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Economic Analysis of the Implications of Implementing EPA's Tier 3 Rules

Prepared for the

Emissions Control Technology Association (ECTA)

by

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TABLE OF CONTENTS

Executive Summary: Economic Analysis of the Implications of Implementing the EPA's Tier 3 Rules

We performed an economic analysis of the implications of the EPA's proposed Tier 3 regulation, which would require oil refiners to reduce the average sulfur content in gasoline from 30 parts per million (ppm) to 10 ppm. Naturally, the oil refineries are resistant to any regulation that increases their private costs, but as we demonstrate, the societal economic benefits associated with Tier 3 are much larger than the private costs.

Our study is not the first to examine the costs of Tier 3: The others we evaluated are a Baker and O'Brien ("B&O") study, sponsored by the American Petroleum Institute ("API"), and a MathPro study, sponsored by the International Council on Clean Transportation. Our study reaches four major conclusions.

- **The B&O study exaggerates the costs of Tier 3 to the refining industry by a factor of 2 to 1.**

B&O estimates that the sulfur reduction requirement of Tier 3 will increase the marginal cost of refining by 6 to 9 cents per gallon. This estimated increase in marginal costs corresponds to an average cost increase of about two cents per gallon. By comparison, the MathPro study estimates that the sulfur reduction requirement of Tier 3 could increase the average cost of refining by about one cent per gallon.

B&O's cost estimate is substantially higher than MathPro's because of B&O's assumptions regarding the annualized capital and operating costs refiners would incur to satisfy the Tier 3 sulfur standards. In particular, B&O estimates that refiners would incur $2.4 billion per year whereas MathPro estimates costs of $1.5 billion per year. We find that the difference in B&O's and MathPro's estimates is primarily due to different capital cost assumptions. B&O's capital cost assumptions are higher than the range of cost estimates obtained in interviews of experts at companies who sell and install desulfurization equipment to refiners. For example, B&O's cost assumption for naptha desulfurization (direct desulfurization of the gasoline) is 257 percent higher than the experts' estimates. Differences in the refinery model methodologies used in the two studies does not account for the difference in their cost estimates.

B&O has a history of exaggerating the negative effects of EPA's sulfur reduction requirements on the refining industry. As part of the 2007 on-road heavy-duty diesel rule ("2007 HDD Rule"), EPA adopted a requirement to reduce the sulfur content of diesel fuel from an average of 500 ppm to 15 ppm. B&O prepared an analysis for API concluding that the 2007 HDD Rule would force refinery closures, substantially reduce the supply of diesel fuel, and make the United States a net importer of diesel fuel. B&O's predictions were wrong, as diesel fuel production increased sharply and exports surged after the rule was adopted. For example, 2010 production was one million barrels per day higher than B&O projected, and in 2010, the United States generated net exports of 458,000 barrels per day compared to a deficit projected by B&O.

Given B&O's inflated capital cost assumptions for Tier 3, and given B&O's history of exaggerating the negative impact of EPA's regulations, the impact of Tier 3 on the average cost of refining is likely closer to about one-cent-per-gallon estimates by MathPro and EPA, rather than to the about two-cents-per-gallon estimate by B&O.

- **It is very unlikely that Tier 3 will increase the retail price of gasoline.**

B&O estimates that Tier 3 will increase the marginal cost of refining by 6 to 9 cents per gallon, implying that retail gas prices will rise by the same amount. If gas prices increase by 6 to 9 cents per gallon, and if the average cost of refining increases by 1.9 cents per gallon as implied by the B&O study, then the refining industry would actually make a profit on Tier 3. Because refiners would not oppose regulation that increased their profits, it follows that their cost estimates are likely wrong.

According to the Energy Department, refining costs account for 16 percent of the retail price of gasoline and the cost of crude accounts for 67 percent. Regression analysis shows that Tier 2 regulations, which required a reduction in the average sulfur content of gasoline from 300 ppm to 30 ppm, had no material impact on the retail price of gasoline. The regression analysis took into account several factors identified in an FTC study that were expected to influence the retail price of gasoline. These factors include the cost of crude oil, refinery margins, the 2005 hurricanes, the 2006-07 transition to ethanol, and the 2008 global recession. Our model explains more than 99 percent of the variation in retail gasoline prices. The price of crude oil was the most significant determinant of the retail price of gasoline, and refining margin was a distant second in importance. Importantly, Tier 2 had no statistically significant impact on the retail price of gasoline.

The EPA estimated that Tier 2 would increase the average cost of refining gasoline by about two cents per gallon, and that Tier 3 will increase the average cost of refining gasoline by one cent per gallon. Because Tier 2 had no material impact on the retail price of gasoline, it is unlikely Tier 3—projected to generate private costs half the size of those generated by Tier 2—will have any impact either.

- **Tier 3 will likely generate substantial health benefits.**

Nitrogen oxide (NOx) emissions increase ozone concentrations, which cause respiratory illness such as asthma, pulmonary disease, and other illnesses. Tier 3 will reduce NOx emissions by 25 percent, thereby generating substantial health benefits. By 2020, Tier 3 is expected to generate $5.2 to $5.9 billion per year in health benefits (valued in 2006 dollars). By 2030, Tier 3 is expected to generate health benefits of $10.1 to $10.8 billion annually (valued in 2006 dollars). These health benefits alone are much larger than the estimated increase in annual refining costs of about $1.5 billion.

- **Tier 3 will likely generate substantial economic value added and jobs.**

Tier 3 will require the installation of refinery upgrades that will cost nearly $4 billion over three years, with recurring annual operating costs of $0.5 billion. Using an input-output model, we calculate that the nationwide value added, employee compensation, and employment effects of installing and operating the refinery upgrades needed to comply with the Tier 3 gasoline sulfur content standards. According to our estimates, installation of the refinery modifications produces almost 24,500 jobs for full-time equivalent employees with total associated employee compensation of $1.2 billion for each of the three years of installation. The continuing annual operation of the refinery modifications produces almost 5,300 jobs for full time equivalent employees with total associated employee compensation of $0.3 billion.

Economic Analysis of the Implications of
Implementing the EPA's Tier 3 Rules

I. Introduction and Overview

Navigant Economics has analyzed the estimated costs to U.S. refiners of complying with the planned EPA Tier 3 gasoline sulfur content reduction from 30 parts per million (ppm) to 10 ppm which is slated to occur, at the earliest, in 2017. We also have analyzed the likely effects of these sulfur content reductions on U.S. refiners' costs and on U.S. retail gasoline prices. Finally, we have estimated the likely health and economic benefits that would be generated as a consequence of reducing the sulfur content of gasoline from 30 ppm to 10 ppm.

Two recent studies have estimated the cost to the U.S. refining industry of implementing the planned EPA Tier 3 gasoline sulfur content reductions. First, the International Council on Clean Transportation has sponsored a study by MathPro Inc. that estimated the potential costs of reducing the sulfur content of motor gasoline to 10 ppm.[1] MathPro calculated that the average cost of reducing the sulfur content of gasoline to 10 ppm would be 0.8 cents to 1.4 cents per gallon.[2] Second, the American Petroleum Institute ("API") has sponsored a study by Baker & O'Brien, Inc. that estimated the potential supply and cost impacts of producing lower sulfur gasoline.[3] Baker & O'Brien stated that reducing the sulfur content of gasoline to 10 parts per million ("ppm") would impose a marginal cost to the U.S. refining industry of six to nine cent per gallon.[4] This result implies that the U.S. refinery with the highest cost of compliance with Tier 3 would experience a gasoline production cost increase of six to nine cents per gallon. While Baker & O'Brien do not report an estimate of the average U.S. refiner cost of reducing the sulfur content of gasoline to 10 ppm, it can be calculated from the information Baker & O'Brien provide and is 1.9 cents per gallon.[5] Further, Baker & O'Brien do not anticipate any refinery shutdowns

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1 See MathPro, Inc., *Refining Economics of A Natural Low Sulfur, Low RVP Gasoline Standard*, prepared for The International Council on Clean Transportation, October 25, 2011 (hereinafter "MathPro Study").

2 See MathPro Study, p. 4.

3 See Baker & O'Brien, Inc. *Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline*, prepared for the American Petroleum Institute, July 2011 (hereinafter "Baker & O'Brien 2011 Study"), and The Baker & O'Brien, Inc., *Addendum to Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline*, Prepared for the American Petroleum Institute, March 2012 (hereinafter "Baker & O'Brien 2012 Study").

4 See Baker & O'Brien 2012 Study, page 12.

5 Baker & O'Brien base their analysis on an assumption that U.S. refiners annually produce 8.152 million barrels per day of hydrocarbon and ethanol gasoline. See Baker & O'Brien 2012 Study, Table 5. This volume equals 124.521 billion gallons per year. Baker & O'Brien's total annual cost of reducing the sulfur content of gasoline produced by U.S. refiners to 10 ppm is $2.390 billion. See Baker & O'Brien 2012 Study, page 9. Dividing this

as a consequence of implementing the Tier 3 standards (i.e., the Baker & O'Brien analysis indicates that all U.S. refineries would find it cost-effective to make the investments necessary to comply with these standards and that the capital required to make these investments will be available).[6]

Regarding other estimates of the cost of implementing Tier 3 standards, in a letter to Congressman Ed Whitfield dated February 27, 2012, the EPA stated that its estimate of reducing the sulfur content of gasoline to 10 ppm was about one cent per gallon, which is consistent with the MathPro estimates. Also, in her Opening Statement before the Subcommittee on Energy and Power of the Committee on Energy and Commerce, EPA Assistant Administrator Gina McCarthy stated that "we estimate the impact on fuel costs [of Tier 3 gasoline sulfur reduction] to be less than one penny per gallon when the program goes into effect in 2017 or later."[7]

We analyze the MathPro and Baker & O'Brien estimates of the U.S. refiners' average cost of compliance with the planned EPA Tier 3 gasoline sulfur-reduction program to identify the source of the difference between two cost estimates. We also assess the reasonableness of the competing cost estimates. In addition, we evaluate the appropriateness of the methodological (modeling) approaches employed by MathPro and Baker & O'Brien and the reliability and relevance of Baker & O'Brien's marginal cost of compliance estimates.

The next issue we evaluate is whether and to what extent the U.S. refiners' Tier 3 compliance costs would be fully passed through to consumers in the form of higher U.S. retail gasoline prices. The analysis of this issue involves identifying the market factors that determine U.S. retail gasoline prices, and, on the basis of this determination, use multiple regression analysis to estimate the likelihood that the compliance costs would be passed on to consumers. Finally, the expected health and economic benefits that would occur as a consequence of implementing the planned EPA Tier 3 gasoline sulfur reduction program are estimated.

II. Summary of Conclusions

MathPro's and Baker & O'Brien's estimates of the average Tier 3 compliance cost for U.S. refineries are about one cent per gallon and about two cents per gallon, respectively. The roughly one

total annual cost by 124,521 billion gallons results in a per gallon cost of \$0.019 per gallon or 1.9 cents per gallon.

6 Baker & O'Brien 2012 Study, pp. 4-5 and Figure 2 on p. 5. See also Baker & O'Brien 2011 Study, pp. 36-37 and 40-41.

7 Opening Statement of Gina McCarthy, Assistant Administrator, Office of Air and Radiation, U.S. Environmental Protection Agency, Hearing on Gasoline Regulations Act of 2012, Subcommittee on Energy and Power, Committee on Energy and Commerce, U.S. House of Representatives, March 28, 2012, p. 5.

cent per gallon difference in the two estimates is due almost entirely to the difference between MathPro's and Baker & O'Brien's estimates of the U.S. refiners' compliance-related investment costs. Interviews with companies engaged in implementing the refinery upgrades required to reduce the sulfur content of gasoline confirm that the MathPro estimates are in the reasonable range and that Baker & O'Brien's estimates are not. On balance, the Baker & O'Brien estimates are too high. When the Baker & O'Brien U.S. refiner compliance-related investment costs are adjusted to be within the reasonable range, the MathPro and Baker & O'Brien total costs of compliance are virtually identical (i.e., in the vicinity of one cent per gallon).

Baker & O'Brien and the API have claimed that the Baker & O'Brien methodology (modeling approach) is superior to that of MathPro. In fact, both methodological approaches have their pluses and minuses with neither being clearly superior to the other. However, the differences in the methodologies employed by MathPro and Baker & O'Brien are not the source of the differences in their estimates of the average cost of the U.S. refiners' compliance with Tier 3.

Baker & O'Brien and API both emphasize Baker & O'Brien's estimate of the marginal cost of the U.S. refiners' compliance with Tier 3. This marginal compliance cost is the highest cost of compliance across all U.S. refineries (i.e., the compliance cost for the U.S. refinery that can least efficiently attain compliance). Because of several deficiencies, the marginal cost estimates produced by Baker & O'Brien are biased upward and not reliable. The Baker & O'Brien deficiencies include a lack of quality data for the individual U.S. refiners and Baker & O'Brien's failure to take into account averaging and trading of sulfur content credits that the EPA allows. Averaging and trading is a well-established market mechanism to provide the refining industry with the means to meet the lower sulfur content standards efficiently. Averaging and trading allows refiners to offset gasoline with an average sulfur content above 10 ppm with gasoline produced by other refiners that has an average sulfur content below 10 ppm. Because averaging and trading reduces the average cost of compliance, the U.S. refining industry's marginal compliance cost is reduced towards its average compliance cost.[8] Although these deficiencies in the Baker & O'Brien Study are not as significant as Baker & O'Brian's capital cost errors, these deficiencies still result in at least a small upward bias in Baker & O'Brien's average cost of compliance estimates.

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8 This result has been demonstrated in the context of carbon cap and trade. For example, see *Environmental Economics: Carbon Tax vs. Cap and Trade,* http://www.env-econ.net/carbon_tax_vs_capandtrade.html; see also Alfred Endres, *Environmental Economics: Theory and Policy*, Cambridge University Press, Rev. Exp. Edition, December 6, 2010, pp. 110-129 and 239-246.

The recent sharp increases in U.S. retail gasoline prices are a major economic concern. However, these gasoline price increases have nothing to do with the EPA's planned Tier 3 reductions in the sulfur content of gasoline in 2017 or later. The recent sharp increases in global crude oil prices account for the entire recent increase in U.S. retail gasoline prices.

The implementation in 2017 or later of the planned EPA Tier 3 gasoline sulfur content reductions would not necessarily result in any increase in U.S. retail gasoline prices. The effect of an increase in U.S. refining costs due to the reduction in the sulfur content of gasoline will be through the effect of this increase on the costs of the marginal supplier of motor gasoline which need not be a U.S. refiner (i.e., it could be a supplier located outside the U.S.). The API and Baker & O'Brien focus on the marginal cost of compliance with Tier 3. There is no basis for assuming that the refinery with the highest cost of compliance will be the marginal supplier of gasoline. Therefore, even if one had a reliable estimate of the marginal cost of compliance, which Baker & O'Brien do not provide, one could not then assume that this marginal cost of compliance would result in an equal increase in the marginal cost of supply of motor gasoline. As a consequence, API's and Baker & O'Brien's inference that the retail price of gasoline would be expected to increase by the marginal cost of compliance has no basis.

Moreover, if the API actually believed that the Baker and O'Brien marginal cost estimates were correct and that refiners would be able to pass these marginal costs on to consumers in the form of higher gasoline prices (as implied by Baker & O'Brien and API), then refiners would make a profit from Tier 3 by selling gasoline for six cents to nine cents per gallon more while incurring only a 1.9 cents per gallon average increase in costs. Given that the API is opposing Tier 3, it appears that it doesn't believe that the marginal compliance costs can be passed on to consumers and/or it doesn't believe that these marginal costs of compliance are substantially above the average cost of compliance.

Further, the likely average increase in U.S. refining costs is expected to be in the vicinity of one cent per gallon so any increase that might occur would be small. There is no certainty that even the small increase in average U.S. refining costs associated with reducing the sulfur content of gasoline to 10 ppm would be passed on to consumers. The U.S. retail price of gasoline is determined by many factors with the global price of crude oil being by far the most important. U.S. refiners' margins are an important determinant of U.S. retail gasoline prices, and these margins reflect overall refined petroleum product supply and demand conditions. Therefore, it is impossible to say with any certainty whether retail gasoline prices would go up after the EPA Tier 3 gasoline sulfur content reductions are implemented in 2017 or later.

To assess the likelihood that the expected one-cent-per-gallon average increase in U.S. refiners' costs associated with Tier 3 compliance would be passed through to consumers, we used a multiple regression analysis to test whether the increased costs to U.S. refiners of implementing the EPA's Tier 2 gasoline sulfur content reduction from 300 ppm to 30 ppm were passed on to consumers in the form of higher U.S. retail gasoline prices. The Tier 2 sulfur reduction program increased U.S. refiners' costs by about two cents per gallon or about double the estimated cost of the Tier 3 gasoline sulfur content reduction. The multiple regression analysis found that the Tier 2 costs were not passed on to consumers in the form of higher U.S. retail gasoline prices. This result suggests that it is highly unlikely that the Tier 3 costs would be passed on to consumers in the form of higher U.S. retail gasoline prices.

The health benefits generated by implementing the planned EPA Tier 3 gasoline sulfur content reduction are substantial. By 2020, the estimated health benefits are between $5 and $6 billion (in 2006 dollars) and, by 2030, are between $10 and $11 billion (in 2006 dollars). These health benefits alone dwarf the MathPro estimates of the average annual in U.S. refiner costs of $1.5 billion. In addition, there are economic benefits stemming from having a healthier more productive workforce, from the Tier 3 compliance-related implementation investments and ongoing annual operating outlays, and from the emission control and auto industry outlays for the development and implementation of Tier 3 motor vehicle technology. We have quantified the economic benefits from the U.S. refining industry's Tier 3 compliance-related investment and ongoing annual operating outlays. Making the investments needed to reduce the sulfur content of gasoline adds $6.1 billion to U.S. gross domestic product (value added) over the three-year investment period. The ongoing annual operation of these refinery modifications supports almost 5,300 domestic jobs each year.

III. Cost to the U.S. Refining Industry of Implementing Tier 3 Rules

A. Background and Overview

In February 2012, the EPA announced that its Tier 3 rules would involve only a reduction in the sulfur content of gasoline and would not include a reduction in gasoline vapor pressure ("RVP").[9] With respect to gasoline sulfur content, the EPA is expected to reduce the allowable sulfur content of gasoline from 30 parts per million ("ppm") to 10 ppm. Two recent studies have estimated the cost of the EPA mandated sulfur reduction to the U.S. refining industry. The first, sponsored by the International Council

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[9] EPA Administrator Lisa Jackson made this clear when she appeared before the House Energy and Commerce Committee on February 28, 2012. EPA Assistant Administrator Gina McCarthy reiterated this limitation in her written opening statement when she testified before the Subcommittee on Energy and Power, Committee on Energy and Commerce on March 28, 2012. Ms. McCarthy stated: "The only fuel requirement we are considering for Tier 3 is one that would lower the amount of sulfur in gasoline, which is necessary to operate the pollution control equipment to achieve new Tier 3 vehicle standards. To be clear, the Agency is not considering addressing issues associated with Reid vapor pressure in any Tier 3 proposal that eventually is released."

on Clean Transportation, was prepared by MathPro Inc. (hereinafter "MathPro Study").[10] The MathPro Study considered the costs of reducing the sulfur content of gasoline on a standalone basis and of jointly reducing the sulfur content and RVP of gasoline. The second, sponsored by the American Petroleum Institute ("API"), was prepared by Baker & O'Brien, Inc. (hereinafter "Baker & O'Brien Study").[11] When it was first released in July 2011, the Baker & O'Brien Study estimated the cost to U.S. refiners of jointly reducing the sulfur content and RVP of gasoline. In an addendum released in March 2012, the Baker & O'Brien Study was expanded to include an estimate of the cost to U.S. refiners of reducing the sulfur content of gasoline on a standalone basis.

The analyses underlying the MathPro and Baker & O'Brien studies are conceptually similar. As demonstrated below, the cost estimates in the two studies differ almost entirely because of the differences in their estimated capital costs of upgrading U.S. refineries to produce the lower sulfur gasoline. The MathPro Study's capital cost estimates imply an increase in the U.S. refiners' average gasoline production cost of about one cent per gallon, whereas the comparable estimate in the Baker & O'Brien Study is about two cents per gallon.

However, the Baker & O'Brien Study and its sponsor, API, have not presented the two cents per gallon average cost increase estimate; instead, they presented an estimated marginal cost of production increase of six to nine cents per gallon. The Baker & O'Brien Study's estimate of the marginal cost increase is not reliable and biased upward because it does not take into account the averaging and trading allowed under the EPA rules. Averaging and trading allows some refiners with a high cost of compliance to offset some gasoline with a sulfur content above 10 ppm with gasoline produced by other refiners with a low cost of compliance that has a sulfur content below 10 ppm. Averaging and trading reduces the average refiners' cost of compliance, and reduces the refiners' marginal cost of compliance towards their average cost.[12]

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10 MathPro, *Refining Economics of a National Low Sulfur, Low RVP Gasoline Standard*, October 25, 2011.

11 Baker & O'Brien, *Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline*, July 2011 (hereinafter "Baker & O'Brien 2011 Study"); and Baker & O'Brien, *Addendum to Potential Supply and Cost Impacts of Lower Sulfur, Lower RVP Gasoline,* March 2012 (hereinafter "Baker & O'Brien 2012 Study").

12 This result has been demonstrated in the context of carbon cap and trade. For example, see *Environmental Economics: Carbon Tax vs. Cap and Trade,* http://www.env-econ.net/carbon_tax_vs_capandtrade.html; see also Alfred Endres, *Environmental Economics: Theory and Policy*, Cambridge University Press, Rev. Exp. Edition, December 6, 2010, pp. 110-129 and 239-246.

B. Evaluation of the MathPro and Baker & O'Brien Studies

The API claims that Baker & O'Brien's modeling approach is superior to that of MathPro.[13] Whereas Baker & O'Brien model costs on a highly disaggregated refinery-by-refinery basis, MathPro's model relies on aggregated data from the Petroleum Administration for Defense District ("PADD"). As we explain below, the more disaggregated Baker & O'Brien approach cannot be presumed to produce more reliable results. Further, our subsequent evaluation of the assumptions underlying the two studies reveals that the difference in the estimates of the average refining cost increase can be explained almost entirely by differences between the capital cost assumptions in the two studies (i.e., the difference in the structures of the two models is not the source of the different results). Finally, the implications of the Baker & O'Brien Study's not taking averaging and trading into account are evaluated.

1. The Differences in the Baker & O'Brien and MathPro Modeling Approaches

The API claims that Baker & O'Brien's modeling approach is better because its U.S. refinery model identifies every U.S. refinery, whereas MathPro's U.S. refinery model combines all refineries within a PADD.[14] This claim rests on the assumption that the quality of data available at the individual refinery level is the same as (or better than) it is at the PADD level. For at least two reasons, however, the quality of data available at the PADD level is much higher. First, the owners of the individual refineries do not disclose detailed information on their individual refinery crude input slates or refined product production slates (i.e., the mix of refined products produced -- e.g., the amounts of gasoline, diesel fuel, jet fuel, etc). Second, the details of each refinery's operating characteristics are not disclosed, and these characteristics cannot be inferred by analyzing their crude input and refined product output slates because data on these slates are not available.

In contrast, public data on crude input and refined product output slates are available at the PADD level, which permit inferences about the characteristics of the average refinery in the PADD. These inferences may be used to adjust the refinery model to produce the actual refined product output

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13 API, *Tier 3 Gasoline Rulemaking*, March 2012, which was released with the March 2012 addendum to the Baker & O'Brien Study; *API Critique of the AAM October 6, 2011 Letter to Lisa Jackson and AAM White Paper*, November 11, 2011, http://www.api.org/~/media/Files/Policy/Alternatives/API-Critique-of-AAM-S-Proposal-Detailed-Comments.ashx.

14 API, *Tier 3 Gasoline Rulemaking*, March 2012, which was released with the March 2012 addendum to the Baker & O'Brien Study; see also *API Critique of the AAM October 6, 2011 Letter to Lisa Jackson and AAM White Paper*, November 11, 2011, http://www.api.org/~/media/Files/Policy/Alternatives/API-Critique-of-AAM-S-Proposal-Detailed-Comments.ashx.

slate of the PADD.[15] Given the lack of individual refinery crude input and refined product output slate data, Baker & O'Brien cannot adjust the individual refinery models to reflect actual operating conditions. Accordingly, when estimating the average refinery cost impact of reducing the sulfur content of gasoline from 30 ppm to 10 ppm, there is no basis for claiming that the Baker & O'Brien refinery modeling approach is superior.

Moreover, the lack of detailed information and data for the individual refineries included in the Baker & O'Brien model makes Baker & O'Brien's calculations of the marginal cost of reducing the sulfur content unreliable. This marginal cost is the highest cost per gallon cost incurred by any refinery to reduce the sulfur content from 30 ppm to 10 ppm. To be at all accurate, this estimate requires detailed data about each refinery, which are not available.

API also claims that MathPro's modeling approach leads to "over-optimization," which, in turn, understates costs.[16] By over-optimization, the API means that the MathPro approach presumes that the actual averaging and trading process does not function as effectively and efficiently as the MathPro model implies. MathPro's modeling approach is consistent with an active and highly efficient averaging and trading process (e.g., refiners that face high compliance costs will trade sulfur credits with other refiners that have low compliance costs).[17] In contrast, Baker & O'Brien's modeling approach does not take into account averaging and trading, and thereby implicitly assumes that averaging and trading do not occur. MathPro's approach more closely conforms with the averaging and trading experience under the Tier 2 gasoline sulfur reduction process.[18] Further, Baker & O'Brien's failure to properly account for averaging and trading biases its marginal cost estimate upward. A highly active and efficient averaging and trading process will reduce the marginal cost towards the average cost as well as reducing the average cost.[19]

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[15] See MathPro Study, pp. 7-8.

[16] API, *Tier 3 Gasoline Rulemaking*, March 2012, which was released with a March 2012 addendum to the Baker & O'Brien Study; see also *API Critique of the AAM October 6, 2011 Letter to Lisa Jackson and AAM White Paper*, November 11, 2011, http://www.api.org/~/media/Files/Policy/Alternatives/API-Critique-of-AAM-S-Proposal-Detailed-Comments.ashx.

[17] Opening Statement of Gina McCarthy, Assistant Administrator, Office of Air and Radiation, U.S. Environmental Protection Agency, Hearing on Gasoline Regulations Act of 2012, Subcommittee on Energy and Power, Committee on Energy and Commerce, U.S. House of Representatives, March 28, 2012, p. 5.

[18] In her oral testimony on March 28, 2012, before the Subcommittee on Energy and Power of the Committee on Energy and Commerce, EPA Assistant Administrator Gina McCarthy testified that the established sulfur averaging and trading program developed when the Tier 2 gasoline sulfur reductions were implemented would continue to operate under Tier 3. See also EPA Document, *Gasoline Sulfur Averaging, Banking, & Trading (ABT)*, www.epa.gov/tier2/frm/abt.pps .

[19] This result has been demonstrated in the context of carbon cap and trade. For example, see *Environmental Economics: Carbon Tax vs. Cap and Trade*, http://www.env-econ.net/carbon_tax_vs_capandtrade.html, see

2. The Differences in the Baker & O'Brien and MathPro Assumptions

Table 1 compares MathPro's and Baker & O'Brien's estimates of the annual total refining compliance cost for reducing the sulfur content of gasoline from 30 ppm to 10 ppm. Baker & O'Brien's total cost estimate is $0.859 billion higher than the MathPro estimate. About 80 percent of this difference is due to the difference between Baker & O'Brien's and MathPro's annual capital and fixed cost charges ($0.690 billion). Therefore, we focus below on identifying the reasons for the differences between their annual capital and fixed cost estimates.

Table 1
Comparison of MathPro's and Baker & O'Brien's
Annual U.S. Refining Compliance Cost Estimates
(Billions of Dollars Per Year)

Annual Compliance Cost Component	MathPro	Baker & O'Brien	Difference: Baker & O'Brien minus MathPro
Capital and Fixed Charges	$0.999	$1.689	$0.690
All Other Costs	$0.532	$0.701	$0.169
Total Compliance Costs	$1.531	$2.390	$0.859

Sources: MathPro Study, Exhibit A-1; Baker & O'Brien 2012 Study, Figure 5, p. 9.

Table 2 presents MathPro's and Baker & O'Brien's estimated annual capital and fixed costs and the assumptions underlying these estimates. Panel 1 of Table 2 presents the annual capital and fixed charge estimates. Panel 2 shows the estimated costs of desulfurization investment on a dollars-per-barrel-per-day basis. The sulfur content of gasoline can be reduced by removing the sulfur from the crude oil inputs to a refinery (FCC feed desulfurization) or by removing the sulfur directly from the gasoline produced by the refinery (FCC naphtha desulfurization). MathPro assumed that FCC naphtha desulfurization would be used by all refineries to reduce the sulfur content of gasoline from 30 ppm to 10 ppm.[20] In comparison, Baker & O'Brien assumed that FCC naphtha desulfurization revamps or new builds would occur at 46 refineries (33 revamps and 13 new builds) and that FCC feed desulfurization revamps or new builds would occur at 24 refineries (23 revamps and 1 new build).[21]

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also Alfred Endres, *Environmental Economics: Theory and Policy*, Cambridge University Press, Rev. Exp. Edition, December 6, 2010, pp. 110-129 and 239-246.

[20] MathPro Study, pp. 14-16.

[21] Baker & O'Brien 2012 Study, pp. 4-5 and Figure 2.

Table 2

Comparison of MathPro and Baker & O'Brien Estimates of Annual Capital and Fixed Charges and The Underlying Assumptions

1. Annual Capital and Fixed Charges (Billions of Dollars Per Year)

MathPro	Baker & O'Brien
$0.999	$1.689

2. Desulfurization Investment Costs for a New Build

	Dollars Per Barrel Per Day	
Type of Desulfurization	MathPro	Baker & O'Brien
FCC Naphtha Desulfurization	$1,830	$6,537
FCC Feed Desulfurization	$6,700	$4,674

3. Revamp/Expansion Investment Costs As A Percentage of New Build Costs

MathPro	Baker & O'Brien
50%	30% to 70%

4. Annual Capital Charge Calculation Assumptions

Assumption	MathPro	Baker & O'Brien
Rate of Return (%)	10% after tax	10% after tax
Operating Life	15 years	15 years
Depreciation Schedule	10 years; double declining balance	10 years; accelerated
Construction Period	3 years	2 years
Tax Rate-Federal & State (%)	40%	38%

Sources: (1) MathPro Study, Exhibit A-1; Baker & O'Brien 2012 Study, Figure 5, p. 9; (2) MathPro Study, p. 13; Baker & O'Brien 2011 Study, p. 24; (3) MathPro Study, p. 12; Baker & O'Brien 2011 Study, p. 24; (4) MathPro Study, p. 13; Baker & O'Brien 2011 Study, p. 25.

Notes: The MathPro estimates are for a unit installed at a Gulf Coast refinery. Baker & O'Brien do not specify a refinery location.

MathPro's FCC naphtha-desulfurization investment costs are much lower than those used by Baker & O'Brien, and, as shown below, the difference in these costs accounts for the entire difference in the Tier 3 compliance cost estimates of MathPro and Baker & O'Brien. To assess the reasonableness of MathPro's estimated investment costs, we interviewed experts at companies that constructed or installed desulfurization units at U.S. refineries, and we asked them to comment on the reasonableness of the MathPro estimates.

Regarding MathPro's estimate of $1,830 per barrel per day for a new build FCC naphtha sulfurization unit at a Gulf Coast refinery, the interviewed experts uniformly stated that this estimate was within a reasonable range (from $1,500 to somewhat above $1,830 per barrel per day). Although the highest upper end of the range response was $2,500 per barrel per day, some respondents stated that the $1,830 per barrel per day estimate was conservative (i.e., near the upper end of the range). These responses indicate that Baker & O'Brien's estimate of $6,537 per barrel per day for a new build is not reasonable and is too high.

Regarding MathPro's estimated $6,700 per barrel per day for a new build FCC feed desulfurization unit at a Gulf Coast refinery, the interviewed experts uniformly stated that this estimate was above the reasonable range (from $5,000 to $6,000 per barrel per day). MathPro did not use this estimate, however, because it assumed that only FCC naphtha desulfurization would be used to reduce the sulfur content of gasoline from 30 ppm to 10 ppm. Baker & O'Brien's FCC feed desulfurization estimate of $4,674 per barrel per day, which was used in its study, is slightly below the reasonable range.

Moreover, the implied ratio of FCC naphtha to feed desulfurization new build investment costs from the Baker & O'Brien study is also outside the reasonable range offered by the companies interviewed. The survey respondents suggested that the naptha-to-feed ratio was approximately one to three. Yet Baker & O'Brien's implied ratio is about four to three ($6,537 per barrel per day for a new build FCC naphtha desulfurization to $4,674 per barrel per day for a new build FCC feed desulfurization unit). In contrast, MathPro's estimated investment cost of $1,830 per barrel per day for a new build FCC naphtha desulfurization unit is about 27 percent of its $6,700 per barrel per day estimate for a new build FCC feed desulfurization unit, much closer to the one-to-three ratio provided by the survey respondents.

Because Baker & O'Brien assumes that almost two-thirds of the new build/revamps by U.S. refiners to reduce the sulfur content of gasoline from 30 ppm to 10 ppm will involve FCC naphtha desulfurization units (46 of 70), Baker & O'Brien's gross overestimate of these costs lead to an overstatement of annual capital charges. In contrast, the underestimation by Baker & O'Brien of the investment cost for a new build FCC feed desulfurization unit was relatively small (i.e., the lower end of a reasonable range provided by the companies interviewed was $5,000 per barrel per day which is only $326 per barrel per day above the Baker & O'Brien estimate of $4,674 per barrel per day). Unfortunately, this relatively more precise estimate is only applicable to 24 of 70 of the assumed new builds/revamps. Therefore, Baker & O'Brien's estimates for the investment costs for a new build naphtha and feed desulfurization units result in a substantial overstatement of the annual capital charges.

The third panel of Table 2 presents MathPro's and Baker & O'Brien's assumptions regarding the relationship between the cost of revamps/expansions and new builds. MathPro assumes that the per-barrel-per-day investment cost of a revamp/expansion is 50 percent of the per-barrel-per-day cost of a new build. Baker & O'Brien provides a range of 30 to 70 percent. Because MathPro's assumed ratio is contained within Baker & O'Brien's assumed range, the differences in these assumptions is unlikely to be the source of significant differences between the investment cost estimates. In an alternative calculation, MathPro adopts a more optimistic assumption that the revamp/expansion investment cost would be 30 percent of the new build investment cost, lending support for the lower end of Baker & O'Brien's range.

The fourth panel of Table 2 presents the assumptions involved in the calculation of the annual capital charges. The first three assumptions are essentially the same for the two studies.[22] MathPro assumes a three-year construction period while Baker & O'Brien assumes a two-year construction period. The longer construction period used by MathPro increases its estimated annual capital charges. MathPro assumes a 40 percent combined federal and state tax rate while Baker & O'Brien assumes a 38 percent combined federal and state tax rate. The higher tax rate used by MathPro slightly increases its estimated annual capital charge. However, the effects of the longer construction period and the higher tax rate are relatively small.

3. The Potential Effect on Retail Gasoline Prices if U.S. Refiners Can Pass on the Cost of Compliance to Consumers

The two compliance cost estimates are shown in Table 3 below, along with an adjusted Baker & O'Brien estimate to correct for its overstatement of capital charges discussed above. In particular, we replace Baker & O'Brien's estimate of the annual capital charges with those calculated by MathPro. The total annual U.S. refiner compliance cost estimates are $1.53 billion for MathPro, $2.39 billion for Baker & O'Brien, and $1.70 billion for the Adjusted Baker & O'Brien.

Table 3
Adjustment of Baker & O'Brien's Annual U.S. Refining Compliance Cost Estimates to Correct for Overstatement of Annual Capital Charges (billions)

Annual Compliance Cost Component	MathPro	Baker & O'Brien	Adjusted Baker & O'Brien
Capital and Fixed Charges	$0.999	$1.689	$0.999
All Other Costs	$0.532	$0.701	$0.701
Total Compliance Costs	$1.531	$2.390	$1.700

Sources: MathPro Study, Exhibit A-1; Baker & O'Brien 2012 Study, Figure 5, p. 9; and Navigant Economics.

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22 Baker & O'Brien do not specify what form of accelerated depreciation they employ. However, a double declining balance methodology is widely used.

If the U.S. refiners could fully pass these compliance costs through to consumers, the effect on the average retail price of gasoline would be the total compliance costs divided by the number of gallons of gasoline (including the ethanol component) produced by U.S. refiners. For PADDs 1, 2, 3 and 4, MathPro estimates that annual U.S. gasoline production to be 7.079 million barrels per day.[23] For PADDs 1, 2, 3, 4, and 5 (the entire U.S.), Baker & O'Brien estimates annual U.S. gasoline production to be 8.152 million barrels per day.[24]

Table 4 below restates the total compliance costs shown in Table 3 in cents per gallon of gasoline produced. The MathPro estimate is 1.4 cents per gallon while the Baker & O'Brien estimate is 1.9 cents per gallon. Finally, the adjusted Baker & O'Brien estimate, which substitutes MathPro's annual capital and fixed charge estimates for Baker & O'Brien's estimate, is 1.4 cents per gallon. This result confirms that the relevant difference between MathPro's and Baker & O'Brien's estimates of the total cost of compliance is the difference between their annual capital and fixed charge estimates.

Table 4
U.S. Refining Compliance Cost Estimates Stated on a Cents Per Gallon Produced Basis

	MathPro	Baker & O'Brien	Adjusted Baker & O'Brien
Total Compliance Cost (Billions of Dollars per Year)	$1.531	$2.390	$1.700
Refining Gasoline Production			
Millions of Barrels Per Day(1)	7.079	8.152	8.152
Billions of Gallons Per Year(2)	108.521	124.970	124.970
Compliance Cost Per Gallon(3) (Cents Per Gallon)	1.4	1.9	1.4

Notes: (1) MathPro Study, Exhibit A-1; Baker & O'Brien 2011 Study; Table 5; (2) Billions of gallons per year equals millions of barrels per day times (365 times 42 divided by 1,000); (3) Compliance cost per gallon in cents per gallon equals total compliance cost in billions of dollars per year times 100 divided by billions of gallons per year.

4. Other Estimates of Tier 3 Compliance Costs

In her Opening Statement before the Subcommittee on Energy and Power of the Committee on Energy and Commerce, EPA Assistant Administrator Gina McCarthy stated that "we estimate the impact on fuel costs [of Tier 3 gasoline sulfur reduction] to be less than one penny per gallon when the program

23 MathPro Study, Exhibit A-1.

24 Baker & O'Brien 2011 Study, Table 5.

goes into effect in 2017 or later."[25] MathPro performed an alternative calculation of the Tier 3 compliance costs, in which it changed two of its assumptions: (1) the investment cost for a revamp/expansion was assumed to be 30 percent of the investment costs for a new build; and (2) a rate of return of 7 percent before tax was adopted, which is the rate of return used by the EPA in its calculations.[26] Based on this alternative MathPro calculation, the Tier 3 gasoline sulfur-reduction cost to U.S. refiners would be less than one penny per gallon (0.8 cents per gallon).

5. Conclusions Regarding the U.S. Refiners' Compliance Cost to Accomplish the Tier 3 Gasoline Sulfur Content Reduction

The reasonable range of the U.S. refiners' cost of complying with the EPA's Tier 3 gasoline sulfur reduction appears to be 0.8 to 1.4 cents per gallon (i.e., in the vicinity of 1 cent per gallon). However, this expression of the compliance costs on a cents per gallon basis does not imply that these compliance costs will be passed through fully to consumers (i.e., result in retail gasoline prices being higher by about 1 cent per gallon). The likelihood that the U.S. refiners will be able to pass the one cent per gallon increase through to consumers is evaluated below. In particular, we evaluate whether U.S. refiners were able to pass through the cost of complying with the Tier 2 gasoline sulfur content reduction from 300 ppm to 30 ppm. This evaluation suggests that refiners were not able to pass through these compliance costs through to consumers.

C. API and Baker & O'Brien Have A History of Overstating the Costs and Impacts of EPA Motor Fuel Sulfur Content Regulations

In 2001, API retained Baker & O'Brien to estimate the compliance costs and to evaluate the other impacts on the U.S. refining industry of implementing the EPA ultra low sulfur diesel (ULSD) program.[27] Compared with other estimates, Baker & O'Brien produced relatively high U.S. refinery compliance cost estimates. The range of ULSD compliance cost estimates was 4.2 cents per gallon to 6.2 cents per gallon. The Baker & O'Brien compliance cost estimate was 6.2 cents per gallon. By comparison, the EPA's

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25 Opening Statement of Gina McCarthy, Assistant Administrator, Office of Air and Radiation, U.S. Environmental Protection Agency, Hearing on Gasoline Regulations Act of 2012, Subcommittee on Energy and Power, Committee on Energy and Commerce, U.S. House of Representatives, March 28, 2012, p. 5.

26 The 7% before-tax rate of return is effectively a discount rate. The 7% before-tax rate discount rate is often used as the societal discount rate.

27 EIA, *The Transition to Ultra-Low-Sulfur Diesel Fuel: Effects in Prices and Supply*, May 2001, hereinafter "EIA ULSD Transition"), p. 3; see also Baker & O'Brien, *An Assessment of the Impact of Non-Road Diesel Fuel Sulfur Regulation on Distillate Fuel Production and Availability in the U.S.*, Prepared for the American Petroleum Institute (API), July 2003 (hereinafter "Baker & O'Brien 2003 Study"). This report discusses the results of Baker & O'Brien's analyses of introducing on-road and non-road ULSD.

compliance cost estimate was 4.5 cents per gallon.[28] Excluding the Baker & O'Brien estimate, the average of all the compliance cost estimates was 4.9 cents per gallon.[29]

In 2003, Baker & O'Brien projected the likely effects of implementing the EPA's on-road ULSD regulations on the U.S. refinery sector in terms of expected refinery closures and U.S. refinery production of ULSD. Baker & O'Brien projected that as many as 13 U.S. refiners might close by 2010 due to an inability to attract or justify the capital required to comply with the EPA's on-road ULSD regulations.[30] Baker & O'Brien further claimed that the implementation of the EPA non-road ULSD regulations would accelerate and increase the likelihood of these 13 refinery closures. Indeed, Baker & O'Brien suggested that the EPA on-road ULSD program would substantially reduce the supply of diesel fuel, and it would even make the U.S. a net importer of diesel fuel. As it turns out, U.S. refinery production of 500 ppm or less sulfur content distillate has increased substantially since 2005 as shown in Figure 1.

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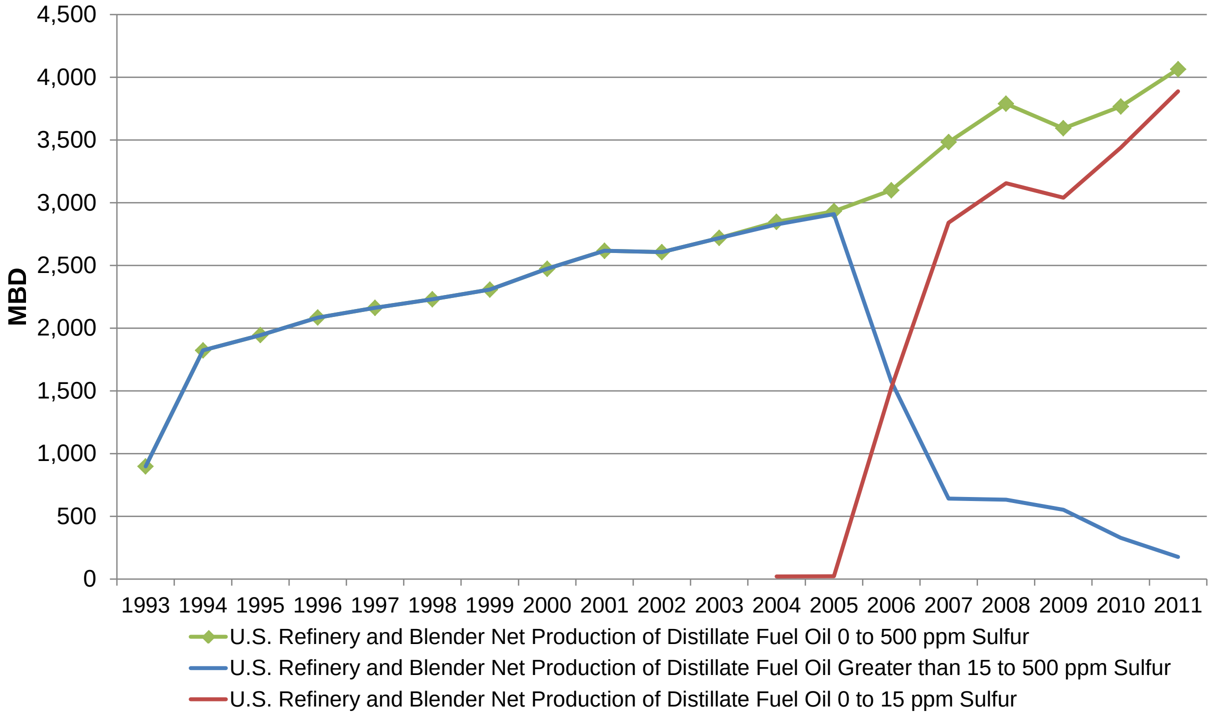
28 John F. Anderson and Todd Sherwood, EPA, *Comparison of EPA and Other Estimates of Mobile Source Rule Cost Changes to Actual Price Changes*, Paper Presented to the SAE Government Industry Meeting, Washington, DC, May 14, 2004, Table 2.

29 *Id*. Two estimates were provided in the form of a range. The average of 4.9 cents per gallon is calculated on the basis of the mid-point of these two ranges.

30 Baker & O'Brien 2003 Study, p. 8.

Figure 1
Refinery and Blender Net Production of Low Sulfur (500 ppm or Less) Distillate Fuel Oil
1993 - 2011



Source: EIA.

After 2005, U.S. refiners' production of ULSD (15 ppm or less sulfur content) increased sharply; as of 2011, ULSD accounted for 96 percent of total low sulfur distillate production. Under the EPA on-road ULSD program, Baker & O'Brien claimed that, by 2010, U.S. refiner's production of low sulfur (500 ppm or less sulfur content) distillate would fall short of U.S. consumption by 601 thousand barrels per day ("MBD").[31] In fact, in 2010, U.S. refiners' production of low sulfur distillate exceeded U.S. consumption by 451 MBD, and U.S. net exports of low sulfur distillate were 458 MBD.[32]

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31 Baker & O'Brien 2003 Study, p. 53.

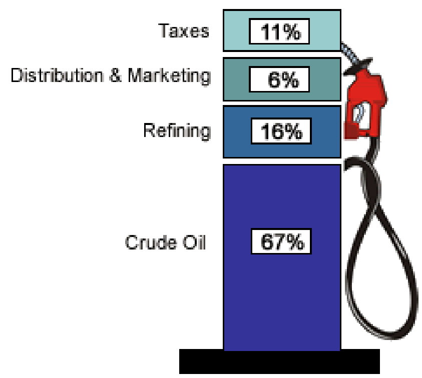
32 U.S. Department of Energy, Energy Information Administration, U.S. Supply and Disposition (http://www.eia.gov/dnav/pet/pet_sum_snd_d_nus_mbblpd_a_cur-1.htm) .

IV. Analysis of the Potential Effects of EPA Gasoline Sulfur Content Regulations on U.S. Retail Gasoline Prices

A. The Factors that Determine the Retail Price of Gasoline

The U.S. retail price of gasoline is determined primarily by global crude oil prices and secondarily by U.S. refinery margins. Figure 2 below shows the components of U.S. retail gasoline prices as of March 2012.

Figure 2
The Components of U.S. Retail Gasoline Prices
March 2012



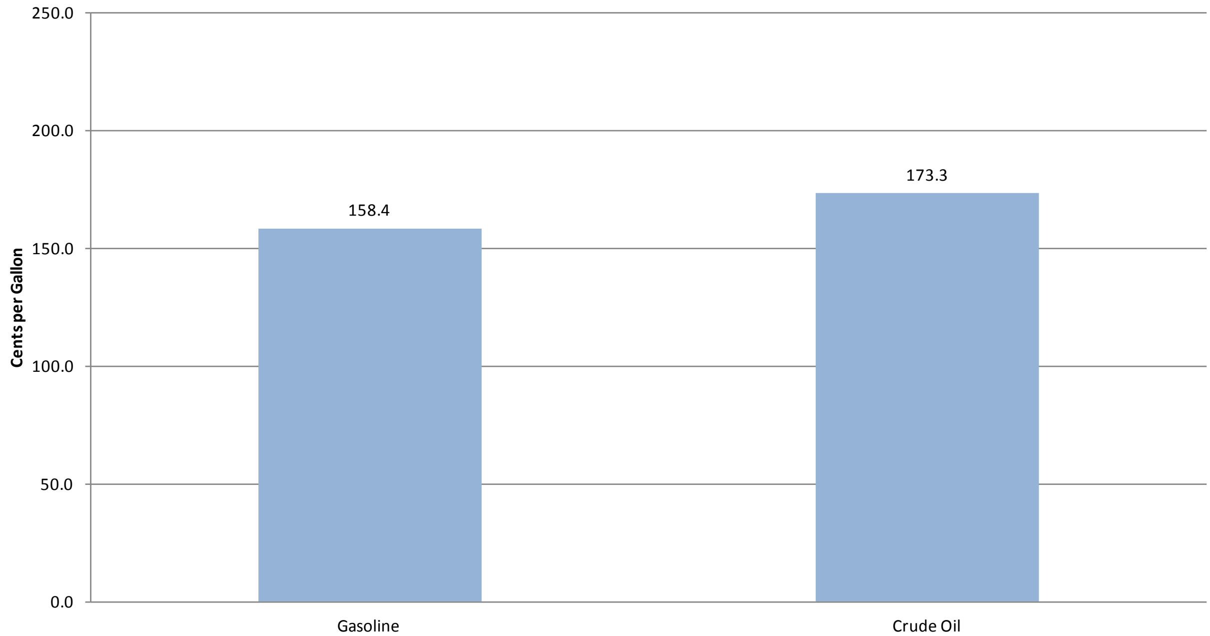
Source: U.S. Department of Energy, Energy Information Administration, Gasoline and Diesel Fuel Update (http://www.eia.gov/petroleum/gasdiesel/).

The tax component of U.S. retail gasoline prices is set by federal and state governments, and it is not sensitive to market conditions. If the gasoline taxes component is eliminated, the shares among the remaining three components (i.e., the shares of the U.S. retail gasoline price excluding taxes) are: (1) global crude oil prices account for 75 percent; (2) U.S. refinery margins account for 18 percent; and (3) distribution and marketing costs account for 7 percent.

B. The Recent Increase in Crude Oil Prices Explains Current High U.S. Retail Gasoline Prices

Sharply rising prices for refined petroleum products (e.g., motor gasoline, diesel fuel, and jet fuel) are a major current economic concern. However, this refined product price inflation is due almost entirely to sharply rising global crude oil prices. As shown in Figure 3 below, the increase in the U.S. retail gasoline prices excluding taxes between March 2009 and February 2012 can be more than fully accounted for by the increase in the Brent crude oil price over the same period. The solution to the problem of sharply increasing global crude oil prices and U.S. refined product prices involves promoting increased global crude oil supplies and reduced consumption of refined petroleum products, which can be achieved through implementation of new energy-efficient technologies. In any event, the planned EPA Tier 3 gasoline sulfur content reduction cannot have an effect on U.S. retail gasoline prices until it is implemented, which is currently slated to occur no sooner than 2017.

Figure 3
Change in U.S. Retail Gasoline Price Excluding Taxes and Brent Crude Oil Price Between March 2009 and February 2012



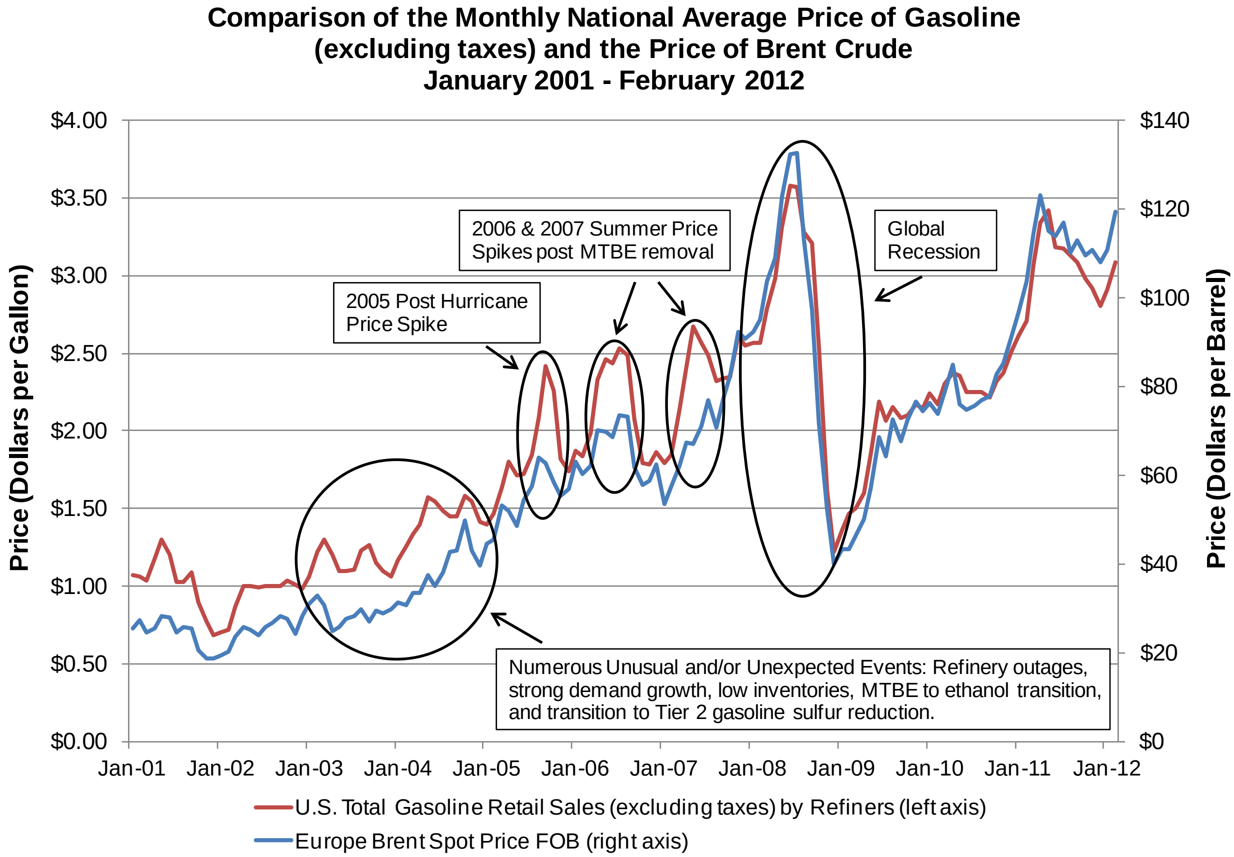
Notes:
Gasoline price is U.S. Total Gasoline Retail Sales by Refiners. Crude oil price is Brent crude oil FOB Europe.

Source: U.S. Department of Energy, Energy Information Administration (www.eia.gov).

C. Using Multiple Regression Analysis to Determine Whether the EPA's Proposed Gasoline Sulfur Reduction Program Compliance Costs Are Likely to Be Passed on to Consumers

Figure 4 below plots the U.S. retail price of gasoline (excluding taxes) expressed in dollars per gallon and the Brent crude oil price expressed in dollars per barrel. Figure 4 also includes circles around the periods when unexpected or unusual events occurred. The circle drawn around 2003 and 2004 corresponds to the period when numerous shocks to the market occurred. The 2003 and 2004 period also is when the transition to attainment of the Tier 2 sulfur standards occurs. As explained in the Technical Appendix, the other unexpected and unusual events that occurred during the 2003 and 2004 period are the primary cause of the "above normal" gasoline prices during this period. However, as discussed below, retail gasoline prices during this period were affected by numerous other unexpected or unusual events. Circles also are drawn around the periods affected by the 2005 hurricanes and around the periods in 2006 and 2007 that were affected by the MTBE-to-ethanol oxygenate transition. Finally, a circle is drawn around the sharp drop in retail gasoline prices in 2008 due to the global recession; this drop can be explained by the corresponding sharp drop in crude oil prices.

Figure 4



Source: EIA.

We used multiple regression analysis to test whether the implementation of the EPA Tier 2 sulfur reduction standards had a statistically significant effect on retail gasoline prices, controlling for all other factors. We used monthly data from January 2001 through January 2012. The control variables in the regression analysis included the global price of crude oil (the Brent price), the U.S. refining margin, and market events (e.g., the 2005 hurricanes and MTBE issues in 2006 and 2007). The role of these factors in explaining the variation in the retail price of gasoline was addressed recently in a study by the Federal Trade Commission.[33] The effects of the transition to Tier 2 on the retail price of gasoline, if any, would have occurred during 2003 and 2004 (but there were numerous shocks to the market during this period),

[33] Federal Trade Commission, Bureau of Economics, *Gasoline Price Changes and the Petroleum Industry: An Update*, An FTC Staff Study, September 2011, pp. i-ii, 5-6, and 23-26, http://www.ftc.gov/os/2011/09/110901gasolinepricereport.pdf .

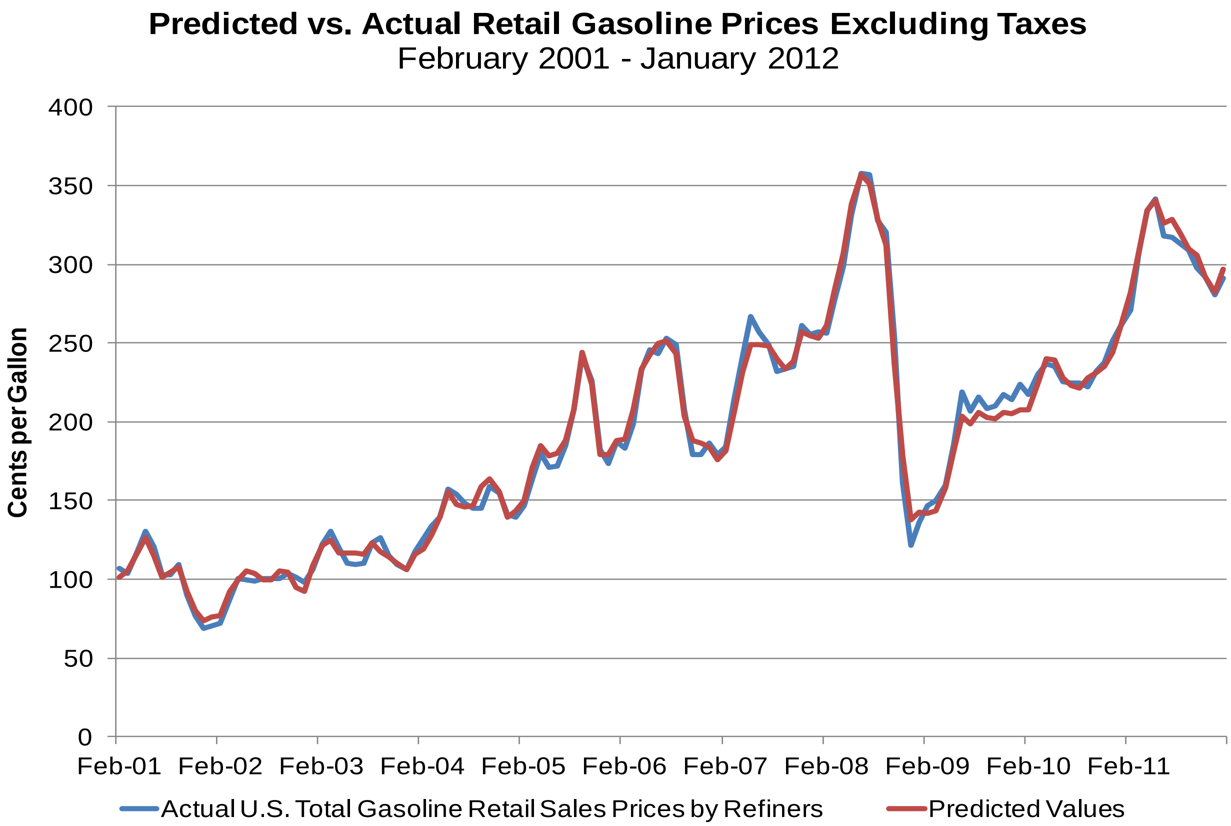
and the permanent effects on the retail price of gasoline, if any, would occur from 2005 forward. The details of the multiple regression analysis are discussed in the attached Technical Appendix.

The EPA's Tier 2 sulfur reduction program for gasoline called for a reduction in the sulfur content of gasoline from 300 parts per million (ppm) to 30 ppm. This sulfur content reduction was phased in over time. During the first phase, the average sulfur content of gasoline had to be reduced from 300 ppm to 180 ppm by the beginning of 2004. During the second phase, the average sulfur content of gasoline had to be reduced from 180 ppm to 30 ppm by the beginning of 2006. The EPA projected that the total cost to U.S. refiners of the Tier 2 gasoline sulfur content reduction would be 1.7 to 1.9 cents per gallon, and the API, based on a study prepared by MathPro, estimated that the cost would be 2.6 cents per gallon.[34] (Both estimates exceed the estimated cost of the Tier 3 gasoline sulfur content reduction to U.S. refiners, which is roughly one cent per gallon.) If the U.S. refiners' compliance costs of the Tier 2 gasoline sulfur content regulation were fully passed on to consumers, one would expect to see about a two cents per gallon increase in U.S. retail gasoline prices.

The U.S. retail gasoline price excluding taxes and its predicted value generated by the estimated regression model are presented in Figure 5 below, which shows that the predicted and actual U.S. retail gasoline prices are very close, indicates a high "goodness of fit." The regression model is highly accurate, as reflected by the model's R-squared (99.3 percent). The R-squared statistic measures the percentage of the variance of the dependent variable (the U.S. retail price of gasoline excluding taxes) that is explained by the regression model (beyond what can be explained by knowledge of the mean). The estimated regression model is statistically significant at the highest level (the 1% level).

[34] John F. Anderson and Todd Sherwood, EPA, *Comparison of EPA and Other Estimates of Mobile Source Rule Cost Changes to Actual Price Changes*, Paper Presented to the SAE Government Industry Meeting, Washington, DC, May 14, 2004, Table 2.

Figure 5



The regression model results presented in the Technical Appendix confirm that the global crude oil price is by far the most important determinant of retail gasoline prices. The U.S. refinery margin, which reflects the relationship between supply and demand for refined petroleum products (i.e., refined product market tightness), is a distant second in importance. As anticipated, the 2005 hurricanes and the 2006 and 2007 MTBE to ethanol transition issues explained some of the variation in retail prices as well. Finally, there were numerous unusual and unexpected market events during 2003 and 2004 that caused U.S. retail gasoline prices to be higher than would be expected given the global crude oil price and U.S. refinery margins, including changes in gasoline specifications.[35] In its assessment of why U.S. retail

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[35] These events include refinery outages, low gasoline inventories, strong gasoline demand growth, the transition from MTBE to ethanol as an oxygenate in California, New York, and Connecticut on January 1, 2004, slighly reduced gasoline supply due to more stringent product specifications (transition from MTBE to ethanol and transition to lower sulfur content gasoline), uncertainty regarding the availability of gasoline imports (due to transition from MTBE to ethanol and transition to lower sulfur content gasoline), and higher transportation costs. *See* EIA, *Inquiry into August 2003, Gasoline Price Spike*, November 2000, pp. 15-17, http://www.eia.gov/pub/oil_gas/petroleum/analysis_publications/gasps/gasps.pdf ; Oil & Gas Journal, *Refining industry to sustain strong margins through 2004*, March 15, 2004,

gasoline prices were substantially higher than expected given global crude oil prices in 2004, the EIA emphasized the transition from MTBE to ethanol.[36] However, in 2003, neither the transition from MTBE to ethanol nor the transition to lower sulfur content gasoline were named by EIA as a contributing factor to higher retail gasoline prices.[37] Given global crude oil prices, the higher than expected U.S. retail gasoline prices in 2003 and 2004 were primarily the result of factors other than the transition to lower sulfur gasoline.

Most importantly, for the period 2005 forward, there is no statistically significant effect of the Tier 2 gasoline sulfur content reduction on U.S. retail gasoline prices (i.e., the EPA Tier 2 gasoline sulfur content regulations had no statistically significant effect on U.S retail gasoline prices). Because the expected impact of Tier 2 regulations was twice the size of Tier 3 (two cents versus one cent per gallon), and because Tier 2 regulations do not appear to have increased retail gas prices, it is highly unlikely that the EPA Tier 3 gasoline sulfur content regulations will have a statistically signiciant effect on U.S retail gasoline prices.

That the U.S. refiners would not likely be able to fully pass-through to consumers even a one cent per gallon cost increase is not surprising. The U.S. refining sector is highly competitive, and the mark-ups over costs for U.S. refiners (i.e., the refiners' margins) are determined by the overall refined petroleum product supply and demand conditions, which are highly volatile.

V. Benefits of Implementing the EPA's Planned Tier 3 Gasoline Sulfur Reduction Program

A. Health Benefits Are Substantial

According to a study by Northeast States for Coordinated Air Use Management ("NESCAUM"), the reduction in the sulfur content of gasoline will improve human health, which is a significant economic benefit that must be considered in any proper cost-benefit analysis. Reducing the sulfur content of gasoline to 10 ppm would reduce nitrogen oxides emissions (NOx) by approximately 25 percent; the

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http://www.eia.gov/pub/oil_gas/petroleum/analysis_publications/gasps/gasps.pdf; U.S. Department of Energy, Energy Information Administration, Short-Term Energy Outlook April 2004, Summer 2004 Motor Gasoline Outlook, p. 1, (http://www.eia.gov/forecasts/steo/special/summer/2004_summer_gas.pdf); Statement of Guy F. Caruso, Administrator, Energy Information Administration, Department of Energy before the Government Reform Subcommittee on Energy Policy, Natural Resources and Regulatory Affairs, United States House of Representatives, July 7, 2004, pp. 2-4, (http://www.eia.gov/neic/speeches/caruso070704.htm .

[36] *Id*.

[37] *Id*.

reduction in NOx is achieved by allowing pollution control equipment to operate more effectively.[38] NOx emissions contribute to ozone concentrations and are a precursor to fine particulate matter. NOx contributes to a number of health and environmental problems, including respiratory problems such as asthma, ground level ozone, haze, water acidification, acid rain, plant damage, soil damage, and oxygen depletion in water.[39] In the Northeast and Mid-Atlantic area, the largest source of NOx is gasoline vehicles, which account for almost 30 percent of NOx emissions.[40]

The NESCAUM study estimated the health benefits of implementing the Tier 3 gasoline sulfur content reduction in the U.S. Northeast and Mid-Atlantic areas only. NESCAUM provides estimates of the health benefits for particulate emissions (referred to as PM2.5 particles) and for ozone. Using data obtained from NACAA and the EPA, we have estimated national health benefits due to the reductions in PM2.5 particle emissions nationwide as a consequence of the Tier 3 gasoline sulfur content reductions.[41] However, for the ozone health benefits, there was no comparable national source. Further, we determined that there was no acceptable methodology for extrapolating NESCAUM's regional estimate of ozone health benefits to the nation. Therefore, we report only the ozone health benefits calculated by NESCAUM for the Northeast and Mid-Atlantic area.

Table 5 below shows the total annual health benefits calculated for 2020 and 2030. In 2020, the range of annual health benefits is \$5.2 to \$5.9 billion (in 2006 dollars). By 2030, the range of annual health benefits is \$10.1 billion to \$10.8 billion (in 2006 dollars). This conservative estimate of annual health benefits by itself substantially exceeds MathPro's estimate of the annual increase in U.S. refining costs of \$1.5 billion per year.

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38 Arthur Marin, NESCAUM, Benefits and Costs of Tier 3 Low Sulfur Gasoline Program, CT DEEP SIPRAC Meeting, January 12, 2012 ("Marin Study"), pp. 6-7 and NESCAUM, Assessment of Clean Gasoline in the Northeast and Mid-Atlantic States, November 21, 2011 ("NESCAUM Assessment").

39 Marin Study, p. 6-7.

40 NESCAUM Assessment, p. 4-1.

41 NACAA, *Cleaner Cars, Cleaner Fuel, Cleaner Air: The Need for and Benefits of Tier 3 Vehicle Fuel Regulations*, October 2011, http://www.4cleanair.org/Documents/NACAATier3VehandFuelRep (hereinafter "NACCA Assessment"); EPA, *PM2.5 Benefit Per Ton Estimates*, http://www.epa.gov/oaqps001/benmap/bpt.html, (hereinafter "EPA Benefits").

Table 5

Value of Annual Health Benefits Resulting from Reducing the Sulfur Content of Gasoline from 30 ppm to 10 ppm (Billions of 2006 Dollars)

Reduced NOx, VOC, and Ozone As Of:	Low End	High End
2020	$5.2	$5.9
2030	$10.1	$10.8

Notes :

1. The NOx and VOC benefits are nationwide, are based on NACAA and EPA analyses, and are for 2020 and 2030.
2. The ozone benefits are for the U.S. Northeast and Mid-Atlantic regions, are based on a NESCAUM analysis, and are for 2018. The 2018 value is used for both 2020 and 2030.
3. The NOx and VOC benefit estimates based on NACAA and EPA analyses are single point estimates. The NESCAUM analysis provided low end and high end figures for ozone-related health benefits which are added to the NACAA point estimates to find the low end and high end figures shown above.

Sources :

1. EPA data from *PM2.5 Benefit Per Ton Estimates* , http://www.epa.gov/oaqps001/benmap/bpt.html.
2. NACAA data from *Cleaner Cars, Cleaner Fuel, Cleaner Air: The Need for and Benefits of Tier 3 Vehicle and Fuel Regulations* , October 2011, http://www.4cleanair.org/Documents/NACAATier3VehandFuelReportFINALOct2011.
3. NESCAUM data from *Assessment of Clean Gasoline in the Northeast and Mid-Atlantic States* , November 21, 2011, http://www.nescaum.org/documents/nescaum-tier-3-low-s-gasoline-20111121.pdf.

B. Economic Benefits Are Substantial

The health benefits described create economic benefits, because healthier people are more productive and miss less work due to illness resulting in a more productive economy. In addition, sulfur content reduction will permit the implementation of cost-effective vehicle technologies, which will provide substantial environmental benefits at a lower cost than would be possible if the sulfur content of motor gasoline were not reduced. Stated differently, reducing the sulfur content of motor gasoline will reduce the costs of the motor vehicles that will satisfy the Tier 3 pollution standards, thereby benefitting automobile consumers.

A national input-output model and its associated multipliers was used to calculate the nationwide economic effect of installation and operation of the refinery upgrades needed to comply with the Tier 3 gasoline sulfur content standards.[42] Based on the MathPro estimates, the investment cost for the installation of the refinery upgrades would be $3.917 billion spread over three years. Annual operating costs for these upgrades are $0.532 billion. The economic effects include the direct effects (i.e., the direct employment and purchases from others) and the indirect effects (i.e., the subsequent spending by the upgrade's direct employees, suppliers, and the employees of these suppliers).[43]

As shown in Table 6 below, installation of the refinery modifications produces almost 24,500 jobs for full time equivalent employees with total associated employee compensation of $1.161 billion for each of the three years of installation. The value added to the national economy is $2.027 billion each year. Federal, state, and local taxes on the corporate profits and personal income created by the refinery upgrades is $0.502 billion per year. According to our analysis, the annual operation of the refinery modifications produces almost 5,300 jobs for full time equivalent employees with total associated employee compensation of $0.294 billion. The value added to the national economy is $0.632 billion. Federal, state, and local taxes on the corporate profits and personal income is $0.138 billion per year.

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[42] Input-Output Models are widely used for economic assessments in both the public and private sector. In the public sector, for example, the Department of Defense uses Input-Output Models to estimate the regional impacts of military base closings. State transportation departments use Input-Output Models to estimate the regional impacts of airport construction and expansion. In the private-sector, analysts and consultants use Input-Output Models to estimate the regional impacts of a variety of projects, such as the development of shopping malls and sports stadiums. The regional input-output models, RIMS II, were developed and are maintained by the U.S. Department of Commerce, Bureau of Economic Analysis (BEA). RIMS II was developed and is maintained by the BEA. The model was developed in the 1970s and has been continuously updated and refined. RIMS II is widely used to determine the economic impacts of projects and programs on the national economy and regional economies within the United States. RIMS II is based on a 62 industry input-output model that accurately captures the interactions among the various industries within the economy. RIMS II is used to determine the economy-wide effects on employment, earnings, and value added of a project taking into account the project's direct employment, its purchases from others, and the subsequent spending by the project's direct employees, suppliers, and the employees of these suppliers (i.e., the indirect effects).

[43] The national economic impacts of installation and operation of the refinery modifications consist of direct and indirect changes in (1): the number of full time equivalent employees each year; (2) total employee compensation each year; (3) increase in value added (i.e., increased GDP) each year; and (4) increased Federal, state, and local tax revenues each year. The installation of the modifications to the refineries is assumed to take place over three years from 2014 through 2016. Installation expenditures are $3.917 billion and are assumed to be spread equally over the three years. Installation expenditures consist of: (1) purchases of industrial controls and control accessories; (2) construction labor to install the industrial controls; (3) construction management labor; and (4) engineering labor to design the installation of the industrial controls. The operation of the modifications to the refineries is assumed to start in 2017 when installation of the refinery upgrades is complete. Operating expenditures each year are $0.532 billion. The expenditures associated with operations consist of: (1) power; (2) labor; (3) chemicals; (4) tools and other materials; and (5) waste disposal.

Table 6
The Economic Impact of Upgrades to Refineries to Conform with Tier 3 Standards

Economic Impacts	Installation Each Year	Annual Operation
Full Time Equivalent Employees (Job Years)	24,456	5,296
Total Employee Compensation (Billions of Dollars)	$1.161	$0.294
Total Value Added (GDP, Billions of Dollars)	$2.027	$0.632
Total Federal, State, and Local Tax Revenues (Billions of Dollars)	$0.502	$0.138

Source: Navigant Economics.

Finally, there will be a further economic benefit due to an increase in value added and jobs created in the emission control industry and in the auto industry due to the development and implementation of the Tier 3 technology. We have not been able to quantify these benefits at this time.

VI. Conclusions

Baker & O'Brien's estimates of the costs to U.S. refineries due to complying with the EPA Tier 3 regulations appear to be greatly exaggerated. An appropriate adjustment to its overstated capital costs yields costs estimates that are similar to those of the EPA and of MathPro. Expressed on a per gallon of gasoline basis, the likely costs are *de minimus* (about one cent per gallon). Even though the EPA's Tier 2 sulfur reduction regulations were expected to increase U.S. refineries' costs by twice as much (two cents versus one cent per gallon), there is no detectable effect of Tier 2 sulfur reduction regulation on the U.S. retail gasoline price. Therefore, it is highly unlikely that the Tier 3 costs would have a detectable effect on the U.S. retail gasoline price.

We estimate that the health benefits alone of adopting Tier 3 sulfur reduction regulation likely compensate (in a Pareto sense) for the costs to U.S. refineries. Other economic benefits, including the reduction in the cost of automobiles that are compliant with Tier 3 pollution standards, will redound to the benefit of consumers. Finally, making the investment needed to reduce the sulfur content of gasoline adds $6.1 billion to the U.S. gross domestic product (value added) over the three-year construction period, and the annual operation of these refinery modifications supports almost 5,300 domestic jobs each year.

Detailed Technical Discussion of the Multiple Regression Analysis of U.S. Retail Gasoline Price Determinants

Methodology

Monthly U.S. retail gasoline price data from January 2001 through January 2012 were analyzed using multiple regression analysis. This analysis tested the statistical significance of factors that were believed to potentially affect the retail price of gasoline. The explanatory factors evaluated in the regression analysis included the global price of crude oil (the Brent price), the U.S. refinery margin, and market events (e.g., the 2005 hurricanes and MTBE issues in 2006 and 2007). The role of these factors in explaining the variation in the retail price of gasoline was addressed recently in a study by the Federal Trade Commission.[1] In addition, the multiple regression analysis was used to test whether the implementation of the EPA Tier 2 sulfur reduction standards had a statistically significant effect on retail gasoline prices.[2] The effects of the transition to Tier 2 on the retail price of gasoline, if any, would have occurred during 2003 and 2004, but there were other "shocks" to the U.S. retail gasoline market during 2003 and 2004. The permanent effects of Tier 2 on the retail price of gasoline, if any, would occur from 2005 forward.

Regarding the other "shocks" to the U.S. retail gasoline market during 2003 and 2004, there were numerous unusual and unexpected market events during 2003 and 2004 which caused U.S. retail gasoline prices to be higher than would be expected given the global crude oil price and U.S. refinery margins. These events include refinery outages, low gasoline inventories, strong gasoline demand growth, the transition from MTBE to ethanol as an oxygenate in California, New York, and Connecticut in January 1, 2004, slightly reduced gasoline supply due to more stringent product specifications (transition from MTBE to ethanol and transition to lower sulfur content gasoline), uncertainty regarding the availability of gasoline imports (due to transition from MTBE to ethanol and transition to lower sulfur content gasoline), and higher transportation costs.[3] Of the two changes in gasoline specifications, the transition from MTBE

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1 Federal Trade Commission, Bureau of Economics, *Gasoline Price Changes and the Petroleum Industry: An Update*, An FTC Staff Study, September 2011, pp. i-ii, 5-6, and 23-26, http://www.ftc.gov/os/2011/09/110901gasolinepricereport.pdf .

2 Multiple regression analysis is a standard empirical technique used in a wide variety of disciplines. A multiple regression model is one that models (or explains) associations between the "dependent variable" under study – here, U.S. gasoline prices – and "explanatory variables" thought to be related to variation in the dependent variable. There are 133 monthly observations in the dataset used to perform the multiple regression analysis.

3 EIA, *Inquiry into August 2003, Gasoline Price Spike*, November 2000, pp. 15-17, http://www.eia.gov/pub/oil_gas/petroleum/analysis_publications/gasps/gasps.pdf ; Oil & Gas Journal, *Refining*

to ethanol was given the greatest emphasis by the EIA in its assessment of why U.S. retail gasoline prices were substantially higher than expected given global crude oil prices in 2004.[4] However, in 2003, neither the transition from MTBE to ethanol nor the transition from MTBE to ethanol were named by EIA as a contributing factor to higher retail gasoline prices.[5] Therefore, given global crude oil prices, the higher than expected U.S. retail gasoline prices in 2003 and 2004 were primarily the result of factors other than the transition to lower sulfur gasoline.

Figure 1 below plots the U.S. retail price of gasoline (excluding taxes) expressed in dollars per gallon and the Brent crude oil price expressed in dollars per barrel. Figure 1 also includes circles around the periods when unexpected and/or unusual events occurred. The circle drawn around 2003 and 2004 corresponds to the period when the effects of the transition to the reduced Tier 2 gasoline sulfur content, if any, would have occurred. However, as outlined above, retail gasoline prices during this period were affected by numerous other unexpected and/or unusual events which are discussed in detail below. Circles also are drawn around the periods affected by the 2005 hurricanes and around the periods in 2006 and 2007 that were affected strongly by the MTBE to ethanol oxygenate transition. Finally, a circle is drawn around the sharp drop in retail gasoline prices in 2008 due to the global recession, but this drop can be explained by the corresponding sharp drop in crude oil prices.

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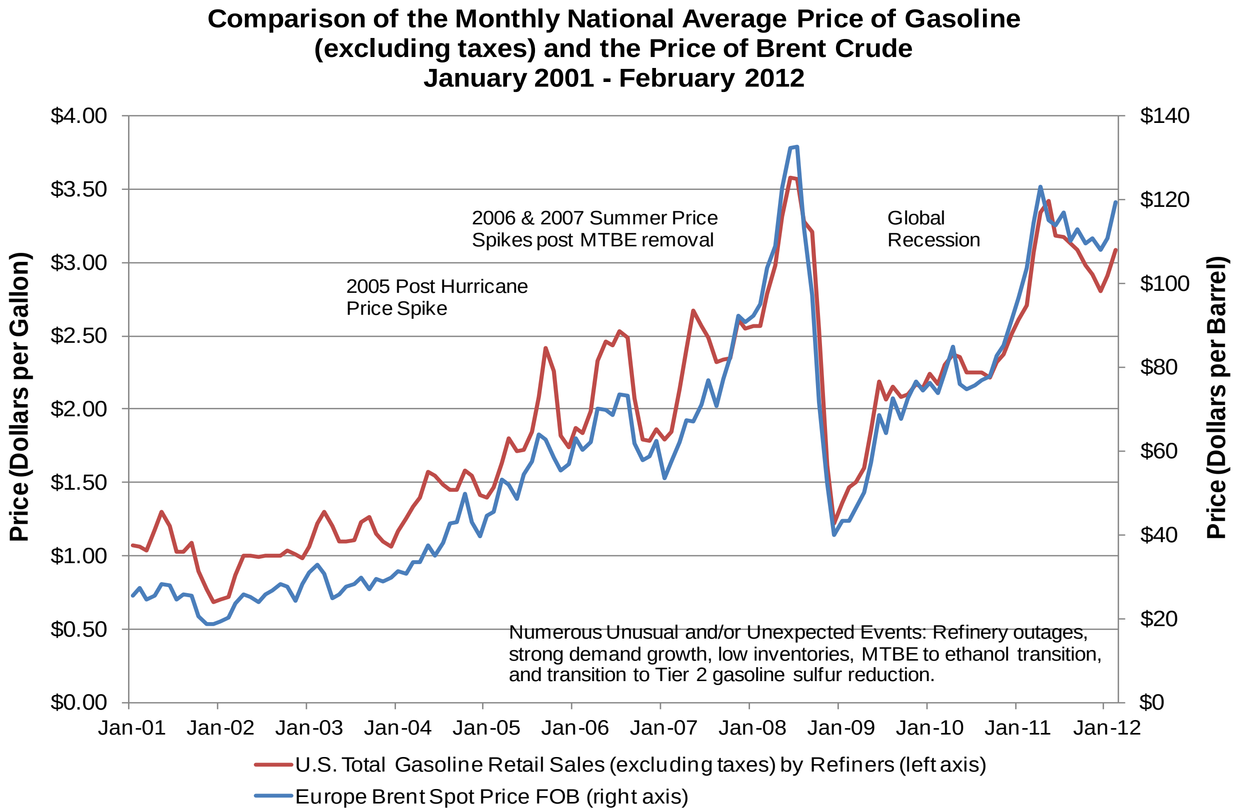
industry to sustain strong margins through 2004, March 15, 2004, http://www.eia.gov/pub/oil_gas/petroleum/analysis_publications/gasps/gasps.pdf; U.S. Department of Energy, Energy Information Administration, Short-Term Energy Outlook April 2004, Summer 2004 Motor Gasoline Outlook, p. 1, (http://www.eia.gov/forecasts/steo/special/summer/2004_summer_gas.pdf); Statement of Guy F. Caruso, Administrator, Energy Information Administration, Department of Energy before the Government Reform Subcommittee on Energy Policy, Natural Resources and Regulatory Affairs, United States House of Representatives, July 7, 2004, pp. 2-4, (http://www.eia.gov/neic/speeches/caruso070704.htm .

4 *Id*.

5 *Id*.

Figure 1



Source: EIA.

Regression Model Specification

The regression model specification estimated is as follows:

$$gasP\_notax_t = \beta_0 + \beta_1 brent_{t-1} + \beta_1 \Delta brent_t + \beta_2 ref\_margin_t + \beta_3 hurr\_dum_t + \beta_4 MTBE\_06_t + \beta_5 MTBE\_07_t + \beta_6 Shocks\_03\_04_t + \beta_7 Tier2\_05\_on_t + \text{Monthly Dummy Variables}_t$$

Table 1 below provides a description of the variables used in estimating the regression model.

Table 1: Description of Variables Used in the Regression Model

Variable	Description
gasP_notax	Dependent variable: U.S. Total Gasoline Retail Sales by Refiners (Dollars per Gallon, excluding taxes). *Source*: EIA.
Brent	Europe Brent Crude Oil Spot Price FOB (converted to Dollars per Gallon). *Source*: EIA. Both the lagged value (i.e., the Brent price in the prior month, $brent_{t-1}$) and the first difference (i.e., the month-to-month change, $\Delta brent_t$) are included in the regression model.
ref_margin	U.S. refining total cash operating margin (converted to Dollars per Gallon). *Source*: Muse Stancil
month_dum1 – month_dum11	Monthly dummy variables to control for recognized seasonality in U.S. gasoline prices.[6]
hurr_dum	A dummy variable equal to 1 for the period Sept. – Oct. 2005 (0 otherwise) to control for the effects on U.S. gasoline prices of hurricanes Katrina and Rita in Fall 2005.[7]
MTBE_06, MTBE_07	Dummy variables equal to 1 for the Summers of 2006 and 2007, respectively (0 otherwise), to control for the Summer "price spikes" attributable to MTBE removal.[8]
Shocks_03_04	Dummy variable equal to 1 for the years 2003 and 2004 (0 otherwise) intended to control for numerous "shocks" potentially affecting U.S. gasoline prices. It was during this period that there was a mandated reduction in gasoline's sulphur content from about 300 ppm 180 ppm by the start of 2004.[9]
Tier2_05_on	Dummy variable equal to 1 for the year 2005 onward (0 otherwise) intended to control for any increase in U.S. gasoline prices during the period when the mandated reduction in its sulphur content was from 300 ppm to 30 ppm was completed by the start of 2006.[10]

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6 See, e.g., Du and Hayes (2008), "The gasoline market is highly seasonal due to stronger demand in spring and summer. Gasoline price tends to gradually rise before and after summer. … We include a set of monthly dummies to account for the seasonal pattern." (Xiaodong Du and Dermot J. Hayes, "The Impact of Ethanol Production on U.S. and Regional Gasoline Prices and on the Profitability of the U.S. Oil Refinery Industry," *Working Paper 08-WP 467*, Department of Economics and Center for Agricultural & Rural Development, Iowa State University, 2008, p.8.)

7 "Hurricane Katrina, which made landfall on August 29, 2005, caused the immediate loss of 27% of the nation's crude oil production and 13% of national refining capacity. … Prices were falling back towards pre-Katrina levels when Hurricane Rita made landfall on September 23 and caused the loss of another 8% of crude production and 14% of refining capacity. By four weeks after Hurricane Rita, prices in many areas had returned to pre-Katrina levels, and by December, prices had returned to where they were early in the summer of 2005. While the price increases following the hurricanes were significant, the price spike was relatively short-lived." Gasoline Price Changes and the Petroleum Industry: An Update. FTC, Bureau of Economic Analysis, September 2001, pp. 24-25.

8 The FTC has identified "price spikes" in gasoline prices relative to crude oil prices in the Summer of 2006 and the Summer of 2007 related to the transition from methyl tertiary butyl ether (MTBE) to ethanol. Gasoline Price Changes and the Petroleum Industry: An Update. FTC, Bureau of Economic Analysis, September 2001, pp. 5, 25-26.

9 The EPA Tier 2 sulfur standards reduced the sulfur content of gasoline from about 300 ppm to 30 ppm by 2006. It occurred in two distinct phases. The first phase called for the reduction in sulphur content to 180 ppm by the start of 2004; the second phase called for the reduction in sulfur content from 180 ppm to 30 ppm by 2006.

10 Id.

The EPA's Tier 2 sulfur reduction program for gasoline called for a reduction in the sulfur content of gasoline from 300 parts per million (ppm) to 30 ppm. This sulfur content reduction was phased-in. During the first phase, the average sulfur content of gasoline had to be reduced from 300 ppm to 180 ppm by the beginning of 2004. During the second phase, the average sulfur content of gasoline had to be reduced from 180 ppm to 30 ppm by the beginning of 2006. The EPA estimated that the total cost to U.S. refiners of the Tier 2 gasoline sulfur content reduction would be 1.7 to 1.9 cents per gallon, and the API, based on a study prepared by MathPro, estimated that the cost would be 2.6 cents per gallon.[11] Therefore, the estimated cost to U.S. refiners of the Tier 2 gasoline sulfur content reduction was about 2 cents per gallon while the estimated cost of the Tier 3 gasoline sulfur content reduction to U.S. refiners is about 1 cent per gallon. If the U.S. refiners' compliance costs of the Tier 2 gasoline sulfur content regulation were fully passed on to consumers, one would expect to see about a 2 cents per gallon increase in U.S. retail gasoline prices.

The purposes of the two Tier 2 related dummy variables are different. The first, Shocks_03_04, is intended to capture the effect of numerous unusual or unexpected events that occur during 2003 and 2004 on the U.S. retail price of gasoline, including the transition from 300 ppm to 180 ppm by the start of 2004, and then the movement towards the 30 ppm goal during 2004 (e.g., any transitory shortages of gasoline related to attaining the sulfur standards). However, contemporaneous with this potential influence are several other substantial market events occurred that would be expected to influence the U.S. retail price of gasoline (See Figure 1 and discussion below). Tier2_05_on is intended to capture any permanent effects on the U.S. retail price of gasoline due to the reduction of the sulfur content of gasoline from 300 ppm to 30 ppm by the start of 2006. Given that the estimated average cost to the U.S. refiners of complying with the Tier 2 sulfur content of gasoline regulations is in the vicinity of 2 cents per gallon, one would expect that the regression coefficient on Tier2_05_on would be in the vicinity of 2 cents per gallon (assuming a full pass-through of the U.S. refiners' compliance costs).

A qualification to the interpretation of the two Tier 2 related dummy variables in Table 1 is necessary because other market factors changed particularly during the 2003 to 2004 period (covered by the Shocks_03_04 dummy variable) and during the 2005 forward period (covered by the Tier2_05_on dummy variable). As a consequence, one cannot presume that a retail price increase during these two

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[11] John F. Anderson and Todd Sherwood, EPA, *Comparison of EPA and Other Estimates of Mobile Source Rule Cost Changes to Actual Price Changes*, Paper Presented to the SAE Government Industry Meeting, Washington, DC, May 14, 2004, Table 2.

periods that is not explained by the other explanatory factors was necessarily due to the implementation of the Tier 2 gasoline sulfur content reduction. As discussed below, as part of the discussion of the regression model estimation results, the factors other than implementing the Tier 2 gasoline sulfur sulfur oil reduction are particularly important during the 2003 to 2004 period covered by the Shocks_03_04 dummy variable.

Regression Model Estimation Results

The regression model estimation results are presented in Table 2 and Table 3 below. The adjusted R-squared statistics underneath Tables 1 and 2 measure the percentage of the variance in the dependent variable that is explained by the regression model. The "adjustment" corrects the R-squared for degrees of freedom. If an explanatory variable is added to a regression model, the adjusted R-squared will rise or fall depending on whether or not the additional explanatory variable makes a statistically significant contribution to the accuracy of the estimated regression model.

The regression specification used in Table 3 is identical to that used in Table 2 except that the variable "Tier2_05_on" is omitted because it is statistically insignificant in the results shown in Table 2 (i.e., Tier2_05_on does not make a statistically significant contribution to the accuracy of the regression model).[12] The adjusted R-squared statistics have identical values in Tables 2 and 3 indicating that the explanatory variable "Tier2_05_on" does not make a statistically significant contribution to explaining the variance in the U.S. retail price of gasoline. While statistically insignificant, the regression coefficient in Tier2_05_on in Table 2 is 2.l cents per gallon which is consistent with the estimated U.S. refiners' cost of compliance of about 2 cents per gallon.

[12] *Stata* 10.1 for Windows was used to perform the estimations. The "β's" in the regression specification represent regression coefficients that are estimated and reported in Tables 2 and 3. Robust standard errors are used to account for a variety of technical issues (e.g., the possible presence of arbitrary forms of autocorrelation and heteroskedasticity). Formal statistical tests indicate that the "residuals" from the regressions are stationary. This indicates that they represent a "cointegrating vector" among the explanatory variables so that standard errors are consistently estimated, and that the regression results are meaningful (and not spurious). In particular, while the times series used in the regressions (i.e., gasoline price, Brent price, and refinery margin) are individually non-stationary, they are cointegrated. Formal statistical tests confirm these findings and are available upon request.

Table 2: Regression Model Estimation Results Including Tier 2_05_on

Linear regression

Number of obs =	132
F(19, 112) =	1379.76
Prob > F =	0.0000
R-squared =	0.9926
Root MSE =	.06812

gasP_notax	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
brent						
L1.	.9515957	.0138523	68.70	0.000	.9241491	.9790422
D1.	.6207283	.0736136	8.43	0.000	.4748725	.7665842
ref_margin	.788483	.0965854	8.16	0.000	.5971114	.9798546
month_dum1	.0188129	.0303161	0.62	0.536	-.0412546	.0788803
month_dum2	.0193204	.0299509	0.65	0.520	-.0400235	.0786644
month_dum3	.0770951	.0291928	2.64	0.009	.0192534	.1349368
month_dum4	.1111136	.026536	4.19	0.000	.0585359	.1636913
month_dum5	.1769586	.0295633	5.99	0.000	.1183828	.2355345
month_dum6	.1562905	.033111	4.72	0.000	.0906854	.2218956
month_dum7	.1119949	.0273339	4.10	0.000	.0578363	.1661535
month_dum8	.0870313	.0262258	3.32	0.001	.0350682	.1389943
month_dum9	.1062632	.0310538	3.42	0.001	.0447341	.1677923
month_dum10	.0664602	.0321564	2.07	0.041	.0027464	.130174
month_dum11	.036027	.0322155	1.12	0.266	-.0278039	.099858
hurr_dum	.1074283	.0453668	2.37	0.020	.0175398	.1973168
MTBE_06	.0943489	.040353	2.34	0.021	.0143947	.1743032
MTBE_07	.1184097	.046843	2.53	0.013	.0255962	.2112231
Shocks_03_04	.0842546	.015392	5.47	0.000	.0537573	.1147518
Tier2_05_on	.0210653	.026774	0.79	0.433	-.031984	.0741146
_cons	.273803	.0261335	10.48	0.000	.2220228	.3255831

Note: The Adjusted R-squared (expressed as a percentage) equals 99.1%.

Table 3: Regression Model Estimation Results Excluding the Tier2_05_0n

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Linear regression                                      Number of obs =     132
                                                       F( 18,   113) = 1391.23
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.9926
                                                       Root MSE      =  .06802
```

gasP_notax	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
brent						
L1.	.9592639	.0092446	103.77	0.000	.9409487	.977579
D1.	.6251273	.0716022	8.73	0.000	.4832705	.7669841
ref_margin	.8079564	.0881157	9.17	0.000	.6333833	.9825296
month_dum1	.0201034	.0297718	0.68	0.501	-.0388798	.0790867
month_dum2	.019367	.0296066	0.65	0.514	-.039289	.0780231
month_dum3	.0760365	.0291377	2.61	0.010	.0183094	.1337636
month_dum4	.1084548	.0261497	4.15	0.000	.0566476	.160262
month_dum5	.1738783	.0291106	5.97	0.000	.116205	.2315517
month_dum6	.1536496	.0324126	4.74	0.000	.0894343	.2178648
month_dum7	.1094042	.0274055	3.99	0.000	.0551091	.1636994
month_dum8	.0840827	.0263907	3.19	0.002	.0317979	.1363675
month_dum9	.1035406	.0312444	3.31	0.001	.0416398	.1654414
month_dum10	.0647937	.0320144	2.02	0.045	.0013675	.1282199
month_dum11	.0355382	.0314156	1.13	0.260	-.0267017	.0977781
hurr_dum	.1063092	.04489	2.37	0.020	.017374	.1952444
MTBE_06	.0944099	.0404674	2.33	0.021	.0142368	.174583
MTBE_07	.1200742	.0462439	2.60	0.011	.0284567	.2116916
Shocks_03_04	.0753474	.0138127	5.45	0.000	.047982	.1027128
_cons	.2756814	.0262263	10.51	0.000	.2237225	.3276404

Note: The Adjusted R-squared (expressed as a percentage) equals 99.1%.

In Table 3 above, the most important explanatory factor is the Brent crude oil price with the U.S. refinery margin being a distant second in importance. The 2005 hurricanes and the issues associated with the transition from MTBE to ethanol as an oxygenate during 2006 and 2007 had a statistically significant effect on the U.S. retail price of gasoline. In addition, as shown in Table 3 above, the variable intended to control for numerous "shocks" to the market during 2003 and 2004 ("Shocks_03_04") is positive and statistically significant. There are numerous market "shocks" that are captured by the Shocks_03_04 explanatory variable. Gasoline prices were unusually high during the summer of 2003 (particularly in August) due to low refiner inventories of refined products and crude oil, unexpected refinery outages, and strong summer gasoline demand.[13] High winter demand for distillates depleted inventories which caused refineries to plan to produce relatively more distillate and less gasoline than normal during the summer of 2003.[14] In addition, there were substantial refinery outages during June and July 2003 in some parts of the country.[15] There also was an electricity blackout in August 2003 which caused refinery shutdowns.[16] There is no mention by the EIA of any issues related to the transition to low sulfur gasoline during 2003.[17]

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13 EIA, *Inquiry into August 2003, Gasoline Price Spike*, November 2000, pp. 15-17, http://www.eia.gov/pub/oil_gas/petroleum/analysis_publications/gasps/gasps.pdf .

14 *Id*.

15 *Id*.

Retail gasoline prices also were relatively high in 2004 due to “strengthening product demand, stagnant capacity growth, and slightly reduced supply due to more-stringent product specifications.”[18] The last of the three factors listed above includes, but is not limited to, the reduction in the sulfur content of gasoline (e.g., California, New York, and Connecticut banned MTBE use beginning January 1, 2004).[19] The EIA indicated that gasoline markets remained tight as the 2004 driving season began, and that conditions were likely to remain volatile throughout the summer.[20] The EIA stated that “[h]igh crude oil costs, strong gasoline demand growth, low gasoline inventories, uncertainty about the availability of gasoline imports, high transportation costs, and changes in gasoline specification have added to current and expected gasoline costs and pump prices.”[21] The EIA went on to say that “[t]he combined impact of high crude oil prices, continuing growth in demand, low inventories, and the ongoing transition from methyl tertiary butyl ether (MTBE) to ethanol in several regions are projected to contribute to high average motor gasoline prices for this driving season.”[22] The EIA’s emphasis related to the effects of changes in gasoline specifications was on the impacts of the switch from MTBE to ethanol in the three states, but it did mention the potential impacts of the transition to the Tier 2 lower sulfur standards. The EIA stated that, in addition to the factors discussed above, retail gasoline prices in the summer of 2004 also could be affected by “the reduction in permissible sulfur content mandated by the Environmental Protection Agency.”[23] The EIA further stated that “for the summer [of 2004], motor gasoline supplies are expected to be tight due to low stocks, more stringent reformulation requirements [resulting from the transition from MTBE to ethanol], and lower sulfur content allowances.”[24]

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16 *Id*.

17 *Id*.

18 Oil & Gas Journal, *Refining industry to sustain strong margins through 2004*, March 15, 2004, http://www.eia.gov/pub/oil_gas/petroleum/analysis_publications/gasps/gasps.pdf .

19 *Id*.

20 U.S. Department of Energy, Energy Information Administration, Short-Term Energy Outlook April 2004, Summer 2004 Motor Gasoline Outlook, p. 1, (http://www.eia.gov/forecasts/steo/special/summer/2004_summer_gas.pdf).

21 *Id*., p. 1.

22 *Id*., p. 3.

23 *Id*., p. 4.

24 *Id*., p. 11, see also *Id*., p. 8.

In testimony before the Government Reform Subcommittee on Energy Policy, Natural Resources and Regulatory Affairs by Guy F. Caruso, Administrator, EIA on July 7, 2004, Mr. Caruso cited high crude prices and high gasoline demand as reasons for the high retail gasoline prices.[25] Mr. Caruso stated that gasoline supply was tight in part because of lower than expected gasoline imports. Mr. Caruso attributed these lower than expected gasoline imports to world market conditions in general and to "the effect of required sulfur content reductions under the Tier 2/Gasoline Sulfur regulations as well as other changes in U.S. requirements for higher-valued cleaner products."[26]

The higher than expected retail gasoline prices during the summer in 2003 and 2004 are due to numerous factors. In 2003, there is no indication that the Tier 2 gasoline sulfur regulations were a factor. In 2004, the evidence is that the Tier 2 gasoline sulfur regulations were a contributing factor among many to the higher retail gasoline prices. The estimated regression coefficient on the Shocks_03_04 explanatory variable in Table 3 of 7.5 cents per gallon is due to the combined effect of all the factors discussed above. Further, given the emphasis in the EIA's discussion of the various risks, it appears that the contribution of the transition to the Tier 2 gasoline sulfur content standards was relatively minor.

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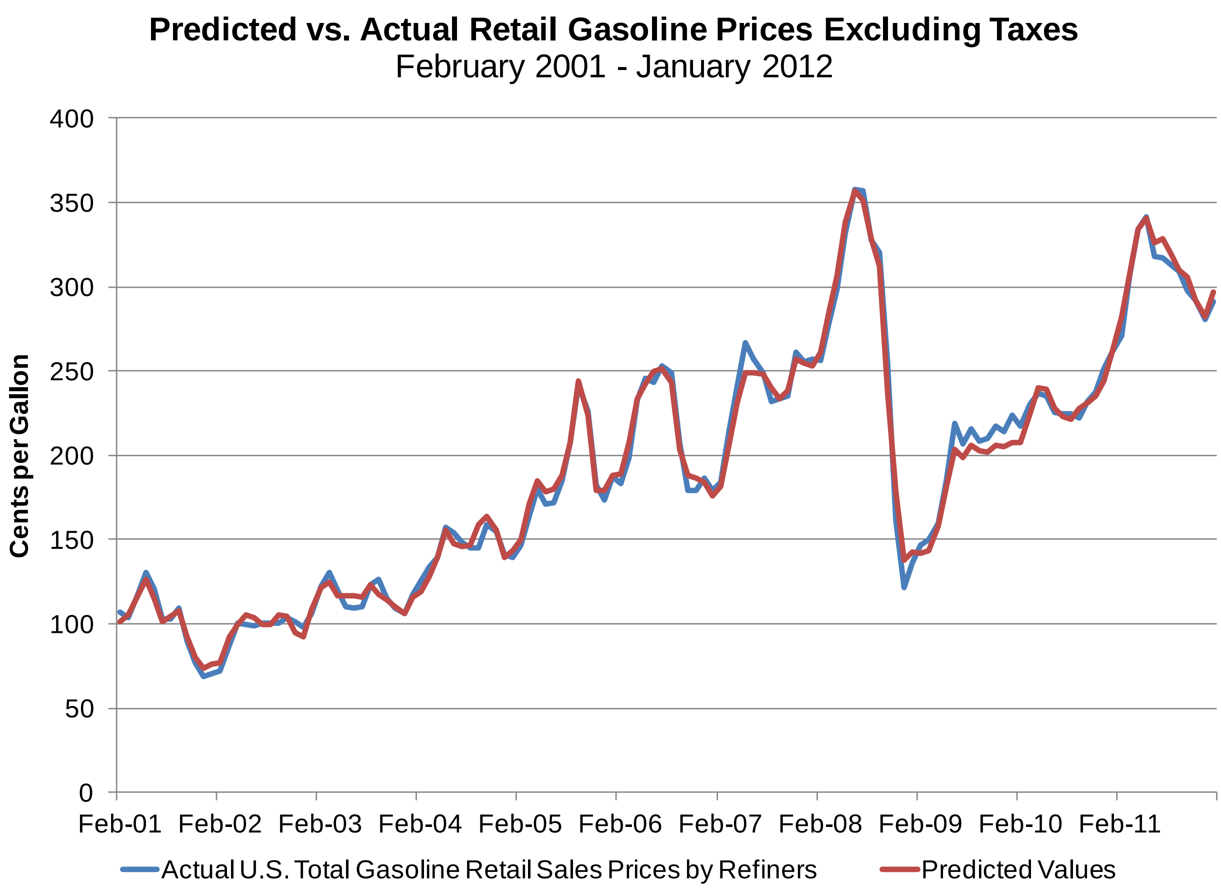
25 Statement of Guy F. Caruso, Administrator, Energy Information Administration, Department of Energy before the Government Reform Subcommittee on Energy Policy, Natural Resources and Regulatory Affairs, United States House of Representatives, July 7, 2004, pp. 2-4, (http://www.eia.gov/neic/speeches/caruso070704.htm).

26 *Id.*, p. 4.

Conclusions

The U.S. retail gasoline price excluding taxes and its predicted value generated by the estimated regression model results shown in Table 3 are presented in Figure 2 below. Figure 2 demonstrates visually that the regression model is highly accurate. The adjusted R-squared statistic measures the percentage of the variance of the dependent variable (the U.S. retail price of gasoline excluding taxes) that is explained by the regression model, which, for the estimated regression model in Table 3 above, is 99.1%. The estimated regression model is statistically significant at the highest level (the 1% level).

Figure 2



The estimated regression model results shown in Table 3 above confirm that the global crude oil price is by far the most important determinant of retail gasoline prices. The U.S. refinery margin, which reflects the relationship between supply and demand for refined petroleum products, is a distant second in importance. The seasonal dummy variables and the various market event variables (hurr_dum; MTBE_06; MTBE_07; and Shocks_03_04) are the third in importance. These market event variables capture the effects of unexpected and/or unusual market events during the regression model estimation period that caused the U.S. retail price of gasoline to be higher than would be expected based on the global crude oil price and the U.S. refinery margins. These market events include the 2005 hurricanes and the 2006 and 2007 MTBE to ethanol transition issues. Finally, there were numerous unusual and unexpected market events during 2003 and 2004 which caused U.S. retail gasoline prices to be higher than would be expected given the global crude oil price and U.S. refinery margins. These 2003/2004 events include refinery outages, low gasoline inventories, strong gasoline demand growth, the transition from MTBE to ethanol as an oxygenate in California, New York, and Connecticut in January 1, 2004, slightly reduced gasoline supply due to more stringent product specifications (transition from MTBE to ethanol and transition to lower sulfur content gasoline), uncertainty regarding the availability of gasoline imports (due to transition from MTBE to ethanol and transition to lower sulfur content gasoline), and higher transportation costs.[27] Of the two changes in gasoline specifications, the transition from MTBE to ethanol was given the greatest emphasis by the EIA in its assessment of why U.S. retail gasoline prices were substantially higher than expected given global crude oil prices in 2004.[28] However, in 2003, neither the transition from MTBE to ethanol nor the transition from MTBE to ethanol were named by EIA as a contributing factor to higher retail gasoline prices.[29] Therefore, given global crude oil prices, the higher than expected U.S. retail gasoline prices in 2003 and 2004 were primarily the result of factors other than the transition to lower sulfur gasoline.

For the period 2005 forward, there is no statistically significant effect of the Tier 2 gasoline sulfur content reduction on U.S. retail gasoline prices (i.e., the EPA Tier 2 gasoline sulfur content regulations which increased U.S. refiner costs by about 2 cents per gallon had no statistically significant effect on U.S retail gasoline prices). Therefore, it is highly unlikely that the EPA Tier 3 gasoline sulfur content regulations

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27 EIA, *Inquiry into August 2003, Gasoline Price Spike*, November 2000, pp. 15-17, http://www.eia.gov/pub/oil_gas/petroleum/analysis_publications/gasps/gasps.pdf ; Oil & Gas Journal, *Refining industry to sustain strong margins through 2004*, March 15, 2004, http://www.eia.gov/pub/oil_gas/petroleum/analysis_publications/gasps/gasps.pdf; U.S. Department of Energy, Energy Information Administration, Short-Term Energy Outlook April 2004, Summer 2004 Motor Gasoline Outlook, p. 1, (http://www.eia.gov/forecasts/steo/special/summer/2004_summer_gas.pdf); Statement of Guy F. Caruso, Administrator, Energy Information Administration, Department of Energy before the Government Reform Subcommittee on Energy Policy, Natural Resources and Regulatory Affairs, United States House of Representatives, July 7, 2004, pp. 2-4, (http://www.eia.gov/neic/speeches/caruso070704.htm .

28 *Id*.

29 *Id*.

which are expected to increase U.S. refiner costs by about 1 cent per gallon will have a statistically significant effect on U.S retail gasoline prices.