A Study of the Relationship between Mineral Rights Allocation and Oil Extraction Rates

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Abstract

This thesis examines the relationship between a country's allocation of mineral rights and the rate of extraction of that country's oil. Empirical analysis shows that countries with privatized oil industries extract oil more quickly than countries with nationalized industries. However, much of the relationship between mineral rights and extraction rates appears to stem from membership in OPEC. Thus, it is unclear whether mineral rights allocation has a direct effect on oil extraction rates.

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Though the earth, and all inferior creatures, be common to all men, yet every man has a property in his own person: this no body has any right to but himself. The labour of his body, and the work of his hands, we may say, are properly his. Whatsoever then he removes out of the state that nature hath provided, and left it in, he hath mixed his labour with, and joined to it something that is his own, and thereby makes it his property. It being by him removed from the common state nature hath placed it in, it hath by this labour something annexed to it, that excludes the common right of other men: for this labour being the unquestionable property of the labourer, no man but he can have a right to what that is once joined to, at least where there is enough, and as good, left in common for others.

-John Locke, *Second Treatise on Civil Government*

Capital is therefore not a personal, it is a social power. When, therefore, capital is converted into common property, into the property of all members of society, personal property is not thereby transformed into social property.

-Karl Marx, *The Communist Manifesto*

I. INTRODUCTION

Oil: in recent years, this three-letter word has come to dominate the worlds of policy, economics, national security, and international trade. With the United States consuming more than twenty million barrels[1]—roughly $1.25 billion—per day, the role and relevance of petroleum in our daily lives needs no introduction. In some cases, oil wealth has allowed small states to grow and prosper. In others, expropriation of natural resource rents has propped up some of most repressive dictatorships in human history. In all cases, however, the mechanisms controlling the extraction and sale of these prized hydrocarbons form a crucial link in the chain leading from petroleum to prosperity or poverty.

Property rights also featured prominently in the events that helped to define the twentieth century, and they promise to help shape the twenty-first. The great battles between Soviet socialism and Western free market capitalism were essentially fought over the rights of individuals to own and control property. These same battles are emerging again today.

Each government, in assigning or retaining the mineral rights to its oil, decides whether to nationalize its industry, often with a national oil company (NOC) controlling production, or to allow private-sector firms to control oil production.

The earliest NOCs, including Argentina's YPF and Mexico's Pemex, date to the early twentieth century. It was the surge of new NOCs (mainly in the Gulf states) in the 1970s, however, that changed the structure of the global oil industry. Given oil's strategic importance and the growing prevalence of state ownership and participation in the industry, many countries grew wary of ceding control of their oil wealth to private—

[1] Estimate from CIA World Factbook 2006

and usually foreign—oil companies. Most NOCs today participate both in upstream (exploration and production) and downstream (refining, marketing, etc) activities, but I will focus on their role in upstream oil production in this paper. The actual extraction of oil from the well presents the critical stage where property rights (mineral rights, when referring to oil) matter most. The property rights at this stage determine who owns the oil once it emerges from the ground and who controls the rate at which the extraction takes place.

With the Iraqi parliament trying to control its transitional democracy, the question of how to manage that country's immense oil reserves has sparked many international debates between scholars, economists, geologists, politicians and activists. The central question, it seems, is who will own and control those reserves. In February 2006, a negotiating committee submitted a draft arrangement for assigning mineral rights to the Iraqi cabinet. According to a report in *The New York Times*, sources indicated that foreign oil companies would participate in Iraqi oil development, though the central government in Baghdad will retain "substantial control over revenues" and the right to review contracts with foreign oil companies (Glanz, 2007).

The oil extraction rate refers, as the term implies, to the rate at which oil is withdrawn from the ground. The extraction rate varies widely among oil-producing states, and carries important economic and environmental consequences. Some governments have expressed concern over hasty depletion of their finite reserve pools and the threats to a sustainable government revenue source this depletion poses. Others have expressed concern over intergenerational equity, with velocious production today depriving future generations of an important commodity. It is widely held that extracting oil too quickly can reduce natural subsurface pressure and trap petroleum, requiring the trapped oil very expensive to extract. For these and other reasons, policymakers should look very carefully at the rate at which oil is extracted in their countries.

This thesis will explore the interplay between oil, mineral rights allocation and extraction rates. What relationship exists between the assignment of ownership and control over oil and the rate at which that oil is extracted in the world's major oil-producing nations? Do national governments endanger the long-term accessibility of their oil reservoirs by ceding control over extraction rates to private companies? While various political, economic, social and scientific factors affect the rate of extraction in the world's oil producing nations, I will concentrate on how the assignment of mineral rights affects this rate.

My thesis proceeds as follows. In Section II, I explore the literature on property rights, extraction rates, and oil industry organization in selected countries. In Section III, I outline the spectrum of mineral rights allocation that I use in the study. In Section IV, I develop hypotheses about the relationship between property rights and extraction rates. In Section V, I introduce the statistics on oil wealth and the data used in the study. In Section VI, I present a statistical comparison, revealing any differences in the mean extraction rate that accompany cross-country differences in the assignment of property rights in the oil industry. In Section VII, I present a discussion of the results found in Section VI, and offer conclusions on the study in Section VIII.

II. LITERATURE REVIEW

Property Rights

In examining mineral rights allocations, many economists study common-property problems surrounding oil extraction. These studies tend to focus on the single-field common pool problem, yet they provide an important backdrop to any analysis in the variability of oil extraction rates across countries and industry structures. The technology behind oil drilling creates a dilemma where pumping at a faster rate today will reduce the amount of extractable oil available in the future. If the rate of extraction is too fast, the reservoir loses subsurface pressure and pockets of oil can become trapped, rendering them unreachable or requiring prohibitively expensive technology for extraction (Viscusi, et al, 2005).

This common property problem manifests itself when two or more wells, owned by two or more different agents, draw from the same reservoir. Each individual owner will pump as quickly as possible to maximize short-term profit, as any oil he leaves in the ground today is available not just for him, but for any of the owners to extract in the future. For every barrel an owner leaves in the ground instead of extracting, he loses a portion of that hypothetical barrel to his co-owners’ drilling. Since the other agents’ drilling reduces the amount of oil available for him to drill in the future, each individual agent will drill at a faster rate under co-ownership than he would if he owned the entire reservoir himself. In doing so, however, the amount of oil available in the future to the group decreases, such that each owner, in seeking to maximize his own short-term profits, actually threatens his long-term potential for profit.

This phenomenon is neither novel nor negligible. As far back as 1914, the U.S. Bureau of Mines estimated that common pool losses equaled a quarter of total domestic oil production. The Federal Oil Conservation Board estimated that recovery rates (the amount of oil that can be extracted from a given well) dropped from roughly 90 percent under complete ownership to 25 percent or less in common pool reservoirs.[2]

Ronald Coase helped bring the common pool problem to the public's attention with his 1960 article, "The Problem of Social Cost." In the paper, Coase acknowledged the tremendous negative externalities parties can impose on society when they bear disproportionately low portions of the costs and consequences of their actions. He argued that, as long as transaction costs remain low, society could overcome these losses by assigning property rights to one party and allowing a market to arise in which these property rights are traded.

Henning Bohn and Robert T. Deacon (2000) take the analysis of property rights and extraction rate variation in a different direction. They argue that the strength or weakness of the property rights system in a given economy can manifest itself through two competing phenomena.

First, they argue, "Weak ownership forestalls the physical and human-capital investments needed for economic development" (526). In their view, outcomes in capital-intensive extractive industries like oil production are closely related to property rights institutions and the degree of risk in the environments in which they exist. In low-risk environments with secure property rights and a stable rule of law, firms will invest in capital "to maximize the present value of output minus investment cost, taking into account the probability that future profits will be expropriated" (529). Thus, in an

[2] Cited in Yuan p. 2

environment with a high perceived probability of capital loss (due to a weak property rights system, political instability or weak rule of law), firms will under-invest in capital, leading to declines in extraction rates, ceteris paribus.

On the other hand, however, high ownership risk could yield higher extraction rates. With the availability of future resources uncertain in a high-risk environment, firms will tend to extract as much as possible in the present period, given the limitations of distribution and storage channels. The authors find, however, that while this second phenomenon exists in some natural resource industries (timber harvesting, for example), it does not apply to capital-intensive industries like oil production.

The authors conclude that "insecure ownership slows the extraction of petroleum" by decreasing investment in capital equipment needed for extraction. Thus, they argue, "stocks of capital-intensive resources should remain largely unexploited in poor countries, because the lack of ownership…hampers accumulation of capital needed for extraction" (527). My study will control for such variables as wealth and corruption that may mediate the relationship between mineral rights allocation and extraction rate.

Extraction Rates

Others have focused more narrowly on the consequences of accelerated extraction. Many economists studying the extraction of depletable natural resources have attempted to derive a profit-maximization function for producers, given the finite (or even declining, if extracted from a well too fast) amount of extractable oil available. Holding all else constant, producers will seek to maximize the present value of returns, given information on the quantity of known reserves, the price they expect to receive from the oil once extracted, and the cost they expect to incur extracting it.

Much of the debate surrounding natural resource depletion policy stems from Harold Hotelling's 1931 article, "The economics of exhaustible resources," in which he proposes an optimal rate of natural resource depletion. Among the first to apply a neoclassical economic analysis to the study of natural resources, Hotelling proposes a hypothetical publicly-owned pool of a nonrenewable natural resource. "How should exploitation take place for the greatest general good, and how does a course having that objective compare with that of the profit-seeking entrepreneur," he asks (139). Hotelling argues that legislation promoting conservation results in a suboptimal rate of extraction for society. This lower rate serves monopolists' interests by artificially restraining supplies of the mineral and driving prices up.

In modeling the natural resource producer's optimal extraction rate, Hotelling notes that, when a producer can affect prices, he will choose a rate of extraction such that the mineral's net price (price minus marginal cost) will rise over time in step with the interest rate. By extracting too much today, he could flood the market and reduce prices. By drilling too slowly, however, he may "postpone profits farther into the future than the rate of interest warrants" (139).

Hotelling's ideas have remained prominent in the natural resource literature to this day. In recent years, economists have debated the best measures of cost to use in calculating Hotelling's price-driven optimal extraction rate. Cairns and Davis (1998), Eisenhauer (2003) and others have argued for alternative measures of the producer's net price in modeling the optimal extraction rate by including average cost, among other measures, in their equations.

Given these ideas about optimal price-driven extraction rates, M. King Hubbert proposed a model for predicting trends in worldwide oil extraction rates. When Hubbert presented his “peak oil theory” to the American Petroleum Institute in 1956, the bell-shaped Hubbert Curve of oil production rose to immediate prominence in literature concerning optimal oil extraction rates. Hubbert predicts that when oil is first discovered, production will increase at an accelerating rate as new exploration activity discovers new reservoirs and technological improvements allow for faster and more efficient extraction. At some point, however, this production will peak. As new fields become increasingly difficult to find, and the geology and technology of existing wells lead to production decreases, overall production rates will steadily decline until production reaches zero.

Hubbert predicted in 1974 that world oil production would peak in 1995 (Grove, 1974), but changes in consumption in the 1970s and 1980s threw his prediction off track. While Hotelling’s model has held enormous sway in the field for nearly a century, its application to this study is less straightforward. In today’s global oil market, large producers and cartels (i.e. OPEC) can certainly affect prices, but smaller producers’ production decisions will exact a much smaller effect on global prices. Holding variations in quality, density, gravity and other distinguishing characteristics of different oil sources constant, crude oil in the world market is relatively fungible. Thus, small non-OPEC producers can vary their extraction rates without drastically affecting global prices.

Property Rights and Extraction Rate

Expanding on Hotelling's work, Varouj Aivazian and Jeffrey Callen (1979) show that a firm's "optimal extraction rate is highly sensitive to the nature of the industry structure governing the production of the resource" (83). Because of both the collective property problem and the ability of monopolists to affect price, Aivazian and Callen argue that industry structure and competition play important roles in determining oil extraction rates. Aivazian and Callen's research supports the idea that international variation in oil extraction rates could be related to the structure of property rights governing the extractive industries in those countries. However, given the nature of the global oil market and the presence of many oil fields within a given country, it is unclear whether their model applies to this study.

Intergenerational Equity

R.M. Solow (1974) discusses natural resource depletion with respect to intergenerational equity—the notion that per-capita consumption remains constant over time. He finds, however, that earlier generations have little obligation to conserve nonrenewable natural resources for their descendants. Assuming that natural resources and capital are inputs in the production of a given bundle of goods, Solow argues, from a utilitarian perspective, that advances in technology and capital accumulation can compensate for declining stores of natural resources. Thus, he argues, "Earlier generations are entitled to draw down the [resource] pool (optimally, of course!) so long as they add (optimally, of course!) to the stock of reproducible capital" (41).

Bohn (2003) also writes that policy makers tend to see future generations as more risk tolerant than current generations. Such a finding may support the hypothesis that current generations will extract oil at a faster than optimal rate if they believe that future generations will bear the risk of depleted oil reservoirs.

National Oil Companies

While many scientists have studied the factors moderating oil extraction rates, national oil companies have, for the most part, escaped the economic lens. As Charles McPherson (2003) points out, “there has been surprisingly little systematic research on NOCs. Literature on NOCs is limited…and organized, comprehensive data is virtually nonexistent”(184). Some studies, however, have highlighted the implications of states' mineral rights allocation choices.

Many economists hold that state-owned enterprises are generally run less efficiently than private-sector corporations that face intense scrutiny from shareholders and debt raters (Viscusi, et al). Particularly in authoritarian states, managers of national oil companies are subject to far less scrutiny than their private-sector counterparts. As a result, these managers make production decisions that deviate from Hotelling's or other extraction optimization models.

In “Global Oil and the Nation State,” Bernard Mommer (2002) explores the history of public and private oil management. According to Mommer's study, “public mineral ownership subject to proprietorial governance offers a greater variety of possibilities than private mineral governance; and one may also expect the former to be less stable than the latter” (96).

Mommer seems to view state-owned companies as the most efficient option for oil-producing countries. He argues that NOCs place the state "in a position to take the fundamental decisions regarding the flow of investment, volumes and prices," allowing it to "focus on maximizing ground rent" (97). He does, however, acknowledge some costs associated with such national oil companies, including lost efficiency and productivity. Because the actions of NOCs are less visible and transparent than those of their private-sector counterparts, managers become susceptible to complacency and corruption, often leading to inefficient production decisions. Policymakers need to balance these consequences against the above benefits that NOCs can provide.

III. Property Rights and Oil: A Closer Look

In this section, I will explain the three different categories of mineral rights allocation into which I place this study's countries. Inevitably in such a study, some countries fail to fall neatly into one of the categories, and are more difficult to classify than others. In these ambiguous cases, I justify and explain why each mineral rights regime was classified as nationalized, privatized or production-sharing agreement (PSA).

According to a report by the Oxford Institute for Energy Studies (Bindemann, 1999), oil reserves are legal property of the state in every country in the world, except for the United States. The distinction, then, comes in the control of the development of fields (the upstream oil production industry). In even the most staunchly free-market economies of the world, the government obtains some revenue from oil production, whether through taxation, royalty payments, licensing fees, or some other contractual measure. However, by establishing a continuum of control over the extraction of the (almost universally state-owned) oil reserves, we can assess the effects of different control mechanisms on the management of this public resource.

This continuum could include dozens of categories, ranging from full nationalization of oil operations to buyback agreements, joint ventures, competition between NOCs and international oil companies for licenses, and full private concessionary systems. However, given the limited number of significant oil-producing nations (43 in this study), I decided to overlook some idiosyncrasies and tried my best to roll this continuum into three categories: nationalized, privatized and PSA. These three categories will allow for the best quantitative analysis of the relationship between mineral rights allocations and oil extraction rates.

Kirsten Bindemann has provided one of the most extensive analyses of the options facing petroleum-producing states in assigning rights to drill for oil. Bindemann distinguishes between four types of contracts: concessions, production-sharing agreements, service contracts and joint ventures. Greg Muttitt (2005) studied the way property rights dictate control over oil production in various countries, and argues, "There are essentially three models a country may choose from for the structure of its oil industry, plus a number of variations on these themes" (5). Muttitt's model varies slightly from Bindemann's, noting that joint ventures really offer only a slight variation on the production-sharing agreement. These studies provide the basis for the three groups I use in examining mineral rights allocations in oil producing states.

Nationalized

First is the nationalized model, in which the state controls the oil reserves, makes all production decisions and keeps all revenue. Under this model, the government believes that the state owns the hydrocarbons beneath the soil or ocean in the country's territory. As a result, the government controls all aspects of extracting these hydrocarbons and is often reluctant to cede control over any part of the extraction process to foreign entities. Generally, a national oil company will coordinate the exploration and production, and accrued revenues stay within the realm of government control.

In some instances, national oil companies contract with private-sector companies, often foreign, to conduct part of the production process. These relationships usually exist as technical service contracts or buyback agreements, with well-defined objectives, limited time periods and fixed fees.

In a buyback agreement, a private-sector oil company invests capital in developing an oil field, but the government retains the mineral rights and the profits from the project. In exchange for its investment, the company receives a fixed rate of return on its capital, agreed to in the contract. As this arrangement brings the mineral rights under the exclusive stewardship of the home government, it should, in theory, mitigate the common pool problem more effectively than any other arrangement. However, in countries with nationalized oil industries, even where the private sector attains technical service or buyback contracts, property rights to the oil are never transferred to the private companies.

In some states—Oman and Norway, for example—national oil companies have sold shares over equity markets. Since this thesis is primarily concerned with the effects of varying degrees of and mechanisms for government control of oil production, I will treat partially-public companies as national oil companies if the state owns more than 50 percent of the company. In owning 50 percent or more of the company's outstanding shares, the government still holds a majority stake in the company and exercises control over production decisions. For example, although Statoil is traded over the New York Stock Exchange and the Oslo Stock Exchange, the Kingdom of Norway retains 70.9 percent of the company's equity, and thus retains control over the company and its production decisions.

In some states, both the national oil company and the private sector can hold mineral rights to oil. Because the government allows non-government entities to hold mineral rights, I consider countries with these cases to have privatized oil industries, except in cases in which the national oil company produces more than 90 percent of domestic oil. Because I am studying the link between mineral rights allocation and extraction rates, classifying a country in which an NOC produces 90 percent of the country's oil as privatized would introduce a serious flaw to the econometric analysis.

The express mail industry in the United States presents an analogous situation, in which a state owned enterprise competes in certain markets with private sector firms. While the United States Postal Service—an organization owned and controlled by the federal government—occupies an important share of the overnight-delivery market, one would be hard-pressed to classify express mail as a nationalized industry, given the presence of UPS, FedEx and DHL, among others.

Privatized

Instead of producing the oil itself, a government can grant concessions to private sector companies to explore and/or drill for oil. Under such a system, the government cedes the mineral rights (often for a limited period of time) to a company or consortium. The company then invests capital in developing the licensed reservoir and owns the oil as soon as it leaves the ground. The government would then collect taxes and/or royalties on the profit the company earns from production, but ownership and control of the field rests with the licensed company for the period the license covers.

In some cases, the NOC competes with private sector companies for exploration and production contracts—perhaps most notably in Brazil. In such cases, the country will fall into the privatized category, unless the NOC has dominant market share. While the NOCs often control major portions of their countries' oil industries, private companies are free to compete and are entitled to the property rights to the oil as soon as it leaves the ground.

PSA

Third, and most complex, is the production-sharing agreement. PSAs are common in many developing nations, and seem to be the favorite option for major international oil companies (Muttitt). In theory, the state still controls the oil under a PSA—or at least controls it in conjunction with the other parties in the PSA. In practice, however, the international oil companies often hold substantial stakes in the agreements and control many of the production decisions. Some energy analysts, including Daniel Johnston (1994), have questioned whether any functional difference exists between PSAs and concessionary systems.

PSAs are most common in developing countries where the governments rely on foreign investors to provide the capital needed to bring a field to production. Often, these home governments lack the capital themselves, or prefer to share the risk of exploration and production activities with foreign entities.

The government grants a concession or license for the private sector company to explore for and drill oil. The foreign company bears most of the risk under PSAs. The first quantities of oil produced from the field in question, often called “cost oil,” are allocated to the foreign company to compensate it for its investment costs and risk. Once costs have been recovered, the remaining “profit oil” is split between the foreign companies and the government in an agreed upon proportion. Countries with more extensive oil deposits naturally attract more prospective investors, and can sometimes leverage this into more favorable PSA terms (i.e. larger shares of profit oil).

National oil companies can participate further in PSAs by joining the consortia of companies that produce the oil as part of a joint venture (JV). In these cases, the state receives not only its share of the profit oil (as specified in the contract) and whatever taxes the private companies owe on their profits, but it also retains the national oil company's share of the consortium's profits. Because of the limited sample in this study, I do not distinguish between PSAs and JVs in placing each country into the designated category.

The PSA, in its modern incarnation, originated in Indonesia in the 1960s and is now widely employed by countries around the world with economies in transition (Paliashvili, 1998). The following table helps to explain the differences in the above categorizations.

Type of Agreement	Petroleum Ownership	Foreign Company Control
Fully Privatized (Tax/Royalty System)	At point of production	Extensive
Production Sharing Contract (PSA)	At point of export	Proportional
Fully Nationalized (buyback agreements)	No title transfer	Minimal to none

Source: Al-Attah and Alomair (2005)

Explanations

The above classification system accounts broadly for the variations in each state's institutions for governing oil extraction. However, in such a cross-country analysis, certain idiosyncrasies inevitably appear that make it difficult to assign each country into one of the above categories. The notes below help to explain how I assigned each country to its group when ambiguities arose.

Angola: Angola is currently a member of OPEC, but only joined in 2007. It is not currently subject to any production quotas and was not a member state during the years of production included in this study. Thus, it is not counted as an OPEC member for this study.

Argentina: While still dominated by Yacimientos Petrolíferos Fiscales (YPF), the Argentine upstream (exploration and drilling) oil production sector underwent major privatization in the 1990s as the Argentine economy spiraled into crisis. The Argentine government sold shares in YPF throughout the 1990s, and Repsol, a major Spanish oil company made a successful takeover bid in 1999, leading to the formation of Repsol YPF (Rehak, 1999). Pan American Energy, Chevron, and Petrobras Energía also have significant projects in the country. The Argentine government created Enarsa, a new state-owned oil company, in 2004 to promote exploration activity. Enarsa, however, remains a minor player in the Argentine oil sector and had little to no impact on 2002-2004 production, which this study examines (Energy Information Administration [EIA], Argentina Country Analysis Brief [CAB]).

<u>Brazil</u>: While the government opened the sector to limited competition in 1997, state-controlled Petrobras still dominates oil production in Brazil. Some energy analysts point to high state and federal taxes and poor licensing terms from the National Petroleum Agency to explain the minimal foreign investment since 1997. Despite a slight increase in foreign investment, Petrobras controlled more than 95 percent of domestic crude oil production in 2004 (EIA, Brazil CAB). Thus, I have listed Brazil's oil industry as nationalized.

<u>China</u>: As part of a major restructuring in the 1990s, the Chinese government divided its oil interests into three companies, each of which controls several subsidiaries: the China National Petroleum Corporation (CNPC), The China Petroleum and Chemical Corporation (Sinopec) and the China National Offshore Oil Corporation (CNOOC). These state-owned companies have contracted with multinationals for certain exploration and production activities. However, according to Chinese law, China's NOCs are guaranteed a 51 percent stake in any joint venture. The state-owned companies can also legally take over operations once the contracted firm has recovered its initial costs (EIA, China CAB).

CNOOC and Sinopec are listed on the NYSE and other international exchanges, but the Chinese government holds more than 70 percent of outstanding shares in each company. Petrochina, CNPC's largest subsidiary is also publicly listed in Hong Kong and New York, with CNPC holding 90 percent of outstanding shares.

<u>Colombia</u>: Colombia has also undertaken significant reforms of its oil industry and has emerged as a major oil exporter to the United States in recent years. State-owned Ecopetrol remains a major player in the Colombian oil industry; however, foreign companies can now hold 100 percent stakes in fields they operate. Under these licensing rules, Ecopetrol controlled 58 percent of production in 2004 and 54 percent in 2003 (Ecopetrol).

<u>Denmark</u>: In 1996, the Danish Energy Authority introduced the Open Door Procedure. Under this policy, all companies are free to compete for exploration and drilling licenses. The Danish government retains a uniform 20 percent of pre-tax profits from oil drilling. Since this "royalty" is a fixed percentage, it really functions as a tax, not a controlling stake for the government in any drilling operations and private sector companies remain free to operate their own rigs (Danish Energy Authority). Thus, I have listed Denmark as a privatized industry, with the government collecting taxes from its licensees.

<u>Ecuador</u>: State-owned Petroecuador's share in domestic oil production has steadily declined since 2001, with the company controlling around 37 percent of production in 2004 (EIA, Ecuador CAB). Thus, I have assigned Ecuador to the privatized category for this study.

<u>Iran</u>: Article 153 of the Iranian constitution prohibits foreign control over any natural resources, including oil. Thus, foreign involvement in the Iranian oil industry is limited to buyback agreements (Al-Attah and Alomair). Iran conducts buyback agreements with foreign oil companies, in which the companies invest in the production process, but do not hold any rights to the oil that is produced. The agreements cover a fixed period of time and stipulate a certain rate of return for the foreign company (van Groenendaal and Mazrati).

Kazakhstan: In 2005, the government of Kazakhstan "amended the subsoil law to preempt the sale of oil assets in the country" (EIA, Kazakhstan CAB). In that same year, the government required that state-owned company KazMunaiGaz must own at least 50 percent of any new production sharing operation and that it must act as a contractor in all offshore PSAs as well. These changes certainly push Kazakhstan toward the nationalized group. However, they occurred in 2005, after the time period studied for this thesis. Since the study covers 2002-2004, Kazakhstan remains in the PSA group.

Kuwait: Kuwait has entered into a number of Operating Service Agreements (OSAs), similar to Iran's buyback agreements. Under these OSAs, foreign companies extract petroleum, which Kuwait contracts to buy at an agreed-upon price. The foreign companies are neither allowed to hold any equity in the production nor to explore for new fields (Al-Attah and Alomair) in Kuwait's nationalized oil industry.

Norway: Although ConocoPhillips, ExxonMobil and BP, among other foreign companies, have invested in the enormous Norwegian oil wealth, the Norwegian government dominates domestic production. State-owned Statoil is one of the world's leading producers. Although Statoil offered a limited number of shares on the Oslo Stock

Exchange in 2001, the state still holds more than 70 percent of the company. Statoil controls the majority of oil production in Norway. The Norwegian government also holds a partial stake in Norsk Hydro, a major energy and aluminum company. Multinational companies wishing to tap into Norway's reserves must act in conjunction with Statoil (EIA, Norway CAB).

Oman: Oman has a unique system for managing oil production. Instead of a traditional NOC, Oman relies on Petroleum Development Oman (PDO), a consortium consisting of the Omani government (60%), Shell (34%), Total (4%) and Partex (2%) to produce oil. PDO produces roughly 85 percent of Oman's oil, with the remaining fraction coming through PSAs (EIA, Oman CAB). Given the significant foreign involvement, the absence of any direct concessionary system and a significant number of PSAs, I have classified Oman in the PSA category.

Thailand: PTT Exploration and Production, the state-owned oil company in Thailand is publicly traded, however, the government of Thailand still holds a controlling (more than 66 percent) stake in the company. ChevronTexaco and CNPC of China, among other international companies, have won exploration licenses in the partially privatized Thai oil industry (EIA, Thailand CAB). Because the private sector competes with PTT, I have classified Thailand as privatized.

Trinidad and Tobago: State-owned Petrotrin controls around 50 percent of domestic production and retains small stakes successful exploration ventures. However, multinationals also flourish in Trinidad and Tobago's major reservoirs in the Caribbean

Sea and Atlantic Ocean (Moon, 2006). Because of the strong presence of multinationals in the market, I classified Trinidad and Tobago as privatized.

UAE: Each of the United Arab Emirates controls its own oil, with Abu Dhabi controlling more than 90 percent of the UAE's reserves (United Arab Emirates). The Abu Dhabi National Oil Company operates primarily through joint ventures (a form of PSA) with multinational oil majors.

Each government must decide how to allocate the mineral rights to the oil within its borders and can choose a system ranging from concessionary to fully nationalized. The rest of this paper will examine the consequences this decision has on the rate at which the country's oil is extracted.

IV. HYPOTHESES

Existing theories and literature on oil ownership and extraction suggest competing hypotheses. In this section, I develop the hypotheses regarding the relationship between the structure of oil ownership in a given country and the rate at which the oil is extracted.

A. Private Ownership Leads to Faster Extraction than State Ownership

One set of theories suggests that, given the characteristics that usually define state-owned oil companies and large corporations (such as BP or ExxonMobil) and the motivations that drive these companies, private ownership of oil will lead to faster extraction from the ground.

Shareholder Pressure May Lead to Increased Extraction Rates for Private-Sector Firms

Most major oil companies face pressure from shareholders and financial markets to secure strong short-term profits. Such pressure could lead to myopic policies and over-extraction that erodes long-term profit potential. While many NOCs have offered shares to the public, including Norway's Statoil and China's CNOOC, governments almost always maintain majority stakes and effective control over the companies. While managers of private sector firms are often forced to offer transparent reports to shareholders, national governments seldom face the same pressure. This ownership and control allows the NOCs to act in a way that will protect long-term profit.

As Saudi Aramco President and CEO Abdallah S. Jum'ah (2004) told a conference on global energy security, "the short term results that financial markets typically desire can undermine some companies' ability to adapt a long-term view. At Saudi Aramco we are fortunate in that we are not subject to undue pressure for short term results [and] this dynamic has allowed us to maintain a much higher reserve to production ratio than is typical for our industry (Jum'ah, 2004)."

Under Concessionary Systems, Free-riding Companies Will Extract Oil Quickly

Many countries that operate under concessionary licensing systems grant private companies mineral rights to drill specific blocks for a limited number of years. In such cases, the companies are really *renting* the mineral rights, not *owning* them. Since the companies have no stake in the long-run viability of the reservoirs, they will over-drill during the period of their lease. As discussed above, over-extraction can trap pockets of oil, rendering them inaccessible for the future. The home government or the next holder of the lease will suffer as a result. These future production losses are foreseeable and avoidable with the right set of mineral rights allocations.

Weak Property Rights Will Affect Extraction Rates in the Private Sector

As Henning and Bohn (2000) argue, private companies will accelerate their extraction when they feel their property rights are threatened. So, in countries with weak rule of law, corrupt governments or non-secure property rights, private-sector firms will likely feel more pressure to over-extract than NOCs would. For example, managers of a multinational oil company might fear that an over-reaching government in a given country might seize their company's assets and fields, as the Russian government allegedly did in the Yukos Oil Company scandal. In such a case, the managers would increase current production, perceiving their future profits as threatened by the prospects of government action. NOCs, inherently tied to their governments, are not subject to the same pressure.

Mark Thoma (2006) has proposed another link between nationalization and production rates. He argues that as governments increase their ownership stakes in oil production, or seize assets of private companies operating in their jurisdiction, foreign companies will reduce their capital investments. This decreasing investment, Thoma argues, decreases long-run production rates as companies fail to replace aging and obsolete equipment. Nationalization will also make companies less likely to invest in exploration activities, as the threat of seizure of profits or assets reduces the expected value of their profits from oil production.

Other Factors Affecting Extraction Rate Variation

Several other factors support the hypothesis that NOCs will extract oil at a slower rate than private sector companies. For one, NOCs may also factor intergenerational equity considerations into their oil production decisions. Some state-owned companies see themselves as guardians of the nation's, and, by extension, the people's oil wealth, and may feel obligated to protect this wealth for future generations. This reasoning would support the hypothesis that national oil companies tend to extract oil at a rate slower than foreign companies'.

Indeed, Mr. Jum'ah believes that NOCs can mitigate the common pool ownership problem and prevent over-extraction. By maintaining a low and steady depletion rate, NOCs can more effectively maximize long-term profit than can private sector firms.

Low depletion rates also harmonize with other goals that help to maximize profit, including OPEC's supply restriction. Some OPEC-member NOCs may even appeal to environmental concerns or "peak oil" depletion theories to justify their production decisions and defend themselves against accusations of cartel behavior.

According to Jum'ah, the average depletion rate of a Saudi Aramco field hovers around two percent per year, less than half the industry average.[3] When building facilities for the vast Sheiba field, Aramco sought to achieve a depletion rate of less than one percent per year, and has met that goal through the first stage of production. Jum'ah argues that this low depletion rate is attributable to Aramco's position as a national oil company, and that private sector firms operating in the same fields would extract at a faster rate. As he explained, the "key principles that govern the management, production and depletion" of Aramco reserves include maximizing ultimate recovery of hydrocarbons, reservoir monitoring and "gradual depletion."

Geopolitics can also play an important role in determining the rate of oil production. In 1973, for example, the Organization of Arab Petroleum Exporting Countries (OAPEC) shut down oil exports to Western nations that supported Israel in the Yom Kippur War. To this day, energy security remains paramount in the minds of diplomats and foreign policy experts. The threat of production decreases or export embargoes constantly influence our posture toward Venezuela, Iran, the Gulf states and other oil exporters. Any time a government controls a nationalized oil industry, politics stand to affect production decisions.

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[3] Some, including energy investment banker Matthew Simmons (2005), challenge the extent and accessibility of Saudi Arabia's remaining reserves. Saudi Aramco, however, claims that it has succeeded in maintaining low depletion rates.

B. Private Ownership Leads to Slower Extraction than Government Ownership

There is also reason to believe that national control could lead to faster depletion than private control would. In some cases, major importing nations—including the Untied States—exert pressure on suppliers to maintain a steady stream of oil inputs, often resulting in faster extraction rates. National oil companies, inherently tied to their home governments and their foreign policy, may more willingly accede to political demands from other governments than multinational private-sector oil companies.

Political Pressure on NOCs Affect Extraction Rates

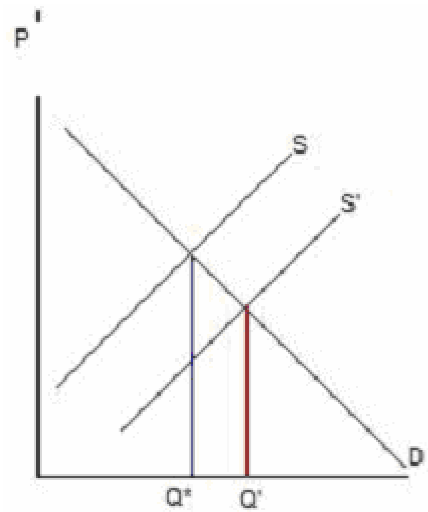
While political pressure can lead to cuts in production (e.g. the 1973 oil crisis), it can also lead to accelerated extraction. Producing nations might increase production to meet the import needs of world powers in exchange for military assistance, favored trade status, decreased scrutiny of human rights violations, or other perks. For example, Matthew Simmons (2005) has argued that undue pressure from the United States is leading Saudi Arabia to overproduce its oil fields, possibly leading to sub-surface pressure loss and damaged reservoirs. Such pressure would not work as well with private-sector companies, who respond to markets and shareholders more than diplomats and political leaders. So, this political pressure would seem to affect extraction rates more for countries in the nationalized group—where political leaders can control NOCs and their production rates—than in the privatized and PSA groups.

In a similar vein, the United States has used its military strength to ensure that its oil suppliers continue to produce oil at a sufficient rate. For example, the U.S. has gone to great lengths to ensure a steady stream of oil imports from Colombia in recent years. Late in his presidency, Bill Clinton promised $1.6 billion in military aid to Bogota, including helicopters, communications equipment and training (Klare, 2000). With Colombia supplying more than ten million barrels of oil to the United States each year, government officials have taken serious interest in securing the supply route (EIA, U.S. Imports by Country of Origin). In 2003, President Bush sent U.S. troops to Colombia's Arauca province to train troops in intelligence gathering and counterinsurgency tactics. The troops hope to prevent further attacks by Marxist rebels against the Cano Limon pipeline, which supplies the U.S. with a significant portion of its foreign oil (BBC, 2003). While such intervention is not unique to Colombia, home governments may be more likely to welcome foreign troops if they hold a controlling stake in their oil than if most of the oil belongs to multinational companies.

Some NOCs engage in politically motivated activity at home that could lead to overproduction. Perhaps most prominent of these activities are the subsidies common in developing countries. Governments with NOCs often try to win favor with their citizens by offering gasoline at prices well below market levels.

For many years, Indonesia’s Pertamina subsidized petroleum products at $3 billion annually, although the government significantly reformed its subsidization policy in September 2005 (McPherson, 190). In Iran, gasoline has hovered under 50 cents per gallon in recent years, supported by major subsidies on imported refined petroleum products. Such subsidization policies from NOCs could distort purchasing incentives and increase the quantity of oil demanded, perhaps creating undue pressure for faster extraction. Figure 4.1, below, depicts this situation. S represents the supply function for gasoline and S^{l} represents the gasoline supply curve with subsidies. Correspondingly, the quantity of gasoline demanded shifts from Q* to Q^{l} under a subsidy program. Thus, a subsidization program in a given country could lead to excess oil production equal to Q*-Q^{l}. \

Figure 4.1



Summary

Political, financial, and engineering factors all bear on a company's decision on how quickly to extract its oil. As I have shown in this section, pressure from shareholders and other operating conditions may lead private sector oil companies to extract oil quickly, in search of short-term profits. On the other hand, political pressure—domestic or foreign—may cause national oil companies to extract at suboptimal rates.

V. DATA

In this section, I discuss the data used in the empirical analysis of the relationship between oil extraction rates and property rights assignments, and the sources used to obtain these data.

Sample—In order to create a broad sample of countries for the study, I decided to use all significant oil-producing states for which data are available. After conducting preliminary research, I found that beyond the top forty or fifty producing states, reliable data about domestic oil-producing industries became difficult to find. As a result, I decided to include all 43 states that produce an annual average of at least 100,000 barrels of crude oil per day.

To conceptualize the sharp drop-off in production after the top forty or fifty countries, consider the following. Saudi Arabia, the world's leading oil supplier, produces roughly 100 times more oil per year as Germany, the number 48 producer (EIA, International Energy Annual 2004). Only 75 countries produced 10,000 barrels per day or more in 2004, and only the 43 countries included in this study produced an average of at least 100,000 barrels per day between 2002 and 2004. In fact, with only 94 countries producing any oil over this period, the number 44-94 ranking countries combined to produce less than Libya, the number 17 producing country. 18 countries in the world produced over one million barrels per day over that period, with Saudi Arabia averaging 8.5 million. Thus, a larger sample of producing countries seems impractical and undesirable. Moreover, it is unlikely that a larger sample size would have produced enough evidence to conclude with confidence that mineral rights allocation significantly affects extraction rates. To account for variations in annual production, I used those states with a three-year average from 2002-2004 of at least 100,000 barrels per day of production.

Dependent Variable

Extraction Rate—The extraction rate is calculated by dividing production by reserves, to give an estimate of the number of years a given country could continue to produce at its current rate of extraction before it runs out of oil. The extraction rate is the inverse of the more commonly used Reserve/Production (R/P) ratio. As Congress described in a 2004 report, "a standard measure of the potential availability of oil over time is the reserve to production ratio (R/P). The R/P can be interpreted as the number of years that the existing reserve base can sustain the current level of production" (Pirog).

In order to control for variations in annual production due to price, natural disasters, or other volatile elements, I have taken the average production figures from the last three years for which the EIA provides data for all this study's countries (2002, 2003 and 2004).

Annual proven reserve estimates also fluctuate over time. Proven reserve estimates represent the known oil reserves that can be extracted at a reasonable price, given existing technology. On the one hand, reserve estimates can decline each year as they are depleted through production. On the other hand, reserve estimates can actually rise from one year to the next if exploration activities find new fields or if new drilling technologies make currently unrecoverable reserves accessible. To incorporate end-of-year estimates that correspond to the above production figures, I have used the proven reserve estimates for each country provided by the EIA on January 1, 2003, January 1, 2004 and January 1, 2005.

To create the variable, I calculated the average annual crude oil production figure for each country and converted the figure into thousands of barrels per year. Annual production figures come from the EIA's World Crude Oil Production 1980-2004 table. The production figures measure the amount of crude oil (including lease condensate) produced within each country in a given year.

I then looked at each country's end-of-year reserve estimates provided by the EIA (in billions of barrels) for the corresponding years (January 1 2003-2005) and calculated an average. I selected the January 1, 2003 reserve estimate as a measure of end-of-year 2002 reserve figures, with the same logic holding in 2004 and 2005. I converted the variable into thousands of barrels and used it to calculate each country's rate of extraction. Figures on reserves come from the EIA's *International Petroleum (Oil) Reserves and Resources Tables and Reports*. Figures represent proved reserves and were compiled by the EIA for the United States. For other countries' reserves, the EIA relies on estimates from *Oil and Gas Journal.*

Independent Variables—Dummy Variables

NATL—This is a dummy variable, set to one if a country is assigned to the nationalized group, and set to zero otherwise. I designed the variable to highlight any causal relationship between mineral rights assignment and extraction rate.

PRIV—Similar to NATL, PRIV is a dummy variable set to one if a nation as a privatized system, and zero otherwise.

PSA—PSA is a dummy variable set to one if a country has uses mainly PSAs to manage mineral rights, and zero otherwise.

OPEC—Of the eleven countries classified as nationalized in their mineral rights structures, six are members of the Organization of Petroleum Exporting Countries. OPEC meets regularly to set production quotas, and its eleven members currently control roughly 40 percent of world's oil supply (Gismatullin, 2007). With such market power, OPEC members' production decisions significantly affect oil prices. As a result, decisions to limit production (low extraction rate) for these countries could result from OPEC cartel behavior—not purely deriving from its mineral rights structure. The OPEC dummy variable attempts to control for this effect. It is set to one if the country is an OPEC member, and zero otherwise.

Other Independent Variables

HDI—The Human Development Index is a summary measure of human development calculated by the United Nations Development Program. For this study, HDI figures were taken from the 2006 Human Development Report. HDI is a composite of three main areas of human development: health and longevity (measured by life expectancy at birth), knowledge (according to various measure of literacy and school enrollment) and standard of living (measured by GDP in purchasing power parity). Higher HDI scores indicate higher levels of human development. I include this variable to control for economic development and general infrastructure that could potentially affect extraction rates.

Oil/GDP—This variable helps to control for the position of oil in each country's economy. While imperfect, the variable picks up important effects, which I explain in detail in Discussion (Section VII). In short, I include the variable to control for any effects that dependence on oil could exert on extraction rates. There are several reasons to suspect a relationship between the two variables.

First, countries with high Oil/GDP values may suffer from Dutch Disease, a decline in manufacturing and other sectors resulting from an inflow of revenue from natural resource development. In some countries, the discovery of vast quantities of petroleum may have distracted governments and investors from developing other industries and meeting other goals. In other countries, an influx of revenue from oil sales may cause inflation in currency exchange rates, which makes their manufacturing sector less competitive in the global market. Table 6.2 confirms this notion. A strong negative correlation exists between Oil/GDP and HDI, suggesting a negative relationship between economic development and economic reliance on oil. These countries, if they understand the consequences of their reliance on oil, may intentionally restrict present extraction of oil to preserve the opportunity to exploit reserves for economic gain in the future. If oil presents their only path to wealth, these countries have incentive to preserve their reservoirs for as long as possible.

Second, consistent with theories of monopoly supply restriction, countries that have deep reservoirs of oil and rely heavily on oil export revenues may intentionally restrict production—and, in turn, extraction rates—in order to receive higher market prices. Thus, we can expect countries in which oil export revenue comprises a larger section of GDP to extract oil at a lower rate than countries with lower values of Oil/GDP. While many OPEC members show high values for Oil/GDP, the Pearson correlation coefficient for the OPEC dummy variable and Oil/GDP is only 0.28, suggesting that these two variables each have an independent effect on extraction rate. I calculated Oil/GDP using export data from the World Petroleum Supply and Disposition, 2003 table in the EIA's *International Energy Annual 2004*, the last year for which export data are available for all countries in this study. I then multiplied total barrels of crude oil exported by the average spot price of one barrel of Brent Crude Oil in 2003. Brent Crude is only one classification of oil, and each country's product varies slightly in gravity, sulfur concentration, ease of refining and other factors. However, Brent Crude is widely used as a benchmark for world crude oil prices.

This variable is imperfect for several reasons. First, while the Brent Crude price is a good estimate of world crude prices, it does not account for the variations due to each country's oil quality. Second, I only looked at exports of crude oil. Some countries, including China, India and the United States export large amounts of refined oil products (i.e. gasoline or jet fuel), but relatively small amounts of crude oil. This figure does not account for these refined exports. Some countries may also produce large amounts of crude oil, but consume it domestically. Thus, while they do not earn revenue from crude oil exports, upstream crude production could still play an important role in these countries' economies. While imperfect, Oil/GDP appears to be the best available measure of the importance of oil to each country's economy.

CPI—The Corruption Perceptions Index, calculated each year by Transparency International, is a composite index of polls and surveys conducted by a variety of institutions. The CPI measures, according to Transparency International's website, "perceptions of the degree of corruption as seen by business people and country analysts." Figures for this study were taken from the 2006 Corruption Perceptions Index report. I include CPI to control for variations in perceived political integrity and rule of law, which, when weak, may lead to higher extraction rates.

Consumption—Consumption measures annual per capita energy usage in each country. Consumption is calculated using 2002 consumption estimates from the World Energy Council's *Survey of Energy Resources* report. I divided consumption estimates by 2005 population figures obtained from the World Development Indicators Online database.[4]

GDP/Cap—GDP per capita statistics help to control for a state's wealth, although they overlap to an extent with Consumption and HDI. I calculated GDP/Cap using a 2002-2004 average of GDP statistics from the World Development Indicators online database.[5]

[4] SER report did not provide estimates for Vietnam, Kuwait, Trinidad and Equatorial Guinea. Estimates for these countries are for 2004 and come from the CIA World Factbook.
[5] WDI GDP data not available for Brunei, Iraq, Qatar and Turkmenistan. Figures for these countries represent the most recent GDP data available for each country on the CIA World Factbook as of March 15, 2007.

Reserves—This variable represents the total number of barrels of crude oil in reserves available to each country, according to the EIA.

Tables and Statistics

Table 5.1: Country Statistics

Country	**Annual Production (1000 barrels)**	**Reserves (Bil. barrels)**	**Extraction Rate**	**NATL**	**PRIV**	**PSA**
Algeria	558911.4	10.77133	0.051889	X		
Angola	346827.7	5.412	0.064085			X
Argentina	281648	2.791227	0.100905		X	
Australia	191514.6	2.830333	0.067665		X	
Azerbaijan	114578.2	7	0.016368			X
Brazil	538821.6	9.140567	0.058948	X		
Brunei	62185.9	1.35	0.046064	X		
Canada[6]	740648.1	4.858	0.152459		X	
China	1251200	18.25	0.068559	X		
Colombia	200316.1	1.742193	0.114979		X	
Congo (Brazzaville)	89002.82	1.50591	0.059102			X
Denmark	138086.3	1.314667	0.105035		X	
Ecuador	162034.2	4.6296	0.035000		X	
Egypt	224338.9	3.7	0.060632			X
Equatorial Guinea[7]	135668.3	1.77	0.076649			X
Gabon	89019.61	2.499	0.035622			X
India	244293.2	5.385081	0.045365			X
Indonesia	425837.7	4.8	0.088716			X
Iran	1361271	113.7667	0.011965	X		
Iraq[8]	738395	112.5	0.006564	X		
Kazakhstan	331530.5	9	0.036837			X
Kuwait	779379.3	99	0.007873	X		
Libya	517601.8	34.83333	0.014859			X
Malaysia	266653.1	3	0.088884			X
Mexico	1208286	14.29867	0.084503	X		
Nigeria	817822	28.085	0.029120			X
Norway	1110473	9.737457	0.114041	X		

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[6] Using EIA 2001 production and January 1, 2002 reserve estimates. After 2002, many analysts began to include Alberta Oil Sands, dramatically increasing reserve estimates. Current production technology, however, cannot produce the oil sands very quickly. Accordingly, it would be misleading to include the Alberta Oil Sands when calculating Canada's extraction rate.

[7] Reserve estimates from World Oil, January 1, 2005

[8] 2002 production and January 1, 2003 reserve figures. The 2003 American-led invasion of Iraq led to instability and a sharp decrease in oil production. Population figures for Kuwait and Iraq were not available from World Development Indicators. Data for these two countries represent 2006 estimates from the CIA World Factbook.

Oman	300113	5.506	0.054507			X
Qatar	264825.9	15.207	0.017415			X
Romania	42947.48	0.95562	0.044942		X	
Russia	2961985	60	0.049366		X	
Saudi Arabia	3103743	261.8667	0.011852	X		
Sudan	103540.9	0.563	0.183909			X
Syria	163761.4	2.5	0.065505			X
Thailand	53670.57	0.58335	0.092004		X	
Trinidad and Tobago	46090.86	0.898667	0.051288		X	
Turkmenistan	69108.13	0.546	0.126572			X
United Arab Emirates	840521.4	97.8	0.008594			X
United Kingdom	758012	4.622333	0.163989		X	
United States	2049486	21.97967	0.093245		X	
Venezuela	912022.6	77.60867	0.011752	X		
Vietnam	133272.3	0.6	0.222121			X
Yemen	160030.5	4	0.040008			X

Summary Statistics for Extraction Rates

Table 5.2: Extraction Rates for all Countries in Sample

Category	Minimum	Maximum	Mean	Stand. Dev.	Median	n
NATL	0.0066	0.1140	0.0431	0.0364	0.0461	11
PRIV	0.035	0.164	0.0892	0.0416	0.0926	12
PSA	0.0086	0.2221	0.0667	0.0553	0.0568	20
Total	0.0066	0.2221	0.067	0.0589	0.0494	43

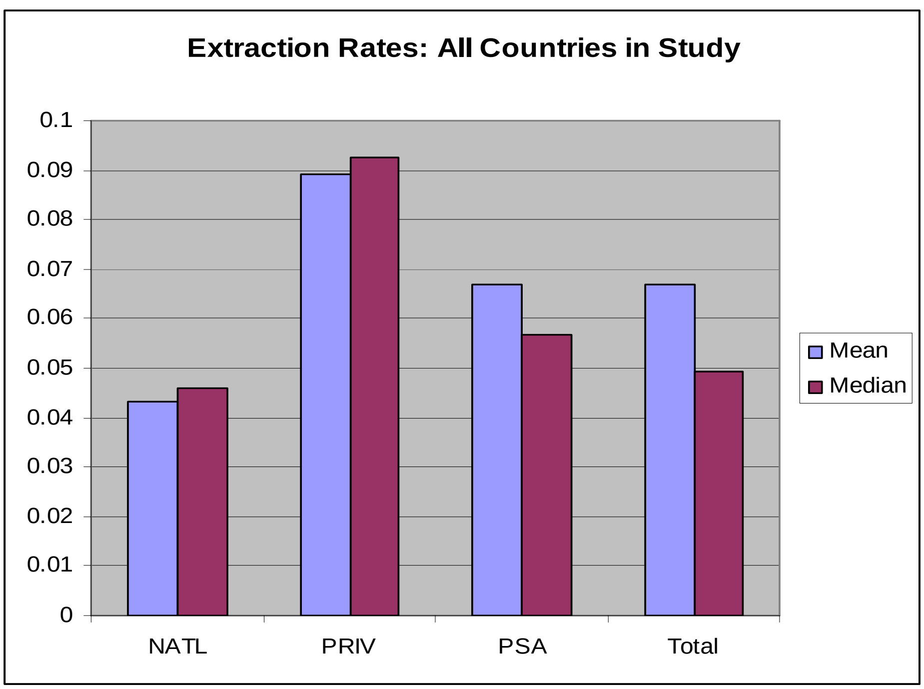
Table 5.3: Extraction Rates for OPEC Members

Category	Minimum	Maximum	Mean	Stand. Dev.	Median	n
NATL	0.0066	0.0518	0.017	0.0172	0.0118	6
PRIV	-	-	-	-	-	0
PSA	0.0086	0.0887	0.0317	0.0327	0.0174	5
Total	0.0066	0.0887	0.0237	0.0252	0.0119	11

Table 5.4: Extraction Rates for Non-OPEC Members

Category	Minimum	Maximum	Mean	Stand. Dev.	Median	n
NATL	0.046	0.114	0.0744	0.026	0.0685	5
PRIV	0.035	0.164	0.0892	0.0416	0.0926	12
PSA	0.0164	0.2221	0.0784	0.0572	0.0606	15
Total	0.0164	0.2221	0.0818	0.0471	0.0666	32

Chart 5.1 Extraction Rates



Difference in Means t-Tests: Two-Sample Assuming Equal Variances

Table 5.5: Difference in Mean Extraction Rates (All Countries in Sample)

	NATL	*PRIV*		*NATL*	*PSA*		*PRIV*	*PSA*
Mean	0.0430	0.0892	Mean	0.0430	0.0667	Mean	0.0892	0.0667
Variance	0.0013	0.001	Variance	0.0013	0.0030	Variance	0.0017	0.0031
Observations	11	12	Observations	11	20	Observations	12	20
Pooled Variance	0.0015		Pooled Variance	0.0025		Pooled Variance	0.0026	
df	21		df	29		df	30	
t Stat	-2.8192		t Stat	-1.2689		t Stat	1.2135	
P(T<=t) one-tail	0.0051		P(T<=t) one-tail	0.1073		P(T<=t) one-tail	0.1172	

Table 5.6: Difference in Mean Extraction Rates (Non-OPEC Members)

	Non-OPEC NATL	*Non-OPEC PRIV*		*Non-OPEC NATL*	*Non-OPEC PSA*		*Non-OPEC PRIV*	*Non-OPEC PSA*
Mean	0.0744	0.0892	Mean	0.0744	0.0784	Mean	0.0892	0.0784
Variance	0.0006	0.0017	Variance	0.0007	0.0033	Variance	0.0017	0.0032
Observations	5	12	Observations	5	15	Observations	12	15
Pooled Variance	0.0015		Pooled Variance	0.0027		Pooled Variance	0.0026	
df	15		df	18		df	25	
t Stat	-0.730		t Stat	-0.149		t Stat	0.5489	
P(T<=t) one-tail	0.2382		P(T<=t) one-tail	0.4417		P(T<=t) one-tail	0.2939	
t Critical one-tail	1.7530		t Critical one-tail	1.7340		t Critical one-tail	1.7081	

Table 5.7: Difference in Mean Extraction Rates (OPEC Members)

	OPEC NATL	*OPEC PSA*
Mean	0.016982	0.031741
Variance	0.000298	0.00107
Observations	6	5
Pooled Variance	0.000641	
df	9	
t Stat	-0.96276	
P(T<=t) one-tail	0.180411	

VI. ECONOMETRIC RESULTS AND TABLES

In this section, I present tables of results from the ordinary least squares regression using different combinations of the independent variables presented in Section V. Extraction Rate was the dependent variable in all equations.

Table 6.1: Table of Summary Statistics

Variable	Minimum	Maximum	Mean	Stand. Dev.	Median	No. Observations
Extraction Rate	0.00656	0.22212	0.06697	0.04947	0.05895	43
NATL	0	1	0.2558	0.4415	0	43
PRIV	0	1	0.2791	0.4539	0	43
PSA	0	1	0.4651	0.5047	0	43
OPEC	0	1	0.2558	0.4415	0	43
Oil/GDP: Percent of GDP derived from Oil exports	0	119.31	21.42	24.81	15.19	43
HDI: Human Development Index	0.4390	0.9650	0.7608	0.1342	0.7840	42
CPI: Corruption Perceptions Index	1.900	9.500	3.910	2.186	3.100	42
Consumption: Per capita energy use	0.64	52.37	10.04	11.37	5.59	43
GDP/Cap	366	37995	7967	10465	2146	43
Reserves: Total barrels	546,000,000	261,867,000,000	24,865,317,930	48,920,412,140	4,858,000,000	43

Table 6.2: Table of Correlations

	R/P	NATL	PRIV	PSA	OPEC	OIL/GDP	HDI	CPI	Consumption	GDP/CAP
NATL	-0.286 0.063									
PRIV	0.283 0.066	-0.365 0.016								
PSA	-0.004 0.978	-0.547 0.000	-0.580 0.000							
OPEC	-0.508 0.001	0.348 0.022	-0.387 0.010	0.044 0.782						
OIL/GDP	-0.316 0.039	-0.030 0.851	-0.440 0.003	0.422 0.005	0.287 0.062					
HDI	0.105 0.507	0.217 0.167	0.485 0.001	-0.624 0.000	-0.157 0.321	-0.518 0.000				
CPI	0.277 0.075	-0.059 0.709	0.419 0.006	-0.329 0.034	-0.174 0.272	-0.344 0.026	0.725 0.000			
Consumption	-0.287 0.062	0.222 0.153	-0.040 0.797	-0.158 0.312	0.420 0.005	0.049 0.754	0.489 0.001	0.429 0.005		
GDP/Cap	0.161 0.302	0.069 0.662	0.322 0.035	-0.350 0.022	-0.041 0.796	-0.191 0.220	0.715 0.000	0.915 0.000	0.580 0.000	
Reserves	-0.460 0.002	0.501 0.001	-0.205 0.187	-0.254 0.100	0.604 0.000	0.140 0.369	0.092 0.561	-0.088 0.579	0.531 0.000	0.021 0.895

Cell Contents: Pearson correlation
P-Value

Table 6.3: Ordinary Least Squares Regression Results

	Regression								
Independent Variable	1	2	3	4	5	6	7	8	9
Constant	0.0795 p(0.00)	0.0768 p(0.000)	0.0646 p(0.000)	0.0810 p(0.000)	0.0933 p(0.000)	0.0815 p(0.000)	0.0864 p(0.000)	0.0962 (0.000)	0.0752 p(0.000)
Mineral Rights									
NATL	-0.0085 (0.620)	-0.0118 (0.494)	-0.0078 (0.666)	-0.0079 (0.653)	-0.0191 (0.279)	-0.0142 (0.441)	-0.0311 (0.089)	-0.0158 (0.363)	-0.0132 (0.469)
PRIV	0.0097 (0.558)	0.0024 (0.893)	-0.0015 (0.932)	0.0110 (0.519)	-0.0117 (0.542)	-0.0119 (0.537)	0.0053 (0.784)	-0.0048 (0.793)	-0.0117 (0.541)
Other Variables									
OPEC	-0.0512 (0.005)	-0.0525 (0.004)	-0.0534 (0.004)	-0.0475 (0.019)	-0.0501 (0.005)	-0.0509 (0.006)	——	-0.0488 (0.006)	-0.0383 (0.068)
GDP/Cap	——	0.0000 (0.283)	——	——	0.0000 (0.283)	——	——	——	——
CPI	——	——	0.0049 (0.159)	——	——	0.0040 (0.247)	——	——	0.0068 (0.111)
Consumption	——	——	——	-0.0003 (0.676)	——	——	——	——	-0.0009 (0.253)
Oil/GDP	——	——	——	——	-0.0005 (0.090)	-0.005 (0.152)	-0.0006 (0.074)	-0.0005 (0.088)	-0.0004 (0.224)
	S= 0.0434 R^2 =28.4% **R^2(adj)=22.9** F = 5.16	S = 0.0433 R^2 =30.6% **R^2(adj)=23.3** F= 4.19	S = 0.0432 R^2 =32.6% **R^2(adj)=25.3** F= 4.47	S = 0.0439 R^2 =28.7% **R^2(adj)=21.2** F=3.83	S = 0.0422 R^2 =35.8% **R^2(adj)=27.2** F= 4.13	S = 0.0425 R^2 =36.4% **R^2(adj)=27.5** F=4.11	S = 0.0462 R^2 =18.9% **R^2(adj)=12.7** F=3.03	S = 0.0423 R^2 =33.8% **R^2(adj)=26.8** F=4.84	S = 0.0423 R^2 =38.7% **R^2(adj)=28.2** F=3.69

Cell Contents: Coefficient
P-Value

VII. DISCUSSION

The above econometric analysis shows that, while theories suggest a relationship between mineral rights structure and rate of extraction, the empirical data do not point to any statistically significant relationship between the two. This “non-effect” appears robust. The coefficients for the mineral rights variables support the hypothesis that countries with nationalized oil industries extract their oil more slowly than countries with fully privatized upstream oil industries. The difference in means tests also show that countries with nationalized oil industries extract at a slower rate than those with privatized or PSA systems. However, when including different combinations of variables in the regression equation, the NATL and PRIV dummy variables appear statistically insignificant, with p values reaching as high as 0.932. Thus, it is likely that other variables intervene in the relationship between mineral rights structure and extraction rate.

Although property rights cannot explain the substantial cross-country variation in oil extraction rate, other variables can. First, the OPEC variable consistently shows a significant and large negative effect on extraction rates. Such a finding makes sense, given OPEC’s usual supply-restricting behavior. In fact, the average OPEC member state extracts its oil at a rate more than three times lower than the average non-OPEC member’s.[9] At the semiannual meetings of the OPEC Conference, representatives of the member states consider forecasts of economic activity, oil demand and supply and agree on production quotas for each country to follow.[10] In extreme cases (such as OAPEC’s 1973 response to the Yom Kippur war), major producers can drastically reduce production, driving world oil prices to record highs. However, even under ordinary geopolitical conditions, OPEC member states

[9] Average OPEC extraction rate = 0.024; average non-OPEC extraction rate = 0.082
[10] OPEC holds regular conferences twice each year. In 2006, they added a third conference in December, at which point they further reduced production on top of the cuts they made at their October meeting.

agree to restrict their production to levels less than those at which they might normally extract oil were they not OPEC members. For example, at its December 2006 meeting, OPEC agreed to restrict its joint output to 25.8 million barrels a day, a two percent decrease from the quotas it agreed upon in October 2006 (Mouawad, 2006). At its March 2007 meeting, OPEC agreed to leave output quotas unchanged, although it would increase pressure on member states to abide by quotas (*The New York Times*, 2007). Given this downward pressure on production levels, the significant negative effect of OPEC membership on extraction rates in this data set fits the theoretical assumptions.

Oil/GDP, a measure of the significance of oil to each country's economy also shows some significant results in the econometric analysis. While the coefficient is consistently low, countries in which oil revenues comprise a larger portion of GDP tend to extract their oil at lower rates than countries in which economic success is less closely linked to oil export revenues.

The results for CPI indicate that countries with higher CPI scores (i.e. countries with lower perceived corruption) tend to extract oil more quickly than others. This result, in and of itself, is neither statistically significant nor revealing. However, one could argue that corrupt officials would lead their countries astray from their ideal energy policies. In other words, those countries that would be best served by extracting oil quickly might have lower extraction rates as a result of corruption. Countries relying on oil for the long term might extract oil more quickly if corrupt managers extract profit by producing oil quickly and skimming revenue for themselves. The CPI results also likely pick up the effects of perceived rule of law. As discussed in Chapter II, extraction rates fall as multinational oil companies cut back on investments they fear they could lose in an environment of corruption or weak governance.

Data on GDP per capita show no effect on extraction rate. GDP/Cap may, in this equation, simply proxy for development, as it is highly correlated with per capita energy use and the HDI index (itself a general economic development indicator.

The coefficients and p-values for Consumption and Reserves do not show any significant effect on extraction rates.

Certain variables that could potentially have affected the regression results were omitted from this study for lack of available data. For example, the cost of producing oil could significantly affect extraction rates, but was not included in this analysis. Al-Attar and Alomair (2005) argue that mineral rights assignments and upstream oil industry structure are largely determined by exploration and production (E&P) costs in a given area. E&P data, however, are not widely available.

While the sample size in this study is low by some econometric standards, a larger sample would have included relatively insignificant oil producers such as Cuba, Italy and Burma. Any cross-country analysis is limited by the relatively small number of independent nations on which economic data are available. This study examines the top 43 oil-producing states.

VIII. CONCLUSION

While the empirical data show no effect of mineral rights allocations on the rate of oil extraction, they point to some important lessons for policymakers working with natural resources, and oil in particular.

For countries that depend heavily on oil for income, distribution of this oil revenue could significantly affect standards of living. As a result, these countries must be careful in managing oil revenue and devise mechanisms for distributing the revenue that will insulate their economies from swings in world prices and from corruption and mismanagement.

Some countries, including Norway, have accomplished this insulation by establishing oil funds. These funds take revenue that accrues to the government from taxes, royalties or direct sales income and invest it in secure funds that ensure that future generations have access to the country's oil—if not in kind, then at least in economic benefits. Such funds address the issues of intergenerational equity that abound in literature on oil revenue management.

The data on OPEC suggest that supranational governments can actually yield profound effects on their member states' economies. It will be interesting to follow Angola's rate of extraction and see how they change once the newest member nation starts subscribing to OPEC production quotas, possibly as early as 2007.

As if enough studies had not already discussed this development issue ad nauseum, the empirical results on economic dependence on oil and its effect on extraction rate prove that Dutch Disease can have a real measurable impact on developing economies. As states develop new reserves of oil and other commodities, policymakers must be cautious not to neglect other areas of their economies.

Further studies that may use different methods for categorizing mineral rights organization can continue to examine the important effects of mineral rights allocation on various indicators of economic or industrial health. Although this study did not directly discover any such effects, I hope that it sheds some light on other related variables and contributes to the debate on the optimal policy for allocating mineral rights.

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