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The Organization of the Oil Industry, Past and Present

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Abstract

For several decades, petroleum has been a commodity of vital importance to the global economy, in which a number of interesting market phenomena has occurred. This monograph represents my efforts to describe several of these phenomenon, along with a few other elements of the oil market. My focus is on elements related to the extraction of petroleum, and the interactions between buyers and sellers of crude oil; issues that are essentially linked to the Industrial Organization of crude oil markets The topics I cover are: the production of crude oil, material that provides a foundation for later material; an example of the behavior employed by John D. Rockefeller in his quest for control of the early petroleum refining industry; the excessive extraction phenomenon observed in the early days of the industry, which was obtained because of the "common property" nature of oil production; the historical battle between the major oil companies (who were collectively dubbed the "Seven Sisters" and Organization of Petroleum Exporting Countries, or [OPEC]); a theoretical discussion of cartel formation, which forms the backdrop for an investigation of OPEC; an empirical model of membership in OPEC; and a handful of key recent events, which offer some insights into the future of the oil industry.

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1

Introduction

Since the end of the Second World War, petroleum has become a critically important element in the economy of every developed country in the world, as well as many emerging economies. During this time frame, the global market has changed dramatically, from one that was largely dominated by a group of large international vertically integrated firms that transformed crude oil deposits into gasoline and related products (the so-called "Seven Sisters"), into a market that is dominated by a handful of oil producing countries (the Organization of Petroleum Exporting Countries, or OPEC).

With only an occasional exception, the OPEC countries have collectively accounted for over 30% of crude oil supplies during the past 40 years or so. But OPEC is not the first major economic force in oil markets, and its potential to manipulate oil markets is not the only example of potential distortions. In the early days of the industry, individuals seeking their fortune rushed to the oil patch, drilling anywhere they could lay claim; the result was excessive drilling levels that dissipated rents. This phenomenon which played out at other times and in other places — most notably in the oil fields of Wast Texas in a 10–15 year period after the end of the first World War — apparently exerted

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an important influence on one of the most infamous characters in the history of petroleum. Disgusted by what he perceived to be a chaotic state of affairs, John D. Rockefeller set out to "organize" the oil industry in the period after the American Civil War [Yergin, 2011]. In this pursuit, Rockefeller undertook a variety of actions, many of which were unpopular and perhaps unethical; the end result was acquisition of the great majority of refining capacity in the (U.S.), as well as the lion's share of the distribution network. His unpopularity no doubt played a role in the promulgation of the first major piece of antitrust legislation in the U.S. — the Sherman Act — which, perhaps unsurprisingly, was then used to disassemble Standard Oil, the company Rockefeller had so painstakingly created.

Despite the divestiture that resulted from the successful prosecution of Standard Oil, the resultant parts coalesced in due course. In the late 1920s, at the instigation of the head of Standard Oil of New Jersey, several of the largest oil companies in the world met at a castle in the Scottish Highlands. This meeting ultimately led to the "Achnacarry Agreement," which was fundamentally a scheme for dividing oil regions in the world into spheres of influence. Each of the firms taking part in the agreement thereby procured virtual monopsony power over some source of supply. This fundamentally led to a situation where the group of firms, the Seven Sisters, acted much as a monopsonist: they induced low prices, and directed most of the rents away from the countries in whose domain the resources lay, and into the companies' coffers. In the end, this situation proved so objectionable to the countries that many of them combined to form OPEC. Over time, the balance of power shifted, and OPEC wound up with most of the resource rents. But that too came to pass, at least for a time, with OPEC's power greatly diminished in the middle 1980s.

This monograph represents my efforts to describe these phenomenon in some detail, along with a few other elements of the oil market. In this way, it represents my personal value judgment regarding aspects that are interesting. My focus is on elements related to the extraction of petroleum, and the interactions between buyers and sellers of crude oil. I have chosen to steer clear of any discussion of end

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use markets — gasoline refining and marketing, for example.[1] Instead, I focus on issues that are essentially linked to the Industrial Organization of crude oil markets.

I start with a discussion of the production of crude oil, in Section 2. This material provides a foundation for a discussion of some important elements in the industry, including the pattern of prices, motivations to explore for, and to then develop located deposits of, oil. It also provides a platform to discuss an interesting topic that has arisen in the last 5–10 years, the "Green Paradox."

In Section 3, I turn my attention to a particularly nasty trick that John D. Rockefeller employed in his quest for control of the early petroleum refining industry. In the early days of the U.S. industry, oil was generally extracted in Pennsylvania and refined in Ohio. Most crude was transported from the oil patch to refineries by rail; three railroads provided this transport service. Following a bitter rate war, these railroads attempted to collude on transport tariffs. Realizing the need to dissuade cartel members from offering secret rate discounts, they hit on an ingenious scheme: they recruited Rockefeller to serve as the cartel "policeman"; his role was to monitor the rates offered. In exchange for this, Rockefeller obtained a discount on rail tariffs, which meant that he was able to ship at lower cost than his rivals refiners. In addition, Rockefeller received a "drawback" — in essence, he was paid a share of the tariffs the railroads collected from the other refiners. In this manner, he gained doubly: once through the lower rate he received, and once by virtue of the rate increases his monitoring activities facilitated.

Section 4 provides a discussion of the excessive extraction phenomenon observed in the early days of the industry. The basic problem here is one of common property, or as it is legally known, the "rule of capture." Under this rule, whichever party extracts oil is entitled to keep and sell it, irrespective of the literal location of the oil prior to extraction. In particular, oil that migrates from under your land — which one might have reasonably thought was yours to begin with — to my oil well then becomes mine. The incentives set into play by this institution are not attractive; they lead to too-rapid extraction, with

[1] For an excellent survey on these topics, see Hilyard [2012].

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excessive efforts made to procure the resource. At times, this excessive effort lead to dramatically low prices, which in turn yielded a host of efforts at supporting prices.

Section 5 considers the tension between the Seven Sisters and OPEC. This conflict can be conceptually separated into two time periods: the 1950s, during which period the Seven Sisters was very successful at extracting rents, and the 1970s, the period that witnessed the rise of OPEC. In between, the balance of power shifted. Later, in the 1980s, OPEC's power fell off dramatically for a time; I offer my interpretation for this effect in Section 5. In both cases I argue that the shift can be linked to an increase in the role played by parties who are much smaller than the key actors: other potential purchasers of oil in the case of the waning of the Seven Sisters' power; other potential sources of supply, in the case of the ebb in OPEC's power.

And how can one explain the constituency of OPEC? Plausibly, it is linked to the importance of the countries' oil reserves; in Section 6, I provide a conceptual discussion of cartel behavior that investigates the role played by reserves. A key feature elucidated by this inquiry is the importance of heterogeneities in reserves. In particular, it turns out that when reserve sizes are sufficiently different across producers it becomes very difficult to provide sufficient incentives for continued participation. By excluding smaller producers, on the other hand, the cartel is more likely to provide sufficient motivation to its members so as to deter cheating. In Section 7, I empirically analyze this conceptual result. While there is compelling evidence for the importance of reserve size, there is an empirical complication: a handful of countries with bountiful reserves in the 1970s that chose to not participate in OPEC. At the same time, there were some countries in OPEC that can generously be described as little fish. In discussing the potential motives for membership in OPEC, I make the case that a combination of the countries' oil consumption and its political freedom play an important role, though one that is perhaps secondary to the magnitude of oil reserves.

And what do key recent events portend for the future of the oil industry? I take up this question in Section 8, where I consider the

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impacts of the turbulence in North Africa and the Middle East associated with the so-called “Arab Spring,” the emergence of hydraulic fracturing, or “tracking,” which has made available substantial new oil shale deposits in the U.S. and elsewhere, and the onset of enormous potential reserves in the oil sands of Canada.

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References

M. Adelman and M. Shahi. Oil development-operating cost estimates, 1955–85. *Energy Economics*, 11:2–10, 1989.

M. A. Adelman. *Genie Out of the Bottle: World Oil Since 1970*. MIT Press, Cambridge, MA, 1995.

Advanced Resources International. Evaluating the potential for "game changer" improvements in oil recovery efficiency from CO2 enhanced oil recovery. Technical report, U.S. Department of Energy. Office of Oil and Natural Gas, 2006.

A.-C. Aycaguer, M. Lev-On, and A. M. Winer. Reducing carbon dioxide emissions with enhanced oil recovery projects:? a life cycle assessment approach. *Energy Fuels*, 15:303–308, 2001.

T. Babadagli. Optimization of co2 injection for sequestration/enhanced oil recovery and current status in canada. In S. Lombardi, L. Altunina, and S. Beaubien, editors, *Advances in the Geological Storage of Carbon Dioxide: International Approaches to Reduce Anthropogenic Greenhouse Gas Emissions*, pages 261–270. Springer, Dordrecht, The Netherlands, 2006.

BP. Statistical review of world energy. Available online at http://www.bp.com/en/global/corporate/about-bp/energy-economics/statistical-review-of-world-energy-2013.html; accessed 28 December 2013, 2013.

B. R. Cook. Essays on carbon policy and enhanced oil recovery. PhD thesis, University of Wyoming, Department of Economics & Finance, 2011.

C. A. Dahl. Refinery mix in the U.S., Canada, and the E.E.C. *European Economic Review*, 16:235–246, 1981.

Full text available at: http://dx.doi.org/10.1561/0700000051

L. Davis. Venezuelan gas guzzlers. Available online at http://energyathaas.wordpress.com/2013/05/13/venezuelan-gas-guzzlers/; accessed 29 December, 2013, 2013.

S. Devarajan and A. C. Fisher. Exploration and scarcity. *Journal of Political Economy*, 90:1279–1290, 1982.

O. A. H. Engen. The development of the norwegian petroleum innovation system: A historical overview. In J. Fagerberg, D. C. Mowery, and B. Verspagen, editors, *Innovation, Path Dependency, and Policy: The Norwegian Case*. Oxford, UK, Oxford University Press, 2009.

Freedom House. Freedom in the world. Available online at http://www.freedomhouse.org/report-types/freedom-world; accessed 29 December, 2013, 2013.

J. Friedman. *Oligopoly Theory*. Cambridge University Press, Cambridge, UK, 1983.

D. Fudenberg and E. Maskin. The folk theorem in repeated games with discounting or with incomplete information. *Econometrica*, 54:533–556, 1986.

R. Gardner, A. Herr, Ostrom E, and J. A. Walker. The power and limitations of proportional cutbacks in common-pool resources. *Journal of Development Economics*, 62(3):515–533, 2000.

R. Golombek, A. A. Irarrazabal, and L. Ma. Opec's market power: An empirical dominant firm model for the oil market. CESifo Working Paper Series 4512, CESifo Group Munich, 2013.

L. C. Gray. Rent under the assumption of exhaustibility. *The Quarterly Journal of Economics*, 28(3):466–489, 1914.

J. Griffin and W. Xiong. The incentive to cheat: an empirical analysis of OPEC. *Journal of Law and Economics*, 40:289–316, 1997.

J. D. Hamilton. Understanding crude oil prices. *The Energy Journal*, 30: 179–206, 2009.

R. Hannesson. *Petroleum Economics. Issues and Strategies of Oil and Natural Gas Production*. Quorum Books, Connecticut, 1998.

J. Hilyard. *Oil and Gas Industry: A Nontechnical Guide*. PennWell, Tulsa, OK, 2012.

E. Hnyilicza and R. S. Pindyck. Pricing policies for a two-part exhaustible resource cartel. *European Economics Review*, 8:139–154, 1976.

Full text available at: http://dx.doi.org/10.1561/0700000051

G. Hochman and D. Zilberman. Opec and cheap oil policies: The export tax paradigm. Technical report, UC Berkeley Department of Agricultural and Resource Economics. No. 1097, 2010.

H. Hotelling. The economics of exhaustible resources. *Journal of Political Economy*, 39(2):137–175, 1931.

R. M. Isaac. The value of information in resource exploration: The interaction of strategic plays and institutional rules. *Journal of Environmental Economics and Management*, 14:313–322, 1987.

L. Karp. Social welfare in a common property oligopoly. *International Economic Review*, 33:353–372, 1992.

D. Kreps, P. Milgrom, J. Roberts, and R. Wilson. Rational cooperation in the finitely repeated prisoners' dilemma. *Journal of Economic Theory*, 27: 245–252, 1983.

P. Lasserre. *Long-term Control of Exhaustible Resources*. Harcourt Academic Publishers, Chur, Switzerland, 1991.

A. Leach, C. F. Mason, and K. van 't Veld. Co-optimization of enhanced oil recovery and carbon sequestration. *Resource and Energy Economics*, 33: 893–912, 2011.

G. D. Libecap and S. N. Wiggins. Contractual responses to the common pool: Prorationing of crude oil production. *American Economic Review*, 74(1): 87–98, 1984.

G. D. Libecap and S. N. Wiggins. The influence of private contractual failure on regulation: The case of oil field unitization. *Journal of Political Economy*, 93(4):690–714, 1985.

C. F. Mason. Exploration, information, and regulation in an exhaustible mineral industry. *Journal of Environmental Economics and Management*, pages 153–166, 1986.

R. S. Pindyck. The optimal exploration and production of nonrenewable resources. *Journal of Political Economy*, 86:841–861, 1978a.

R. S. Pindyck. Gains to production from the cartelization of exhaustible resources. *Review of Economics and Statistics*, 60:238–251, 1978b.

R. S. Pindyck. Uncertainty and exhaustible resource markets. *Journal of Political Economy*, 88:1203–1225, 1980.

S. Polasky. Do oil producers act as oil'igopolists? *Journal of Environmental Economics and Management*, 23:216–247, 1992.

Full text available at: http://dx.doi.org/10.1561/0700000051

L. Samuelson. A note on uncertainty and cooperation in a finitely repeated prisoner's dilemma. *International Journal of Game Theory*, 16:187–196, 1987.

J. C. Shaw and S. Bachu. Evaluation of the CO2 sequestration capacity in alberta?s oil and gas reservoirs at depletion and the effect of underlying aquifers. *Journal of Canadian Petroleum Technology*, 42:51–61, 2003.

H.-W. Sinn. Public policies against global warming: a supply side approach. *International Tax Public Finance*, 5:360–394, 2008.

J. Stiglitz. Monopoly and the rate of extraction of exhaustible resources. *American Economic Review*, 66:655–661, 1976.

U.S. Energy Information Administration. International energy statistics. available online at http://www.eia.gov/countries/data.cfm; accessed 29 December, 2013, 2013.

H. L. Wagner. *The Organization of Petroleum Exporting Countries*. Chelsea House, New York, 2009.

S. N. Wiggins and G. D. Libecap. Oil field unitization: Contractual failure in the presence of imperfect information. *American Economic Review*, 75(3): 368–385, 1985.

S. N. Wiggins and G. D. Libecap. Firm heterogeneities and cartelization efforts in domestic crude oil. *Journal of Law, Economics, and Organization*, 75(3):1–25, 1987.

N. A. Wilmot and C. F. Mason. Jump processes in the market for crude oil. *The Energy Journal*, 34:33–48, 2013.

D. Yergin. *The Prize: The Epic Quest for Oil, Money & Power*. Free Press, 2011.

G. Zuckerman. *The Frackers: The Outrageous Inside Story of the New Billionaire Wildcatters*. Portfolio/Penguin Publishers, New York, NY, 2013.