65 switches in regime types, making a change in control rights over petroleum a rare event. However, more than half of our countries (35 out of 68) switch regimes at least once, meaning we have a good amount of within-country variation.¹⁴ The most common regime in our dataset is Foreign (1,597 out of 3,874 country-years, or 41.2%), followed by Partnership (1,227 or 31.7% of country-years), and finally Domestic (1,050 or 27.1% of country-years). Although Foreign is the most frequently found regime among the countries that never change ownership structure (17 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 (23 changes away), and Partnership (14 changes to another regime). Finally, the most common switch from Foreign is towards

¹²The 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.

¹³This ranges from a maximum of 141 years of ownership information for Canada, to a minimum of 6 years for East Timor.

¹⁴Few countries change more than twice; Bolivia is the outlier with 6 regime switches from the time it enters the dataset in 1906.

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).

Although we have data for potentially 68 countries, we will include a maximum of 63 countries in the regressions, because some countries no longer exist and/or have poor coverage on other variables.

We next describe the history of the initial choice for ownership regime and the reasons for switching, which will inform our identification strategy in Section 3.

2.3 A short history of petroleum ownership regimes

As described above, countries can adopt one of three possible oil sector ownership regimes in our dataset. Figure 2 shows the evolution of the prevalence of each ownership regime, tracking the switches between the three regimes, as well as the entry of new countries over time. The number of countries with any such legislation steadily increased.

[Figure 2 about here]

Along this trend, we can determine four broad ownership ‘waves’ or periods since the beginning of our dataset in the late 19th century, which we argue are driven by key (political) events in the oil industry (for simplicity, we henceforth concentrate on the period since 1900). The first wave occurs between 1900 and 1951; the second from 1951 to 1960; the third from 1960 until 1980; and the fourth and (so far) final one from 1980 until the end of our period of observation in 2008. We can describe each wave as encompassing (roughly) opposing movements in the prevalence of Foreign and Domestic ownership: while the number of countries under a Foreign ownership regime generally waxes and wanes over the period, i.e. increases at the start and then decreases towards the end, the number of countries under Domestic ownership follows the opposite pattern. As for our third ownership regime, Partnership, we see from Figure 2 that the number of countries adopting Partnership steadily increases throughout our long observation period, with minor dips and peaks along the way which do not influence the overall upward trend that begins even before 1900, and gains momentum after WWII.

The big picture that emerges is one of a (sometimes literal) battle between the extremes - Foreign and Domestic ownership - as evidence of the shifting balances of power

between foreign oil companies and the host country governments. This struggle over the control of oil mirrors the political struggles going on as, over the period, oil producers seek to affirm their independence and put national development before the business interests of foreign companies.

At the same time, the major and smaller independent oil companies seek to counter the seizure of control over oil deposits by the producing country governments and their national oil companies by exploring for and developing new reserves elsewhere (Skeet, 1988). These efforts are dictated by a fundamental characteristic of the petroleum industry, as explained by Wright (2017, p77):

“Successful discovery, development, and production of oil and gas reserves is fundamental to the survival of any [exploration and production] company. Oil and gas 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.”

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’ proved 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 (Wright, 2017). Crucially, ‘bookable reserves’ are largest under majority Foreign ownership – traditionally awarded through a concessionary contract – while they are lower under a Partnership contract such as a production-sharing agreement, and very low or even zero under a service contract such as the ones typically offered under majority Domestic ownership.¹⁵

The underlying positive trend in Partnership regimes suggests that the union between foreign expertise and domestic (often national) oil companies has emerged as the best compromise to achieve both good profits and economic development.

We describe below in more detail the key occurrences in the global oil industry that delimit each wave, as well as the driving forces behind the intervening shifts in ownership regime frequencies.

¹⁵See Wright (2017) for more details on the reporting of reserves under different types of contracts and the history of accounting practices in the sector.

1900-1951: The era of concessions and the domination of major oil companies

This is the big era of concessions¹⁶ and the heyday of the ‘majors’, the small number of large oil companies that together dominate world oil production and marketing in this period. They drive a strong increase in the incidence of Foreign ownership until the second half of the 1930s, cementing their power in host countries, mainly in the Middle East and Latin America.¹⁷ We then see a slow but steady decline in the prevalence of this regime around the time of rising nationalism in Latin America and the nationalizations of the Bolivian and Mexican oil industries (1937 and 1938, respectively). These nationalizations – and particularly the Mexican one – sent a shockwave through the industry (Yergin, 2008) and mark the beginning of the first rise in Domestic ownership, which culminates in the 1951 expropriation of Anglo-Iranian in Iran.

Although there is a very small uptick in Foreign ownership after WWII, overall the trends in Foreign and Domestic ownership are going in opposite directions during this first period, as petroleum discoveries in new countries are limited (recall that our dataset includes only independent countries). Partnership is still an unusual choice during this time: only four out of the 25 countries in our dataset have adopted a mixed ownership regime by 1951.

1951 to 1960: Trying to stem the rising tide of oil nationalism

This short, interim period of adjustment follows the Iranian nationalization and subsequent oil embargo, events which trigger a brief but sharp decline in the expansion of Domestic ownership. This was very likely due to a negative demonstration effect: for example, Myers Jaffe (2007) argues that the failed oil sector 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.¹⁸

¹⁶Concessions were granted for petroleum exploration and production in large areas for very long periods, usually to one company or a consortium of companies. 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.

¹⁷The situation was quite different in Europe, where the Russian Empire, followed by its successor the Soviet Union, was established as the big counterweight to the major oil companies. Though the Russian/Soviet petroleum sector was under Domestic control throughout the period, foreign companies’ investment was sought to develop the large oil deposits, particularly during the 1920s. Once Soviet industrialization took off, however, opportunities for foreign involvement melted away. See Yergin (2008) for an interesting description of Russian oil during this early period.

¹⁸On international diffusion as a possible exogenous explanation for nationalization, see also Kobrin (1985).

The milestone agreement of 1954 between the Iranian government and a newly formed foreign oil producers' consortium (including small, independent companies) marks the definite end of the 'concession era' and the beginning of a new era of negotiated agreements in markets outside North America and Europe (Yergin, 2008). It also demonstrates the increasing importance of small, independent oil companies across the globe. Foreign oil companies, especially independents, seek - and find - new producing countries in this period of uncertainty, primarily in Northern Africa (Algeria, Libya); and they are able to agree favorable terms (i.e. Foreign ownership), at least for a while.

Overall, Foreign and Domestic ownership trends are again going in opposite directions during this second period, while Partnership slowly gains ground, having been chosen in 8 out of 33 countries by 1960 (against 10 countries under Domestic ownership regimes).

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

The formation of the Organization of Petroleum Exporting Countries (OPEC) marks a major change, though one that is slow to show its full effect. Once again, the majors and independent oil companies adapt to the new challenge: they seek different forms of cooperation with OPEC countries, e.g. through technical service or long-term supply contracts. Most importantly, "they sought new areas for oil exploration"; and areas that were previously not economic became viable thanks to higher oil prices, especially during the 1970s (Skeet, 1988, p.235). The latest wave of new exploration by foreign oil companies in Asia and Africa soon sees sizable deposits being discovered in Indonesia and Nigeria, among others. This period also sees the start of offshore North Sea oil production in Europe.

The efforts at finding new petroleum reserves come with an accompanying increase early in the period in the number of countries with Foreign ownership in their petroleum sectors. In contrast to the first two waves, Domestic ownership at first follows a similar upward trend, but then loses momentum during the late 1960s, when Arab nationalism stalls. During this third period, national oil companies emerge as ever more important players (Yergin, 2008). Another significant development is the introduction of the production-sharing agreement (PSA) in 1967 in Indonesia. The PSA becomes the ownership division of choice under mixed-control-rights regimes. This signals the start of

another waning in the popularity of Foreign ownership. By the end of this period, Partnership for the first time surpasses the other two regimes as the number one choice for oil-producing countries, and it will not relinquish its leadership position for the rest of the analysis period. The oil sectors in 20 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.

In Figure 3 we zoom in on this period and split countries between OPEC membership, and non-OPEC members between those open to trade and relatively closed economies. The aggregate drop in the countries that allowed foreign investment is clearly seen to be concentrated among OPEC members, but is also visible in the group of non-OPEC countries that are closed to trade.

[Figure 3 about here]

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

Another new wave of exploration follows the oil crises of the 1970s and the nationalization of Aramco (now Saudi Aramco) in 1980 - when the incidence of Domestic ownership reaches its apex - and provokes an increase in Foreign ownership numbers among countries that are open to trade. This is shown most clearly in the middle graph of Figure 3.

At the end of the period, around the same time as Foreign ownership falls out of favor again, we see the opposite trend in Domestic ownership due to a renewed nationalism in Latin America and - in different guise - in Russia. This latest increase in the popularity of Domestic ownership this time comes at the expense of both Foreign ownership and Partnership. However, Partnership remains firmly in place as the regime of choice for 28 out of the 63 oil producing countries in our dataset in 2008. Jones Luong and Weintahl (2010, pp.14-15) characterize the final years of this period as a time of “proliferation of both new international norms concerning the obligations of foreign oil companies to host countries and [international non-governmental and financial institutions] seeking to impose these norms.” In addition, ‘foreign’ oil companies include not only private, but also an increasing number of state-owned firms, as several oil producers that emerged in the second wave become mature economies and begin exporting their expertise.¹⁹

¹⁹Previously, the number of national oil companies seeking opportunities abroad was circumscribed:

The broad pattern that emerges is that when setting petroleum legislation, countries respond to events in other countries and to the incentives of international oil companies searching for new reserves. This resembles the gradual spread of institutions and democracy described by Buera et al. (2011) and Acemoglu et al. (2019), respectively, where countries learn from neighboring countries or other countries in their geographical region, albeit at a more global level in the case of oil sector-specific institutions.

3 Methodology

The historical overview suggests that the choice of petroleum ownership regime affected discovery rates around the world: when foreign firms lost influence through nationalization in one country, they sought favorable terms in another and made new discoveries there. Often, the cycle was repeated, and yet new reserves were discovered elsewhere. We formally test the basic hypothesis that oil and gas exploration and discovery are affected by petroleum-sector ownership legislation in two ways. First, we uncover the basic links in OLS regressions:

$$Y_{ct} = \beta_1 Partnership_{ct} + \beta_2 Foreign_{ct} + \beta_3 Openness_{ct} + \beta_4 X_{ct} + \alpha_c + \delta_t + \epsilon_{it} \quad (1)$$

where Y_{ct} is our outcome variable of interest and includes giant oil and gas discoveries or the sum of barrels of oil discovered; or wildcat drilling activity or exploration costs, for each country c and year t . These capture success of exploration (for discoveries) and exploration effort (for wildcat drilling and costs).²⁰ β_1 captures the effect of switching from the baseline legislation of domestic ownership to a *Partnership*, and β_2 captures the effect of switching from the baseline to *Foreign* ownership.²¹ *Openness* to trade

British Anglo-Iranian/British Petroleum was the first, followed by Elf Aquitaine of France and ENI of Italy (Yergin, 2008). These are now joined by the likes of Norway’s Statoil (now Equinor), Brazil’s Petrobras, and Malaysia’s Petronas.

²⁰We also experimented with defining a measure of exploration efficiency directly, such as the ratio of discoveries to wildcat drilling. However, this is very sensitive to which cumulative period of drilling up to the next discovery is included in the ratio. Moreover, it is not clear how to treat drilling that occurs during periods of successive discoveries. For these reasons, we model success (discoveries) and effort (drilling) separately.

²¹We 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

proxies for general change in economic institutions.²² We extend the dataset by Sachs and Warner (1995) and Wacziarg and Welch (2008) and use the same criteria to include Middle Eastern countries and to include recent years up to 2008. A country is defined as being closed in a given year if at least one of the five following criteria hold: (1) the simple average of *ad valorem* rates across tariff lines is 40% or more; (2) non-tariff barriers cover 40% or more of trade; (3) there is a black market exchange rate that is depreciated by 20% or more relative to the official exchange rate, on average, during the 1990s; (4) there is any form of state monopoly on major exports; and (5) there is a socialist economic system (as defined by Kornai, 1992). X_{ct} includes other control variables such as OPEC membership, cumulative discoveries made in the past (the sum of ultimate recovery equivalent, from Horn, 2014), and in robustness tests other measures of democratization and institutional change. We exploit the within-country variation of our long time period and always include country (α_c) fixed effects and cluster standard errors at the country level. Finally, year-effects (δ_t) absorb global shocks that may trigger both exploration and the adoption of specific legislation, such as world demand for oil and the oil price.

In this preliminary specification we cannot rule out that the choice of oil sector legislation is endogenous to discoveries made. First, a discovery may increase expectations of future discoveries, increasing incentives to attract foreign investors. Second, there may be unobserved trends of institutional change such as improved investor protection or improved political stability that both increase exploration efforts and make oil sector legislation possible and credible. Third, it may be that partnerships and foreign ownership is adopted in regions where finding oil is harder and in which countries rely more on foreign expertise and technology. Although the country fixed effects absorb the time-invariant effects of geology, unobserved technological progress changes which types of geology are technically and economically feasible to extract oil from. For this reason, the error term and legislation may be negatively correlated, resulting in a downward bias of the OLS estimates of β_1 and β_2 .

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.

²²We include openness in our main estimations to make our results directly comparable to those of Arezki et al. (2019). However, our main findings are robust to dropping openness, as discussed below.

3.1 Identification strategy

To identify the effect of changes in legislation on discoveries, we lag and instrument the main explanatory variables and construct four sets of instrumental variables. Our second-stage estimation equation becomes:

$$Y_{c,t+1} = \theta_1 \widehat{Partnership}_{ct} + \theta_2 \widehat{Foreign}_{ct} + \theta_3 \widehat{Openness}_{ct} + \theta_4 X_{ct} + \alpha_c + \delta_t + \mu_{it} \quad (2)$$

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 and resource discoveries, 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 underlying assumption is that policy change in neighboring countries does not affect the outcome variable of interest in a country directly. In our setting it is very unlikely that a change in oil sector legislation in one country changes the probability of discovering oil in another country directly, *ceteris paribus*.

We argue 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 historical overview above. One example is the fact that OPEC draws members from four continents.²³ We have shown in the discussion above that host country governments look at what is happening in other oil countries when deciding on oil sector ownership legislation, and that broad institutional characteristics play a greater role than geographical proximity (though we do not exclude regional diffusion of legislation). In practice, we believe that petroleum ownership regime choice is influenced mainly by changes in ownership legislation in OPEC countries, and by the ownership legislation in countries that are integrated

²³We do not attempt to model OPEC membership itself. 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.

into world markets – as measured by a trade openness dummy – and exploit these factors, along with geographical distance, to construct four sets of exogenous instruments.²⁴

We thus specify a first stage regression for each of the three endogenous regressors $Z_{ct} = \{Partnership_{ct}, Foreign_{ct}, Openness_{ct}\}$:

$$\begin{aligned}
Z_{ct} = & \gamma_1 E(Partnership_{j,t-1} | Region_{cj} = 1) + \gamma_2 E(Foreign_{j,t-1} | Region_{cj} = 1) \\
& + \gamma_3 E(Partnership_{j,t-1} | Openness_{j,t-1} = 1) + \gamma_4 E(Foreign_{j,t-1} | Openness_{j,t-1} = 1) \\
& + \gamma_5 E(Partnership_{j,t-1} | OPEC_{j,t-1} = 1) + \gamma_6 E(Foreign_{j,t-1} | OPEC_{j,t-1} = 1) \\
& + \gamma_7 \widetilde{Openness}_{j,t-1} + \gamma_8 X_{ct} + \alpha_c + \delta_t + \nu_{it}.
\end{aligned} \tag{3}$$

Following the literature and using the World Bank classification of regions, we construct $E(Partnership_{j,t-1} | Region_{cj} = 1)$, which equals for each year the average of *Partnership* in all countries j other than country c that belong to the same geographical region as country c . This should capture waves of institutional change that apply to the oil sector specifically. Similarly, $E(Partnership_{j,t-1} | Openness_{j,t-1} = 1)$ is for each year the average of *Partnership* in all countries j (other than country c) that are open to trade. Third, we allow for oil countries to have a global perspective when choosing to adopt different policies and define $E(Partnership_{j,t-1} | OPEC_{j,t-1} = 1)$, which equals for each year the average of *Partnership* in all countries j (other than country c) that are members of OPEC. The *Foreign* variables are defined analogously. Finally, $\widetilde{Openness}_{j,t-1}$ 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 a negative relationship between average foreign ownership legislation in a reference group of countries j and the likelihood of having foreign ownership in country c . As Figure 2 showed, most countries start out with a majority foreign ownership legislation. In fact, 51 out of 63 countries adopt foreign ownership as their first petroleum ownership regime, but many of these switch to another regime later on. 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). A decrease in foreign ownership in the reference region, while

²⁴Each set is based on dummy variables for foreign and partnership ownership, with domestic ownership being the relevant omitted variable.

keeping the prevalence of partnerships constant, implies a switch from foreign to more domestic ownership in the region.

Changes away from foreign ownership often force international oil companies to search for reserves in other countries, and 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. We thus hypothesise that when one country restricts foreign ownership legislation, it creates an incentive for oil companies to bargain for foreign ownership legislation in other countries, and for these countries to facilitate this to attract investment. 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 balance sheet loss, as companies can no longer book the reserves. Petroleum reserve reports are used in the valuation of an oil company, its application for loans, long-term planning, and a host of other financial decisions (Wright, 2017). Moreover, losing reserves hurts a petroleum company’s key performance indicator, namely the ratio at which they replace reserves that are being depleted as oil is extracted, refined, and sold. The only way to make up for this loss is to increase reserve holdings elsewhere, through acquisitions, or exploration and discovery. Acquisition of known reserves is considered much more expensive than undertaking own exploration (Wright, 2017), providing a strong incentive for international oil companies to diversify their activities and seek new reserves elsewhere after a nationalization. Crucially, a petroleum company can only book reserves to the degree that it has effective control over extraction: access to reserves under service contracts – the typical form of foreign involvement under majority domestic ownership regimes –

cannot be booked, while concessions or shares in production-sharing agreements can be booked (Wright, 2017).

Similarly, the correlation between the reference region's average adoption of partnerships correlates negatively with a country's own choice for partnership legislation. An increase in partnerships in the reference region, while keeping the prevalence of foreign ownership constant, implies a switch from domestic to partnerships in the region. This reduces the incentives for international oil companies to set up partnerships in country c , everything else equal.

Specific events after the inception of OPEC exemplify the proposed mechanism. The oil embargo of 16 October 1973 initiated OPEC's tighter control over its own level of oil production, after years of 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),²⁵ 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).²⁶ 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 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

²⁵Outright 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).

²⁶Partial 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.

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).²⁷

Openness to foreign control in the petroleum sector is seldom decoupled from openness in other sectors of the economy. Our final instrument is therefore inverse-distance weighted openness, and 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).

We always test the relevance of our instrumental variables formally, using the Sander-son and Windmeijer (2016) first stage conditional F-tests for weak identification of *individual* endogenous regressors.

4 Results

4.1 Baseline estimations

In Table 1 we show the results from estimating equation 1 without openness, exploiting the full petroleum ownership dataset to show the correlation between petroleum ownership regimes and discoveries and exploration drilling. As a first observation, we note that across this long time period, allowing a significant degree of involvement of foreign oil companies – i.e., with at least some foreign managerial control – is linked to more discoveries and drilling than relying on Domestic ownership (our base ownership regime). Foreign ownership is consistently and significantly related to more giant discoveries (columns 1-2); more discoveries overall in terms of barrels of oil equivalent (column 3); and to more wildcat drilling (columns 4-5). This finding is robust to including the stock of discoveries already made (column 2). Partnership, or mixed Domestic-Foreign ownership, is linked to significantly more wildcat drilling (columns 4-5), but not to more giant discoveries or total barrels discovered.

In Table 2 we additionally control for trade openness, which reduces the sample size by around 1,300 country-years because openness is available only from 1960. Neverthe-

²⁷The process is not unique to the petroleum industry: Smart (1976) describes similar mechanisms for the global spread of rubber and coffee production.

less, the preliminary findings from Table 1 hold for all cases save total barrels discovered (column 3). Moreover, the size of the coefficients for the ownership dummies is comparable to what was found over the longer term in Table 1. For example, switching to Foreign ownership is related to around 12% more giant discoveries in the subsequent year than Domestic ownership (Table 2, columns 1-2), and between 50% and over 100% more wildcats drilled. We find a similarly large link between Partnership and wildcats. Finally, it appears that oil sector-specific institutional change has more explanatory power than broad-based trade reform, as openness is never significant at conventional levels.

Our main interest however lies in uncovering the causal impact of petroleum ownership regimes on discoveries. Table 3 shows 2SLS estimates of equations 2 and 3 for our two main dependent variables, the number of giant discoveries from the Horn dataset (columns 1-4), and the number of wildcats drilled from the ASPO dataset (columns 5-8). Columns (1-3) and (5-7) report first stages, while columns (4) and (8) show second-stage results for the number of discoveries and wildcats, respectively. The first notable difference with respect to Table 2 lies in the size and significance of the two ownership dummy coefficients: the effect is now highly significant in the case of Foreign ownership and discoveries, with countries adopting foreign ownership seeing around 43% more giant discoveries in the following year than those under Domestic ownership (column 4). The increase in the size of the effect is consistent with a negative correlation between the adoption of Foreign ownership legislation and the error term of equation 1. One possible explanation is that Foreign ownership is adopted by countries where discoveries are relatively rare and in which countries stand to benefit more from foreign technology. The impact of Partnership on discoveries is no different from that of Domestic ownership. However, Partnership countries drill more than twice as many wildcat wells as countries under Domestic ownership regimes. Countries under Foreign ownership also see substantially more drilling activity, but the effect is only weakly significant (column 8). We also see that trade openness is again insignificant.

The instrumental variables follow the pattern described above: keeping the prevalence of Foreign constant, a switch from Partnerships to Domestic in the reference region of a country (a negative change in the prevalence of Partnership in the region) predicts a higher likelihood of adopting Partnerships locally.²⁸ Analogously, keeping the prevalence

²⁸The magnitudes are $-1 * -0.751 = 0.751$ where the reference region is the geographic regional average, 2.944 for the average of countries open to trade, and 1.675 for OPEC countries.

of Partnerships constant, a switch from Foreign to Domestic in the reference region of a country predicts a higher probability of adopting Foreign locally.²⁹ Presumably, the reason is that in those cases the international oil companies loose access to reserves, increasing the incentive for them to explore in other countries and negotiate favorable terms. This holds for the reference group being OPEC countries, countries that are open to trade, and to a lesser extent to countries in the same geographical region. We also confirm the spread of trade openness across regions and find that both Partnership and Foreign legislation in the oil sector in the reference region is positively correlated with openness to trade locally. Each of the endogenous variables is identified according to the first stage F-tests, and the Hansen overidentification test cannot reject validity.³⁰

4.2 Extensions

Temporal delays in discoveries

So far, we concentrated on the effects of (switches in) ownership regimes on petroleum discoveries and drilling activities one year later. However, it is unrealistic to focus exclusively on such a short time frame, as it can take many years of exploration to find an economically viable petroleum deposit. We explore this possibility by looking at effects up to five years ahead on our two main dependent variables, discoveries and wildcats. We show the results graphically for easier interpretation, using the baseline 2SLS specifications from Table 3.³¹ Panels A and B in Figure 4 show the impact of Foreign and Partnership ownership, respectively, on discoveries from one to five years after a regime switch. Panels C and D show impacts over the same time period on wildcat drilling activity. Domestic ownership is always the base category.

[Figure 4 about here]

We see that a switch to Foreign ownership continues to lead to significantly more discoveries than under Domestic ownership for up to five years later. Adopting a Partnership

²⁹The magnitudes are $-1 * 0.121 = -0.121$ (but insignificant) where the reference region is the geographic regional average, 2.137 for the average of countries open to trade, and 1.396 for OPEC countries.

³⁰In additional robustness tests discussed below, we re-run our estimations instrumenting only our ownership dummies, with very similar results.

³¹Results are shown in the Appendix table A2.

regime instead shows no substantial difference in discoveries with respect to Domestic ownership; coefficients are positive, but significance never goes below the 10%-level.

The results for wildcat drilling also strengthen the findings from our main, short-term estimations: allowing majority Foreign ownership has only a weak positive impact on drilling activity compared to Domestic ownership during the first three years after a regime switch, with diminishing coefficient sizes that become zero after around five years. Coefficient sizes for Partnership also decrease over time, but mixed ownership continues to lead to significantly more drilling activity for five years after a regime change.

Accumulated experience after foreign ownership

So far we have shown that the foreign ownership regime is generally more successful in discovering oil, presumably due to better incentives or better access to the latest technology. Since most countries start out with allowing foreign ownership and switch to a majority domestic or a partnership regime later, a natural question is whether a country's oil industry under these regimes discovers more after accumulating experience – with other words, greater domestic involvement may depress the rate of drilling and discovery for a few years, but these then pick up again as domestic know-how improves. Alternatively, lengthening time periods since significant foreign involvement may go hand-in-hand with ever-lower investment, depreciation, and reduced probability of discovering oil.

We test this by specifying experience variables equal to a country and period-specific linear trend. *Partnership experience since foreign* equals a linear trend during the partnership period immediately following on foreign ownership. *Domestic experience since foreign* equals a linear trend during the domestic period immediately following on foreign ownership, and *Domestic experience since partnership* equals a linear trend in the domestic period immediately following on partnership. Finally, we also specify *Domestic experience since foreign or partnership* which is the union of the previous two variables. The variables are thus interactions between the legal regime dummy and a trend, but defined relative to a specific preceding ownership regime. Appendix Table A3 shows that when it comes to making major discoveries, neither form of experience makes up for switching away from majority foreign ownership. For example, column 3 shows that switching from Foreign to Domestic changes the probability of discoveries by $-1 * 0.531$

(second row). Each year that passes since this switch, which we call experience, actually further reduces the effect on discoveries by -0.005 , but this interaction is not significant. Likewise, a switch from Partnership to Domestic reduces discoveries ($-1 * 0.443$), but not significantly so. Each year of experience somewhat mitigates the point estimate by 0.022 , but this is also not significant. Partnership experience since Foreign is also not significant in any specification. We thus conclude that experience does not make up for the benefits of majority foreign ownership when it comes to making new discoveries.

4.3 Robustness analysis

Exploration intensity

The results above show that Foreign ownership in the petroleum sector leads to more (giant) discoveries, as well as more drilling activity, than Domestic Ownership, and the effect seems to last for several years. While the positive effect of Partnerships on drilling is even greater, we do not find that Partnerships are significantly more successful in finding new oil and gas fields. These findings suggest that foreign firms make more effective exploration decisions, possibly investing more heavily in geological and seismic surveys to determine the most likely exploration areas. An alternative explanation could be that foreign firms are simply luckier than domestic ones and therefore make more discoveries, even without drilling more wells. While discovering petroleum undoubtedly involves some degree of chance, good luck seems an unsatisfactory explanation when looking at the evidence on the effect of petroleum ownership on discoveries over several decades and in over 60 countries.

In Table 4 we therefore examine multiple measures of exploration intensity, including costs. Column 1 repeats the main finding of the number of wildcats drilled estimated both with OLS (Panel A) and 2SLS (Panel B). Columns 2 to 4 draw on proprietary data from Rystad Energy for a second measure of wells drilled, and exploration costs. Costs are split into expensed and capitalized, where the latter includes capital expenditure on durables and the former mostly includes wages and the cost of renting drilling rigs. Although Rystad claims to capture the universe of drilling and costs, petroleum exploration and production companies are rarely upfront about their exploration and production costs, which explains the large number of ‘zeros’ in the data. With this in mind, we find some

evidence for more wells drilled when a country switches to Partnerships in column 2. We also find more robustly that Partnership leads to more aggregate capital spending on exploration, while Foreign ownership does not.

The last two columns use principle component analysis to construct a single principle component that captures most of the variation in the variables of columns 1 to 4 and 2 to 4, respectively.³² The most robust finding is that countries with Partnership regimes explore with significantly greater intensity and costs than those under Domestic ownership arrangements. Finally, note that OPEC members generally have significantly lower exploration intensity, both in terms of the number of wells drilled and expenditure incurred.

We conclude that exploration under Foreign ownership is not particularly more costly, but is of higher quality than that performed under Domestic ownership, given that it results in significantly more discoveries. This is in line with the findings of Victor et al. (2012), who show that international, mainly private oil companies, rely on gathering ever-better geological knowledge in order to compete for petroleum licenses in a global market, while most national oil companies are comfortably sheltered from competitive pressures in their home markets.

Additional sensitivity analysis

In our main 2SLS estimations shown in Table 3, we instrument not only our ownership regime dummies, but also the trade openness dummy for easier comparison with existing literature. However, our findings do not depend on this third endogenous regressor: instrumenting only our ownership regime dummies and adding trade openness as an exogenous control variable instead, we find qualitatively and quantitatively very similar results (see Table OA1).

An important part of our proposed mechanism for changes in and the spread of oil sector legislation is a country's reaction to the decisions originating in OPEC countries. To gauge the contribution of the OPEC channel we drop the OPEC dummy and the OPEC instruments in Table OA2. Our basic result still holds, but we see a drop in the first stage F-tests, signifying that OPEC was important in driving legislation change

³²The method is iterated principle components and we keep factors with an eigenvalue larger than 1, which results in only one factor. In columns 5 and 11 the factor has an eigenvalue of 2.9. In columns 6 and 12 the factor has an eigenvalue of 2.4.

in other countries during our sample period. Note also that the OPEC variables were relatively weak in predicting trade openness: dropping them increases the F-statistic for openness, which is however still not a significant predictor of discoveries or drilling.

Some countries had already seen major petroleum discoveries before passing the first oil-specific law, which usually coincided with independence, raising the question of path dependence in ownership regimes. 24 countries saw one or more giant discoveries before they passed their first petroleum-specific law; most of these are former colonies. Although the median time between the first law and the first giant discovery (of 500 million barrels) is +1 year, the literature suggests that petroleum ownership regimes are themselves endogenous to discoveries; where discoveries are made and production is underway, host countries are more tempted to take control of the industry (see e.g. Victor et al., 2012). Indeed, using the ASPO data from Cotet and Tsui (2013) on the first minor discovery (of at least 5,000 barrels), we find that the median time between the first law and the first minor discovery is -1 year. Even with a 2SLS approach, this could bias our results in countries where discoveries precede petroleum legislation, where ownership choice is influenced by what happened ‘outside’ the confines of our dataset. We can control for this by dropping the country-years in which discoveries preceded initial legislation. Our results remain very similar both for the number of discoveries and of wildcats drilled (see [OA3](#)). Partnerships appear somewhat more successful in finding oil, but still require much more drilling.

Finally, in [Table OA4](#) we control for additional measures of institutional change including democracy as captured by the polity2 score (Polity IV dataset, Marshall et al. 2016) and the regional average polity (own construction); the private civil liberties index and the property rights index from the V-Dem dataset (Coppedge et al., 2017; Pemstein et al. 2017); financial development (private credit over GDP; World Bank Development Indicators); OECD membership; and regional average trade openness instead of a country’s own trade openness (own construction). Only the regional average polity score and OECD membership are significantly linked to discoveries or wildcat drilling. More importantly, none of these additional control variables change our main result: discoveries and drilling remain endogenous to industry-specific institutional change.

5 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. Using this data, we show that the laws governing the ownership of key natural resources such as oil and gas influence exploration activity and the number of new petroleum discoveries made. Adopting a majority Foreign ownership legal regime results in more discoveries of oil and gas than under Domestic ownership. Switching to Partnership yields much more drilling and more spending on exploration, but exploration under Partnership regimes is of lower quality as it does not yield more discoveries. Moreover, accumulating experience after switching away from foreign involvement does not make up for the benefits of foreign investment.

What these results suggest is twofold: first, exploration for and discovery of petroleum are endogenous to industry-specific institutional change. This complements the recent findings of Arezki et al. (2019) and Cust and Harding (forthcoming), who show that exploration and discoveries are endogenous to trade openness and overall institutional quality at the national level, respectively. We argue that our findings imply that the literature that uses (the timing of) oil and gas discoveries as exogenous variation should control for the specific ownership regime under which those discoveries were made. Second, the results show that in order to increase the chances of making a new petroleum discovery, host country governments would do well to allow foreign companies a substantial level of control over exploration decisions. The more control foreign companies have over management and investment decisions, the more efficient their investment decisions seem to be in terms of finding new petroleum deposits.

Of course, these findings are limited to the exploration and discovery stage; we cannot make any predictions regarding production or the contribution to the domestic economy under different resource ownership regimes. 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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Figures

Figure 1: All sample countries by ownership regime at end of period, 2008

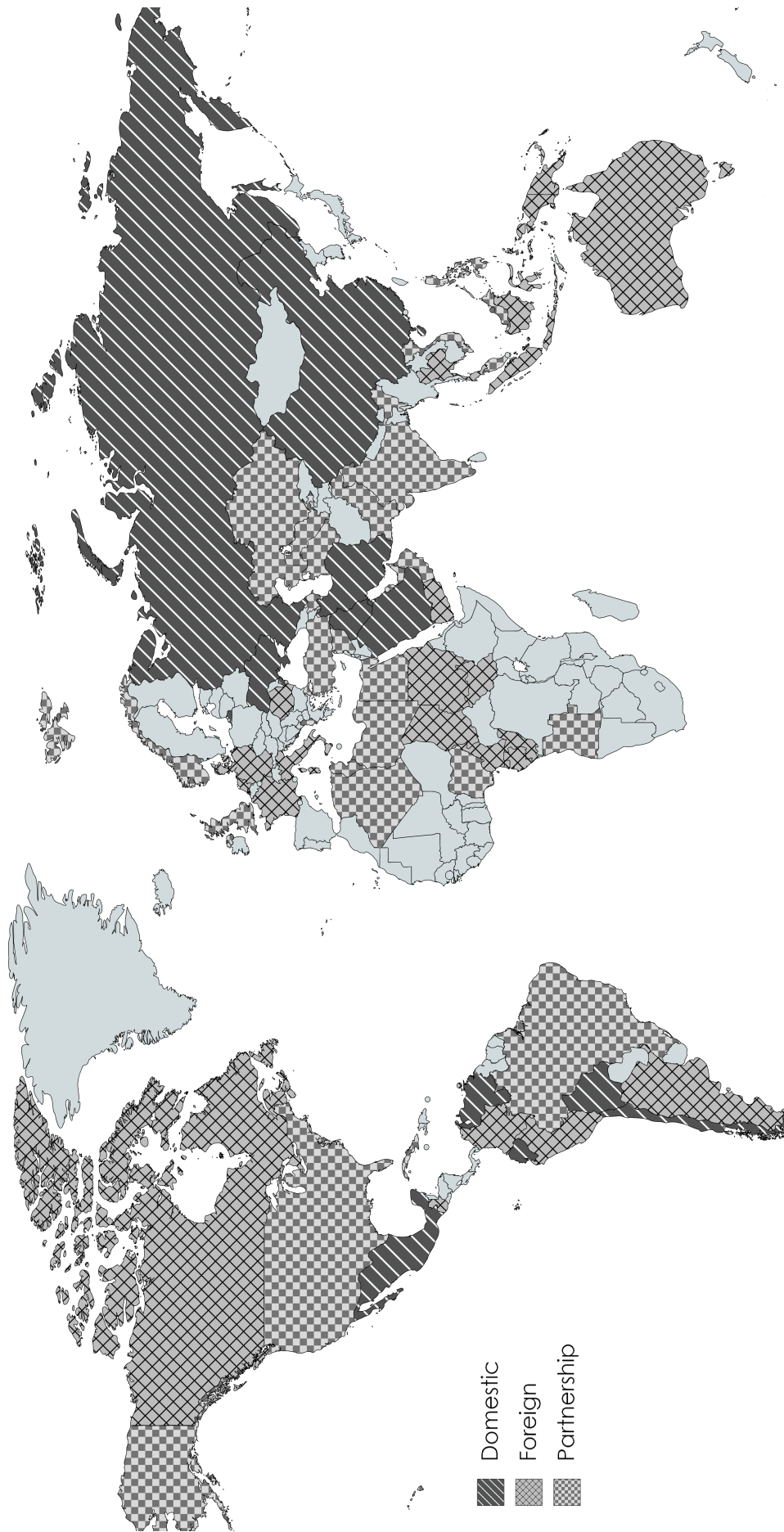
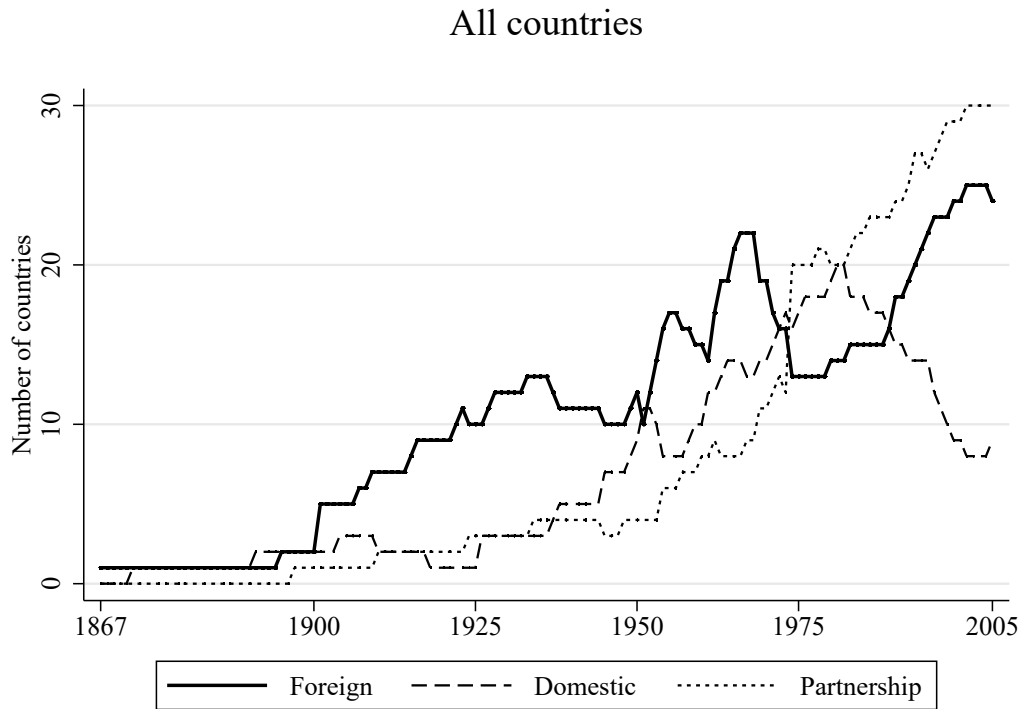


Figure 2: Petroleum ownership legislation since 1867



Note: Countries are included in our dataset from the year that they introduce the first petroleum-specific legislation as an independent nation.

Figure 3: Petroleum ownership legislation since the inception of OPEC

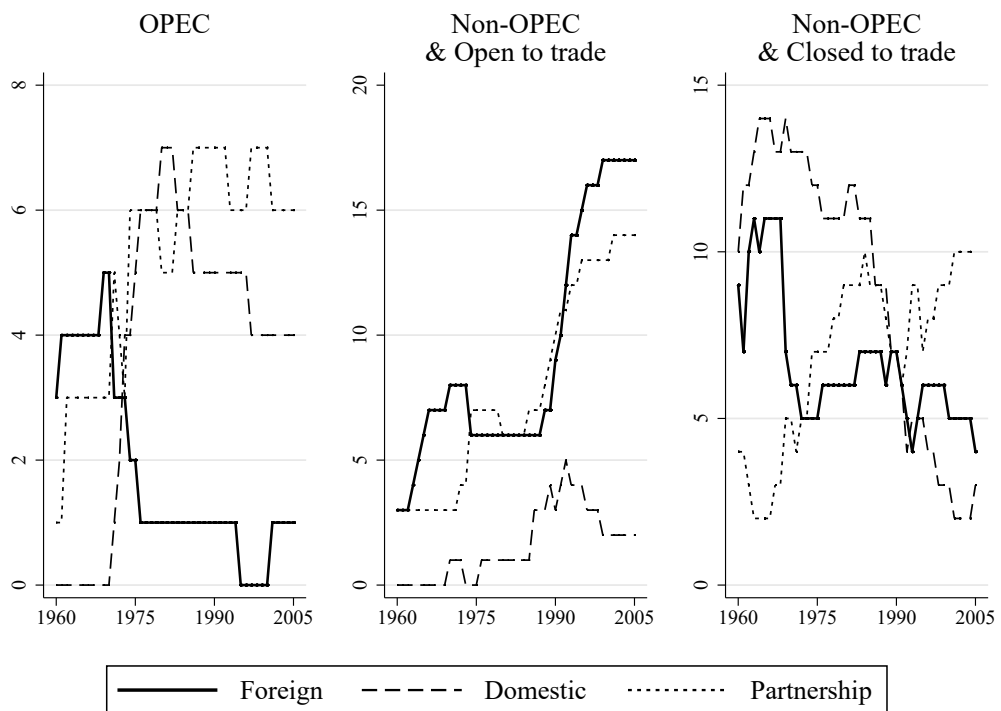
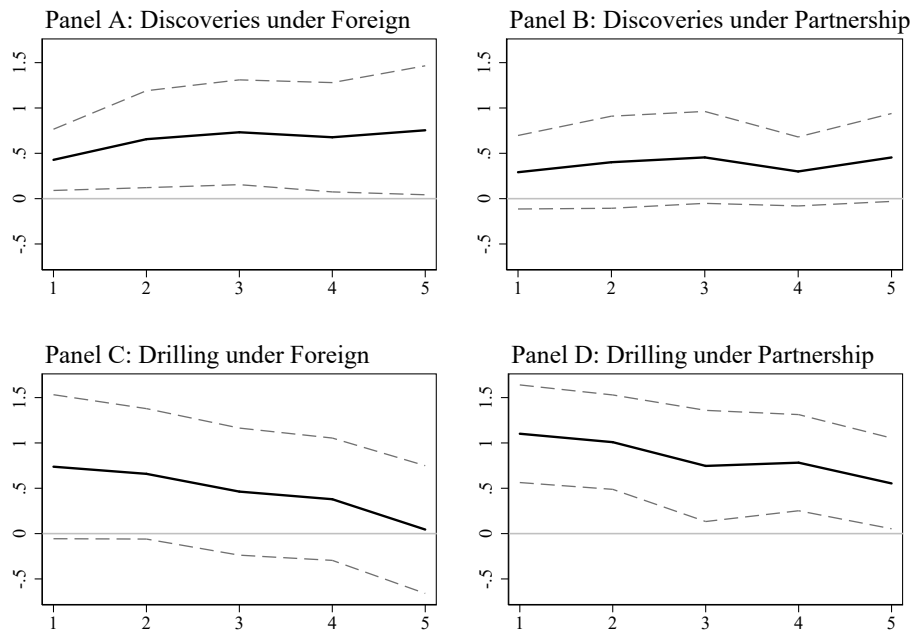


Figure 4: Effects of petroleum ownership regimes over time



Note: The graphs shows coefficients (solid lines) and 95% confidence intervals (dashed lines) for the marginal effect of changing to the stated ownership regime on discoveries (Panels A and B) and drilling (Panels C and D) for one to five years ahead. Estimations are displayed in Appendix Table A2. The base outcome is Domestic ownership.

Tables

Table 1: Discoveries, drilling, and petroleum ownership for full period

Dependent variable →	Oil & gas discoveries		Barrels discovered (log +1)	Wildcats (log)	Wildcats (log +1)
	(1)	(2)	(3)	(4)	(5)
Partnership ownership	0.093 (0.075)	0.091 (0.066)	0.326 (0.271)	0.408*** (0.112)	1.209*** (0.249)
Foreign ownership	0.104** (0.049)	0.109** (0.046)	0.429** (0.211)	0.409** (0.176)	1.253*** (0.336)
OPEC dummy	0.038 (0.207)	0.019 (0.204)	-0.265 (0.553)	-0.794* (0.464)	-0.653 (0.656)
Cumulative barrels discovered (log +1, billions), t-1,		0.017** (0.007)			
Country and year FE	Yes	Yes	Yes	Yes	Yes
Clusters	63	63	63	56	56
Observations	3,723	3,722	3,723	2,198	2,570

Note: This table shows panel regressions of the effect of petroleum ownership regimes on discoveries and drilling activity using OLS. We use a parsimonious specification to show results for the entire period for which we have petroleum ownership data. The base petroleum ownership regime is Domestic ownership. *Barrels discovered* is the log of the oil equivalent sum of the size of all discoveries made in a year in billions of barrels plus 1. Robust standard errors (clustered by country) in parenthesis: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$, + $p < 0.15$. Table A1 contains summary statistics. See Section 2 for variable definitions and sources.

Table 2: Discoveries, drilling, and petroleum ownership, baseline sample

Dependent variable →	Oil & gas discoveries		Barrels discovered (log +1)	Wildcats (log)	Wildcats (log +1)
	(1)	(2)	(3)	(4)	(5)
Partnership ownership	0.113 (0.091)	0.112 (0.084)	0.300 (0.313)	0.473*** (0.151)	1.015*** (0.344)
Foreign ownership	0.120* (0.065)	0.121* (0.062)	0.340 (0.248)	0.533** (0.223)	1.258*** (0.453)
Openness dummy	0.087+ (0.056)	0.087+ (0.057)	0.336+ (0.218)	-0.241+ (0.161)	-0.296 (0.297)
OPEC dummy	-0.223 (0.179)	-0.229 (0.170)	-0.472 (0.520)	-0.231 (0.172)	-0.132 (0.333)
Cumulative barrels discovered (log +1, billions), t-1		0.005 (0.009)			
Country and year FE	Yes	Yes	Yes	Yes	Yes
Clusters	62	62	62	56	56
Observations	2,400	2,400	2,400	1,751	1,978

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. *Barrels discovered* is the log of the oil equivalent sum of the size of all discoveries made in a year in billions of barrels plus 1. Robust standard errors (clustered by country) in parenthesis: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$, + $p < 0.15$. Table [A1](#) contains summary statistics. See Section [2](#) for variable definitions and sources.

Table 3: Instrumenting petroleum ownership regimes

Dependent variable →	Partnership		Foreign		Openness		Discoveries t+1		Partnership		Foreign		Openness		Wildcats (log) t+1		
	1st stage		2nd stage		(3)		(4)		(5)		(6)		(7)		(8)		
Partnership ownership	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)									
Foreign ownership																	
Openness dummy																	
Partnership ownership, (other) regional average, t-1	-0.751** (0.327)	0.125 (0.185)	0.540*** (0.196)	0.292 (0.207)	-1.209*** (0.340)	0.269 (0.281)	0.356 (0.288)	1.102*** (0.275)									
Foreign ownership, (other) regional average, t-1	-0.193 (0.307)	0.121 (0.199)	0.717*** (0.243)	0.428** (0.172)	-0.605* (0.316)	0.284 (0.247)	0.735** (0.314)	0.738* (0.405)									
Partnership ownership, (other) open countries average, t-1	-2.944*** (0.870)	1.350* (0.740)	3.646*** (1.359)	-0.006 (0.114)	-2.585*** (0.822)	1.167* (0.662)	3.969*** (1.323)	-0.272 (0.329)									
Foreign ownership, (other) open countries average, t-1	0.834 (1.187)	-2.137** (0.958)	4.135*** (1.233)		0.772 (1.099)	-1.993** (0.921)	4.322*** (1.154)										
Partnership, (other) OPEC countries average, t-1	-1.675*** (0.422)	-0.412* (0.231)	-1.054 (0.750)		-1.381*** (0.342)	-0.194 (0.153)	-0.789 (0.812)										
Foreign, (other) OPEC countries average, t-1	-0.656 (0.500)	-1.396*** (0.273)	-1.722* (1.002)		-0.621+ (0.408)	-1.369*** (0.256)	-1.696* (0.889)										
Openness, inverse distance weighted, t-1	0.214 (0.559)	1.485** (0.647)	2.626*** (0.626)		0.217 (0.704)	0.889 (0.718)	2.715*** (0.668)										
OPEC dummy	0.217** (0.109)	-0.342*** (0.126)	-0.157** (0.069)	-0.015 (0.086)	0.181+ (0.117)	-0.335*** (0.120)	-0.203*** (0.065)	-0.285 (0.259)									
Country and year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes									
Clusters	62	62	62	62	56	56	56	56									
1st stage SW F-test	14.15	18.74	10.36		12.49	22.03	9.282										
Hansen				0.486													
Observations	2,301	2,301	2,301	2,301	1,640	1,640	1,640	1,640									

Note: This table shows 2SLS regressions of the effect of petroleum ownership regimes on discoveries and drilling activity. Columns (1)-(3) and (5)-(7) show first-stage results, while columns (4) and (8) show second-stage results for discoveries and (log) wildcats, respectively. The base petroleum ownership regime is Domestic ownership. $SW F$ is the Sanderson-Windmeijer F-test. Robust standard errors (clustered by country) in parenthesis: *** p < 0.01, ** p < 0.05, * p < 0.10, + p < 0.15. Table A1 contains summary statistics. See Section 2 for variable definitions and sources.

Table 4: Different proxies of exploration intensity

Dependent variable →	Wildcats (log) t+1	Well count (log) t+1	Exploration cost, log, t+1		Exploration intensity (Principal component) based on:	
			expensed	capitalized	(1)-(4)	(2)-(4)
Panel A: OLS	(1)	(2)	(3)	(4)	(5)	(6)
Partnership ownership	0.501*** (0.159)	0.400* (0.219)	0.399*** (0.152)	0.537** (0.225)	0.349*** (0.103)	0.255** (0.112)
Foreign ownership	0.536*** (0.207)	0.363 (0.341)	0.225 (0.238)	0.519 (0.365)	0.470*** (0.117)	0.252 (0.177)
Openness dummy	-0.229+ (0.158)	-0.065 (0.167)	-0.046 (0.170)	0.036 (0.206)	-0.087 (0.094)	-0.040 (0.092)
OPEC dummy	-0.296+ (0.196)	-0.411** (0.205)	-0.295 (0.277)	-0.219 (0.174)	-0.325*** (0.086)	-0.170* (0.094)
Country and year FE	Yes	Yes	Yes	Yes	Yes	Yes
Clusters	56	62	62	62	55	62
Observations	1,708	1,934	2,386	2,067	1,542	1,931
Panel B: 2SLS	(7)	(8)	(9)	(10)	(11)	(12)
Partnership ownership	1.102*** (0.275)	0.396 (0.334)	0.442 (0.342)	0.767** (0.380)	0.549*** (0.156)	0.350* (0.179)
Foreign ownership	0.738* (0.405)	0.404 (0.377)	-0.176 (0.631)	0.256 (0.525)	0.459** (0.188)	0.184 (0.245)
Openness dummy	-0.272 (0.329)	-0.216 (0.246)	-0.335 (0.380)	-0.004 (0.353)	-0.092 (0.176)	-0.098 (0.162)
OPEC dummy	-0.285 (0.259)	-0.416** (0.205)	-0.293 (0.367)	-0.335* (0.191)	-0.315*** (0.119)	-0.203* (0.109)
Country and year FE	Yes	Yes	Yes	Yes	Yes	Yes
Clusters	56	62	62	62	55	62
Hansen J-stat	0.225	0.517	0.797	0.248	0.582	0.548
SW F-test (Partnership)	12.49	35.65	14.01	20.95	23.88	35.54
SW F-test (Foreign)	22.03	43.38	19.18	33.20	31.71	42.99
SW F-test (Openness)	9.282	13.12	10.72	12.73	8.389	12.97
Observations	1,640	1,870	2,291	1,996	1,488	1,867

Note: This table shows 2SLS regressions of the effect of petroleum ownership regimes on various proxies of exploration intensity, including wildcats (reproduced from Table 3); well count (Rystad Energy); two types of exploration costs (Rystad Energy); and two variations of principal component measures. *SW F* is the Sanderson-Windmeijer F-test. Robust standard errors (clustered by country) in parenthesis: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$, + $p < 0.15$. Table A1 contains summary statistics. See Section 2 for variable definitions and sources.

Appendix

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).

Table A1: Descriptive statistics, 1960-2005

All country-periods	N	mean	s.d.	min	max
Oil & gas discoveries	3,087	0.15	0.49	0.00	5.00
Wildcats (log)	1,755	2.58	1.65	-0.69	9.19
Barrels of oil equivalent discovered (log +1, billions)	3,087	0.50	1.81	0.00	10.01
Wildcats (log +1)	1,969	6.41	2.72	0.00	13.79
Partnership ownership	2,604	0.39	0.49	0.00	1.00
Foreign ownership	2,604	0.35	0.48	0.00	1.00
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	0.37	0.21	0.00	1.00
Foreign ownership, regional average	3,071	0.37	0.25	0.00	1.00
Partnership ownership, other open countries average	2,415	0.53	0.08	0.20	1.00
Foreign ownership, other open countries average	2,415	0.28	0.13	0.00	0.67
Partnership, (other) OPEC countries average	2,604	0.35	0.13	0.00	1.00
Foreign, (other) OPEC countries average	2,604	0.20	0.23	0.00	1.00
Openness, inverse distance weighted	2,415	0.30	0.17	0.05	0.67
Wells drilled (log)	2,104	2.03	1.44	-0.00	7.12
Exploration cost expensed, (log, millions USD)	2,584	2.71	1.87	-3.24	8.81
Exploration cost capitalized, (log, millions USD)	2,248	3.97	2.02	-13.82	10.13
Exploration intensity (Principle component)	1,585	0.10	0.95	-1.83	3.39
Exploration intensity (Principle component, Rystad data)	2,101	0.19	0.90	-1.95	3.40

Note: This table shows descriptive statistics. See Section 2 for variable definitions and sources.

Table A2: Effects of petroleum ownership regimes over time, from 1-5 years after a change in ownership regime

Panel A					
Dependent variable →	Discoveries				
Dependent variable timing →	t+1	t+2	t+3	t+4	t+5
	(1)	(2)	(3)	(4)	(5)
Partnership ownership	0.292 (0.207)	0.402+ (0.259)	0.455* (0.259)	0.300+ (0.194)	0.455* (0.247)
Foreign ownership	0.428** (0.172)	0.656** (0.273)	0.732** (0.295)	0.677** (0.308)	0.754** (0.363)
Country and year FE	Yes	Yes	Yes	Yes	Yes
Clusters	62	62	62	62	62
Observations	2,301	2,301	2,301	2,241	2,181
Panel B					
Dependent variable →	Wildcats (log)				
Dependent variable timing →	t+1	t+2	t+3	t+4	t+5
	(6)	(7)	(8)	(9)	(10)
Partnership ownership	1.102*** (0.275)	1.009*** (0.266)	0.747** (0.313)	0.783*** (0.271)	0.554** (0.255)
Foreign ownership	0.738* (0.405)	0.659* (0.367)	0.463 (0.358)	0.380 (0.344)	0.045 (0.360)
Country and year FE	Yes	Yes	Yes	Yes	Yes
Clusters	62	62	62	62	62
Observations	1,640	1,597	1,554	1,509	1,464

Note: This table shows 2SLS regressions of the effect of petroleum ownership regimes on discoveries and drilling activity. Only second-stage stage results for the two main variables of interest are shown; all specifications control for OPEC membership and trade openness. The base petroleum ownership regime is Domestic ownership. *SW F* is the Sanderson-Windmeijer F-test. Robust standard errors (clustered by country) in parenthesis: *** p < 0.01, ** p < 0.05, * p < 0.10, + p < 0.15. Table A1 contains summary statistics. See Section 2 for variable definitions and sources.

Table A3: Accumulated experience since previous ownership regime

Dependent variable →	Discoveries t+1			
	(1)	(2)	(3)	(4)
Partnership ownership	0.292 (0.207)	0.225 (0.167)	0.443 (0.334)	0.354 (0.346)
Foreign ownership	0.428** (0.172)	0.396** (0.188)	0.531* (0.305)	0.494* (0.277)
Partnership experience since foreign		0.019 (0.026)	0.026 (0.025)	0.016 (0.024)
Domestic experience since foreign			-0.005 (0.025)	
Domestic experience since partnership			0.022 (0.033)	
Domestic experience since foreign or partnership				0.004 (0.009)
Openness	-0.006 (0.114)	0.102 (0.197)	0.254 (0.339)	0.088 (0.197)
OPEC	-0.015 (0.086)	-0.076 (0.171)	-0.054 (0.210)	-0.039 (0.158)
Country and year FE	Yes	Yes	Yes	Yes
Clusters	62	62	62	62
Hansen	0.486	0.881	0.917	0.813
SW F-test (Partnership)	14.15	3.913	46.59	4.250
SW F-test (Foreign)	18.74	10.50	24.41	5.952
SW F-test (Openness)	10.36	3.968	7.774	4.653
SW F-test (Exp. Part. since For.)		1.487	3.312	1.166
SW F-test (Exp. Dom. since For.)			3.386	
SW F-test (Exp. Dom. since Part.)			7.818	
SW F-test (Exp. Dom. since any)				6.017
Observations	2,301	2,301	2,301	2,301

Note: This table shows 2SLS regressions of the effect of petroleum ownership regimes on discoveries and drilling activity. Only second-stage stage results are shown. The base petroleum ownership regime is Domestic ownership. *SW F* is the Sanderson-Windmeijer F-test. Robust standard errors (clustered by country) in parenthesis: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$, + $p < 0.15$. Table A1 contains summary statistics. See Section 2 for variable definitions and sources.

Online Appendix

Table OA1: Instrumenting only ownership regime variables

Dependent variable →	Partnership		Discoveries		Partnership		Foreign		Wildcats	
	1st stage	Foreign	2nd stage	t+1	1st stage	Foreign	1st stage	Foreign	(log) t+1	2nd stage
	(1)	(2)	(3)		(4)	(5)	(6)			
Partnership ownership			0.292 (0.209)				1.097*** (0.278)			
Foreign ownership			0.434** (0.180)				0.745* (0.394)			
Partnership ownership, (other) regional average, t-1	-0.813** (0.327)	0.032 (0.181)			-1.263** (0.337)	0.230 (0.269)				
Foreign ownership, (other) regional average, t-1	-0.275 (0.310)	-0.003 (0.186)			-0.715** (0.307)	0.203 (0.232)				
Partnership ownership, (other) open countries average, t-1	-3.360*** (0.921)	0.724 (0.801)			-3.179*** (0.865)	0.732 (0.711)				
Foreign ownership, (other) open countries average, t-1	0.362 (1.284)	-2.847*** (1.087)			0.125 (1.235)	-2.466** (1.047)				
Partnership, (other) OPEC countries average, t-1	-1.554*** (0.417)	-0.231 (0.265)			-1.263*** (0.393)	-0.108 (0.188)				
Foreign, (other) OPEC countries average, t-1	-0.459 (0.464)	-1.101*** (0.265)			-0.367 (0.444)	-1.183*** (0.270)				
Openness, inverse distance weighted, t-1	-0.086 (0.580)	1.034* (0.593)			-0.190 (0.726)	0.591 (0.648)				
Openness dummy	0.114 (0.093)	0.172** (0.085)			0.150 (0.105)	0.110+ (0.075)				-0.294 (0.212)
OPEC dummy	0.234** (0.112)	-0.315** (0.123)			-0.014 (0.085)	-0.313*** (0.120)				-0.284 (0.258)
Country and year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Clusters	62	62	62	62	56	56	56	56	56	56
SWF	11.71	15.32			11.05	17.08				
Hansen			0.543							0.338
Observations	2,301	2,301	2,301	2,301	1,640	1,640	1,640	1,640	1,640	1,640

Note: This table shows 2SLS regressions of the effect of petroleum ownership regimes on discoveries and drilling activity, instrumenting only the petroleum ownership dummies and adding trade openness as a control variable. *SWF* is the Sanderson-Windmeijer F-test. Robust standard errors (clustered by country) in parenthesis: *** p < 0.01, ** p < 0.05, * p < 0.10, + p < 0.15. Table A1 contains summary statistics. See Section 2 for variable definitions and sources.

Table OA2: 2SLS estimations with fewer instruments

Dependent variable →	Partnership		Foreign		Openness		Discoveries t+1		Partnership		Foreign		Openness		Wildcats (log) t+1	
	1st stage		2nd stage		1st stage		2nd stage		1st stage		2nd stage		1st stage		2nd stage	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Partnership ownership				0.202*				1.151***								
				(0.103)				(0.358)								
Foreign ownership				0.308**				0.562								
				(0.120)				(0.514)								
Openness dummy				-0.024				-0.319								
				(0.112)				(0.326)								
Partnership ownership, (other) regional average, t-1	-0.827**	0.134	0.523**		-1.289***	0.265			0.315							
	(0.360)	(0.191)	(0.210)		(0.339)	(0.296)			(0.342)							
Foreign ownership, (other) regional average, t-1	-0.180	0.132	0.728***		-0.648**	0.315			0.744**							
	(0.320)	(0.202)	(0.245)		(0.311)	(0.252)			(0.318)							
Partnership ownership, (other) open countries average, t-1	-2.969***	0.627	3.060**		-2.661***	0.577			3.420***							
	(0.899)	(0.699)	(1.219)		(0.921)	(0.688)			(1.215)							
Foreign ownership, (other) open countries average, t-1	0.796	-2.849***	3.553***		0.690	-2.587***			3.765***							
	(1.178)	(0.937)	(1.136)		(1.143)	(0.931)			(1.088)							
Openness, inverse distance weighted, t-1	0.183	1.523**	2.653***		0.202	1.007			2.824***							
	(0.553)	(0.649)	(0.642)		(0.703)	(0.725)			(0.720)							
Country and year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Clusters	62	62	62	62	56	56	62	62	56	56	56	56	56	56	56	56
1st stage SW F-test	8.620	12.22	17.31		6.477	7.977			15.84							
Hansen				0.949												
Observations	2,301	2,301	2,301	2,301	1,640	1,640	2,301	2,301	1,640	1,640	1,640	2,301	2,301	1,640	1,640	2,301

Note: This table shows 2SLS regressions of the effect of petroleum ownership regimes on discoveries and drilling activity, dropping OPEC instruments. $SW F$ is the Sanderson-Windmeijer F-test. Robust standard errors (clustered by country) in parenthesis: *** p < 0.01, ** p < 0.05, * p < 0.10, + p < 0.15. Table A1 contains summary statistics. See Section 2 for variable definitions and sources.

Table OA3: 2SLS estimations excluding countries where discoveries precede legislation

Dependent variable →	Discoveries t+1		Wildcats (log) t+1	
	Horn	ASPO	Horn	ASPO
Excluding early discoveries according to →	(1)	(2)	(3)	(4)
Partnership ownership	0.460** (0.191)	0.450*** (0.156)	1.211*** (0.312)	1.333*** (0.364)
Foreign ownership	0.376*** (0.135)	0.324** (0.157)	0.895** (0.421)	0.857* (0.467)
Openness dummy	0.094 (0.121)	0.123 (0.130)	-0.471 (0.382)	-0.445 (0.392)
OPEC dummy, t-1	0.007 (0.096)	-0.094 (0.179)	-0.282 (0.258)	-0.644* (0.368)
Country and year FE	Yes	Yes	Yes	Yes
Clusters	35	26	30	21
Hansen J-test	0.247	0.195	0.533	0.475
SW F-test (Partnership)	20.05	21.15	23.43	31.63
SW F-test (Foreign)	33.67	18.08	73.54	45.29
SW F-test (Openness)	9.219	9.782	17.62	25.20
Observations	1,466	1,072	1,022	715

Note: This table shows 2SLS regressions of the effect of petroleum ownership regimes on discoveries and drilling activity, dropping countries where discoveries were made in a country before it adopts oil sector legislation. *SW F* is the Sanderson-Windmeijer F-test. Robust standard errors (clustered by country) in parenthesis: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$, + $p < 0.15$. Table A1 contains summary statistics. See Section 2 for variable definitions and sources.

Table OA4: Other institutions

Dependent variable →	Oil & gas discoveries t+1			Wildcats (log) t+1		
	(1)	(2)	(3)	(4)	(5)	(6)
Partnership ownership	0.294 (0.221)	0.286 (0.223)	0.303 (0.251)	1.122*** (0.289)	1.056*** (0.260)	1.227*** (0.305)
Foreign ownership	0.455** (0.191)	0.408** (0.206)	0.406** (0.172)	0.801* (0.430)	0.538+ (0.329)	0.882** (0.449)
OPEC dummy	-0.008 (0.085)	-0.003 (0.087)	-0.020 (0.089)	-0.281 (0.256)	-0.283 (0.272)	-0.229 (0.262)
Openness dummy	-0.025 (0.061)		0.004 (0.054)	-0.302 (0.216)		-0.354* (0.209)
PolityIV score	-0.002 (0.004)		-0.001 (0.004)	-0.011 (0.011)		-0.019 (0.013)
Openness dummy, regional average		-0.012 (0.113)			-0.077 (0.262)	
PolityIV score, regional average		0.005** (0.003)			0.012*** (0.004)	
Private civil liberties index			0.261 (0.277)			0.383 (0.621)
Property rights			-0.174 (0.315)			-0.530 (0.878)
Financial development			0.000 (0.001)			-0.001 (0.003)
OECD member			-0.518*** (0.135)			0.541 (0.396)
Country and year FE	Yes	Yes	Yes	Yes	Yes	Yes
Hansen J-stat	0.549	0.503	0.263	0.422	0.258	0.434
SW F-test (Partnership)	11.92	8.472	12.13	10.94	9.390	14.23
SW F-test (Foreign)	13.94	8.351	14.44	16.12	12.30	16.67
Observations	2,275	2,352	1,935	1,622	1,660	1,460

Note: This table shows 2SLS regressions of the effect of petroleum ownership regimes on discoveries and drilling activity. The base petroleum ownership regime is Domestic ownership. Robust standard errors (clustered by country) in parenthesis: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$, + $p < 0.15$. Table A1 contains summary statistics. See Section 2 for variable definitions and sources.