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# Testimony Before the Senate Committee on Commerce, Science, and Transportation

## *Ensuring Transparency in Petroleum Markets*

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I have never known much good done by those who affected to trade for the public good. It is an affectation, indeed, not very common among merchants, and very few words need be employed in dissuading them from it.

The Wealth of Nations, Adam Smith, 1776, Book IV., Chapter 11.

Trust, but verify

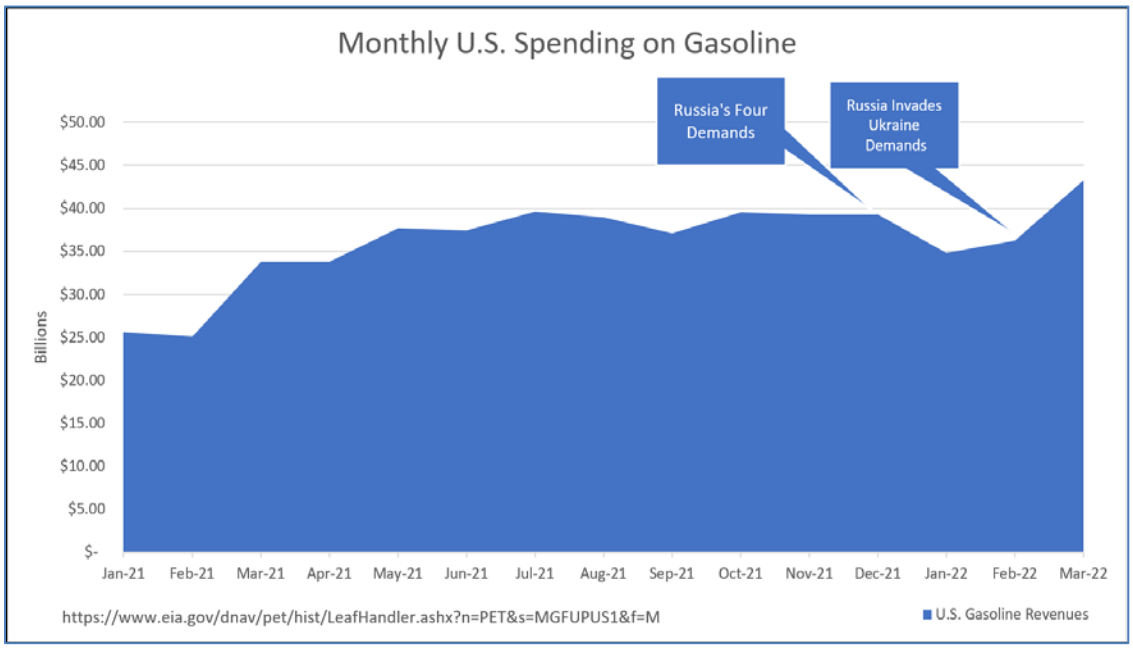
Remarks on Signing the Intermediate-Range Nuclear Forces Treaty, Ronald Reagan, 1987.

The economic impacts of the Russian Federation's war on Ukraine have surprised many. The rapid increase in oil prices reflect a legitimate concern that the world's largest oil exporter – Russia – may restrict exports or be subject to international boycotts or embargoes. However, in many cases, public perceptions of the United States and its energy balance have lagged behind market developments. This has led to unfounded fears of a 1970s style energy crisis.

In reality, the United States is now roughly able to supply its own requirements and is not in any risk of reliving the painful days of the 1972 oil boycott. As the world's largest oil producer, the U.S. buys and sells petroleum and natural gas products on an ongoing basis. Mexican cars and trucks run on U.S. refineries that, in turn, rely on Canadian crude. This means that potential shortages in Europe and China can affect prices in Akron, Ohio and Spokane, Washington.

To a lesser extent, the expansion of liquified natural gas exports from the U.S. to international markets has also begun to link prices in U.S. and foreign natural gas markets.

The war is having massive impacts on the U.S. economy. National gasoline prices have increased 38% since last March. Combined with the recovery from the pandemic, spending on gasoline has increased 44%:




The most effective policy to curb Russian aggression in Ukraine is to displace Putin's oil exports with enhanced U.S. production while protecting U.S. consumers from unnecessary price increases at the pump.

I have conclusions and recommendations in three areas: transparency, drilling, and windfall taxes:

Transparency:

1. Transparency is the least expensive and most effective tool in guaranteeing efficient markets. U.S. Oil and gasoline markets are less transparent than almost any other commodities – and vastly less transparent than competing fuels like electricity and natural gas. A database of wholesale transactions for oil and gasoline similar to FERC's database for electricity is critical to discourage anomalous trading.

2. Pivotal price reporting agencies need to provide pricing information to at least one of the relevant federal agencies – the FTC, FERC, or the CFTC. Assigning this critical function to the Federal Trade Commission is appropriate.

3. The well-known "up like a rocket, down like a feather" phenomenon needs to be explored. This form of pricing is neither equitable nor efficient. In volatile times – like today – it penalizes consumers and benefits suppliers.

4. Certain markets, like California, are prone to mysterious price excursions. In the second week of March, as oil and gasoline prices fell across the U.S., California's gasoline prices continued to increase. There is some evidence that trades which caused this increase may have been doubtful.

Drilling:

1. The duration of the war between Russia and Ukraine is impossible to forecast and the unpredictability of its scale and duration appears to be making it difficult for smaller oil producers to expand capacity as rapidly as in earlier years.

2. The Federal government's existing oil inventory could be "loaned" to the market and replaced by forward purchases in 2023. This would allow drillers with financing constraints to guarantee revenues for wells drilled today. President Biden took first steps down this path just a few days ago.

3. Replacement of draws from the strategic reserve should be undertaken by purchases of crude in West Texas Intermediate forward markets. This will expand liquidity and provide broad incentives for additional production in the Anadarko, Appalchia, Bakken, Eagle Ford, Haynesville, and Permian basins.

Windfall Profits:

1. It is logical to believe that first quarter 2022 earnings are going to be enormous. However, impacts on consumers and other businesses from higher cost fuels may also be enormous.

2. This is a case where a "windfall" tax, with proceeds specifically targeted to benefit at risk individuals and businesses, may be beneficial for society as a whole.

3. Adding an incentive to increase oil production to the windfall tax – perhaps by adding a credit against the windfall tax based on additional investments in oil production – would be helpful in speeding recovery of U.S. production.

**Overview:**

Transparency is the simplest and cheapest way to lower energy prices. Since the Chicago Board of Trade commenced operations in 1848, commodity traders have created hundreds of variants on commodity pricing schemes. As the traders evolved new versions, the law and regulatory agencies have evolved with them. The collapse of the Insull empire in the 1930s brought into existence FERC, the SEC, and the CFTC. The collapse of the Enron empire twenty years ago also increased awareness of just how fragile commodity marks can be.

In 2003, FERC released a virtual encyclopedia of market manipulation schemes in electricity and natural gas.[1] This described many, many different energy commodity "games" that had created rolling blackouts, bankruptcies, and massive overcharges in California.

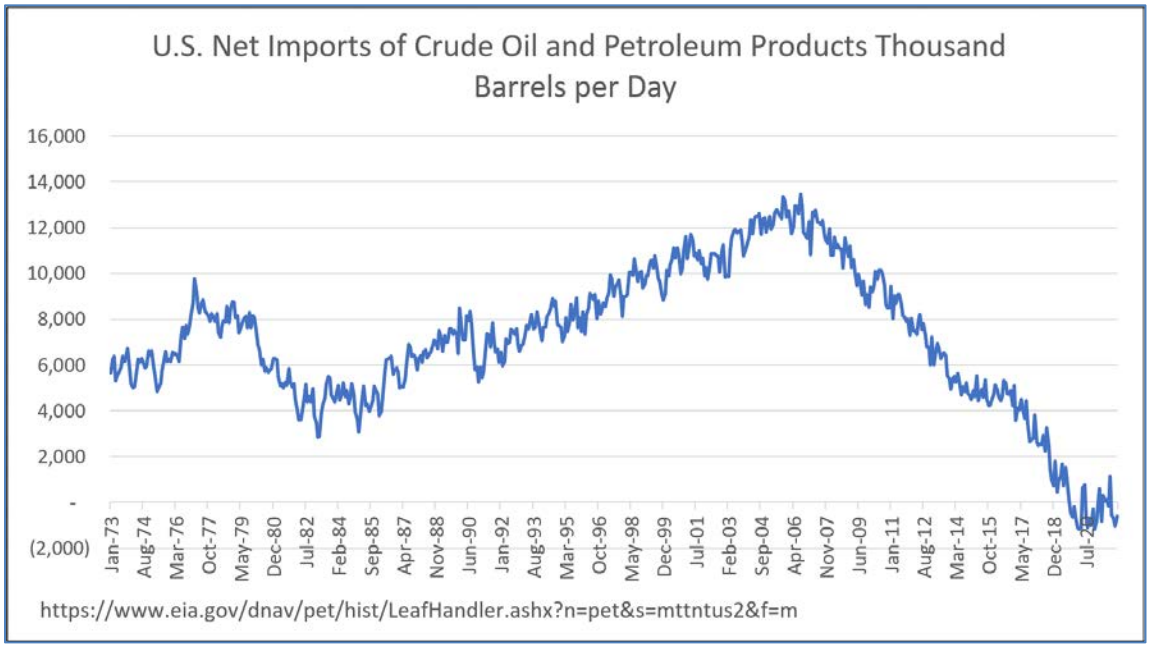
Many of these "games" are still in place today – although less so in electricity and natural gas. The ability to manipulate price reporting agencies – exchanges and industry newsletters – by wash trades did not go away since they are now prohibited at FERC and the CFTC.

Some years ago in Texas, my staff identified a disgraced Enron trader from Portland, Oregon who had simply moved to Dallas, Texas to take up his old manipulations. Below, I will identify a possible manipulation of a price reporting agency in California who may well be a victim of exactly the same techniques – at a cost of $500 million to California gasoline customers last month.

These are easily discouraged when the indexes that drive markets are calculated transparently. When the calculations are opaque, this is a continuing temptation to take advantage of consumers and make our economy less efficient.

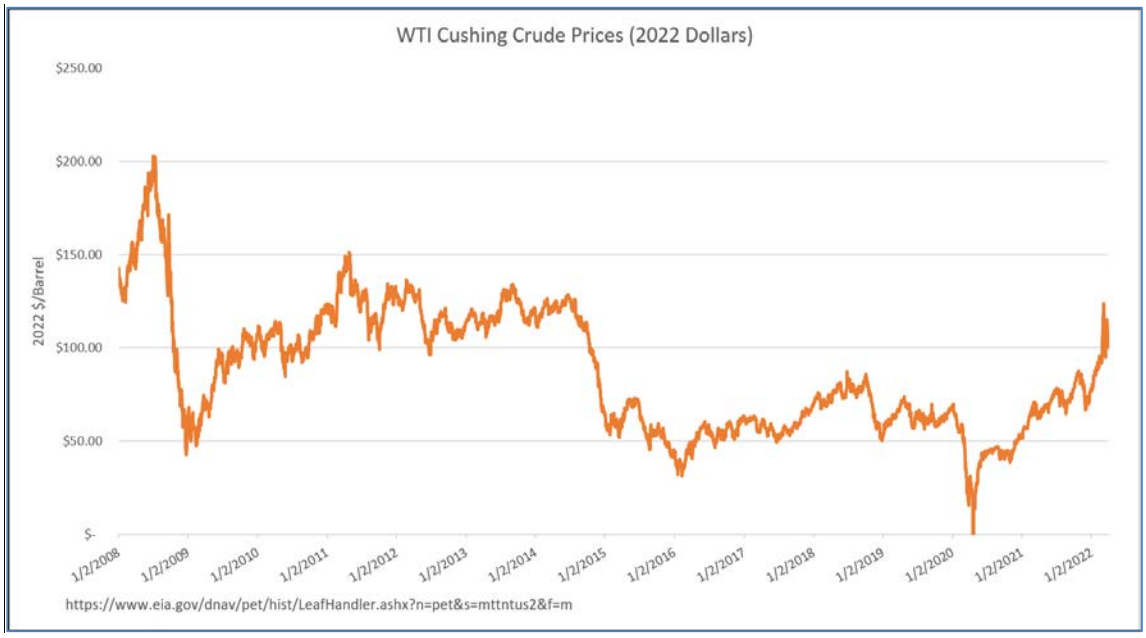
[1] Final Report on Price Manipulation in Western Markets, Docket No. PA02-02-000, Donald J. Gelinas Associate Director – OMTR, Federal Energy Regulatory Commission, March 26, 2003.

The last peak in oil prices took place in 2008. At that time, the U.S. imported a significant portion of its needs. Since then, crude prices and U.S. imports have declined, although they continue to reflect shifts in global supply and demand. In the recent years, the U.S. exported more petroleum products than it imported.[2]




In real and nominal terms, crude prices have remained below the July 2008 peak, but the increase in prices over the past three months have nonetheless been significant:

[2] Supply and Disposition Total Crude Oil and Petroleum Products at https://www.eia.gov/dnav/pet/PET_SUM_SND_A_EP00_MBBL_M_CUR.htm




Below, I address three basic issues in the current crisis: transparency, drilling, and windfall profits.

**Transparency:**

While competing fuels like natural gas and electricity are reviewed for market manipulation at the Federal Energy Regulatory Commission and futures are reviewed by the Commodity Futures Trading Commission, no specific agency has jurisdiction over spot oil and gasoline transactions. This is surprising since firms that are active in oil and gasoline trading have often faced investigations and penalties at both FERC and the CFTC.

To a degree, some state attorney generals have attempted the daunting task of deconstructing petroleum industry pricing, but have always been hampered by a lack of resources and data.

The one exception to this unfortunate state of affairs was with the Interagency Task Force on Commodity Markets Interim Report on Crude Oil in 2008.[3] The task force issued a useful interim report in June 2008, soon after oil prices peaked. However, following this, the final report and the entire interagency task force was never heard from again.

[3] Interagency Task Force on Commodity Markets Interim Report on Crude Oil, CFTC, July 2008.

Data transparency is the least expensive and most effective method of regulating market manipulation. Unfortunately, oil and gasoline has only a fraction of available information compared to competing fuels. A case in point is the public release of electric transaction data by the Federal Energy Regulatory Commission. The Electric Quarterly Report provides the vast majority of wholesale electric transactions including buyer, seller, price, location, and many other details.[4]

Adam Smith's famous study on the wealth of nations addresses the benefits of such transparency measures:

> The landlord and tenant, for example, might jointly be obliged to record their lease in a public register. Proper penalties might be enacted against concealing or misrepresenting any of the conditions; and if part of those penalties were to be paid to either of the two parties who informed against and convicted the other of such concealment or misrepresentation, it would effectually deter them from combining together in order to defraud the public revenue.[5]

Wash trades (FERC's term) or prearranged trades (CFTC's term) are trades without an underlying economic purpose. Such trades are often used to create a false impression of quantities or prices.

A similar database for wholesale oil and gasoline transactions meeting reporting definitions would be considerably smaller than the current electric database maintained by FERC. The advantage of such a database is that prohibited transactions like wash trades can easily be reviewed.

Anomalies in oil and gasoline markets are not unusual. One continuing mystery concerns the inconsistent response of gasoline markets to changes in the price of feedstocks. For example, the phrase "up like a rocket, down like a feather" has often been used to describe the rapid increase in retail gasoline prices when oil prices rise, but the very slow decrease in gasoline prices when oil prices fall.

The rocket/feather effect occurred recently when the price of oil increased markedly in the first week of March and then fell even more dramatically in the second week of March:

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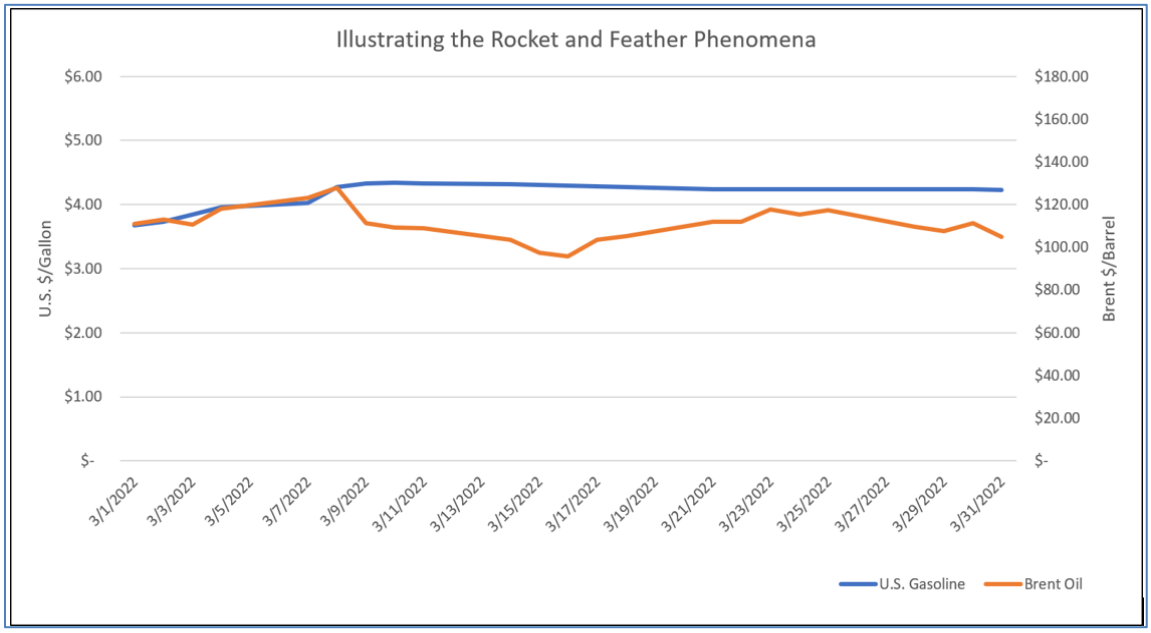
[4] https://www.ferc.gov/power-sales-and-markets/electric-quarterly-reports-eqr
[5] The Wealth of Nations, Adam Smith, 1776, Ch. II, Pt. II.




There is nothing mysterious in the rapid response of gasoline prices to oil price increases. The contracts between refineries and downstream customers often specify specific wholesale market prices. Such contracts should also reduce the price of gasoline when oil prices fall – unless transactions are affecting the indices used in the contract.

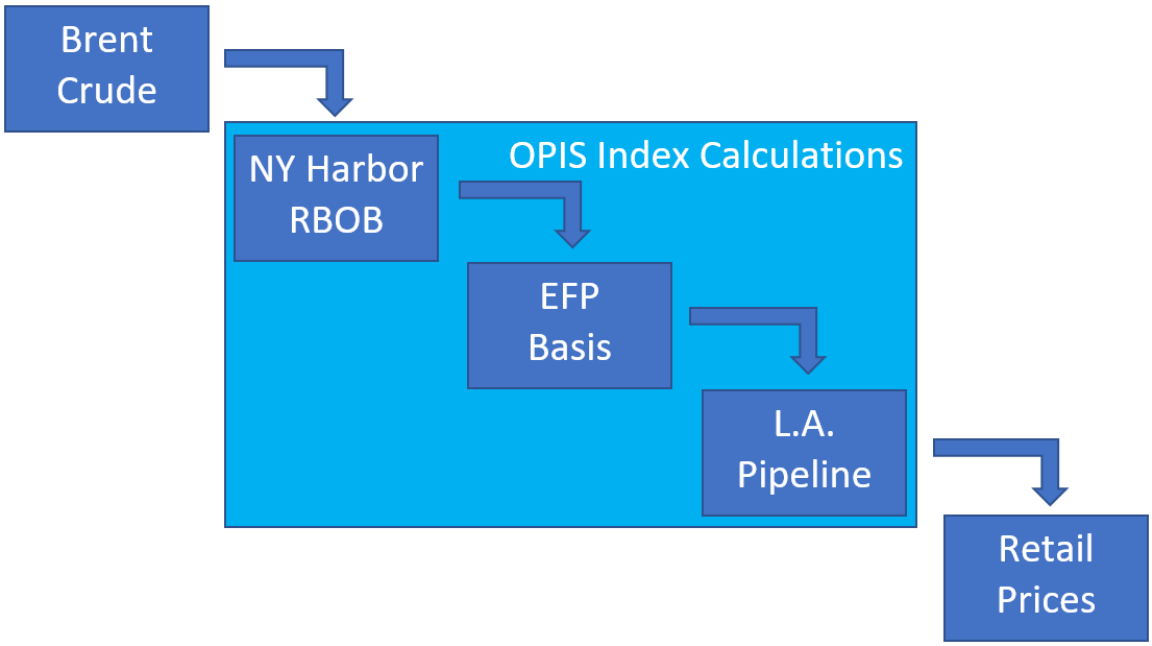
The mystery lies in the "feather" pricing – what transactions are affecting market indices and why these transactions are at odds with economic theory.

In a volatile oil market, as is present today, the rocket/feather pricing is an undue burden on consumers. It also misprices oil and gasoline throughout the entire economy with significant negative impacts on inflation and employment. Put more simply, a sudden increase and following decrease in oil prices should not be creating a prolonged rise in downstream prices.

North America is largely separated into two market areas: the West Coast and the states and provinces east of the Rockies. While oil and gasoline are produced in both areas, the West Coast tends to rely more on world markets – priced at the Brent market price – than the area east of the Rockies which receives much of its supplies at the slightly lower Cushing or WTI market price.

As with other major commodities, wholesale oil and gasoline can be purchased in the bi-lateral market and on one of the commodity exchanges. For the West Coast, there are fewer options and, significantly, a single industry newsletter dominates pricing.

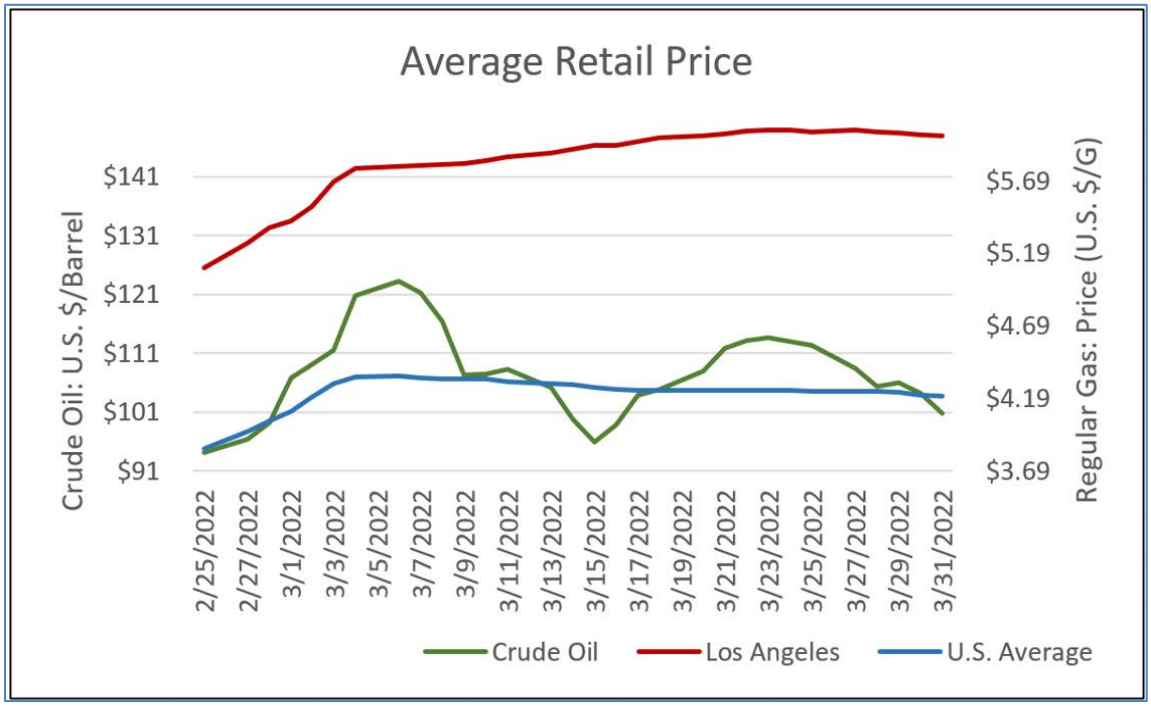
For example, many transactions specify indices published by the Oil Price Information Service (OPIS) newsletter. OPIS staff collect transactional data from industry participants and calculate indices for a variety of products and services from California to Washington.




The center of this diagram is the "EFP Basis". This is an industry term for Exchange of Futures for Physical where oil or gasoline is exchanged for a futures contract. In the case of California, the forward market of gasoline at the NY Harbor is a common choice for the futures contract. OPIS staff assemble the index from transactions submitted to them by traders.

These transactions are not easily understood. Moreover, there is very little transparency concerning the identity of the traders making these transactions, the quantities transacted, and whether the transactions are consistent with rules normally enforced in commodity markets which are nearly impossible to monitor. This is a continuing problem in California and needs to be addressed by a formal investigation.

There has been considerable interest in explaining why Los Angeles prices continued increasing after oil prices began declining on March 8, 2022.[6] National prices decreased during the same period. There were no major events on the 8th of March that would explain the different directions in California and elsewhere in the United States.




California is a very complex market with high taxes and expensive carbon programs borne primarily by the consumer.[7] Unfortunately, the market is both highly concentrated and even more opaque. As Enron's chief West Coast trader remarked twenty years ago: "California Market Structure ISO and PX have a complex set of rules that are prone to gaming".[8] This is still true today for petroleum products in California.

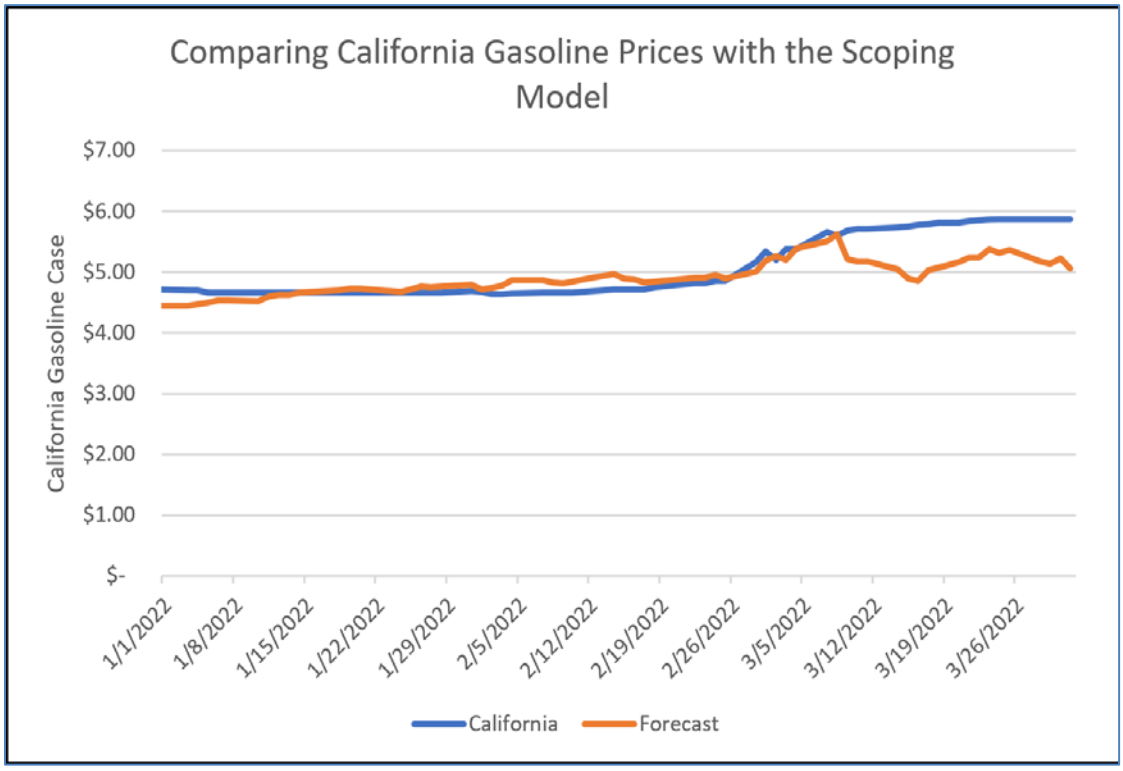
It is not unusual for trades used in the index to be very few in number. This has created the potential for market manipulation in the past and a similar situation exists today.

[6] U.S. Gas Prices Are Coming Back Down, but Not in California, Soumya Karlamangla, New York Times, March 24, 2022.
[7] See Fuel Tax Incidence and Supply Conditions, Justin Marion and Erich Muehlegger, M-RCBG Faculty Working Paper Series | 2010-02, for example.
[8] Western Power Markets, Tim Belden, May 3, 2000, Slide 12.

In the case of California's gasoline prices in March, the prices in the transactions reported to OPIS apparently increased markedly after oil prices started to fall.
A second factor in the opaque California market is an unexplained increase in gasoline prices that occurred in 2015.

Severin Borenstein, a respected professor at UC Berkeley, has identified an unexplained surcharge on California prices that began in February 2015.[9] This curious situation is currently under investigation by state authorities.[10]

We have used a simple scoping model over the past decade to look for periods when California gasoline prices are anomalous. The week of March 6, 2022, for example, had high prices while our scoping model would have indicated a substantial reduction:




[9] Calculation of California's Mystery Gasoline Surcharge, Severin Borenstein, May 20, 2019.
[10] Why California gas prices are so high and vary so widely: 'Mystery surcharge' and more, Connor Sheets, L.A. Times, March 14, 2022.

What happened in mid-March to increase prices in California even after oil prices fell? While inventive minds may hypothesize a sudden increase in driving just before the spring school break or the anticipation of a strike that took place a week afterwards, the reality is even simpler. The basic index of transactions in California – used in contracts between refiners, middlemen, and retailers – took a sudden leap to almost one dollar per gallon.

The appendix to this report provides the statistical evidence from the simple scoping model.

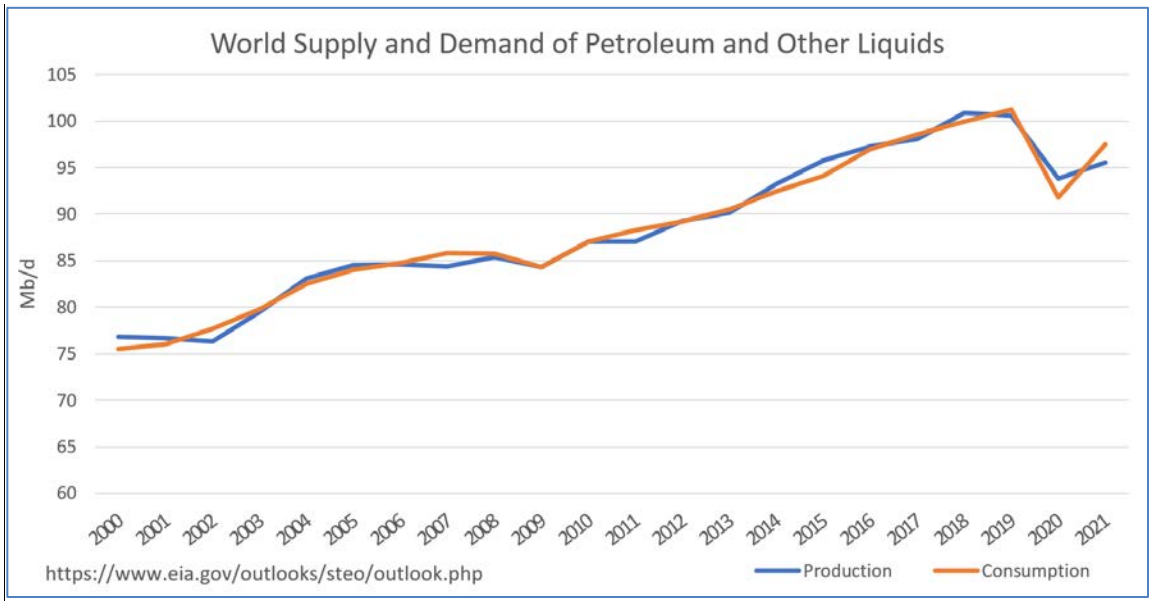
If gasoline sales in California are comparable in March 2022 to those that took place in March 2021, the impact on consumers was on the order of $500,000,000 last month.

In passing, it also indicates that the mystery surcharge identified by Professor Borenstein added an additional $0.4471/gallon.

We used a similar scoping model to look for anomalies in neighboring states – Washington and Oregon – and major market states like Illinois, New York, and Texas. The situation in California in March stands out compared to the prices elsewhere in the United States.

**Drilling:**

Declines in consumption during the pandemic triggered a decline in prices and a corresponding decline in oil discovery.




Seeking more oil production and a reduction of sanctions against Venezuela and Iran has been suggested. Unfortunately, neither of these countries is likely to act against the interest of the Russian Federation.

Other possible sources include increased production by OPEC and/or a reduction in the disruption of the Libyan oil fields. There are a variety of reasons why this might be problematic as well.

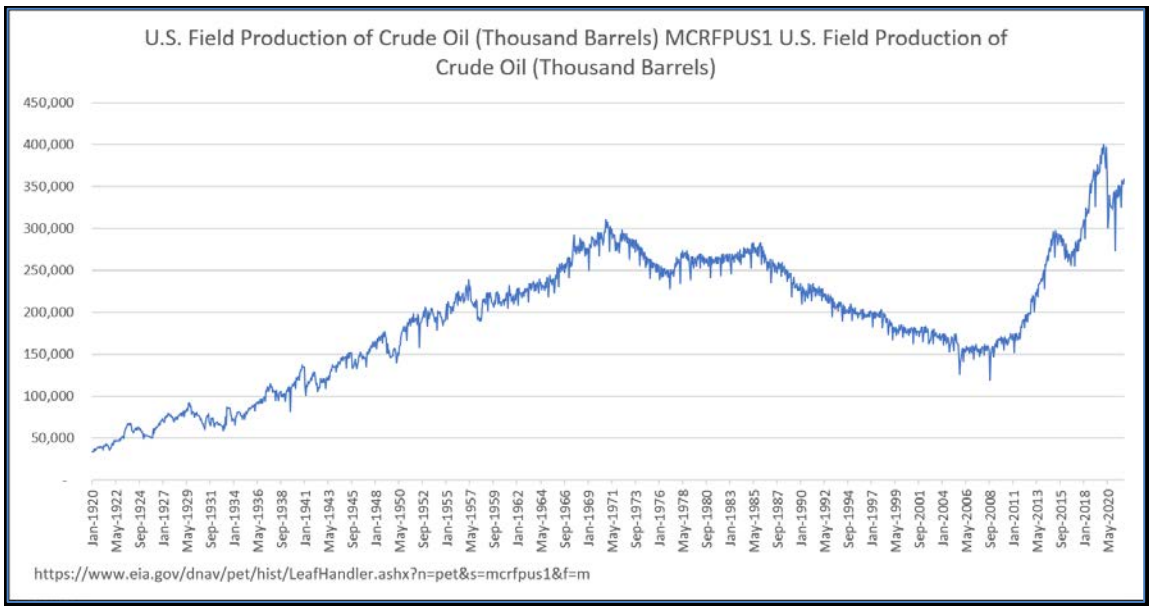
The most straightforward solution is to increase production from existing fields in the U.S. and Canada. This has two major benefits:

1. U.S. shale production is easily expanded
2. Additional North American exports can be directed to allies in need – especially in Europe.

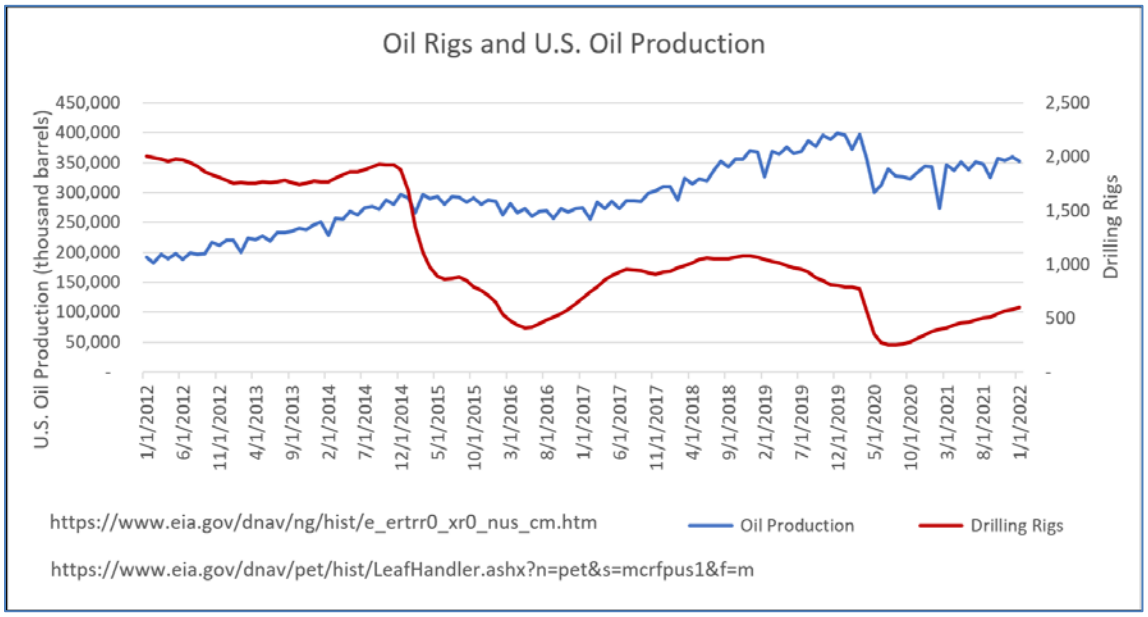
Successful oil sanctions against Russia will cause less harm to the world economy if U.S. oil production ramps up. Unfortunately, the U.S. response to high oil prices has been slow and cautious. To meet needs in Europe, the U.S. may need to consider financing support for independent wildcatters in mid-continental oil fields to accelerate U.S. oil production.

The still unexplained spike in oil prices on July 3, 2008 had momentous impacts on U.S. oil production. The high prices spurred innovation in three areas – discovery, access, and

extraction. Put more colloquially, supercomputers have allowed a high degree of precision in finding oil, while horizontal drilling allows a broader access per well, and fracturing (aka fracking) has accelerated oil recovery. The resulting oil production for the United States was striking:




U.S. oil production is roughly based on the number of drilling rigs in operation – particularly over the past decade:




The shift in technology also changed the business considerably. Using older technologies, a virtual forest of wells could occupy an oil field. Today, a single well exploits a much larger area. This is reflected in the continuing downward slope of the number of drilling rigs even as U.S. oil production has increased.

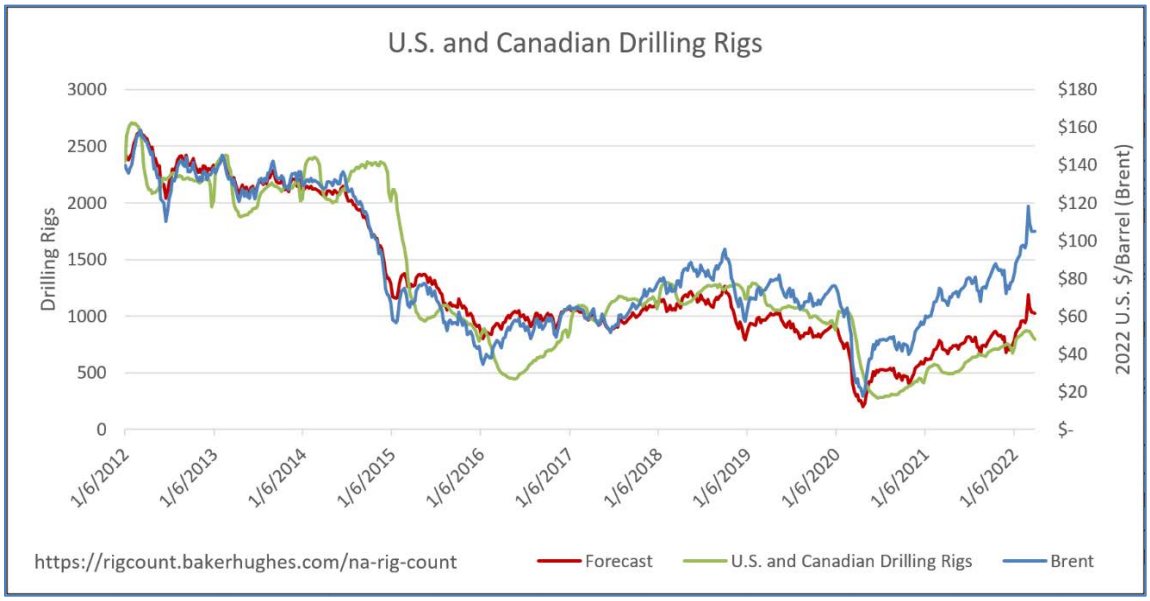
Mathematicians describe the point on a curve when it changes direction as an inflection point. For drilling rigs, the inflection point is approximately $60/barrel. Below $60/barrel, the number of active drilling rigs falls. When the prices are above $60/barrel the number of active rigs increases.

We are currently in a period of increase. Since the price of oil passed $60/barrel one year ago, the number of active rigs has increased by 17 per month. During the previous period in which drilling increased, as can be seen in the chart above, the number of active rigs increased by 31 active rigs per month, nearly twice as many.

A more scientific approach is to construct a simple mathematical model as a function of the real oil price and the date. The oil price represents the incentive to increase or decrease drilling. The date variable is a rough representation of the greater efficiency of modern drillings – finding more oil while drilling fewer wells:

Active Drilling Rigs = Constant + 13.0 Rigs/$1 increase in the WTI price
- 0.03 Rigs per day

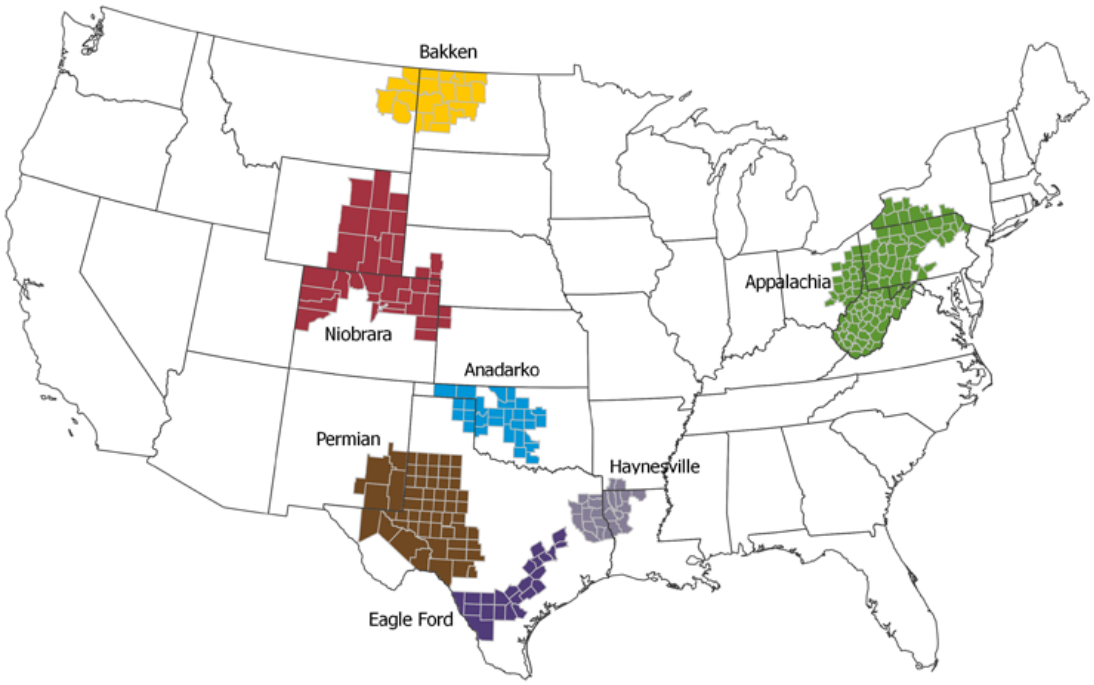
This simple model is statistically significant at the 99.9% level and explains 84.2% of the explanatory variable.




The area highlighted in red reflects a much slower pace of added drilling rigs than in previous high oil price periods.

Given current incentives, we would expect approximately 300 more rigs to be active as we see today. Based on the relationship between active oil rigs and oil production, this would increase U.S. production by 2% -- a sizable increment in world oil production.

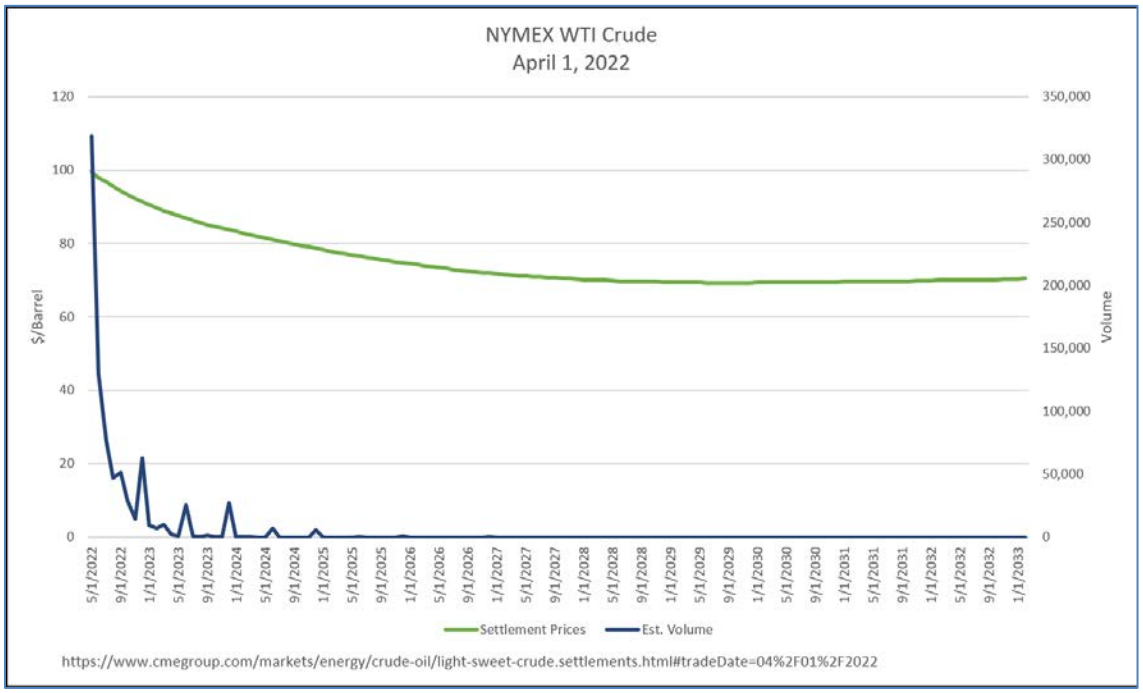
While market structure in some areas – such as California – have raised market power concerns over the years, oil drilling in U.S. mid-continental basins are highly competitive. The map below illustrates a variety of basins where the constraint may well be financing for smaller companies:




eia Source: U.S. Energy Information Administration

Short term financing guarantees may provide needed relief for oil price increases while displacing Russian oil exports.

An important part of the problem may be explained by the forward curve for WTI crude. The NYMEX curve shows a surge of prices in the short run, but a gradual decline to long term historical levels:




Thin trading in later months may prove a challenge to smaller drillers. In a perfect world they could depend on forward markets to finance their projects. In the current environment there is relatively little volume past September and a steady decline to long-term break-even prices in the $60 to $70/barrel range.

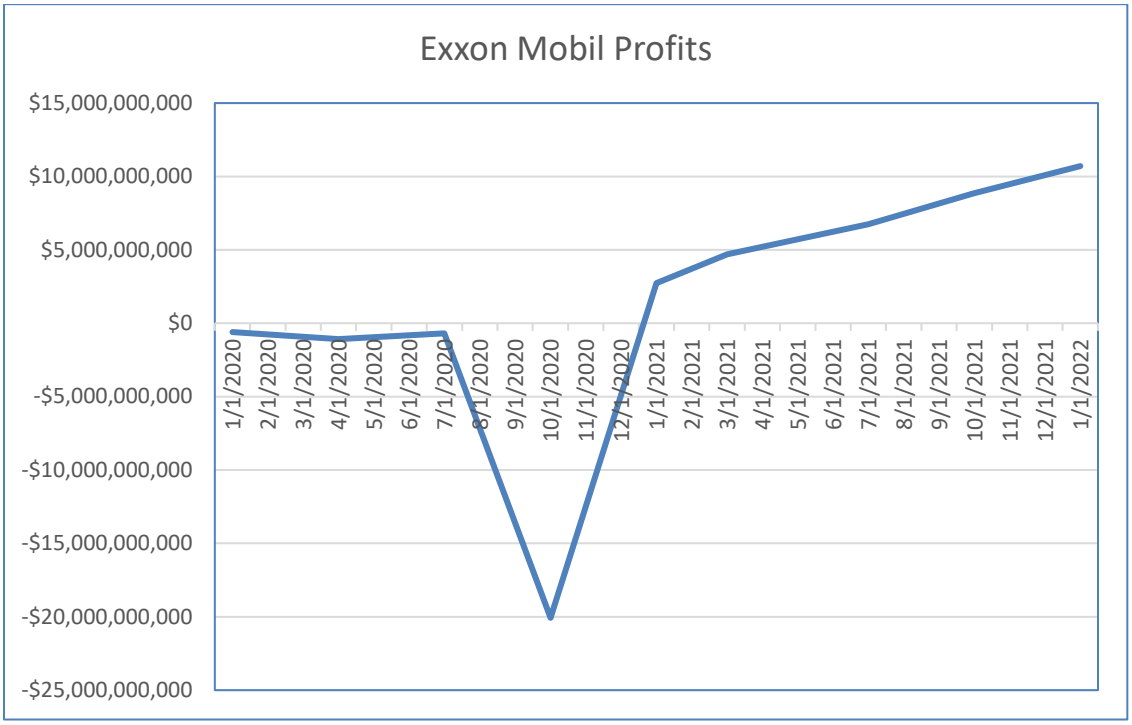
There is an industry model for solving this problem that might be useful. When a commodity is needed earlier in the market than can easily be produced, the product can be "borrowed" from existing inventories and "returned" later. The U.S. government maintains a large inventory of oil which made more sense when the U.S. was a net importer. One approach to make financing current product easier would be for the U.S. government to contract for forward supplies of oil from U.S. producers. This would free up existing stocks for needy European allies.

It should be noted that nothing in this proposal will increase global emissions. Increased oil production will simply reduce Russian oil sales – and Russian oil revenues – as U.S. production provides supplies to European allies.

**Windfall Profits:**

An unjust foreign war raises many complex ethical questions. Most of these go far beyond the scope of this testimony. However, the sheer scale of dollars involved make this an important policy question – what is the appropriate response to massive windfall profits? This is also important when, as the United States is the largest consumer of petroleum products, much of the windfall profits come from transactions that affect U.S. consumers businesses.

Exxon-Mobil, for example, has the potential to earn over $10 billion in the first quarter of 2022. This estimate is based on changes in market prices and has – very conservatively – assumed that costs will increase by the same margin.




The following table shows comparable estimates for eight other major participants in the industry:

| Company | First Quarter 2021 | First Quarter 2022 | % Change |
|---|---|---|---|
| BP | $ 4,667,000,000.00 | $ 6,985,417,380.18 | 50% |
| Chevron | $ 1,377,000,000.00 | $ 8,815,047,585.41 | 540% |
| ConocoPhillips | $ 982,000,000.00 | $ 2,953,606,092.59 | 201% |
| Equinor | $ 1,854,000,000.00 | $ 3,503,407,667.03 | 89% |
| Exxon-Mobil | $ 2,730,000,000.00 | $ 10,605,047,399.46 | 288% |
| Marathon Petroleum | $ 64,000,000.00 | $ 3,182,164,319.77 | 4872% |
| Occidental Petroleum | $ (346,000,000.00) | $ 3,591,071,365.41 | N/A |
| Phillips 66 | $ (654,000,000.00) | $ 719,023,744.88 | N/A |
| Shell | $ 5,660,000,000.00 | $ 13,249,651,986.97 | 134% |

[11]

These are remarkable levels of earnings.

The previous oil price peak – on July 3, 2008 – lasted for a very short period. Given the current news from Ukraine, it is conceivable that the high level of profits may extend beyond just one quarter.

This unprecedented situation will soon be showing up throughout the supply chain – potentially reducing production and employment for commercial and industrial customers. This is even more important. In addition, there will be significant inflationary impacts.

As noted in the previous section, the most important issue is to increase oil production. This will alleviate supply issues in Europe as well as lower prices.

A windfall tax might also be a useful tool. A windfall tax can be constructed to provide incentives for expansion of output as well as to recapture windfall profits. If the windfall tax was calculated on the basis of earnings/barrel, rather than just earnings, it would create a major incentive to resume drilling and producing.

Here is one possible formulation:

The windfall tax would only be paid on profit levels – as a percentage of oil and natural gas producing assets – higher than the 2021 level. Additions to oil and gas producing assets will lower the taxable percentage.

[11] The rate of increase for Occidental and Phillips are not reported since the growth rate from loss to profit does not yield a meaningful percentage.

$$\text{Taxable Profit Rate} = \frac{\text{2021 Earnings}}{\text{2021 Producing Assets}} - \frac{\text{2022 Earnings}}{\text{2022 Producing Assets}}$$

Our primary objective is to increase oil producing investments. This would be poorly served if we did not add incentives to increase production while, at the same time, raising revenues to offset the impact of inflationary pressures on U.S. consumers.

**Conclusions:**

Our conclusions reflect the three primary areas addressed in this report.

Transparency:

Transparency is the least expensive and most effective tool in guaranteeing efficient markets. Oil and gasoline are less transparent than almost all other commodities – and vastly less transparent than competing energy products, like electricity and natural gas. The easiest and least complicated solution to anomalous market outcomes in oil and gasoline would be to implement a database similar to that of FERC's Electric Quarterly Reports, for transactions recorded by price reporting agencies.

Critical price reporting agencies need to provide pricing information to at least one of the relevant federal agencies – FTC, FERC, or CFTC – on transactions used to implement market indices.

The well-known "up like a rocket, down like a feather" phenomena needs to be explored. This form of pricing is neither equitable nor efficient. To the degree that the "feather" reflects anomalous trading behavior, a formal investigation is appropriate.

Certain markets, like California, are prone to mysterious price excursions. In the second week of March as oil and gasoline prices fell across the U.S., California's gasoline prices continued to increase. Our scoping model indicates that prices in California reflected very different trading patterns in gasoline than elsewhere in the United States.

It also appears that Professor Borenstein's gasoline surcharge concerns are supported by the data.

Drilling:

The duration of the war between Russia and Ukraine is impossible to forecast and the unpredictability of its scale and duration appears to be making it difficult for smaller oil producers to expand capacity as rapidly as in earlier years.

To the degree oil production is subject to financing constraints, this needs to be addressed directly and solved in the short run.

The Federal government's existing oil inventory could be "loaned" to the market and replace by forward purchases in 2023. This would allow drillers with financing constraints to guarantee revenues for wells drilled today.

Windfall Profits:

It is logical to believe that first quarter 2022 earnings are going to be enormous. However, negative impacts on consumers and businesses from higher fuel costs may also be enormous.

This is a case where a "windfall" tax specifically targeted to at-risk individuals and businesses may be beneficial for society as a whole. A windfall tax need not be restricted to a tax on earnings. It is possible to structure a tax that both recaptures some of the profits and provides an incentive to increase production. A good choice would be a tax on earnings above previous levels – based on the ratio between earnings and producing assets.

I would close with one more quote from Adam Smith:

> People of the same trade seldom meet together, even for merriment and diversion, but the conversation ends in a conspiracy against the public, or in some contrivance to raise prices. It is impossible indeed to prevent such meetings, by any law which either could be executed, or would be consistent with liberty and justice. But though the law cannot hinder people of the same trade from sometimes assembling together, it ought to do nothing to facilitate such assemblies; much less to render them necessary.[12]

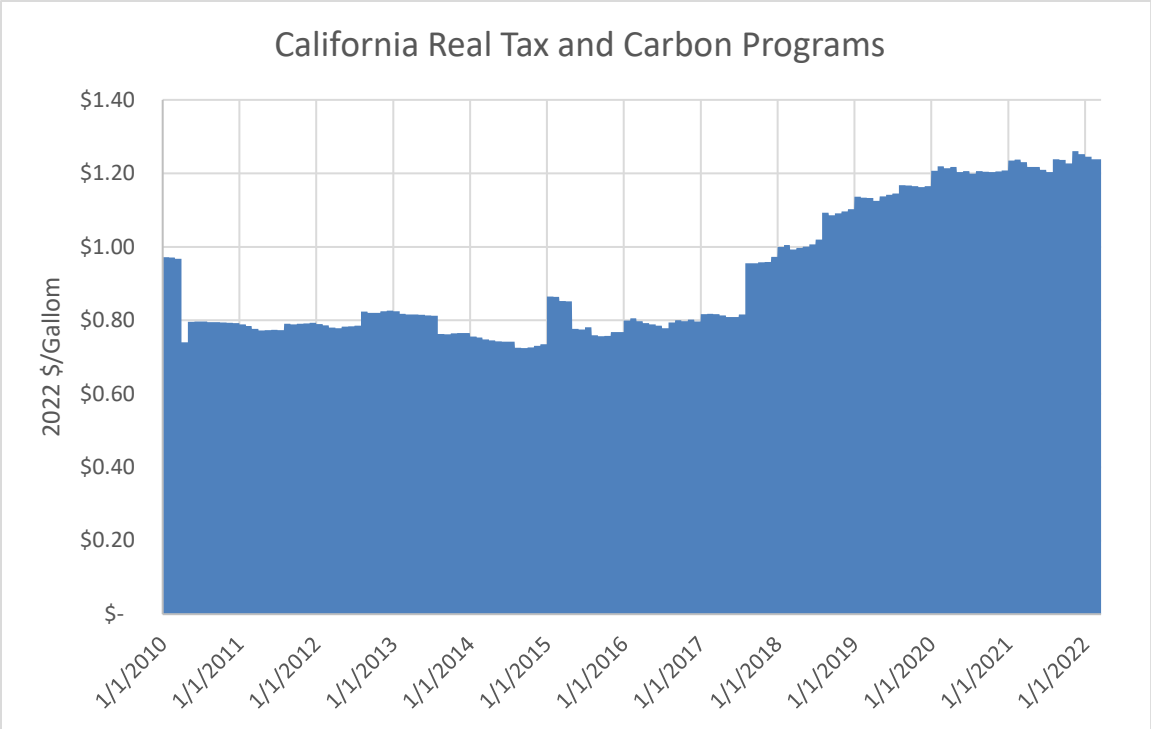
[12] The Wealth of Nations, Adam Smith, 1776, Chapter X, Part I

**Statistical Appendix:**

For the past decade, we have used a simple scoping model to see if specific states and cities have departed from fundamentals. The basic theory is straightforward – in an efficient market, gasoline prices should track closely to feedstocks. The primary feedstock, of course, is crude oil.

California is a special case in the United States because of the size and complexity of gasoline taxes. The standard analysis of gasoline tax incidence was formulated in a study by Justin Marion and Erich Muehlegger.[13] They found, not surprisingly, that such taxes are primarily paid by consumers.

In California, real taxes over the past decade have increased dramatically:




[13] Fuel Tax Incidence and Supply Conditions, Justin Marion and Erich Muehlegger, M-RCBG Faculty Working Paper Series | 2010-02.

Professor Borenstein's observation that gasoline prices increased sharply in February of 2015 is now being investigated by state authorities.[14]

Given the scale of this unexplained gas price increase, we have added a "dummy variable" for February 2015 to the present.

The analysis uses the standard tool of the economic analyst, linear regression. This method identifies the quality of the regression (also known as its significance) and the impact of its explanatory variables.

The dependent variable is the real retail price of California CARBOB reduced by the level of gasoline taxes. The independent variables are Brent and WTI crude plus a dummy variable for Professor Borenstein's unexplained retail price increase post February 2015.

```
. tsset datenumber
        time variable:  datenumber, 1 to 2500
                delta:  1 unit

. reg california brent wti borenstein
```

| Source | SS | df | MS | Number of obs | = | 2,500 |
|---|---|---|---|---|---|---|
| | | | | F(3, 2496) | = | 4508.32 |
| Model | 883.029344 | 3 | 294.343115 | Prob > F | = | 0.0000 |
| Residual | 162.960932 | 2,496 | .065288835 | R-squared | = | 0.8442 |
| | | | | Adj R-squared | = | 0.8440 |
| Total | 1045.99028 | 2,499 | .418563536 | Root MSE | = | .25552 |

| california | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| brent | .0201464 | .0009573 | 21.04 | 0.000 | .0182691 | .0220236 |
| wti | .0041536 | .0010849 | 3.83 | 0.000 | .0020263 | .0062809 |
| borenstein | .4470857 | .02229 | 20.06 | 0.000 | .4033769 | .4907946 |
| _cons | .8456218 | .0416732 | 20.29 | 0.000 | .7639042 | .9273395 |

```
. dwstat

Durbin-Watson d-statistic(  4,  2500) =  .0318818
```

[14] Why California gas prices are so high and vary so widely: 'Mystery surcharge' and more, Connor Sheets, L.A. Times, March 14, 2022.

As with all time series regressions including prices, there is a substantial degree of auto-correlation. This does not affect the estimated coefficients, but it does overstate the statistical significance of the results.

A standard solution to the problem of autocorrelation is to re-estimate the model using the Cochrane-Orcutt procedure:

```
. prais california brent wti borenstein, corc

Iteration 0:  rho = 0.0000
Iteration 1:  rho = 0.9848
Iteration 2:  rho = 0.9993
Iteration 3:  rho = 0.9993
Iteration 4:  rho = 0.9993

Cochrane-Orcutt AR(1) regression -- iterated estimates
```

| Source | SS | df | MS | | |
|---|---|---|---|---|---|
| | | | | Number of obs | = 2,499 |
| | | | | F(3, 2495) | = 4.81 |
| Model | .009339112 | 3 | .003113037 | Prob > F | = 0.0024 |
| Residual | 1.61595506 | 2,495 | .000647677 | R-squared | = 0.0057 |
| | | | | Adj R-squared | = 0.0046 |
| Total | 1.62529417 | 2,498 | .000650638 | Root MSE | = .02545 |

| california | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| brent | .0011037 | .0003484 | 3.17 | 0.002 | .0004206 | .0017868 |
| wti | .0001011 | .0002523 | 0.40 | 0.689 | -.0003937 | .0005958 |
| borenstein | .0051877 | .0255125 | 0.20 | 0.839 | -.0448402 | .0552155 |
| _cons | 3.100217 | .7147603 | 4.34 | 0.000 | 1.698633 | 4.501801 |
| rho | .9992868 | | | | | |

```
Durbin-Watson statistic (original)    0.031882
Durbin-Watson statistic (transformed) 1.755452
```

The model is highly significant after correction for autocorrelation, although the WTI and Borenstein variables are not significant. This is not unexpected. WTI crude – priced at Cushing, Oklahoma – is not a primary feedstock for West Coast refineries. The dummy variable for the Borenstein variable is hardly exact and is likely to vary over time.