The Economics of an Integrated World Oil Market

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Keynote Address
International Energy Workshop
Venice, Italy
June 17-19, 2009

The United States and other high-income countries face several long-term challenges relating to energy. The headline issue, which is engaging a small army of scientists and international negotiators, is that of climate change. Here the key economic policy requires placing a price on carbon emissions from fossil fuels that reflects their social cost. Over the longer run, nations will need to find an economical way to make the transition from today's technologies, so dependent upon fossil fuels, to others that are essentially carbon-free.

Another set of issues, also highly complex and controversial, involves oil. For the United States these issues include, among others, the rising share of imports in U.S. oil consumption, local and regional pollution, the interaction with national security and our Iraq strategy, the rising dollar burden of imports, the recycling of oil revenue, price volatility, the unacceptably high profits of U.S. oil companies, trade-offs between drilling and environmental preservation, and oil's contribution to global warming.

I. The Integrated World Oil Market

A. The Nature of an Integrated Market

The major point I would emphasize is that much thinking about oil is misguided, because analysts often have misunderstood the nature of the oil market. It is fruitful to think of the oil market as a single integrated world market. Transactions in such a market will be the outcome of a multitude of individual supplies and demands, but the price and the total quantity will be determined only by the *sum* of the demands and the *sum* of the supplies. Their composition is irrelevant. Granted, this is an oversimplification: the concept of a single world oil market is not 100 percent correct, only about 99.8 percent correct. However, 99.8 percent is pretty close to 100 percent, and

so it makes sense to treat it as 100 percent. And as soon as one looks at the world through these spectacles, many conventional precepts are seen to be wrong.

I begin with some technical details. In this discussion, I will consider the polar case of a 100 percent integrated world market and recognize that it is oversimplified and only 99.8 percent accurate. However, 99.8 percent is pretty close to 100 percent, so the analysis of the pure case is very close to the more complete truth.

Begin with a technical note on prices. The crude oil prices considered here are wholesale prices in U.S. dollars as reported by the U.S. Energy Information Administration. They are prices for standardized cargos loaded on large tankers from the major loading point for a particular crude oil (and are therefore "f.o.b.," or free-on-board). For example, Libyan crudes are priced for cargos from the Libyan port of Es Sider for delivery into the Mediterranean, and Iraqi oil is priced as Iraqi Kirkuk crude loading at Ceyhan in Turkey. These prices will differ from wellhead prices and definitely will differ from consumer prices of retail petroleum products. I emphasize that this discussion applies to crude oil but not to other energy sources such as natural gas or coal, and to producer, not consumer, prices. The appendix discusses the sources of the price data in more detail.

In this integrated-market view, we can envision the oil market as a giant bathtub (see Figure 1). The bathtub contains the world inventory of oil that has been extracted and is available for purchase. There are spigots from Saudi Arabia, Russia, the United States, and other producers that introduce oil into the inventory; and there are drains from which the United States, Japan, Denmark, and other consumers draw oil from the inventory. Nevertheless, the price and quantity dynamics are determined by the sum of these demands and supplies and the level of total inventory, and are independent of whether the faucets and drains are labeled "U.S.," "Russia," or "Denmark."

Why is crude oil an integrated world market? The reason is that the costs of transporting oil are low, crude oils of different geographic origins (and their products) are largely interchangeable, and in any case these different crudes can be blended. This means that crude oil is fungible: a shortfall in one region can be made up by shipping the same or similar oil there from elsewhere in the world.

B. Tests for an Integrated Market

How do we know that it is in fact an integrated market? A standard test is whether the "law of one price" holds. The law of one price is an economic hypothesis stating that the common-currency price of a standardized commodity should be the

same in different markets.[1] For a homogeneous product with negligible transportation and transactions costs, the price of that product would be the same in all markets.

In the case of crude oil, we would not expect prices to be identical in different markets. Rather, for an integrated market, differences in prices should be "small" relative to crude oil costs. We examine as a test the prices of crude oils of different origins in different markets. The more integrated the market, the more these prices will move in tandem. Figure 2 plots weekly oil prices since 1997 for 31 different crudes with long historical records and widely dispersed markets. The figure shows in striking fashion how all these prices move closely together: their median correlation over this period was 0.997.

Crude oils differ primarily by sulfur content (measured in percent), API gravity (a measure of density developed by the American Petroleum Institute), and location. The sulfur content varies within a range of zero to about 3 percent, and the API gravity index from 21 to 44. Crudes of lower sulfur content and higher density command a premium over less desirable crudes. Figures 3 and 4 show estimates of these premiums from rolling regressions over the period since 1994 for the same 31 crude oil categories as above. The dates at the bottom indicate the center of the period for each regression. Both premiums are relatively stable over the period as a whole. A statistical analysis indicates that the sulfur premium has declined by about one-quarter over the period but that there has been no significant change in the API premium.

As a formal test, using data for the 28 crudes with the longest price history for the period since 1990, I ran a panel regression of the difference in price (in logarithms) over a benchmark price, that for Brent (North Sea) crude, on sulfur content and API gravity (the sample is incomplete for the early years). Table 1 shows the results. There is clearly a close relationship: the regression coefficient on the benchmark price is essentially 1, with a standard error of approximately 0.0008. Sulfur and API are highly significant determinants of the price difference, as expected. Applying the estimated coefficients for these variables to the ranges for sulfur content and API gravity above would produce approximately a 13 or a 15 percent difference, respectively, in the price.

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[1] Pinelopi Koujianou Goldberg and Michael M. Knetter, "Goods Prices and Exchange Rates: What Have We Learned?" *Journal of Economic Literature*, Vol. 35, No. 3, Sept. 1997, pp. 1246. "The law of one price in international trade is that if there were no obstacles to trade and no costs of transporting goods, the price of a given good would be the same all over the world." Stanley Fischer and Rudiger Dornbusch, *Economics*, New York: McGraw-Hill, 1983, p. 203.

It is not possible to explain relative prices perfectly, however. If we take the most recent period (since 2005) and add dynamic factors such as lagged prices and quadratic terms, the standard error of the regression is around $1 per barrel. This is close to transportation costs, so that seems a reasonable error for an integrated oil market.

Figure 5 compares the prices of two benchmark crude oil prices, one U.S. and one European, over a long period. The figure shows that even though prices varied roughly 10-fold over the period, at any given time the prices of the two benchmarks were nearly always almost identical to each other—further evidence of an integrated market.

These correlations among crude oil prices are markedly higher than are observed for virtually any other traded good or service. For comparison, Figure 6 shows a more typical example, namely, prices of standardized saw logs (#2 sawmill Douglas fir logs in different regions of the U.S. Pacific Northwest). These prices show substantial variation one from another, with a median correlation of 0.75. Similar empirical findings on the failure of the law of one price have been seen for virtually all other products that have been analyzed, even very homogeneous ones.[2]

II. Implications of the Integrated View

Many observers of the oil market will find the discussion up to this point hardly surprising. It is useful primarily to lay the empirical foundation for the main burden of my discussion, which is to examine several common received notions about oil policy in the context of an integrated world oil market. This section concentrates on the economic issues, and the next one addresses security-of-supply issues. For this discussion, I will abstract from the national security implications as such. These are important questions but involve issues far beyond the scope of this presentation.

[2] In their survey of international macroeconomics, Obstfeld and Rogoff state: "A large body of empirical evidence shows, however, that the law of one price fails dramatically in practice, even for products that commonly enter international trade. The reasons include transport costs, official trade barriers, and noncompetitive market structures. Transport costs are so high for some commodities that they become nontraded goods." Maurice Obstfeld and Kenneth Rogoff, *Foundations of International Macroeconomics,* Cambridge, MA: The MIT Press, 1996, p. 202 (footnotes, italics, and paragraph break omitted). In his review of the LOP, Peter Isard states, "In reality the law of one price is flagrantly and systematically violated by empirical data." (Peter Isard, "How Far Can We Push the 'Law of One Price'?" *The American Economic Review*, Vol. 67, No. 5, Dec., 1977, pp. 942-948).

The major analytical point concerns the way we should understand externalities in the oil market. I will suggest that most of these externalities involve a nation's total oil consumption and the effect of that consumption on either national or global magnitudes. The surprising and controversial point that I will emphasize is that virtually none of the externalities associated with using oil involve oil imports or oil "dependency." Rather, the national externalities, such as air and water pollution, arise primarily from the total quantity of oil consumed, whatever the source, and the global externalities involve the impact of oil prices on inflation, output, and unemployment. From an analytical point of view, the latter externalities involve "global public goods," not national public goods. To some extent, then, the analytical basis of oil policy resembles the theory involved in global warming because the linkages are global. We will see that this involves several interesting paradoxes.

A. Limiting imports to "secure" sources

Let us begin with one of the most common fallacies in oil policy. A hardy perennial is the idea that we should limit our consumption to oil procured from countries that are "secure sources." In the case of the United States, this might mean concentrating on producers in the Western Hemisphere, or perhaps only our nearest neighbors Canada and Mexico, or perhaps relying only on our own output, or we might even exclude Alaska lest it decide someday to secede.

These policies make no sense in an integrated world oil market. They have zero value. Suppose that the United States decided to obtain its imports only from completely reliable sources – ones that would never, ever cut off supplies– and specifically to prohibit imports from unreliable country A. This would lead country A to send its oil to other countries. One might think that the additional supply of oil to those countries would lower the price in those countries, to their advantage. But in an integrated world market, the price would stay the same, because the total quantity supplied has not changed, nor has total demand. Hence, the result would be simply to reallocate other global production from other countries to the United States to make up the shortfall here and eliminate the excess there. Unless a country actually reduces its flow into the world bathtub, there will be no impact on the United States of sourcing imports from secure regions only.

B. The peril of oil disruptions

One of the primary concerns of oil policy is to prevent disruptions to oil supply. The primary instrument that the United States has in place to counter short-run supply interruptions is the Strategic Petroleum Reserve (SPR). The objective of this reserve is typically seen in terms of "import coverage." For example, the U.S. Department of Energy states that the SPR currently has enough oil to cover a total suspension of imports for 62 days. Most analyses of the value of a larger reserve consider the potential for buffering the U.S. economy from oil price shocks in case of disruption.

Most of this analysis ignores the fact that any release of oil from the SPR will go into the bathtub of the world oil inventory. The relevant question, then, is how long the reserve would cover the shortfall in world consumption due to any oil supply disruption. Building up a reserve thus contributes to the *global public good* of damping oil price shocks, but how many days of U.S. imports the reserve will cover is irrelevant in an integrated world oil market.

This analysis must be qualified to the extent that countries take steps to insulate their domestic markets from international oil price shocks. The United States undertook an experiment in this regard in the 1970s, imposing domestic oil price controls during the oil price shocks of that decade, with results that are generally regarded as highly inefficient and undesirable. This experiment was not repeated in the 2000s, and U.S. domestic oil prices continued to be fully integrated with the world market during this period of volatile prices.[3]

C. The "oil premium"

Let us turn next to the broader question: What is the true cost of oil consumption in the context of an integrated world oil market? Answering this requires pricing the externality generated by oil consumption, that is, the cost of the harm done to society and the planet that is not counted in the price paid to the producer. In other words, what is the "oil premium," or the difference between the social cost and the private cost of oil consumption?

[3] A useful discussion of policies toward supply disruptions is contained in Ian W. H. Parry and Joel Darmstadter, "The Costs of US Oil Dependency," Resources for the Future, November 17, 2004, paper prepared for the National Commission on Energy Policy (available at www.energycommission.org).

Literature on the oil premium has identified four sources: the first is a premium for the vulnerability of the world economy to the disruptions just discussed; the second is the technological externalities (such as air pollution and traffic congestion), which this discussion will ignore; the third is the price effect, or the fact that higher consumption drives up the price and therefore raises costs to other consumers (this being a pecuniary externality); and the fourth is macroeconomic externalities, that is, the extent to which an increase in the oil price tends to produce or worsen recessions.[4]

Energy independence would be valuable to the extent that it reduces these external costs of oil consumption. The important point is that none of these costs relates to oil independence or the share of imports; rather, each of them is determined by the total consumption of oil along with the elasticities of supply and demand for oil in the world market.

Begin with the price externality. If the United States consumes an additional unit of oil, this adds to world demand. The impact on the oil price is determined solely by the *world* price elasticities of supply and demand and is independent of domestic demand and of the share of imports in domestic consumption. Take the simple example where the world elasticities of demand and supply are -0.5 and +0.5, respectively. Then the oil price externality is exactly equal to the initial oil price. The share of imports does not enter into this calculation.

This reasoning indicates why oil independence will also have no effect upon the macroeconomic externality. Most analyses of the recessionary impact of oil prices find that the impact works through two mechanisms. The first is the "tax increase effect," through which consumers find that their real incomes decline as oil prices rise (just as they do when taxes rise). The second is the monetary policy effect. Rising oil prices increase the rate of inflation, all else equal. To the extent that central banks target inflation and do not completely disregard oil price shocks when comparing actual inflation with their target inflation rate, higher oil prices will lead to higher interest rates. The contractionary impact of higher interest rates reinforces the tax increase effect.

Note, again, that both of these impacts are affected by total domestic expenditure on oil, not by how much oil is imported. The fraction of oil consumption that is

[4] There is a large literature on the oil premium. See for example Paul N. Leiby, "Estimating the Energy Security Benefits of Reduced U.S. Oil Imports," Oak Ridge National Laboratory, Oak Ridge, Tennessee, Revised July 23, 2007.

imported has, to a first approximation, no influence either on the tax increase effect or on the monetary policy effect. Therefore, here again, the key focus of policy should be on the world market and the U.S. contribution to total world consumption, and not on oil imports.

D. The balance of payments connection

I have ignored up to now the implications of oil consumption on a country's balance of payments, foreign indebtedness, and the external accounts. For many people this is a central concern. We in the United States are, it might be thought, impoverishing ourselves because of our addiction to oil. Figure 7 shows the trend over the last four decades. In value terms (that is, measured in dollars rather than barrels), oil imports as a share of total imports peaked at about 28 percent in 1979-80, fell to around 5 percent in the late 1990s, and then rose to between 15 and 20 percent in the last few years. People might naturally be concerned that oil imports are a serious issue for our external accounts.

Two points are important here. The first relates to the microeconomic principle of comparative advantage. We import oil because the cost of domestic oil is higher than the cost of foreign oil. It is more economical for us to grow and export corn and use the proceeds to import oil than to drill for high-cost oil or to extract oil from corn. Comparative advantage applies just as much to oil as to textiles, to bananas, or -- dare I mention it -- to automobiles. There is no more reason to engage in uneconomic import substitution for oil for balance of payments reasons than to engage in import substitution for tennis shoes, paper boxes, or automobiles.

The second point is a deeper one. Macroeconomists have gradually changed their view of the reasons for countries' trade deficits and surpluses. We in the United States can best understand our trade deficit and China's trade surplus as the result of national and world saving and investment patterns, not as the result of the microeconomics of oil drilling, free trade, or cheap foreign labor. The large U.S. current account deficit is primarily the result of low U.S. saving and high foreign saving, not of our addiction to Saudi oil and Chinese toys.[5]

We could reduce the value of our oil imports through the same mechanism by which we might reduce our overall trade deficit. Higher governmental and private

[5] A standard intermediate textbook in macroeconomics will explain this approach. For example, see Andrew Abel and Ben Bernanke, *Macroeconomics,* fifth edition, Addison Wesley, New York, 2005.

saving would sum to higher national saving. The full-employment equilibrium would then come at lower domestic interest rates and a depreciated dollar. This would raise import prices, including dollar oil prices, which would in turn reduce domestic consumption of oil. So here again, the key variable to keep one's eye on is domestic and world oil consumption, not imports of oil.

III. National Security Concerns

Oil policy is about more than economics. One also has to consider the costs of protecting oil supplies, which includes the cost of going to war to protect oil-producing countries from predation or chaos. As the late Jack Hirshleifer noted, economists pay far too much attention to the Coase theorem and too little to Machiavelli's theorem. The former holds that externalities can be internalized in a market economy if property rights are clearly defined; the latter reminds us that someone, somewhere is usually willing to steal our property if we do not protect it.[6] Thus, in addition to concerns about the economic impacts of oil consumption, national security concerns have played an important role in oil policy.

Note at the outset that the structure of the national security "game" is quite different from that for economic activity. We can conceptualize economic production, consumption, and trade as voluntary transactions, each of which improves the perceived welfare of each of the participants. Leaving aside externalities, the core nature of economic transactions is that they make all parties better off. In more formal terms, economic transactions are inherently Pareto-improving, positive-sum games.

The nature of military transactions is quite different. They are not voluntary but instead involve coercion of one party or set of parties by another. They are by their nature *not* Pareto improving, and indeed when they involve actual fighting they are generally negative-sum games, destroying wealth rather than creating it. A full discussion of national security concerns is well beyond the scope of this paper, but a few comments will be useful in the context of an integrated oil market.

A. Grabbing oil

For more than a century, the major security issues related to oil have been the attempts by countries to grab oil from others. A relatively recent and highly visible case was Iraq's attempt to seize the oil resources of Kuwait in 1990, which resulted in the Persian Gulf War of 1990-1991. Kuwait's oil reserves were at the time around 100 billion

[6] Jack Hirshleifer, "The Dark Side of the Force," *Economic Inquiry*, 1994, pp. 1–10.

barrels, which, at a scarcity rent on oil-in-the-ground of around $8 per barrel, would be valued at approximately $800 billion in 1990 prices (perhaps $3 trillion in today's prices).[7] So this was at the very least a worthy prize.

The international community reacted strongly against this oil grab, and Iraq was forcibly expelled from Kuwait in 1991. Hence, what would have been the impact on the oil market of a successful Iraqi grab is not easily estimated. However, there is no reason to think that Iraq would have sold less oil from Kuwait than Kuwait would have, and it might well have sold more. Moreover, Iraq had little market power to exercise outside of OPEC, and since both Iraq and Kuwait were OPEC members, OPEC's size would have remained unchanged. The major threat at that time was that Iraq could have seized the Saudi oilfields, which would have given it significant market power in the oil market. But the relevant context here is again the effect on the world oil market, not on U.S. imports or dependency on particular countries. The point here is that "oil grabs" are quite a different issue from standard oil economics. They are part of a more general issue of protecting property rights in an international context.

B. <u>The cost of protecting trade routes or going to war over oil</u>

In the modern world, countries will sometimes spend large sums to protect their access to oil supplies. The total cost of the 1990-1991 Persian Gulf war was around $100 billion in today's prices. The cost of the Iraq war that began in 2003 has been estimated to lie in the range of $1 trillion to $3 trillion. Were those conflicts about oil? Alan Greenspan, who as Federal Reserve chairman was closely involved in economic policy discussions at the time, wrote subsequently, "I am saddened that it is politically inconvenient to acknowledge what everyone knows: the Iraq war is largely about oil."[8] In fact, neither of these wars was entirely about oil, but it seems unlikely that they would have been launched had the neighborhood held no resources other than sand.

People will continue to argue about whether these wars were about oil, but in no case should they have been about protecting oil imports into the United States. In an

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[7] These figures are based on estimates of Hotelling rents from Phoebe Clarke, "An Adjustment of Indonesian GDP Growth for the Depletion of Petroleum Reserves, 1988 – 2007," Yale University, 2009.

[8] Alan Greenspan, *The Age of Turbulence: Adventures in a New World* (Penguin Press, 2007, p. 463). It should be noted that Greenspan had the analytically clear view about oil dependence, writing, "The only meaningful definition of energy independence is world price leadership based on the availability of extensive, unexploited reserves in the ground" (p. 456).

integrated world oil market, unfriendly regimes need to sell oil into the world oil bathtub just as much as do friendly regimes, and again, it is the total amount sold into the world oil bathtub that primarily determines U.S. economic welfare.

C. The value of sanctions and embargoes

Sometimes sanctions or embargoes are launched as less destructive means of coercion. Recent examples involving oil producers have been the U.S. embargoes on Libya and Iran. Figure 8 plots (in logarithms) the prices of Iranian and Libyan crude oils against the benchmark in both sanction and non-sanction periods. There is little difference, which indicates that the sanctions were less than effective. We can also test the impact of the embargoes by regressing the logarithm of the export price for each of the three products (one Libyan and two Iranian) on a dummy variable equal to 1 in periods when an embargo or sanctions were in effect and 0 otherwise. The estimated coefficients are as follows:

Dummy for Libyan crude	0.00268 ($\pm$ 0.0070)
Dummy for Iranian light	0.00976 ($\pm$ 0.046)
Dummy for Libyan crude	0.0133 ($\pm$ 0.064)

A coefficient of 0.00268 indicates that the punitive actions raised the export price by approximately 0.3 percent. Thus, the impact was essentially zero. Indeed, the coefficients have the "wrong" sign—the measures should have lowered the price, not raised it; in any case they are not statistically significant. This suggests that to a first approximation, such embargoes should be expected to have no effect on world prices or production, no impact on the target countries, and no impact on the United States or other consuming countries. They are purely symbolic measures.

We should not conclude from this discussion that we should relax our concerns about security of supply and price volatility. Rather, the point is that these are global problems that arise from the balance of global supply and demand. The world oil market is vulnerable if global supply is tightly constrained, say, because there is no excess capacity. Even if the United States has limited its purchases to secure sources, a crisis anywhere is a crisis everywhere.

D. National security and the competition for resources

Another commonly expressed concern is the "competition for resources." Recently, for example, Russia threatened war over Arctic energy resources, stating, "In a competition for resources it cannot be ruled out that military force could be used to

resolve emerging problems that would destroy the balance of forces near the borders of Russia and her allies."[9] This is actually a variant of the grab for oil, the difference being that in this case, who holds the rights to the resources is ambiguous at the outset.

In either case, however, the issue of *control* of the oil—the resource grab –should be distinguished from that of *access* to the oil. Should we worry about who will control oil production in distant lands? As an example, national security specialists fret about whether China will dominate drilling in the South China Sea, or whether India will have concessions in the Sudan. These concerns are more appropriate to the 19th century than to the 21st. In fact, the major interest of the United States and other consuming countries here is that the world's oil resources be fully and quickly developed, not who develops them. If India can find and develop Sudan's oil resources quickly and efficiently, that will add to the flow into the oil bathtub, reduce the world oil price, diversify world supply, and benefit all countries, the United States included. Confusion in this area is dangerous, however. If the United States and Russia were to agree that *access* to oil is itself a valuable resource, even in the face of economic evidence to the contrary, they would risk stumbling into an irrational conflict, just as those who followed Leninist theories of imperialism fought costly battles over nothing of value.

IV. Appropriate Policies for Oil in the Integrated World Market

Enough of fallacies. If we look at the world through the lens of an integrated world oil market, how should we think about oil policy? What measures are appropriate to deal with our oil problem? What exactly *is* our oil problem?

A full discussion will require another presentation, but I will sketch a couple of points. First, and beginning with the basics, the United States and the rest of the developed world have two major but closely related objectives. The first is that oil prices should be low, stable, and sustainable. The second, however – and this is a big however! – is that what "low" means must be determined in the context of the proper pricing of carbon in a warming world. Low oil prices are beneficial to the economy as long as they do not drive us into dangerous climatic waters. Hence, it is critical for sensible oil policy to get climate change policy right. Until countries put an appropriate

[9] "Russia Warns of War within a Decade over Arctic Oil and Gas Riches," *The Times* (London), May 14, 2009 (available at www.timesonline.co.uk/tol/news/environment/article6283130.ece).

price on carbon emissions, energy policy will be incoherent, and energy and environmental policies will be working at cross-purposes. The determination of the appropriate price of carbon emissions is a major topic that I have addressed elsewhere and will leave for another occasion.

Once we have determined the correct price of carbon, the major objective is to adopt policies that will ensure that oil prices are stable, sustainable, and consistent with the carbon price. Within this framework, we need to consider oil policy in terms of world demand and world supply, rather than domestic demand and supply. In terms of supply, we should encourage development and production by all producers, independent of whether or not they will benefit our own domestic consumers or producers. The world oil price will be lowered equally by increased production by Chinese, Indian, or American companies in any part of the globe. This also implies that we should not subsidize domestic production. The U.S. tax code presently grants around $2 billion in tax expenditures for oil and gas production annually. Much of this is rationalized as encouraging domestic production to reduce dependence on imported oil and is wasteful in the context of an integrated world oil market.

The second point is to encourage policies that lower the demand for oil everywhere, not just in the United States. There are many examples, but a particularly important one is to work to reduce subsidies to oil consumption wherever they occur. According to the International Energy Agency, such subsidies amount to around $100 billion worldwide, with the biggest in (in descending order) Iran, Indonesia, Saudi Arabia, Egypt, and China. Not only are these policies inefficient and costly to these countries, but they have spillover effects and drive up the world market price of oil.

The key lesson from all of this is that we need to broaden our horizons when thinking about oil policy. We are all in this tub together.

Technical appendix.

EIA crude oil prices are gathered from three sources. Most are from Platts, while a small number are from *The Wall Street Journal* and Statistics Canada. This appendix focuses solely on the methodology underlying the Platts estimates, as described in Platts, *Methodology and Specifications Guide: Crude Oil*, April 2009, available at platts.com/Oil/Resources/ Methodology%20&%20Specifications/index.xml.

Platts undertakes a substantial effort to determine the market prices of different categories of crude oil. The firm tracks price quotations at different horizons and markets for a standardized cargo, grade, and forward date. The discovery of prices is described as follows: "new bids/offers published by Platts on page 3 of its Platts Global Alert electronic screen service (PGA003) must be received by Platts no later than the published cut-off periods" (p. 2). The benchmark crude for several years was Brent crude from the North Sea, but with the decline in that field, the benchmark as of 2009 is a mix of Brent, Forties, and Oseberg oil known as BFO. Other crude prices are sometimes quoted as a premium or discount to this benchmark. The following, also from the Platts methodological guide, provides a useful discussion of the methods for non-benchmark crudes:

> West African grades are assessed for cargoes loading 15-45 days after date of publication. While a cargo size of 950,000 bbl is the standard in the daily-assessed grades, part-cargoes are occasionally traded and may be factored into the assessment process. Underlying market dynamics may also play a role in determining the value of grades. Market backwardation and contango within the 15-45 day window will be taken into account for assessment purposes in Angolan grades and within a 18-48 day window for Nigerian crude. All West African assessments are on an FOB basis, for loading at each grade's specific terminal. (p. 8)

Here "backwardation and contango" refer to technical aspects of the market for forward sales that affect pricing.

The following provides the details on Nigerian Bonny Light:

> This crude oil is produced in Nigeria from ChevronTexaco and Shell concessions. ChevronTexaco's exports are throughput and loaded from the Shell-operated Bonny Terminal, which can accommodate Very Large Crude Carrier (VLCC) loading. The typical cargo size is 950 thousand barrels. The API gravity for Bonny Light is 35 degrees and the sulfur content is 0.2%. The typical cargo size for this FOB assessment is 950,000 bbl and the grade loads at the Shell-operated Bonny Terminal. The current bbl/mt

[barrel-to-metric tons] conversion factor for Bonny Light crude oil is 7.526 and typical output is around 540,000 barrels per day. Specifications are: API 35.4°, S.G. 0.85, Sulphur 0.14, Pour point -18°C, TAN 0.27 mg KOH/g, Nickel 3.6 wppm, Vanadium 0.4 wppm, Visc. (50°C) 2.9 cSt. (p. 8)

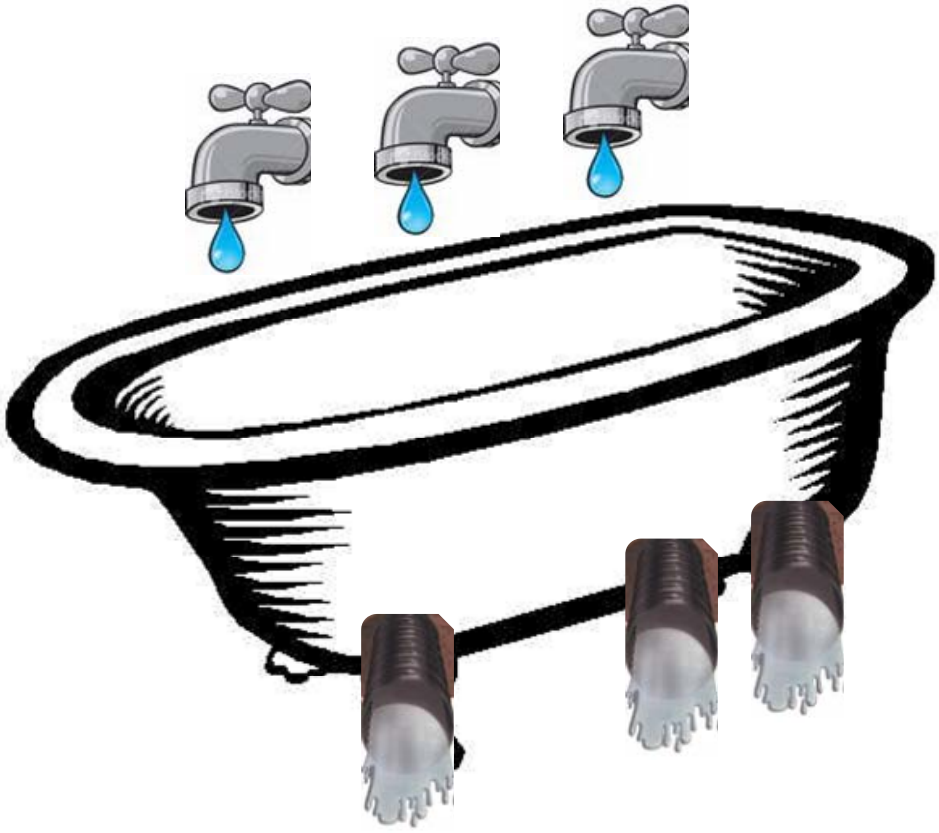

Figure 1. The World Oil Market à la Magritte

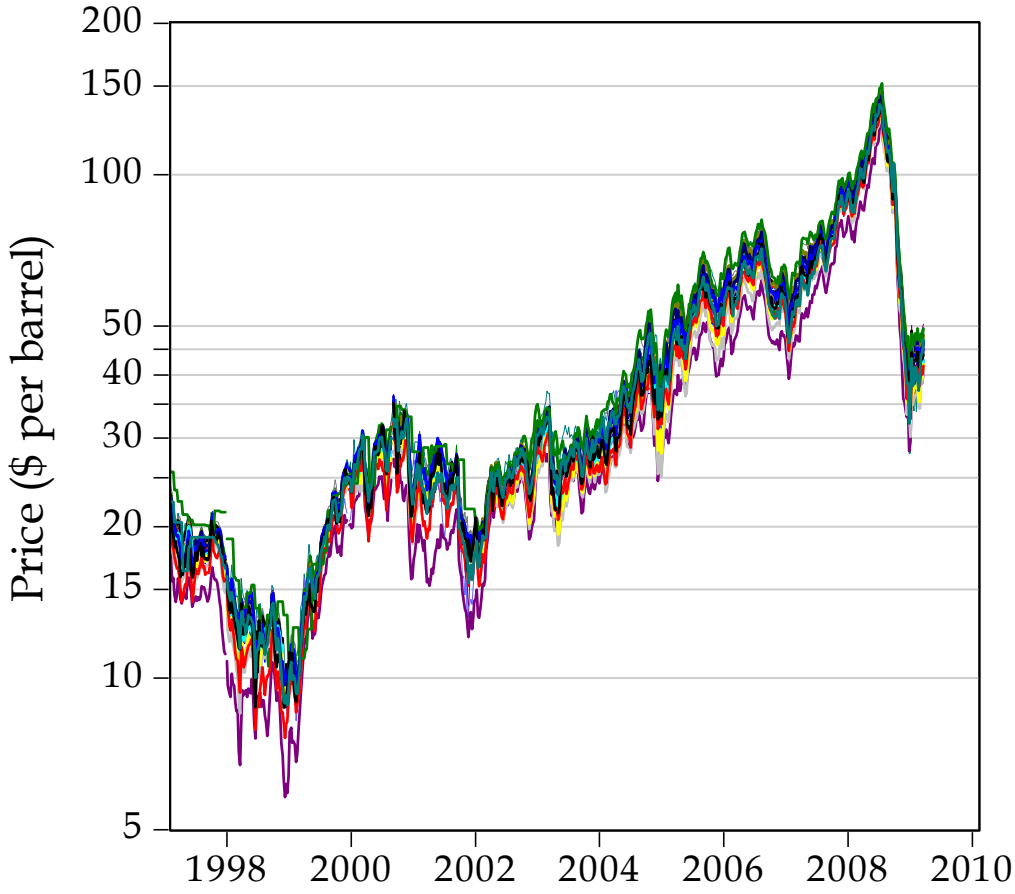

Figure 2. Prices of Crude Oil in 31 Regional Markets Worldwide

Source: U.S. Energy Information Administration (tonto.eia.doe.gov/dnav/pet/pet_pri_wco_k_w.htm).

Note: The crude oils depicted are Algeria Saharan, Blend Angola Cabinda, Europe (U.K.) Brent Blend, Cameroon Kole, Canadian Par, Colombia Cano Limon, China Daqing, Asia Dubai Fateh, Europe (Forcados, Nigeria), Australia Gippsland, Mediterranean Sidi Kerir Iran Heavy, Mediterranean Sidi Kerir Iran Light, Iraq Kirkuk Netback Price at U.S. Gulf, Kuwait Blend, Qatar Dukhan, Indonesia Minas, Abu Dhabi Murban, Mexico Isthmus, Mexico Maya, Nigeria Bonny Light, Europe (Ekofisk, Norway) Blend, Neutral Zone Khajji, Oman Blend, Saudi Arabia Heavy, Saudi Arabia Light, Saudi Arabia Medium, Libya Es Sider, Egypt Suez Blend, Malaysia Tapis Blend, Mediterranean (Russia, Urals), Venezuela Tia Juana Light.

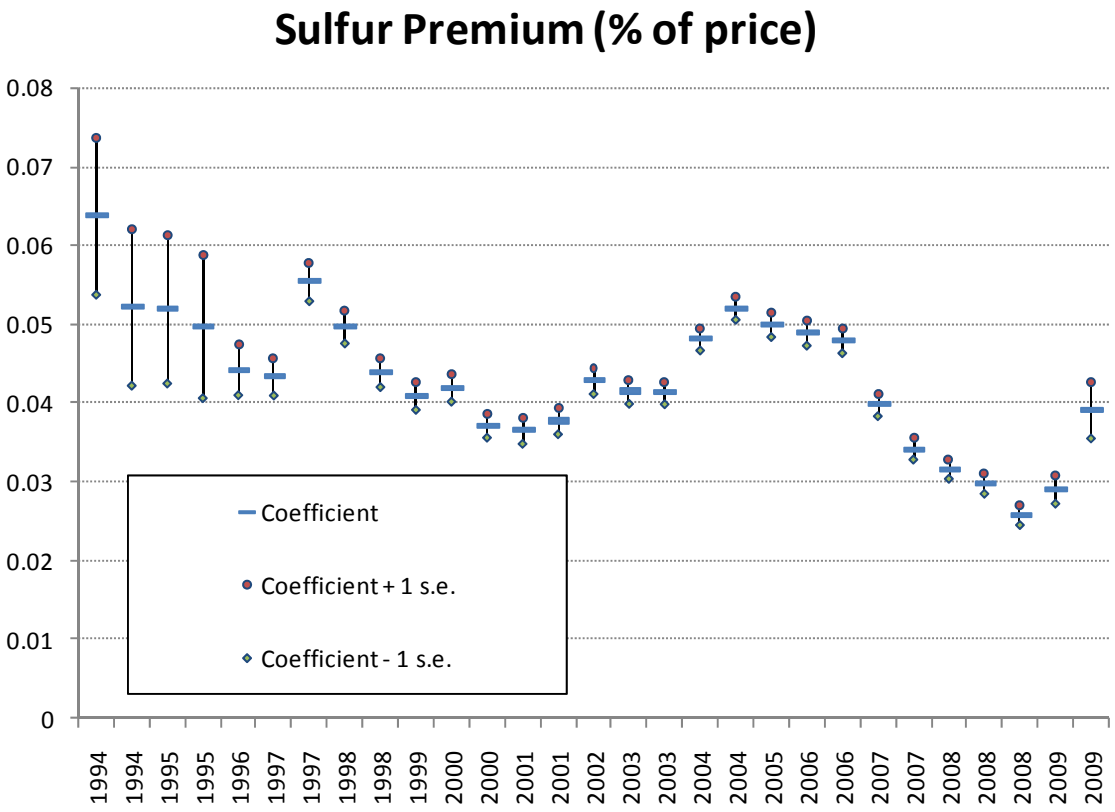

Figure 3. Sulfur Premium in Crude Oil Prices

Source: Author's regressions using data from the U.S. Energy Information Administration.

Note: Estimates from rolling five-year regressions centered on the indicated year.

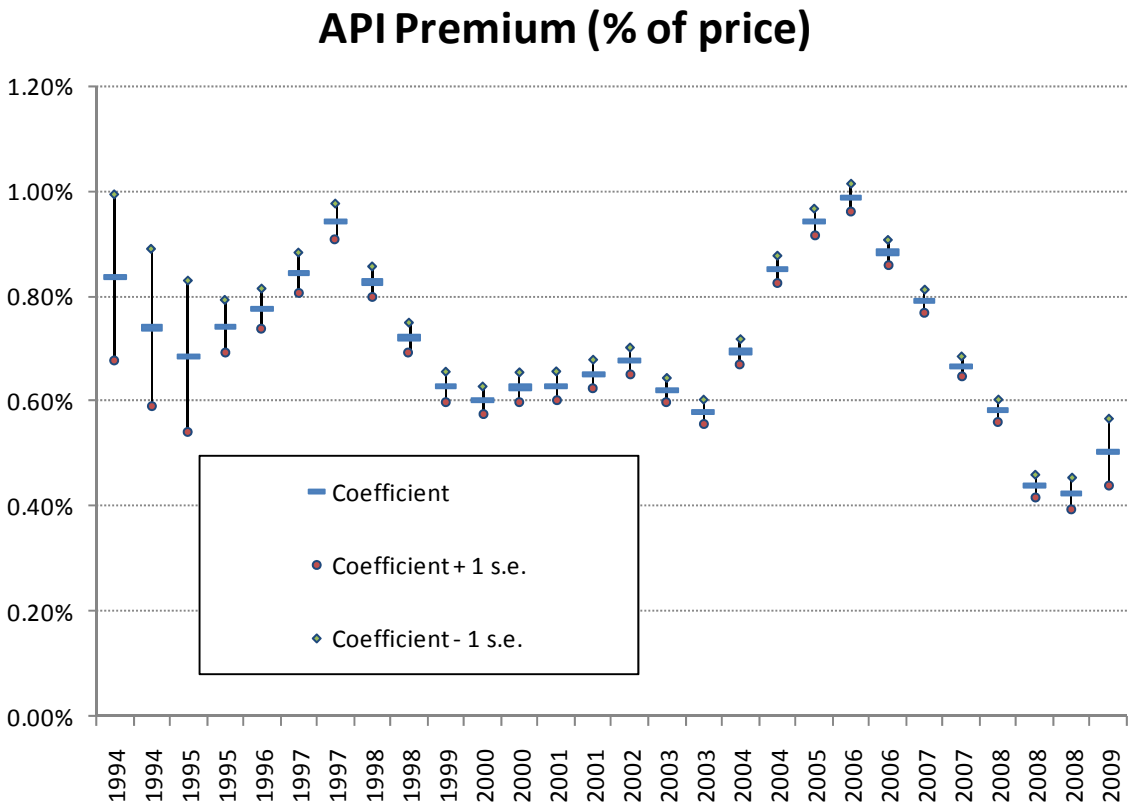

Figure 4. API Premium in Crude Oil Prices

Source: Author's regressions using data from the U.S. Energy Information Administration.

Note: Estimates from rolling five-year regressions centered on the indicated year.

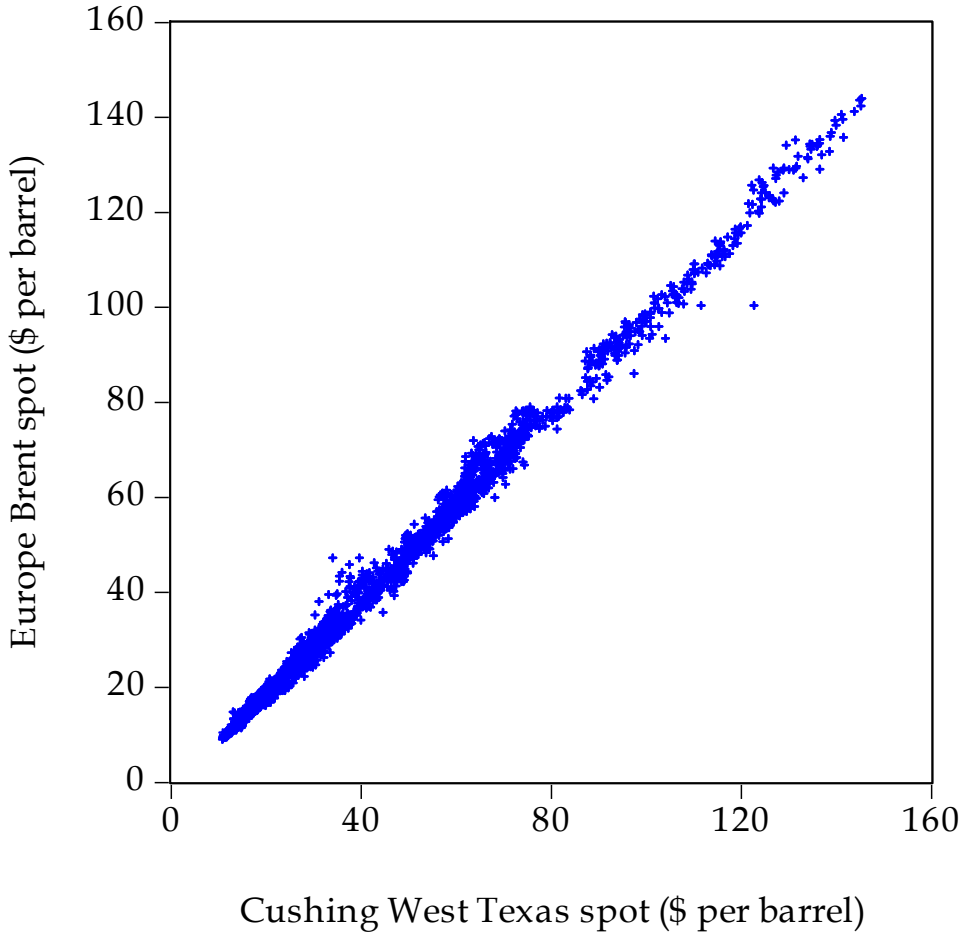

Figure 5. Comparison of U.S. and European Benchmark Crude Prices

Source: U.S. Energy Information Administration
(tonto.eia.doe.gov/dnav/pet/pet_pri_wco_k_w.htm)

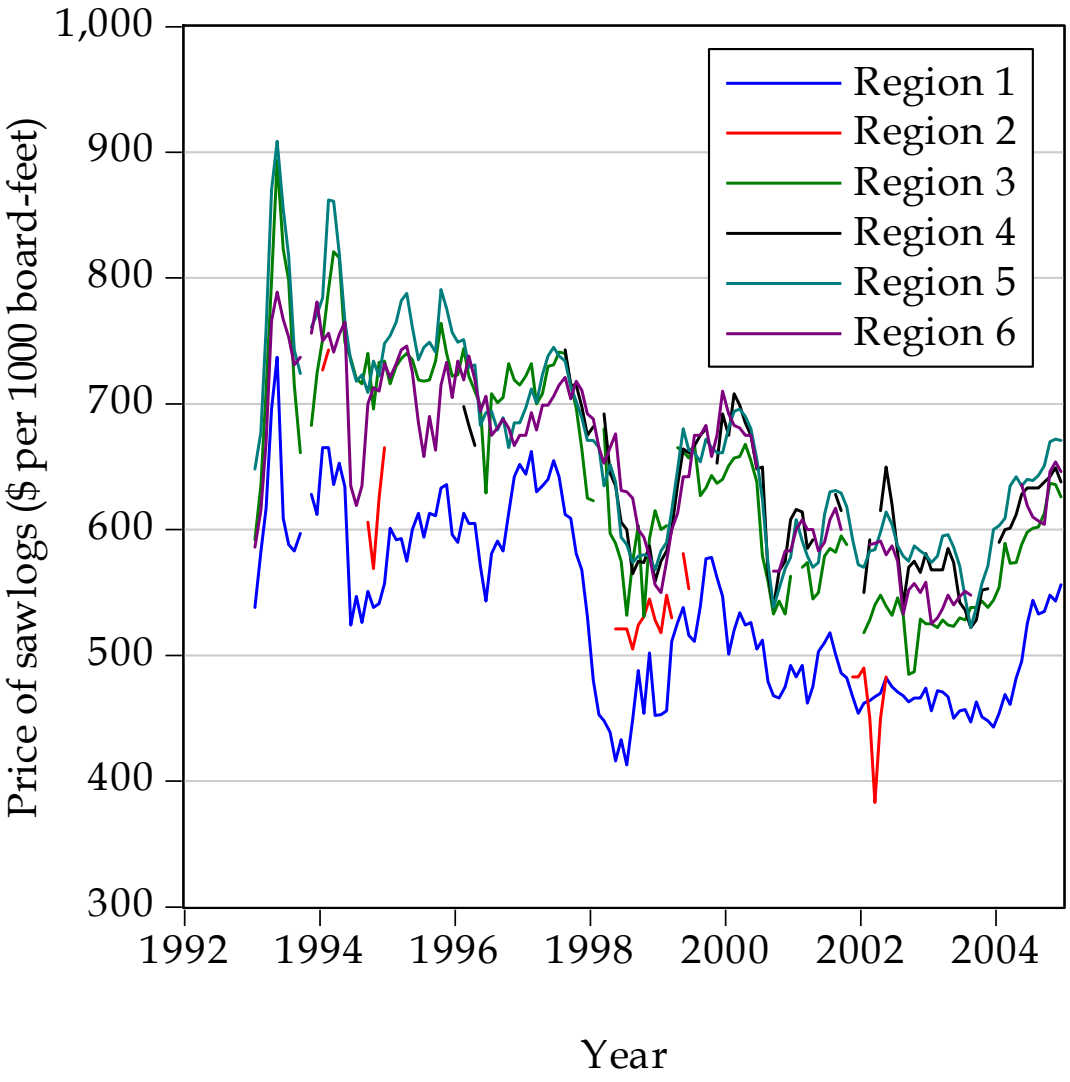

Figure 6. A Not-So-Unified Market: Prices of #2 Douglas Fir Logs in Six Regions of the Pacific Northwest

Source: *Log Lines,* various dates.

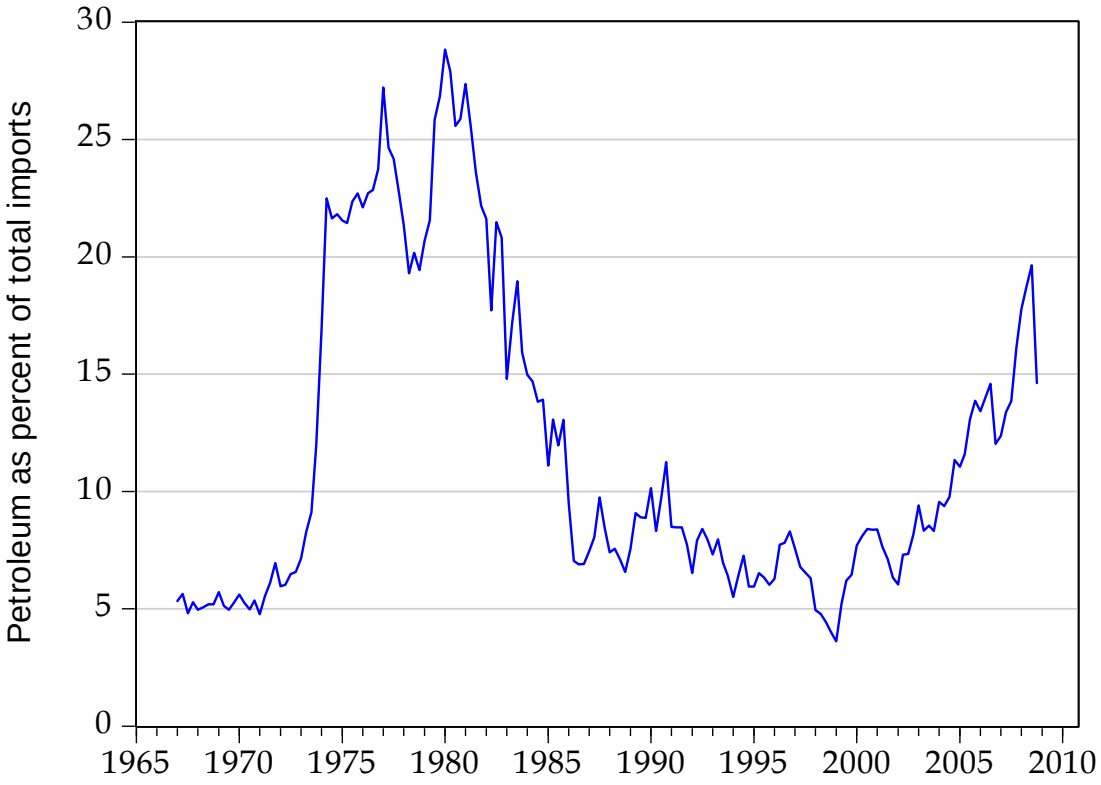

Figure 7. Petroleum Imports as a Share of Total Imports, United States

Source: U.S. Bureau of Economic Analysis data.

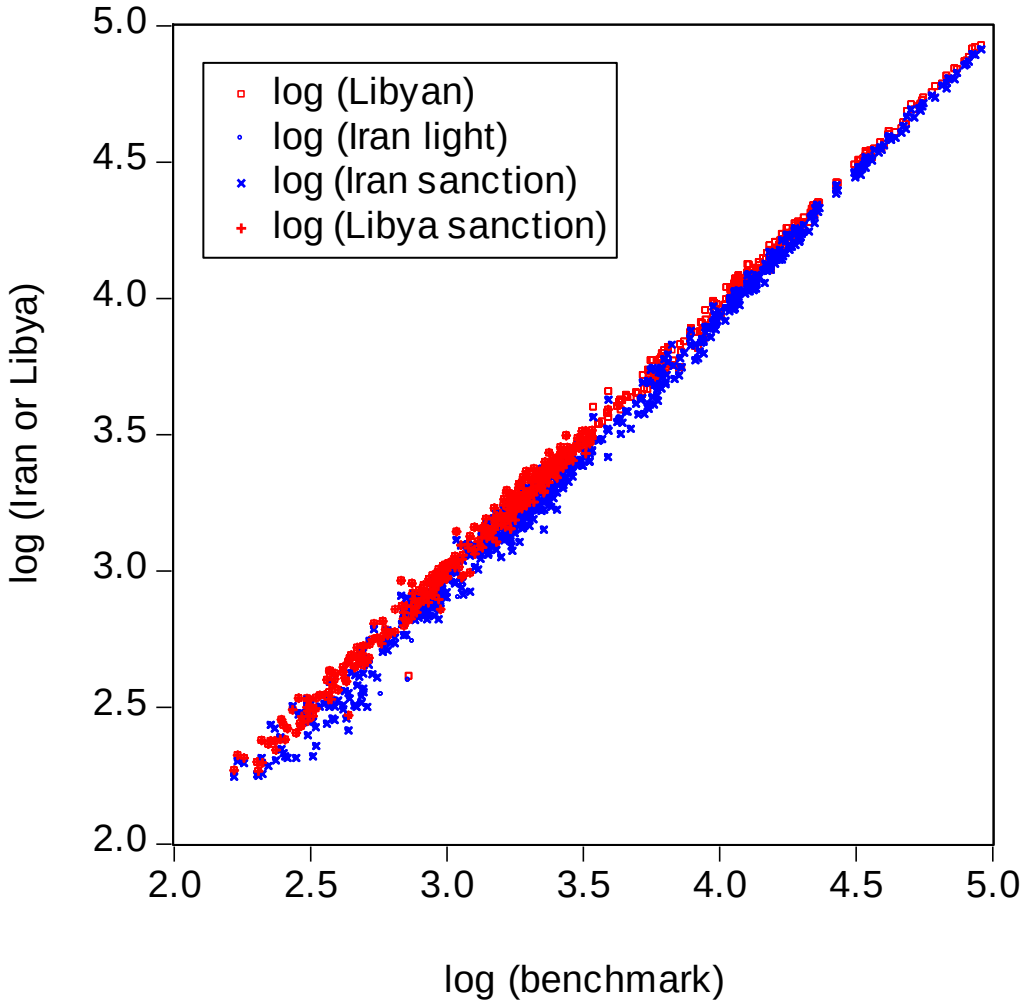

Figure 8. Comparison of Iranian and Libyan Crude Prices with Benchmark Price

Source: U.S. Energy Information Administration (tonto.eia.doe.gov/dnav/pet/pet_pri_wco_k_w.htm).

Note: The benchmark is Brent crude.

Independent variable	*Regression coefficient*	*Standard error*	*t statistic*	*Probability*
Price of Brent crude (logarithm)	0.999	0.0008	1212.8	0.0000
Sulfur content (percent)	-0.041	0.0006	-62.4	0.0000
API gravity	0.006	0.0001	56.3	0.0000
Constant	-0.223	0.0051	-43.3	0.0000
Summary statistics				
Adjusted R^2		0.988		
Standard error of the regression		0.068		
Mean of the dependent variable		3.426		
Standard deviation of the dependent variable		0.626		

Table 1. Regression of Oil Prices on Benchmark Price and Physical Characteristics

Source: Author's regressions using data from the U.S. Energy Information Administration.

Note: The dependent variable is the price of crude oil (in logarithms); data are panel data consisting of weekly observations in each of 28 regions from 1990 to the present (18,169 total observations). The estimation method is panel least squares.