United States Government Accountability Office

GAO

Report to Congressional Requesters

July 2009

ENERGY MARKETS

Refinery Outages Can Have Varying Gasoline Price Impacts, but Gaps in Federal Data Limit Understanding of Impacts

GAO

Accountability * Integrity * Reliability

GAO-09-700

Highlights of GAO-09-700, a report to congressional requesters

July 2009

ENERGY MARKETS

Refinery Outages Can Have Varying Gasoline Price Impacts, but Gaps in Federal Data Limit Understanding of Impacts

Why GAO Did This Study

In 2008, GAO reported that, with the exception of the period following Hurricanes Katrina and Rita, refinery outages in the United States did not show discernible trends in reduced production capacity, frequency, and location from 2002 through 2007. Some outages are planned to perform routine maintenance or upgrades, while unplanned outages occur as a result of equipment failure or other unforeseen problems. GAO was asked to (1) evaluate the effect of refinery outages on wholesale gasoline prices and (2) identify gaps in federal data needed for this and similar analyses.

GAO selected refinery outages from 2002 through September 2008 that were at least among the largest 60 percent in terms of lost production capacity in their market region and lasted at least 3 days. GAO developed an econometric model and tested a variety of assumptions using public and private data.

What GAO Recommends

We recommend that the Administrator of the Energy Information Administration (EIA) convene a panel of agency officials, industry representatives, and experts to determine if existing data meet the current and future needs of the Congress and analysts who use such data. We provided a draft of this report to EIA, the Environmental Protection Agency (EPA), and the Department of Transportation (DOT). EIA agreed with our recommendations, and EPA and DOT made technical comments only.

View GAO-09-700 or key components.
For more information, contact Frank Rusco at (202) 512-3814 or ruscof@gao.gov.

What GAO Found

While some unplanned refinery outages, such as those caused by accidents or weather, have had large price effects, GAO found that in general, refinery outages were associated with small increases in gasoline prices. Large price increases occurred when there were large outages; for example, in the aftermath of hurricanes Katrina and Rita. However, we found that such large price increases were rare, and on average, outages were associated with small price increases. For example, GAO found that planned outages generally did not influence prices significantly—likely reflecting refiners' build-up in inventories to meet demand needs prior to shutting down—while for unplanned outages, average price effects ranged from less than one cent to several cents-per-gallon. Key factors influenced the size of price increases associated with unplanned outages. One such factor was whether the gasoline was branded—gasoline sold at retail under a specific refiner's trademark—or unbranded—gasoline sold at retail by independent sellers. Our analysis showed that during an unplanned outage, branded wholesale gasoline prices had smaller price increases than unbranded, suggesting that refiners give preference to their own branded customers during outages, while unbranded dealers must seek out supplies in a more constrained market. Another factor that affected the size of price increases associated with outages was the type of gasoline being sold. Some special blends of gasoline developed to reduce emissions of air pollutants exhibited larger average price increases than more widely used and available conventional gasoline, suggesting that these special gasoline blends may have more constrained supply options in the event of an outage.

Existing federal data contain gaps that have limited GAO's and Department of Transportation's (DOT) analyses of petroleum markets and related issues. For example:

- Data linking refiners to the markets they serve were inadequate for GAO to fully evaluate the price effects of unplanned outages on individual cities, limiting the analysis to broader average effects.
- Pipeline flow and petroleum product storage data were inadequate for DOT to fully address a January 2009 Congressionally mandated study to identify potential pipeline infrastructure constraints, and limited GAO's ability to identify re-supply options for cities experiencing outage disruptions.

Federal agencies generally have continued to update their data collection surveys to meet their respective needs and emerging changes in the energy sector. However, in some cases the individual agency efforts have resulted in the collection of information that does not necessarily meet the data needs of other agencies or analysts who monitor petroleum product markets.

Contents

Abbreviations

CARB	California Air Resources Board
CBG	Cleaner burning gasoline
DOE	Department of Energy
DOT	Department of Transportation
EIA	Energy Information Administration
EPA	Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
HHI	Hirschman Herfindahl Index
IIR	Industrial Information Resources, Inc.
MTBE	Methyl Tertiary Butyl Ether
OPIS	Oil Price Information Services
PADD	Petroleum Administration for Defense Districts
PSRS	Petroleum Supply Reporting System
RFG	Reformulated Gasoline
RFS	Renewable Fuel Standard
RVP	Reid Vapor Pressure

United States Government Accountability Office
Washington, DC 20548

July 30, 2009

Congressional Requesters

The 150 refineries in the United States play an important role in the nation's economy and energy security by supplying consumers and industry with needed petroleum products. Unplanned refinery outages—such as those caused by hurricanes, fires, or refinery equipment failures—have raised questions about the stability and cost of U.S. gasoline and other petroleum product supplies. In addition to unplanned outages, refineries must periodically undergo planned outages, during which they shut down major pieces of equipment to perform maintenance, overhaul, and repair operations. In October 2008,[1] we reported that, with the exception of impacts in 2005 related to Hurricanes Katrina and Rita, refinery outages across the United States generally did not show discernible trends in reduced production capacity or in the frequency and location of outages from 2002 through 2007. In addition, in March 2007, the Department of Energy's (DOE) Energy Information Administration (EIA) reported that unplanned refinery outages can result in local supply disruptions that result in temporary price increases; however, refinery outages do not always affect prices.[2] Moreover, analyses by EIA and the California Energy Commission have described how an unplanned refinery outage under certain conditions—for example, a tight market supply and demand balance for refined products coupled with low inventories or other sources of re-supply to meet demand in the event of an unplanned outage—can trigger price increases. Still, the impacts on gasoline prices due to refinery outages and other disruptions are not fully understood. In particular, while it is well understood that extreme events that disrupt crude oil or petroleum product supplies can have significant effects on the prices of these commodities, the price effects of less dramatic disruptions, such as routine refinery outages, are not well understood.

---

[1]GAO, *Energy Markets: Refinery Outages Can Impact Petroleum Product Prices, but No Federal Requirements to Report Outages Exist*, GAO-09-87, (Washington, D.C.: Oct. 7, 2008).

[2]Department of Energy, *Energy Information Administration, Refinery Outages: Description and Potential Impact on Petroleum Product Prices* (Washington, D.C., March 2007).

Further compounding the potential impact of refinery outages, in recent years prior to the current economic recession, global demand for crude oil and petroleum products such as gasoline, diesel fuel, and jet fuel had grown more quickly than available capacity to produce them. Furthermore, some refiners had been running near capacity, particularly during the peak-demand summer months. During tight market conditions, unexpected refinery outages could stress the petroleum product supply system, affecting operations at refineries, pipelines, and storage terminals. In addition, the proliferation of special fuel blends—gasoline that has special characteristics designed to meet federal, state, and local air quality requirements—as well as the increasing use of biofuels such as ethanol as a component of gasoline, have complicated the manufacturing and distribution processes for petroleum products. Once produced, the various blends of petroleum products must be kept separate throughout shipping and delivery. Other disruptions, such as a pipeline break, can hamper the ability of the supply infrastructure to deliver the steady supply of gasoline and other petroleum products that U.S. consumers and businesses depend on. In the past, local supply disruptions could be addressed more quickly because additional fuel of the same formulation could be purchased from numerous sources, but with the proliferation of special fuel blends, replacement supplies of a special blend might not be as readily available, and refineries with the capability to produce them could be hundreds of miles away.

A number of federal agencies—including EIA, the Environmental Protection Agency (EPA), the Department of Transportation (DOT), and the Federal Energy Regulatory Commission (FERC)—have a role in monitoring the effects of outages and ensuring the safe, efficient, and adequate supply of petroleum products during and after those outages. In this context, you asked us to study and evaluate (1) how refinery outages have affected U.S. wholesale gasoline prices since 2002 and (2) to what extent available federal data allow for the evaluation of the impacts of refinery outages on petroleum product prices and reflect emerging trends in petroleum product markets that may be important to future analytical needs.

To evaluate how refinery outages have affected U.S. wholesale gasoline prices since 2002, we purchased data that included detailed information on refinery outages from Industrial Information Resources, Inc. (IIR); data estimating the quantity flows of gasoline and other petroleum products produced at most U.S. refineries and then transported to those U.S. cities that make up the main markets for those products from Baker & O'Brien; and weekly wholesale price data for 75 U.S. cities from the Oil Price

Information Service (OPIS). We also obtained and analyzed data from EIA's monthly refinery production survey, form EIA-810, and other EIA data collection surveys. We determined that these data were sufficiently reliable for the purposes of this report. Specifically, we determined these data were sufficient to complete our analyses of the immediate average wholesale price impacts associated with refinery outages on various gasoline types, but they were neither sufficient to determine the effects experienced by individual cities nor the longer term or dynamic effects of outages on prices.[3] We developed, and extensively tested, an econometric model that examined the statistical relationship between refinery outages and gasoline prices. We analyzed commercial data for 20 gasoline types and distinguished between branded and unbranded gasoline to determine if those factors influenced the price effect of an outage. We limited our analysis to outages that were determined to be 1) at least among the largest 60 percent of outages in terms of lost production capacity within their market region and 2) that lasted at least 3 days.[4] In our model, we limited the effect of an outage on prices to one week, after which time we assumed that petroleum products were supplied from an alternate source. As a result, our analysis evaluated the short-term effects of outages but did not evaluate the length of time those effects occurred.[5] Limitations on available public data on the production and supply of petroleum products restricted our analysis to those cities for which Baker & O'Brien had collected and maintained data; these cities generally represented the United States geographically, but might not have been representative of all cities. To control for the effects on gasoline prices, our model incorporated data on numerous factors—such as gasoline inventory levels, refinery capacity utilization, and gasoline specifications. Our modeling results reflect a particular city's reliance on the refinery experiencing the outage.[6]

[3]Although these commercial data are estimates, we have a large number of observations across a large number of cities, and therefore believe our results are a reasonable estimation of the averaged effects across our study period.

[4]We analyzed about 1,100 observations of unplanned outages and about 1,200 observations of planned outages.

[5]We recognize that in many cases, the price effect may extend beyond the one-week period analyzed in our study. The amount of time the price effect, if any, can be expected to endure depends upon a number of factors, including the length of time it takes to re-supply the market from an alternative source.

[6]The results we report in the body of this report are all statistically significant at the 10 percent level or better.

To assess the extent to which available federal data allowed for the evaluation of refinery outage impacts, we reviewed federal government data collection surveys from federal agencies including EIA, EPA, and FERC, as well as private companies. We reviewed the surveys for comprehensiveness, utility, potential gaps or limitations, and to understand the extent to which the surveys collect useful data to analyze the impacts of disruptions. We reviewed past GAO reports and other federal agency or intergovernmental agency studies on petroleum product markets to identify data gaps, limitations, or inconsistencies. Furthermore, we interviewed key industry and expert institution representatives regarding data utility and limitations in their own work. Our work was not a comprehensive evaluation of all federal energy data, but rather an assessment of key data GAO used in this and past reports, and other select data that we determined during the course of our review to have posed limitations for GAO's or other agencies' evaluations of important policy questions related to petroleum markets. See appendix I for a more detailed description of our objectives, scope, and methodology.

We conducted our work from October 2008 through July 2009 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

Refineries process crude oil into petroleum products through a combination of distillation and other processes. A single barrel of crude oil produces a varying amount of gasoline, diesel, jet fuel, and other petroleum products depending on the configuration—or complexity—of the refinery and the type of crude oil being refined.

This report focuses on the production of finished gasoline.[7] Finished gasoline is primarily defined by three characteristics: blendstock, vapor pressure, and oxygenate content. Blendstock is the designation for the base gasoline produced so that other materials can be blended in to meet

[7]According to EIA, finished gasoline includes conventional gasoline, all types of oxygenated gasoline, including gasohol and reformulated gasoline, and gasoline comprised of a blendstock with an oxygenate such as ethanol, which has been blended to satisfy emissions and other federal standards.

various air quality or other local specifications. Vapor pressure, also known as Reid Vapor Pressure (RVP), measures the gasoline's evaporation characteristics or volatility. Oxygenates are fuel additives, particularly alcohols and ethers, which increase gasoline octane levels and reduce carbon monoxide pollution associated with automobile emissions. The most widely used oxygenate in the United States is ethanol, which may be added to gasoline in varying percentages. Federal regulations specify that no more than 10 percent ethanol can be blended into gasoline. Ethanol is generally blended with gasoline at the terminal or wholesale "rack"—the distribution center between refineries and retail fueling stations. For the purposes of this report, conventional gasoline does not contain special federal, state, or local blendstock, RVP, or oxygenate requirements unless otherwise noted, while "special fuel blends" refer to blends of gasoline that are designed to be cleaner burning and generally contain either a certain blendstock, RVP, or oxygenate requirement to meet federal, state, or local fuel specifications. An example of a gasoline used to meet a state fuel specification is California Air Resources Board (CARB) gasoline, which is designed to reduce harmful exhaust emissions that cause smog and is used exclusively in California.

Petroleum product markets are evolving in part as a result of the increasing use of biofuels—fuels derived from plant or animal products—throughout the country. The Energy Policy Act of 2005 generally required that at least 7.5 billion gallons of biofuels be blended into motor vehicle fuels in the United States by 2012. These targets were later amended under the Energy Independence and Security Act of 2007, which increased the volume of biofuels to be blended with gasoline from 9 billion gallons in 2008 to 36 billion gallons in 2022. EPA was charged with implementing the Renewable Fuel Standard (RFS) program and issuing regulations to ensure that the annual volumes of biofuels specified by the legislation are being blended into motor vehicle fuels. In addition, some states require the use of biofuels. For example, in Minnesota all fuel must contain 10 percent ethanol, while a number of other states offer consumers incentives—such as tax credits and rebates—for purchasing ethanol or other biofuels. The steadily increasing use of biofuels in the United States has complicated the production and distribution of gasoline. Biofuels such as ethanol are produced at dedicated biofuel production facilities—not at refineries—and currently cannot be transported by most petroleum product pipelines.[8]

[8]Ethanol corrodes pipelines and may attract water, which renders pipelines unable to transport petroleum products without investing in costly upgrades.

Therefore in order for ethanol to be blended with gasoline, it must be shipped to the terminal by truck or rail, where it is then mechanically mixed with gasoline as it is delivered into trucks for shipping to retail.

Gasoline with or without biofuels is typically sold as either branded or unbranded. Branded gasoline is that supplied from major refiners and sold at retail stations under these refiner's trademarks, and often contains special additives. Contracts for branded gasoline tend to be less flexible than contracts for unbranded gasoline but guarantee a more secure supply. Conversely, unbranded gasoline may be supplied by major or independent refiners, but is not sold under a refining company's trademark. Buyers of unbranded gasoline may or may not have a binding contractual arrangement with a refiner.

The supply infrastructure—which includes pipelines and terminals that hold supply inventories—is a critical component of the nation's petroleum product market in that it facilitates the flow of crude oil and petroleum products from one geographic region to another. Crude oil pipelines connect several large refining centers to crude oil sources, and petroleum product pipelines connect these refineries to population centers all over the country. Thus, a disruption in one geographic region can affect the supply and prices in another geographic region. To help mitigate the effects of potential supply disruptions caused by refinery outages or sudden increases in demand and to facilitate smooth supply operations, refiners, distributors, and marketers of petroleum products maintain inventories of crude oil and petroleum products. Inventories represent the most accessible and readily available source of supply in the event of a production shortfall, such as one caused by a refinery outage, or increase in demand.

In October 2008,[9] we reported that unplanned and planned refinery outages across the United States did not show discernible trends in the frequency or location of outages from 2002 through 2007, with the exception of impacts beginning in 2005 related to Hurricanes Katrina and Rita. During that study, however, we found that EIA does not collect information on refinery outages directly and thus the information it collects on its monthly refinery survey and uses to indirectly estimate outages has a number of limitations. Specifically, EIA's method of using EIA-810 data to estimate outages cannot distinguish between planned and

[9] GAO-09-87.

unplanned outages, which could have different impacts on petroleum product prices for consumers.[10] Also, as we reported, because the monthly refinery survey data are monthly aggregate data, major outages that straddle the end of one month and the beginning of the next may be difficult to identify and the observable effects of those outages could be diluted. We further reported that the exact date and length of an outage may be difficult to determine from EIA's monthly refinery survey data, making it difficult to use the data to determine whether a specific outage had a significant effect on the production capacity for some petroleum products as well as market prices.[11]

Several U.S. agencies have jurisdiction over and monitor the U.S. refining and supply infrastructure industries and petroleum product markets.

- Within the Department of Energy (DOE), the Energy Information Administration (EIA) collects and analyzes data, including supply, consumption, and prices of crude oil and petroleum products; inventory levels; refining capacity and utilization rates; and some petroleum product movements into and within the United States. Much of the data that the agency collects is obtained by surveys under EIA's Petroleum Supply Reporting System (PSRS). The PSRS is comprised of 16 data collection surveys and includes, among others, weekly and monthly surveys of

[10]In some situations, a planned outage may last longer than expected, which EIA sources stated might cause the planned outage to, in essence, become an unplanned outage. A planned outage that extends beyond the announced or expected window is different from an unplanned outage. For example, experienced market operatives will know that such announcements are in general, the best estimates of the duration of an outage, and will take the uncertainty of timing into account. This is distinct from a situation where an apparently random unplanned event occurred, for example, caused by a sudden explosion. Therefore, it may be inappropriate to treat these as the same types of events. Further, without more information, we do not know to what degree the extended planned outage came as a surprise. Therefore, we do not consider these outages unplanned.

[11]It may be noted that in some circumstances, a production facility may have been operating below capacity prior to the start date of an unplanned outage or have a gradual comeback after the outage end date. EIA officials suggested a more ideal way to define the length and extent of an outage is to use EIA-810 data on monthly capacity utilization and production combined with the IIR data, which identifies when a refining unit goes completely down. However, the fact that the EIA-810 data do not identify which day or even week the outage or the gradual slow-down of a refining unit begins, makes this approach incompatible with the structure of the model we used.

refiners, terminals, and pipelines.[12] The purpose of the PSRS is to collect and disseminate basic and detailed data to meet EIA's responsibilities and energy data users' needs for credible, reliable, and timely information on U.S. petroleum product supply. EIA generally updates its PSRS surveys every 3 years and has issued such updates in 2003, 2006, and 2009. EIA also conducts analyses in support of DOE's mission and in response to Congressional inquiries. For example, EIA recently conducted its semiannual forecast of planned refinery outage effects. EIA evaluates a wide range of trends and issues that could have implications for U.S. petroleum product trends and markets, and each year issues a publication known as the Annual Energy Outlook.

- The Environmental Protection Agency (EPA), among other things, develops and enforces regulations that implement environmental laws that aim to control the discharge of pollutants into the environment by refiners and other industries. The EPA, with the concurrence of DOE, can grant waivers on fuel requirements that allow petroleum product markets to be more easily re-supplied should an "extreme and unusual" situation—such as a problem with distribution of supply to a particular region, a natural disaster, or refinery equipment failure—occur.[13] In addition, EPA oversees the Reformulated Gasoline (RFG) program. This program was developed in response to a requirement in the Clean Air Act that cities with the most severe smog pollution use reformulated gasoline—gasoline blended to burn cleaner and reduce smog-forming and toxic pollutants in the air—to reduce emissions.[14] EPA is also responsible for implementing and issuing regulations to ensure that gasoline sold in the United States contains a minimum volume of biofuels, such as ethanol or biodiesel, and its reports,

[12]EIA-800 "Weekly Refinery and Fractionator Report"; EIA-801 "Weekly Bulk Terminal Report"; EIA-802 "Weekly Product Pipeline Report"; EIA-803 "Weekly Crude Oil Stocks Report"; EIA-804 "Weekly Imports Report"; EIA-805 "Weekly Terminal Blenders Report"; EIA-810 "Monthly Refinery Report"; EIA-811 "Monthly Bulk Terminal Report"; EIA-812 "Monthly Product Pipeline Report"; EIA-813 "Monthly Crude Oil Report"; EIA-814 "Monthly Imports Report"; EIA-815 "Monthly Terminal Blenders Report"; EIA-816 "Monthly Natural Gas Liquids Report"; EIA-817 "Monthly Tanker and Barge Movement Report; EIA-819 "Monthly Oxygenate Report"; EIA-820 "Annual Refinery Report."

[13]EPA officials told us that the ability of EPA to grant waivers for certain fuel requirements may be limited because some fuel specifications may damage vehicle emissions control equipment. For example, gasoline vehicle catalysts can be compromised by using gasoline with too high a sulfur content.

[14]The Clean Air Act allows other states and counties to opt-in to the Reformulated Gasoline (RFG) program as part of their State Implementation Plans for air quality. Once states opt-in to the program, they are required to use reformulated gasoline unless they receive a waiver from EPA.

according to EPA officials, are geared toward collecting data on fuel quality which is enforced at the refinery. Under EPA's Renewable Fuel Standard (RFS) program, refiners, importers, and blenders are required to use a minimum volume of biofuels each year, determined as a percentage of the total volume of fuel the company produces, blends, or imports. Entities that are unwilling or unable to meet this percentage standard may purchase biofuel credits from other obligated parties in order to satisfy the requirement. EPA monitors RFS program compliance and has the authority to waive the standard if it determines that specified biofuel volumes would cause severe harm to the economy or the environment in a particular region, state, or the country or that there is an inadequate domestic supply.

- The Department of Transportation's (DOT) Pipeline and Hazardous Materials Safety Administration focuses on pipeline safety and establishes standards for transmission and distribution systems for crude oil and petroleum product pipeline. Among other things, it oversees pipelines' design, maintenance, and operating procedures to maintain the safe, efficient, and reliable delivery of petroleum products.
- The Federal Energy Regulatory Commission (FERC) monitors energy markets and regulates rates and practices of oil pipeline companies engaged in interstate transportation of natural gas, oil and electricity. It establishes and enforces the rates, known as "tariffs," for transporting petroleum and petroleum products by pipeline.

While Refinery Outages Can Have Large Price Effects on Rare Occasions, in Most Instances and on Average, Price Effects of Outages Are Relatively Small

While it can be expected that some refinery outages have quite large price effects, the results of our analysis found that on average refinery outages were associated with small increases in gasoline prices. Based on our analysis of wholesale prices across 75 U.S. cities from 2002 through September 2008, planned outages generally did not influence prices, while unplanned refinery outages had generally small wholesale gasoline price effects in the cities they serve. Price increases varied depending on whether the gasoline was branded or unbranded and according to the gasoline type affected by the outage.

Extreme Outage Events Can Lead to Large Temporary Price Increases

On rare occasions, refinery outages can have large temporary effects on gasoline prices. For example, as we recently testified, petroleum product prices increased dramatically following Hurricanes Katrina and Rita.[15] This occurred in part because many refineries are located in the Gulf Coast region and power outages shut down pipelines that refineries depend on for crude oil supplies and to transport refined petroleum products, including gasoline to wholesale markets. DOE reported that 21 refineries in affected states were either shut down or operating at reduced capacity in the aftermath of the hurricanes. In total, nearly 30 percent of the refining capacity in the United States was shut down, disrupting supplies of gasoline and other products. Two pipelines that send petroleum products from the Gulf Coast to the East Coast and the Midwest were also shut down as a result of Hurricane Katrina. For example, Colonial Pipeline, which transports petroleum products to the Southeast and much of the East Coast, was not fully operational for a week after Hurricane Katrina due to large-scale power outages and flooding. Consequently, according to the Federal Trade Commission, average gasoline prices for the nation increased 45 cents-per-gallon between August 29 and September 5, 2005; short-term gasoline shortages occurred in some places; and the media reported gasoline prices greater than $5 per gallon in Georgia. The hurricane came on the heels of a period of high crude oil prices and a tight balance worldwide between petroleum demand and supply, and illustrated the volatility of gasoline prices given the vulnerability of the gasoline infrastructure to natural or other disruptions.

While extreme outages can cause large temporary price increases, such events were relatively uncommon during the period of our analysis. For example, for unbranded prices, of the approximately 1100 unplanned outages we evaluated, 99 percent of the time they were associated with wholesale price increases of no more than about 32 cents-per-gallon, and 75 percent of the time they were associated with price increases of less than 6 cents-per-gallon in the cities affected.

[15]GAO, *Strategic Petroleum Reserve: Issues Regarding the Inclusion of Refined Petroleum Products as Part of the Strategic Petroleum Reserve*, GAO-09-695T (Washington, D.C.: May 12, 2009).

On Average, Price Effects Associated with Outages Are Relatively Small, and Depend on Key Factors

Overall, our analysis indicated that planned outages—where refineries temporarily shut down to perform routine maintenance or equipment upgrades—generally did not have a significant effect on wholesale gasoline prices. As we reported in October 2008,[16] planned outages are typically scheduled during periods of less demand and interspersed among refiners and refineries. In addition, the equipment and labor are generally booked months—or even years—in advance, and can be arranged with those customers with whom the refiners have long-term contracts at a cost less than would be required in an emergency or unplanned situation. Industry representatives told us that because a refinery must draw on a limited number of equipment makers and skilled laborers, the refinery's plans for maintenance eventually become public knowledge. In this case, the market "expects" the outage to occur, therefore planned outages do not generally trigger significant price responses, unless something unexpected occurs or the market is disrupted elsewhere. Furthermore, refineries stockpile petroleum products in preparation for planned outages and therefore do not experience the same shortage of production materials experienced during unplanned outages.

Unplanned outages, on the other hand, were associated with gasoline price increases but these increases were generally small and depended on key factors, including whether or not the gasoline was branded or unbranded and the type of gasoline being sold. With respect to the distinction between branded and unbranded gasoline, our analysis showed that in the event of an unplanned refinery outage, unbranded gasoline was generally associated with greater wholesale price increases than branded gasoline. Specifically, we found that for conventional gasoline—the most common and widely available gasoline blend—unbranded gasoline had an average 0.5-cents-per-gallon increase in price associated with unplanned refinery outages, while branded gasoline had a smaller—about 0.2-cents-per-gallon—increase. The price effects observed in these cases reflect an average increase in prices at the wholesale terminals in the 75 cities over the study period. These results suggest that—as some traders and other market participants have told us—during disruptions, refiners generally choose to give priority in supplying those customers with whom they have long-term supply contracts, which typically are for branded gasoline. Therefore, in such conditions independent marketers—which typically sell unbranded gasoline—may be forced to pay higher prices to obtain product to sell. On the other hand, industry experts told us that unbranded sellers

[16]GAO-09-87.

may be able to buy wholesale gasoline at lower prices than branded sellers during normal market conditions.[17]

With regard to the type of gasoline fuel blend being sold, our analysis shows that the price increases associated with an unplanned refinery outage were significantly greater for 8 of the 19 “non-base-case” gasoline types we identified than our “base case” conventional clear gasoline, while the price increases for other gasoline types were generally about the same as those of conventional gasoline. In our analysis, we selected conventional gasoline as our base case and used our model to determine whether there were significant differences between this base case and other fuel types with respect to the relationship between unplanned refinery outages and price changes. We looked at 19 other non-base case fuel types that were in use in the 75 cities we reviewed. We compared the results of these 19 other fuel types to our conventional gasoline base case and measured the price differences. The price increases associated with unplanned refinery outages for various branded and unbranded gasoline types that were higher than our conventional gasoline base case are shown in table 1.

Table 1: Special Fuel Blends that Experienced Price Increases Greater than Conventional Gasoline Due to Unplanned Refinery Outages[a]

Gasoline type	Cents-per-gallon increases for unbranded gasoline types	Cents-per-gallon increases for branded gasoline types	Locations that require this gasoline type	Time period sold
Conventional[b] base case	0.5	0.2	Numerous cities, counties, and states	Throughout the time period
California Air Resources Board (CARB) gasoline with 2% Methyl Tertiary Butyl Ether (MTBE) as oxygenate[c]	3.2		California	Beginning of study period (January 2002) to November 2003
CARB with no oxygenate	10.1		None, although found in California[c]	Beginning of study period to May 2006
Conventional with 5.7% ethanol as oxygenate	4.1	1.3	Pima County, (Tucson) AZ	Winters, from beginning of study period to present

[17]In the absence of such arrangements and under normal market conditions, unbranded wholesale prices tend to be lower than branded wholesale prices, in part because unbranded distributors are able to shop around for the lowest wholesale price.

Gasoline type	Cents-per-gallon increases for unbranded gasoline types	Cents-per-gallon increases for branded gasoline types	Locations that require this gasoline type	Time period sold
CARB with 5.7% ethanol as oxygenate		1.4	California	Beginning of study period to present
Conventional with 10% ethanol as oxygenate, 7.0 RVP	8.0		Clay, Jackson, and Platte counties, MO	Summers, from June 2004 to present
Conventional with 10% ethanol as oxygenate, 9.0 RVP		1.5	Iowa, Minnesota, many parts of Oregon	Sold year round in Iowa, and in the summer in all other locations; used since the beginning of study period to present
Low sulfur	3.9		Georgia	April 2003 to present
Reformulated gasoline (RFG)	1.3	0.9	Numerous cities, counties, states	Beginning of study period to present

Source: GAO analysis of data from various sources, as described in appendixes I and II.

Note: All reported figures are statistically significant at the 10 percent level or less.

[a]Price increases for special blends include the base case increases of 0.5 and .02 for unbranded and branded fuel types respectively. We calculated price effects using our model estimates of the impact of outages on wholesale gasoline prices.

[b]Conventional gasoline used as the base case is gasoline that does not have a special RVP or oxygenate content specified to meet local air quality needs or preferences.

[c]Although Methyl Tertiary Butyl Ether (MTBE) was not specifically required to be the oxygenate used in California, an oxygenate was required under federal RFG provisions. The use of MTBE was banned in California on December 31, 2003. Following the phase out of MTBE and the transition to ethanol, according to California Energy Commission (CEC), California refiners and gasoline marketers began using ethanol at a minimum concentration of 5.7 percent by volume. Although nearly 20 percent of the gasoline sold could have been non-oxygenated, according to the CEC, due to segregation limitations in the distribution infrastructure system and concerns about maintaining fungible gasoline production for purposes of exchange agreements and periodic unplanned refinery outages, the gasoline market gravitated towards a near-unanimous mix of ethanol at roughly 6 percent volume by January 2004.

The results suggest that some special fuel blends that include such characteristics as unusual oxygenate requirements, lower RVP requirements, or unusual oxygenate/RVP combinations may be more sensitive to unplanned outages than other special fuel blends. For example, for unbranded gasoline, the prices of some special fuel blends—such as CARB, conventional gasoline with oxygenate formulations such as 5.7 percent ethanol, or uncommon oxygenate/RVP formulations such as conventional gasoline with 10 percent ethanol and a 7.0 RVP—were more sensitive to unplanned refinery outages than conventional gasoline without such specifications. Specifically, the largest price differences between our conventional gasoline base case and special gasoline blends, were for CARB without oxygenate and conventional gasoline blended with 10 percent ethanol and a 7.0 RVP. In these instances, prices were about 10-

cents and 8-cents-per-gallon higher than our base case. The results show that the prices of unusual oxygenate/RVP combinations that are not commonly produced at most refineries may be more sensitive to unplanned outages than conventional gasoline, which can be more readily re-supplied to a city experiencing an outage.

Our analysis also shows that a number of other special fuel blends did not experience significant price increases associated with unplanned refinery outages above that of conventional gasoline, although the fuel types affected depended partly on whether the gasoline was branded or unbranded. These fuel types and the locations that require them are shown in table 2.

Table 2: Special Fuel Blends that Experienced Price Increases About the Same as Conventional Clear Gasoline in the Event of Unplanned Refinery Outages

Fuel type	Locations that require this gasoline type	Time period sold
Conventional base case	Numerous cities, counties, and states	Throughout the time period
Cleaner burning gasoline (CBG)	Maricopa County (Phoenix), Arizona	March 2005 to present
CBG with 10% ethanol as oxygenate	Maricopa County (Phoenix), Arizona—winters	February 2005 to present
Conventional RVP 7.0	Jefferson and Shelby counties, Alabama; Johnson and Wyandotte Counties, Kansas; Livingston, Macomb, Monroe, Oakland, St. Clair, Washtenaw, Wayne, and Lenawee counties Michigan; El Paso, Texas	Summers only, from the beginning of study period to present
Conventional RVP 7.8	Numerous cities, counties, and states	Beginning of study period to present
Conventional RVP 9.0	Numerous cities, counties, and states	Beginning of study period to present
Conventional 7.7% ethanol as oxygenate	Although not required in any location, this gasoline occurs frequently in Iowa and Minnesota; and the cities of El Paso, Texas; Missoula, Montana; Fargo, North Dakota; and Sparks/Reno, Nevada	Beginning of study period to present
Conventional 7.7% ethanol as oxygenate, RVP 9.0	Although not required in any location, this gasoline occurs frequently in numerous cities, counties, and states	Beginning of study period to present
Conventional 10% ethanol as oxygenate	Numerous cities, counties, and states	Beginning of study period-present
Conventional 10% ethanol as oxygenate, RVP 7.8	Denver and Boulder, Colorado; Clackamas, Marion, Multnomah, Polk, and Washington counties, Oregon	Summers, beginning May 2004 in CO; May 2005 in OR counties
Low Sulfur RVP 7.0	Atlanta and 45 other counties in Georgia	Summer, since April 2003
Reformulated Gasoline with Methyl Tertiary Butyl Ether (MTBE) as oxygenate	Numerous cities, counties, and states	Beginning of study period to May 2006

Source: GAO analysis of data from various sources, as described in appendixes I and II.

Finally, it should be noted that individual outages may have different effects on prices depending on a variety of factors beyond those discussed above. As discussed previously in this report, and in work by EIA and the California Energy Commission, under certain conditions—such as low inventories, high seasonal demand, certain special fuel requirements, and geographic conditions that may hinder easy re-supply to the market—an unplanned refinery outage could be expected to result in a price surge in some cases. However, in some cases, unobserved factors can mitigate the effects of outages, or even cause prices to fall, making it appear as if the outage caused prices to fall. For example, a large shipment of a particular special fuel blend located just offshore or beyond the Canadian border could be a significant source of re-supply in the event of a disruption. In addition, while our analysis examined the effect of about 1,100 unplanned outages and 1,000 planned outages, our model did not differentiate between the types of refinery equipment that went out of service, which could have varying effects on wholesale gasoline prices. For example, an unplanned outage of a fluid catalytic cracker—a type of processing equipment used to maximize the production of gasoline—could be expected to have a more significant effect on wholesale gasoline prices than an unplanned outage on a piece of equipment—such as a certain type of hydrotreater—that is designed to maximize production of distillates such as diesel fuel or heating oil. Because our model does not distinguish between the type of unit experiencing an outage, our results show average impacts across different types of refining units, which means we tend to underestimate the effect of an outage at a unit such as a fluid catalytic cracker, and overestimate that of a non-gasoline producing unit.[18]

[18]We believe the under- and over-estimation of results to be small because the bulk of the outages we evaluated were related to refining units that primarily would have an impact on gasoline production. One could use a case study approach and examine the dynamics of price effects experienced based on the type of equipment experiencing the outage—and such a case study may even look at multiple products. However, this was not possible given the model we chose, which was developed based on the data available and our intent to cover the geographic United States and determine the immediate and average effects of outages. EIA's analysis of the impacts of outages on production, depending on the type of equipment experiencing the outage, was published in its March 2007 report *Refinery Outages: Description and Potential Impact on Petroleum Product Prices*. We believe that building a body of work and analyses will contribute to our collective knowledge of the effects of outages on gasoline prices.

Gaps in Federal Data Constrain Analyses of Outage Effects and Other Related Issues

Existing federal data contain gaps that limit analyses of refinery outages on petroleum product prices and in some cases do not reflect emerging trends—although agencies continue to take steps to improve their data collection. These data gaps created challenges to our, and another federal agency's, analyses and ability to respond to Congressional inquiries. Specifically, we were limited in this report in our ability to fully evaluate 1) the price effects of unplanned outages at individual cities and 2) a city's gasoline re-supply options in the event of an outage.

Our ability to fully evaluate the price effects of unplanned outages at individual cities—for example, price effects in Atlanta, Georgia associated with outages related to Hurricanes Ike and Gustav—was limited because federal data do not link refiners to the cities they serve. Although federal data exist regarding most refinery activities, the refiner-to-market link contains key gaps.[19]

- While EPA's annual reformulated gasoline area report requires each refinery to identify the cities the refinery believes it supplies with reformulated gasoline, this reporting is limited to reformulated gasoline. As such, the reports do not capture the estimated refiner-to-city link for a majority of gasoline types—including conventional gasoline and special fuel blends—sold in the United States. Further, the reports are not intended to identify the quantities of gasoline distributed.
- EIA's monthly refinery survey, the EIA-810, collects data regarding the volume of certain petroleum products being produced at refineries, including gasoline and unfinished gasoline blending components, but does not distinguish among all types of gasoline, such as premium versus

[19]The refinery-to-market link would be useful in understanding relationships between refineries and the markets they serve, including which refineries produce special fuel blends designed to meet federal, state, or local requirements. Refiners have an interest in producing products that meet a market need, and therefore can be expected to know which markets they intend to serve. In addition, jobbers and retailers have an interest in knowing where their supply typically originates, so they may monitor market developments and price their gasoline accordingly. However, the refinery-to-market link may be necessarily imprecise, and in some cases the linkage cannot be tracked because the pipeline distribution system is designed to enhance fungibility of product shipped. For example, the Colonial pipeline system ships product in batches that are not segregated by shipper—a single batch of gasoline may be comprised of the intermingled production of several refineries. While it may not be possible to track the "molecules" of production that enter and exit the system, the market participants in the system have a strong incentive to know the flows that affect their operations.

regular or summer versus winter RVP, or identify which cities refineries serve.

Our ability to identify a city's gasoline re-supply options in the event of an outage was also limited because of gaps in federal pipeline flow data.[20] Although we identified flow data collected at three agencies, the data were of limited use because they did not show the volumetric entry, flow, and exit of specific petroleum products through the pipeline. These specific data are important to understanding which refiners can and cannot supply various cities in the event of an outage and thus can be used to help determine potential price impacts.

- FERC's quarterly reports by pipeline operators specify the number of barrels of petroleum products pipeline companies transport, but these data do not identify the entry and exit points of petroleum products along the pipeline infrastructure system, or the specific type of fuels transported.
- EIA's monthly pipeline survey collects data on pipeline shipments between Petroleum Administration for Defense Districts (PADD)—a geographic aggregation of the 50 states and the District of Columbia split into five districts—as well as pipeline inventories by PADD. However, data at the PADD level do not correspond to particular cities and therefore the data cannot be used to identify the states and/or cities in which petroleum product flows originate and terminate.
- DOT's annual report on hazardous liquids collects pipeline flow data, but DOT officials told us, and we also found, that these data are highly aggregated and the annual collection of information is too infrequent to be informative in many cases. Further, these data are not designed to show the discrete movement of petroleum products through the pipeline infrastructure.

To help address these gaps in federal data, we purchased commercial data for our analysis from the energy consulting company Baker & O'Brien (see

[20]In addition to our current work, we reported in December 2007 that it was difficult to assess the extent of supply infrastructure constraints, or the impacts of these constraints on product prices, as there is no central source of data which tracks the entry, flow, and exit of petroleum products or the capacity at which pipelines operate or the location of system bottlenecks. See GAO, *Energy Markets: Increasing Globalization of Petroleum Products Markets, Tightening Refining Demand and Supply Balance, and Other Trends Have Implications for U.S. Energy Supply, Prices and Price Volatility,* GAO-08-14 (Washington, D.C.: Dec. 20, 2007).

app. I). These data estimate the quantity flows of gasoline and other petroleum products produced at most U.S. refineries and transported to those U.S. cities that make up the main markets for these products. While we found the Baker & O'Brien data to be sufficiently reliable for the purposes of our analysis, these data are estimates only. Although we determined the commercial data that we purchased to perform our analyses were sufficient to describe the wholesale price impacts associated with refinery outages on various gasoline types, the data were not sufficient to accurately estimate the effects experienced by individual cities. Further, the comprehensiveness of the data we purchased was limited in part because private companies do not have the same ability as the federal government to require refiners to provide comprehensive and accurate information.[21]

Similar gaps in federal data also limited a recent effort by another federal agency to fully address Congressional concerns regarding potential pipeline constraints and agency concerns regarding refinery outages.

- In a January 2009 Congressionally mandated study to identify potential pipeline infrastructure constraints, DOT was unable to fully address the study's objectives due to the lack of appropriate federal pipeline flow and petroleum product storage data.[22] In its report, DOT noted that "a need exists to develop more robust metrics for such (pipeline flow) measurements." The report also stated that "reliable data on storage facilities is sparse" and emphasized the need for additional data on oil and petroleum product storage terminals, including the location, size, and volumetric capacity of existing facilities to assess whether stored petroleum products are sufficient to mitigate supply disruptions.[23] In

[21]Federal agencies, as required under the Pub. L. No. 106-554 § 515 (2000), known as the Information Quality Act and related guidelines, are generally required to meet high standards in collecting data from industry and disseminating information to the public, including having sufficient internal controls in place to assure its accuracy and reliability.

[22]"America's Energy Pipeline Network: Assessing Current Strengths and Identifying Future Challenges" was issued in January of 2009. The study was conducted in response to Section 8 of the Pipeline Inspection, Protection, Enforcement and Safety Act, Pub. L. No. 109-468 (2006). The study was to identify where shortages of pipeline capacity, pipeline reliability concerns, or unplanned losses of pipeline facilities might contribute to price disruptions or petroleum product shortages, as well as to determine whether the current level of pipeline regulation is sufficient to minimize future capacity constraints.

[23]A DOT official noted that pipeline size is not the only limiting factor for pipeline utilization capacity. Specifically, using drag-reducing agents or adding pumps to a pipeline may increase its product flow capacity thereby eliminating potential constraints. Moreover, storage and other inventory data are generally under EIA's purview.

addition, the study noted that additional data regarding the changing location and arrangement of petroleum product pipelines would be necessary to evaluate volumes of petroleum products transported. DOT concluded that an analysis sufficient to address Congress's directives in the 2006 law would require further quantitative and analytical modeling. In particular, DOT officials told us the federal interagency effort to collect data would need to result in more comprehensive data—including volumetric pipeline entry, flow, and exit information[24]—as well as more reliable storage terminal and inventory data in order to more fully assess the current and future reliability of the nation's pipeline infrastructure and ability to respond to market disruptions.

The absence of key data also limits the ability of federal agencies to monitor the effect of emerging trends such as the use of biofuels—for example, ethanol—in petroleum product markets. Specifically, we found that gaps in federal data do not allow agencies to track where gasoline blended with ethanol ultimately winds up in the fuel stream. Not having this information may be at odds with consumer's interests. Since, according to EPA, a gallon of ethanol contains two-thirds the energy of a gallon of gasoline, when gasoline blended with ethanol is sold in areas with no ethanol or oxygenate requirement, consumers may be purchasing fuel that provides fewer miles-per-gallon without being aware of it.[25] Our analysis of gasoline sales data shows that from 2002 through 2008, conventional gasoline blended with ethanol had been sold in areas with no ethanol or other oxygenate mandates in at least 32 states.[26] Agency and

[24]In interviews with us, pipeline and other industry officials noted that reporting product flow data on a monthly basis—which would include volumetric entry and exit information—might not be overly burdensome as equipment is already in place to track such flows and bill shippers. However, product flow information is considered highly sensitive for competitive reasons and would need to be treated as confidential by agencies.

[25]Our analysis of state fuel and biofuel requirements, as reported by OPIS, shows that one state, Illinois, specifies conventional gasoline and has a so-called "label law" at gasoline stations' pumps to advise consumers the gasoline being sold may contain ethanol. Other states that specify various types of reformulated gasoline may also have label laws advising the possible inclusion of ethanol—a common component of reformulated gasoline—in the retail station's gasoline, but our analysis identified areas in which conventional, not reformulated, gasoline with ethanol content was being sold.

[26]The 32 states are: Alabama, Alaska, Arkansas, Colorado, Florida, Georgia, Idaho, Illinois, Indiana, Kansas, Kentucky, Maine, Maryland, Michigan, Mississippi, Nebraska, New Mexico, New York, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, Utah, Vermont, Virginia, Wisconsin, West Virginia, and Wyoming.

industry officials told us that as the volume of biofuels to be blended with gasoline continues to grow to 36 billion gallons in 2022, ethanol will increasingly be distributed in locations that do not have requirements for oxygenate content.

Despite these gaps in federal data, individual agencies have generally continued to take steps to update their data collection surveys to meet their respective agency objectives or needs, and have often coordinated to more efficiently obtain petroleum product data needed for a variety of purposes at multiple agencies.

- In 2009, EIA began collecting data regarding the production, stocks at production facilities, sales for resale, and end-use sales of biodiesel fuel.[27] Also, three existing EIA forms were expanded to collect biodiesel imports and biodiesel blending and stocks at terminals and refineries. Our work indicates this new survey will help analysts identify how and where biodiesel is being used, a key emerging trend in the petroleum industry. In addition, these data will be used by EPA to help monitor the volumes of biofuel use specified in the RFS.

- Effective January 2009, EIA consolidated reporting of inventory information at refineries, pipelines and terminals from two surveys to one. This action will permit a more detailed and reliable analysis of petroleum product terminal operations and provide a baseline for the volume of petroleum products at various terminal locations that can potentially re-supply a city in the event of a major disruption. While this partially addresses our need to have federal data that shows the re-supply options in the event of a disruption, it neither shows the refiner-to-market link nor does it provide detailed batch information on petroleum product flows that would facilitate future analyses. Comprehensive inventory information may be particularly useful to DOT should it be tasked with completing another study to identify potential petroleum product infrastructure constraints.

- EPA officials told us they have worked with the Department of Agriculture and DOE in recent years regarding the recently issued 2007 Renewable Fuels Standard program guidance. The aim of such guidance is to monitor

[27]This survey, Form EIA-22M, collects company and plant information, operating status, annual production capacity, stock changes at production facilities, feedstock and other inputs, resale sales of biodiesel, and end-use sales of biodiesel data from registered U.S. producers of biodiesel.

biofuel use—a key emerging market trend—and monitor compliance with biofuels specified in the RFS.

Nonetheless, in some cases the individual agency efforts have resulted in the collection of information that does not necessarily meet the data needs of other agencies or analysts who monitor petroleum product markets. For example, federal reporting efforts have evolved such that EIA maintains primary responsibility for collecting information on total gasoline supply, including gasoline blendstocks, while EPA maintains primary responsibility for capturing another key characteristic—RVP—of certain gasoline blendstocks. Specifically, EIA's surveys are structured to collect data on total gasoline supply, including blendstocks, on a monthly basis, whereas EPA collects RVP information on each batch of reformulated gasoline on a quarterly basis, and for all conventional gasoline supplied by a particular refiner on an annual basis. This means that companies report key information regarding gasoline components to two different federal entities, and analysts who need information regarding the blendstock and RVP of gasoline must go to two federal entities to obtain what is available; in addition, the data are not comparable in terms of periodicity. Finally, as described earlier, three different agencies collect a limited amount of pipeline flow data to meet their specific agency's objectives, but collectively these data do not allow analysts to fully monitor the flow of petroleum product markets. This limited not only our ability to identify a city's gasoline re-supply options in the event of an outage in this analysis, but also DOT's efforts to fully address a Congressional mandate. In sum, these separate pieces of data do not come together to form a complete picture of current petroleum product markets.

Conclusions

To the extent reasonable, the collection of petroleum product data by federal agencies should allow these and other agencies and analysts to form a clear picture of U.S. petroleum product markets while minimizing the government's costs of collecting and maintaining, as well as the costs to industry of providing, these data. In our work we identified gaps in public data, some of which we could address by purchasing privately collected data, and some of which led to limitations to what our analysis could address. Specifically, we were unable, with publicly available data, to identify which refiners serve various cities across the country, and by extension, which refineries produce special fuel blends designed to meet federal, state, and local requirements. While the available public data, along with the commercial data we purchased, allowed us to analyze the broad impacts of refinery outages on various gasoline types on average;

during the initial week of the outage, the data were not sufficient to determine the effects at individual cities. We also found an absence of some data on emerging market trends in biofuels that is troubling, given the rapid expansion of biofuel production and use in recent years. Some data gaps we identified may exist because data collection efforts generally reflect individual agency needs and, thus, may not necessarily consider the broader needs of other federal agencies and analysts. We recognize that agencies have a primary responsibility to perform their individual missions and that these agencies face their own specific budgetary constraints. However, we note the importance of each agency acknowledging that the collection of individual pieces of federal data contributes to a larger data universe and taking reasonable steps to ensure that the totality of these data allow for meaningful understanding and oversight of petroleum markets. In addition, agencies must be conscious of efficiency by considering the costs associated with gathering and maintaining data.

Improving the usefulness and completeness of publicly held data—as well as reducing the associated costs—will require that each agency be aware of the part of the overall data picture it is responsible for, as well as the usefulness of these data beyond the immediate agency mission. Continued and improved coordination between such agencies, including EIA, EPA, DOT, and FERC, could improve the collective understanding and oversight of the refining industry and petroleum product markets.

Recommendations for Executive Action

To evaluate existing, publicly held petroleum products market data and to determine if they are sufficient to meet the current and expected future missions and needs of the Congress, federal agencies, and other public and private stakeholders, we recommend that the Administrator of the EIA convene a panel comprised of agency officials from EIA, EPA, DOT, FERC, and other relevant agencies, industry representatives, public stakeholders, and other analysts and data users, to collect these data and develop a coordinated interagency data collection strategy. The panel should:

- assess the costs and benefits of collecting
    - more systematic information about which refiners serve which cities and

- more discrete reporting of the volumetric entry, flow, and exit of petroleum products through the pipeline infrastructure system;

- identify additional data that would be useful to track and evaluate emerging market trends—such as the proliferation of biofuels and special blends—and assess the costs and benefits of collecting such data;

- identify opportunities to coordinate federal data collection efforts so that agencies can respond fully to Congressional requests and meet governmentwide data needs to monitor the impact of petroleum product market disruptions; and

- identify areas where data collection is fragmented—such as multiple survey instruments collecting similar information—to determine if those efforts can be consolidated and modified to enhance the overall usefulness and improve the efficiency of collecting and reporting these data.

Agency Comments and Our Evaluation

We provided a draft of this report to the Department of Energy (DOE) and its Energy Information Administration (EIA), the Environmental Protection Agency (EPA), and the Department of Transportation (DOT) for review and comment. DOE's EIA agreed with our recommendations and provided additional comments regarding the recommendations and the report's discussion of data gaps, which are summarized below. EIA also provided technical and clarifying comments, which we incorporated as appropriate into the report. EPA and DOT provided only technical comments, which we also incorporated as appropriate.

Regarding our recommendations, EIA stated that it supports the recommendations, including our specific suggestions to review data adequacy, strengthen interagency coordination of data collection and use, and fully engage government, industry and public stakeholders. EIA stated that it believes it has a strong program to address all of these suggested actions, and is working closely with other federal entities through established joint programs, as well as informally to coordinate data collection. For example, the agency noted it has been working with an interagency group comprised of 40 federal agencies to facilitate the development of a trade processing system for U.S. Customs and Border Patrol.

In commenting on the report's discussion of data gaps, EIA stated it agrees that a review of possible data gaps is necessary and noted that it is currently—as of July 2009—reviewing the adequacy and quality of currently collected and commercially available refinery outage information. The agency believes, and we agree, that the adequacy of refinery outage data for analysis is one that EIA has taken seriously. To this end, EIA noted it published Federal Register notices on December 9, 2008, and February 28, 2009, informing the public of the agency's intended review of refinery outage data. EIA plans to complete its review and provide its recommendation regarding additional government data collection this fall in its mandated semiannual refinery outage study. EIA stated it then plans to publish its analysts' assessment and recommendations to solicit the broadest possible comment. At that time EIA will consider the use of a panel of government, industry, and public stakeholders—as we suggested—to determine its future steps. We support EIA's efforts to address data issues and believe that its current plans are a step in the right direction toward ensuring that the best data are available to help achieve its mission of producing independent and unbiased research to help the Congress, public, and international community better understand energy markets and promote sound policy-making.

We are sending copies of this report to interested Congressional committees; the Administrator of the Energy Information Administration, the Administrator of the Environmental Protection Agency; the Secretary of the Department of Transportation; and other interested parties. This report also will be available at no charge on the GAO Web site at http://www.gao.gov.

If you or your staffs have any questions concerning this report, please contact me at (202) 512-3841 or ruscof@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Major contributors to this report are acknowledged in appendix III.

Frank Rusco
Director, Natural Resources and Environment

List of Requesters

The Honorable Charles E. Schumer
Vice Chairman
Joint Economic Committee
United States Senate

The Honorable Christopher J. Dodd
United States Senate

The Honorable Byron L. Dorgan
United States Senate

The Honorable Joseph I. Lieberman
United States Senate

The Honorable Joseph Courtney
House of Representatives

The Honorable Rosa DeLauro
House of Representatives

The Honorable John B. Larson
House of Representatives

The Honorable Christopher S. Murphy
House of Representatives

Appendix I: Scope and Methodology

We addressed the following questions during our review: (1) How have refinery outages affected U.S. wholesale gasoline prices since 2002? (2) To what extent do available federal data allow for the evaluation of the impacts of refinery outages on petroleum product prices, and do these data reflect emerging trends in petroleum product markets that may be important to future analytical needs? For the purposes of this report, we define the various types of outages as follows:

- Planned outages are periodic shutdowns of one or more refinery processing units or possibly the entire refinery to perform maintenance, inspection, and repair of equipment or to replace process materials and equipment that have worn out or broken, in order to ensure safe and efficient operations.
- Unplanned outages are events where an entire unit or refinery must be brought down immediately and without advance notice and are caused by unplanned circumstances such as a fire or a power outage.

To determine trends in refinery outages over the time period from 2002 through September 2008, we purchased data from Industrial Information Resources, Inc. (IIR) that contained detailed information on refinery outages, including the estimated dates of the outages, whether the outages were planned or unplanned, and the amount of reduced production capacity due to each outage. We evaluated the data and found they provide reliable estimates of outages from 2002 onward. In our analysis, we counted an outage event as the halting of production capacity on any piece of equipment at the refinery; where multiple units such as a crude distillation and one or more secondary processing units were simultaneously down, we counted this as a single outage event in our model.[1]

To evaluate how refinery outages have affected U.S. wholesale gasoline prices we obtained and analyzed data from Energy Information Administration (EIA)'s monthly refinery production survey form, EIA-810, from 2002 through 2006, and other EIA surveys. We also purchased (1) data that included detailed information on refinery outages between 2002 and 2008 from Industrial Information Resources, Inc. (IIR), a private company that provides research and forecasts for various large industries;

[1]Therefore, in our analysis, there can only be one outage event during one time period at a given refinery.

(2) data estimating the quantity flows of gasoline and other petroleum products produced at most U.S. refineries' and transported to those U.S. cities that make up the main markets for these products from Baker & O'Brien, an energy consultancy company whose software is licensed to 9 of the 10 top U.S. refining companies; and (3) weekly wholesale price data for 75 U.S. cities gasoline markets from Oil Price Information Service, a private company that provides pricing and other data at the wholesale or "rack" level. We determined that these data were sufficiently reliable for the purposes of this report. We used the Baker & O'Brien quantity flow estimates to measure the proportion of each city's product that is generally supplied by a particular refinery. We developed, and extensively tested, an econometric model that examined the statistical relationship between refinery outages and gasoline prices. We limited our analysis to outages that (1) were determined to be of the largest 60 percent within their market region and that lasted at least 3 days, (2) had a corresponding market city in the Baker & O'Brien data, and (3) for which we had useful and complete gasoline price data at the wholesale terminal level. In our model, we limited the effect of an outage on prices to one week, after which time we assumed that petroleum products were supplied from an alternate source. As a result, our analysis evaluated the short-term effects of outages but did not evaluate the length of time those effects occurred. In our model, we incorporated data on numerous factors that could affect gasoline prices—such as gasoline inventory levels and gasoline specifications—in order to rule out, or "control" for their effects on prices. Because we were able to control for these other factors, we believe we were able to isolate the impacts of outages on prices given the inherent issues with the various datasets. There were some factors that potentially affected gasoline prices over time and city-specific information that we could not include, although we were able to use econometric techniques to control for some of these factors.[2] After controlling for the additional factors that affected gasoline prices, we were able to estimate the average impact of outages on wholesale gasoline prices. The statistical significance of our findings are noted throughout the report. Although we focused our study on wholesale prices, we cannot be certain that the price effects at the retail level would be the same, although some research has shown that wholesale price changes are generally passed on to the retail level.[3] In

[2]Refer to appendix II GAO's Quantitative Methodology for Determining Impacts of Refinery Outages on Wholesale Prices, for more information on the econometric techniques used.

[3]See EIA, John Zyren and Michael Burdette, *Gasoline Price Passthrough*, (Washington D.C. January 2003) and GAO, *Motor Fuels: California Gasoline Price Behavior*, RCED-00-121 (Washington D.C.: Apr. 28, 2000).

developing our model, we consulted with a number of economists and incorporated their suggestions wherever possible. Finally, we performed an analysis to test the robustness of our model, including changing various assumptions regarding the model in order to ensure that our results were not highly dependent on any single specification of the model.

To assess the extent to which available federal data allow for the evaluation of the impacts of refinery outages and determine whether the data reflect emerging trends in petroleum product markets, we reviewed data collection instruments from federal agencies—including EIA, the Environmental Protection Agency (EPA), the Federal Energy Regulatory Commission (FERC), and the Department of Transportation (DOT)—and reviewed them for comprehensiveness, utility, accessibility, and potential gaps or limitations. In addition, we reviewed past GAO and other federal agency or intergovernmental agency studies on refined product markets to identify data gaps, limitations, or inconsistencies. Finally, we interviewed key industry, expert institution, and academic representatives regarding data limitations and utility in their own work and what other data concerns or needs they might have for future analyses. Our work was not a comprehensive evaluation of all federal energy data, but rather, an assessment of key data GAO used in this and past reports, and select other data that were determined during the course of our review to have posed limitations for GAO's or other agencies' evaluations of important policy questions.

We conducted this performance audit from October 2008 through July 2009 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: GAO's Quantitative Methodology for Determining Impacts of Refinery Outages on Wholesale Prices

Introduction

We developed an econometric model to explain the impact of refinery outages on gasoline prices. Our model controlled for as many contributing factors as possible, however, there were not always sufficient data available to control for all possible factors affecting wholesale gasoline prices. Our model examined how wholesale gasoline city rack prices were affected in the week during which a large unplanned refinery outage occurred.

Econometric Model Specification and Methodology

We examined weekly average data on wholesale city rack gasoline prices. We used data from 75 wholesale city racks from January 2002 through September 2008. We believe that the increased information from higher frequency data—for example, by using daily data—would be outweighed by the extra noise generated by such relatively high frequency data. Further, using lower frequency data, such as monthly data, runs the risk of obscuring some of the less extended but important effects of unplanned outages on gasoline prices. Another limitation of our analysis is that, in some cases, our data series for the control variables, described below, are generally available only on a monthly basis,[1] in which case these values are assigned to the corresponding weekly observations. We consulted with government and academic experts to help develop our econometric model.

The Dependent Variable–Wholesale Gasoline Price

Our variable of interest was the price of gasoline, specifically the wholesale rack price of gasoline.

- Our dependent variable was the logarithm of the wholesale city rack price of gasoline. Note that we include a time dummy variable for every time period so we do not have to deflate the wholesale price by a price index such as the producer price index or the price of crude.[2] We used an Augmented-Dickey-Fuller test designed for panel data to test for

[1]State-level personal income data were quarterly.

[2]We do not need to include a price of crude deflator in order to model the ratio of the price of gasoline to the price of crude—"the crack ratio." Both the price of crude oil and the producer price index do not vary across cities, only over time, and would therefore be perfectly collinear with the time dummy variables. Therefore, given that we include these time dummies, deflating our dependent variable by the price of crude oil, would have no effect on our results. While our model controls for these time-varying-only effects, it does not estimate the contribution of any of these variables to explaining city gasoline prices.

stationarity in levels of our dependent variables, in the case of both unbranded and branded prices.[3] Our tests showed that our unbranded and branded dependent variable was stationary in levels.[4]

- We examined separate models for unbranded and branded products to test for the consistency of our results.
- There may be multiple gasoline prices reported for a given city rack on a given date. In general, we used the wholesale rack price of gasoline that is required in that specific city because we were interested in determining whether areas with non-standard gasoline specifications[5] experienced larger gasoline price increases when a refinery that supplied their particular specification had an outage.
- By including a complete set of time dummy variables–one for each week's observation in the data–our model controlled for factors that vary only over time (and are invariant across cities), such as the national average price level, the price of crude oil, and seasonal effects.

Explanatory Variables—Measuring the Impact of an Outage on Gasoline Prices

Our primary interest was to examine the impact of refinery outages on gasoline prices. There are two key issues:

1. *Identifying an outage.* We acquired data on outage occurrences from IIR. These data provide information about the outage, including whether the outage was planned or unplanned, the date of the outage, the duration of the outage, and the capacity of the unit that was offline due to the outage.

[3]See Im, Kyong So, M. Hashem Pesaran, and Yongcheol Shin. "Testing for Unit Roots in Heterogeneous Panels," *Journal of Econometrics*, vol. 115, 53-74 (2003).

[4]In general, the outcome of stationarity tests on gasoline prices and crude oil prices varies according to the periodicity of the data, the sample period of estimation, and the model specification. While some authors have found evidence of stationarity in levels of these prices, others have found this not to be the case. Our data are not a single time series of the national rate but a panel. Therefore it is not unreasonable that our results are consistent with the results of some researchers but at variance with others.

[5]We take the standard type of gasoline as conventional clear, which contains no oxygenate additives and does not have a special RVP.

2. *Measuring the impact of a given outage on a particular city.* For each city, we estimated the proportion of its product that it generally received from each refinery; a city may be served by one or more refineries.

Our measure of an outage's impact was the proportion of a city's product that was generally supplied by the refinery (or refineries) experiencing an outage. If a city was generally estimated to receive no product from the refinery experiencing the outage, then the effect was zero, the explanatory variable was zero, and the refinery outage had no impact on that city's gasoline price. Alternatively, if, for example, a city received 20 percent of its product from said refinery, the explanatory variable had a value of 0.20 for that time period. It is also possible that a single city may have been impacted by more than one refinery outage at the same time, so in that case we would sum these effects. For instance, if in addition to the 20 percent impact example above, there was an outage at a refinery supplying 10 percent of the city's product, the explanatory variable would take a combined value of 0.30.[6]

Other Explanatory Variables

In addition to the impact of outages, our model includes other important variables that may influence the price of gasoline.

- *Volume of inventory of gasoline relative to the volume of sales of gasoline.* This could affect the availability of gasoline at the wholesale level and hence affect prices. Prices should decrease when inventories are high relative to sales and should rise when inventories are low relative to sales. However, inventories and sales may themselves respond to changes in wholesale gasoline prices, so this variable may be endogenous.
- *Capacity utilization rate.* This could affect the wholesale price of gasoline through changes in the availability of gasoline product. One possibility is that, when utilization rates are high, there would be more gasoline available, which would tend to lower prices; conversely if utilization rates are low, less gasoline would be available, which would

[6]We recognize that the production of the affected refinery may not be zero in some situations, namely, when a refinery supplying 20 percent of a city's product may reduce supply to only 10 percent in the event of an outage. Ideally, we would have preferred accurate estimates of production lost due to the outage. This might have been possible using EIA data, but likely only for major outages. Regardless, this was not feasible for the approximately 1,100 unplanned outages used in our analysis.

tend to raise prices. However, it is possible that as utilization rates approach very high levels, there are significant increases in cost of production, which could then result in higher prices. Further, capacity utilization may react to changes in gasoline prices, so it is possible that this variable is endogenous.

- *Market concentration.* Markets with fewer sellers of product or that are more highly concentrated, may be associated with higher gasoline prices. However, the direction of effect may run the other way too, such that markets with higher prices may attract entrants, which may reduce the level of market concentration. We treat market concentration as an endogenous variable.

- *Lagged dependent variable.* Our model includes lagged values of the left hand side variable; namely, the logarithm of the wholesale price of gasoline. Gasoline price data may be serially correlated and it is reasonable to include the effect of past gasoline prices on current gasoline prices.

- *Time fixed effects.* We included a dummy variable for each time period in the analysis.

- *City fixed effects.* We included a dummy variable for each city in the analysis. These city fixed effects may assist in controlling for unobserved heterogeneity.

- *Product specification.* We included a dummy variable for each of the different types of gasoline used in our model.

- *Interaction between the product specification dummy variables and the outage impact variable.* We included a set of interaction terms to test whether cities that with special fuel requirements experience higher price increases due to outages.

Econometric Model Specification

Our fixed effects model can be written as follows:

$$y_{it} = (x_{it}, w_{it})B + c_i + f_t + u_{it}, \quad i = 1, 2, ..., N; t = 1, 2, ..., T \quad (1),$$

where:

y_{it} is the logarithm of wholesale rack gasoline price at city i in week t.

x_{it} is a vector of predetermined variables for city i in week t that are assumed to be independent of our error term, u_{it}, including a lagged value of our dependent variable.

w_{it} is a vector of possibly endogenous variables at city i in week t.

c_i is the fixed effect or dummy variable for city i.

f_t is the fixed effect of dummy variable for week t.

B is a vector of parameters to be estimated.

Our key outage effect variable measures the percent of a city's product supply affected by an outage; that is:

$$s_{ir't} = Outage_{ir't} * Q_{ir't} / \sum_{r=1}^{r=R} Q_{irt}, \qquad (2),$$

where $Outage_{ir't}$ is equal to 1 when an outage occurs at time t in the r'-th refinery that serves the i-th city, and the remaining term is the proportion of product provided by that refinery to that city. When there is no outage, $Outage_{ir't}$ is equal to zero. Thus, this variable measures a city's reduction in product due to an outage (or outages). In the extreme case, there may be a single refinery that supplies 100 percent of a city's product, in which case the impact on product of an outage at that refinery on that city would be large, with a concomitant effect on that city's gasoline prices.

The outage impact may also have varied according to the type of fuel. The variable, s_{irt} measures the percentage of supply of product that was interrupted; it may not account completely for the difficulty in finding a replacement for that product. If a city used a fuel that is commonly produced, such as conventional clear gasoline, it would likely be more straightforward to find an alternative source of supply. However, if the city uses a special fuel, it may be more difficult to find an alternative refinery to supply that product. Therefore, in addition to a set of dummy variables for each fuel specification, we included a set of interaction terms of our outage supply affect variable with each of the fuel specification dummy variables.

- We used xtiverg2 in STATA.[7] The xtivreg2 estimation procedure allowed us to estimate standard errors that are robust to heteroskedasticity and autocorrelation.

- We estimated the model using the logarithm of price as the dependent variable. Note that because we have time dummies, we do not need to control for crude oil prices or price inflation because these variables are invariant across cities for a given time period and so are collinear with the time dummies. Our specification necessarily subsumes the impact those variables that only vary over time and not vary across cities.

- We used a C-statistic test to ascertain whether the inventory-sales ratio and the capacity utilization rate should be treated as endogenous or exogenous.[8] In the case of both the unbranded gasoline prices and the branded gasoline price models, our test could not reject the null hypothesis that these variables were exogenous.

- Measures of market concentration, such as the Hirschman Herfindahl Index (HHI), have been shown to be endogenous,[9] so we tested for whether it was exogenous and use two-stage least squares when appropriate, using merger events as instruments. We used a C-statistic to test for the exogeneity of the spot market HHI. In the case of the unbranded gasoline price model, the test rejected the null hypothesis of exogeneity. In the case of the branded price model, the test could not reject the null hypothesis of exogeneity. We estimated both models treating the spot market HHI as endogenous, which we recognize might be a less efficient estimator but is nevertheless a consistent estimator.

- We used Hansen's J-statistic to test for over-identification of our instruments; namely, that they should be correlated with the regressors, but uncorrelated with the regression errors.[10] In every case, the J-statistic accepted the null hypothesis that our instruments were valid.

---

[7]The xtiverg2 procedure in STATA implements Instrumental Variable/General Method of Moments estimation of the fixed-effects and first-differences panel data models with possibly endogenous regressor.

[8]See Fumio Hayashi. "Econometrics," *Princeton University Press*, 220-221 (2000). This test can be used to test for the endogeneity of a subset of the regressors.

[9]See, for example, W. N. Evan *et al.* "Endogeneity in the Concentration-Price relationship: Causes, Consequences, and Cures." *The Journal of Industrial Economics*, vol. XLI, no. 4, December 1993.

[10]For a detailed derivation of this test statistics, see Fumio Hayashi "Econometric" *Princeton University Press*, 217-218 (2000).

- We estimated separate models for unplanned and planned outages. While unplanned outages can be reasonably viewed as exogenous—random—events, planned outages need to be scheduled more than a year in advance and may be scheduled to coincide with time periods of typically lower seasonal demand. Therefore, we believe it was appropriate to model these two types of outages separately.

- We estimated separate models for unbranded prices and branded prices.

- We estimated the model (1) except that we dropped those observations where waivers were in effect.

Table 3: Data Used In Our Econometric Model

Data Sources		
Variable	**Description**	**Source**
Prices	Wholesale gasoline price in cents-per-gallon. Branded and unbranded. Weekly averages.	OPIS
Spot market HHI	Market concentration, measured by refinery capacity of corporations in each spot market. Monthly data.	EIA, GAO analysis
Merger dummy variables	Dummy variable equal to 1 from the effective date of the merger. Equal to 0 before the effective date of the merger. Similarly for announced dates of each of the mergers.	OPIS, IHS Herold
Inventory-sales ratio	Ratio of total motor gasoline inventories to finished gasoline product supplied. Monthly data at the PADD level.	EIA
Capacity utilization rate	Capacity utilization rate. Monthly data at the PADD level	EIA
Fuel type dummy variables	Set of dummy variables for the gasoline fuel type. Details the main fuel type, presence of additives and RVP. Weekly data.	OPIS
Employment growth	Percentage growth in employment at the state level. Monthly data	Department of Labor
Unemployment rate	Percentage unemployment rate at the state level. Monthly data.	Department of Labor
Real personal income growth	Percentage growth in personal income at the state level deflated by the consumer price index. Quarterly data.	BEA
Consumer price index	Consumer price index. Monthly data.	Department of Labor
Percent of general product supply affected by the outage	Proportion of the usual amount of supply affected by an outage or outages. Quarterly data.	IIR for outage events. Baker & O'Brien for determining the amount of product generally supplied by each refinery to each city.

Source: Baker & O'Brien, BEA, EIA, IHS Herold, IIR, Department of Labor, OPIS and GAO analysis.

Table 4: Regression Results for Effect of Unplanned Outages on Unbranded Gasoline Prices—Dependent Variable is the Logarithm of Unbranded Gasoline Price

		Coefficient	Standard error
	Spot market HHI	0.26751	0.08108[a]
	Inventory-to-sales ratio	-0.00177	0.00168
	Utilization as a % of operating capacity	-0.00033	0.00006[a]
	Log of unbranded gasoline price lagged 1 period	0.85919	0.00573[a]
	% supply reliance (% reliance on refinery experiencing outage)	0.00014	0.00004[a]
Fuel types			
	CBG	0.00632	0.00391
	CBG with 10% ethanol	0.00956	0.00277[a]
	CARB with 5.7% ethanol	0.00871	0.00322[a]
	CARB with 2% MTBE	0.00681	0.00342[b]
	Conventional RVP 7.0	0.01048	0.00195[a]
	Conventional RVP 7.8	0.00314	0.00106[a]
	Conventional RVP 9.0	0.00343	0.00094[a]
	Conventional 5.7% ethanol	0.00903	0.00410[b]
	Conventional 7.7% ethanol	0.00465	0.00189[b]
	Conventional 7.7% ethanol RVP 9.0	0.01727	0.00205[a]
	Conventional 10% ethanol	0.00532	0.00116[a]
	Conventional 10% ethanol RVP 7.0	0.00894	0.00263[a]
	Conventional 10% ethanol RVP 7.8	0.00818	0.00176[a]
	Conventional 10% ethanol RVP 9.0	0.00680	0.00154[a]
	Low sulfur	0.00374	0.00191[b]
	Low sulfur RVP 7.0	0.00822	0.00239[a]
	RFG 10% ethanol	0.01572	0.00416[a]
	RFG MTBE	0.01433	0.00400[a]
Fuel types interacted with % supply reliance			
	CBG interaction with % supply reliance	0.00007	0.00025
	CBG with 10% ethanol interaction with % supply reliance	-0.00010	0.00007
	CARB with 5.7% ethanol interaction with % supply reliance	0.00009	0.00013
	CARB with 2% MTBE interaction with % supply reliance	0.00123	0.00049[b]
	CARB without oxygenate interaction with % supply reliance	0.00430	0.00033[a]
	Conventional RVP 7.0 interaction with % supply reliance	-0.00026	0.00017
	Conventional RVP 7.8 interaction with % supply reliance	0.00000	0.00007

	Coefficient	Standard error
Conventional RVP 9.0 interaction with % supply reliance	0.00001	0.00006
Conventional 5.7% ethanol interaction with % supply reliance	0.00135	0.00033[a]
Conventional 7.7% ethanol interaction with % supply reliance	0.00009	0.00013
Conventional 7.7% ethanol RVP 9.0 interaction with % supply reliance	-0.00033	0.00006[a]
Conventional 10% ethanol interaction with % supply reliance	-0.00001	0.00013
Conventional 10% ethanol RVP 7.0 interaction with % supply reliance	0.00108	0.00041[a]
Conventional 10% ethanol RVP 7.8 interaction with % supply reliance	-0.00009	0.00012
Conventional 10% ethanol RVP 9.0 interaction with % supply reliance	0.00004	0.00011
Low sulfur interaction with % supply reliance	0.00084	0.00046[c]
Low sulfur RVP 7.0 interaction with % supply reliance	0.00012	0.00024
RFG 10% ethanol interaction with % supply reliance	0.00015	0.00007[b]
RFG MTBE interaction with % supply reliance	-0.00003	0.00012
R-squared	0.996	
J-test for over-identification (signif. level)	18.8%	
Observations	26325	
Number of cities	75	

Source: GAO analysis of various data sources.

Notes: The standard error estimates are robust to heteroskedasticity and autocorrelation. The regression model included fixed effects for cities and time dummies for each week of data. The model is estimated using two-stage least squares, treating the spot market HHI as endogenous. The fuel dummy variable for CARB without any MTBE or ethanol was not estimated due to collinearities.

See table 3 for a list of data sources used in this table.

[a]significant at the 1 percent level

[b]significant at the 5 percent level

[c]significant at the 10 percent level

Table 5: Regression Results for Effect of Unplanned Outages on Branded Gasoline Prices—Dependent Variable is the Logarithm of Branded Gasoline Price

	Coefficient	Standard error
Spot market HHI	0.17803	0.05804[a]
Inventory-to-sales ratio	-0.00057	0.00452
Utilization as a % of operating capacity	-0.00020	0.00004[a]
Log of branded gasoline price lagged 1 period	0.90106	0.00452[a]
% supply reliance (% reliance on refinery experiencing outage)	0.00006	0.00002[a]

		Coefficient	Standard error
Fuel types			
	CBG	0.00784	0.00784
	CBG with 10% ethanol	0.00429	0.00460
	CARB with 5.7% ethanol	-0.00681	0.00224[a]
	CARB with 2% MTBE	0.00556	0.00137[a]
	Conventional RVP 7.8	0.00142	0.00073[b]
	Conventional RVP 9.0	0.00256	0.00066[a]
	Conventional 5.7% ethanol	0.01362	0.00333[a]
	Conventional 7.7% ethanol	0.00219	0.00139
	Conventional 7.7% ethanol RVP 9.0	0.00945	0.00260[a]
	Conventional 10% ethanol	0.00349	0.00071[a]
	Conventional 10% ethanol RVP 7.0	0.00798	0.00208[a]
	Conventional 10% ethanol RVP 7.8	0.00350	0.00094[a]
	Conventional 10% ethanol RVP 9.0	0.00602	0.00094[a]
	Low sulfur	0.00389	0.00181[b]
	Low sulfur RVP 7.0	0.00582	0.00199[a]
	Low sulfur RVP 9.0	0.00083	0.00724
	RFG 10% ethanol	0.02147	0.00916[b]
	RFG MTBE	0.02142	0.00910[b]
Fuel types interacted with % supply reliance			
	CBG interaction with % supply reliance	-0.00024	0.00014[c]
	CBG with 10% ethanol interaction with % supply reliance	-0.00044	0.00016[a]
	CARB with 5.7% ethanol interaction with % supply reliance	0.00022	0.00013[a]
	CARB with 2% MTBE interaction with % supply reliance	-0.00007	0.00037
	Conventional RVP 7.0 interaction with % supply reliance	-0.00008	0.00010
	Conventional RVP 7.8 interaction with % supply reliance	-0.00010	0.00004[a]
	Conventional RVP 9.0 interaction with % supply reliance	-0.00004	0.00005
	Conventional 5.7% ethanol interaction with % supply reliance	0.00143	0.00506
	Conventional 7.7% ethanol interaction with % supply reliance	-0.00002	0.00021
	Conventional 7.7% ethanol RVP 9.0 interaction with % supply reliance	-0.00004	0.00028
	Conventional 10% ethanol interaction with % supply reliance	0.00006	0.00010
	Conventional 10% ethanol RVP 7.0 interaction with % supply reliance	0.00045	0.00048
	Conventional 10% ethanol RVP 7.8 interaction with % supply reliance	-0.00001	0.00005

	Coefficient	Standard error
Conventional 10% ethanol RVP 9.0 interaction with % supply reliance	0.00014	0.00007[a]
Low sulfur interaction with % supply reliance	0.00040	0.00031
Low sulfur RVP 7.0 interaction with % supply reliance	0.00004	0.00009
RFG 10% ethanol interaction with % supply reliance	0.00015	0.00005[a]
RFG MTBE interaction with % supply reliance	-0.00013	0.00005[a]
R-squared	0.997	
J-test for over-identification (signif. level)	19.2%	
Observations	26325	
Number of cities	75	

Source: GAO analysis of various data sources.

Notes: The standard error estimates are robust to heteroskedasticity and autocorrelation. The regression model included fixed effects for cities and time dummies for each week of data. The model is estimated using two-stage least squares, treating the spot market HHI as endogenous. The fuel dummy variable for CARB with MTBE, and the interaction variable between the fuel dummy for low-sulfur with 9.0 RVP and outage variable was not estimated, due to collinearities.

See table 3 for a list of data sources used in this table.

[a]significant at the 1 percent level

[b]significant at the 5 percent level

[c]significant at the 10 percent level

- We found unplanned outages were significantly associated with an increase in unbranded gasoline prices. We found this impact is generally positive with respect to the price of all fuels. We further found this impact is significantly greater than the comparative or base effect (measured relative to the effect on conventional clear) for several special fuels.

- In addition, we found unplanned outages were significantly associated with an increase in branded gasoline prices but the effect was smaller than for unbranded prices. This impact is generally positive with respect to the price of all fuels. There is also evidence that the impact is greater for some special fuels although in fewer cases compared to the unbranded price results.

- Our results using planned outages to explain prices found no general statistically significant impact on gasoline product prices, either branded or unbranded.

- We found no substantive difference in our results for outage effects when we estimated the model (1) without those observations where waivers were in effect.

Limitations of Our Econometric Model and Data

Cities included in model. Our selection of cities was based on data availability from the Baker & O'Brien data. There are in excess of 350 city wholesale racks in the U.S. however:

- The Baker & O'Brien data contain data on only 89 cities, and only 75 of those had complete series data that we could use for our model.
- The Baker & O'Brien cities comprise the most important city racks.
- Treating each of the 350 city racks as independent rack markets may not be appropriate. Rather, we can obtain a national picture by selecting the most important cities as per the list of cities in the Baker & O'Brien data.

Time period of analysis. We selected January 2002 through September 2008 because we deemed the IIR data to provide reliable information from 2002 onward.

Gasoline type. The gasoline data from OPIS were selected so as to generally reflect the type of gasoline that would be sold in a city, given its local fuel regulations. In most cases, we were able to assign prices accordingly but in some cases other types of fuel were used in the data. However, in the regression model, we control for whatever fuel type we did use.

Outages data. We believe the outages data from IIR are fairly comprehensive but there are no federal requirements for refineries to report outages or an effort by the federal government to collect these data on a national basis. Consequently, some outages may not appear in the data, though it is unlikely that any major outages were missed during our study period. Further, we limited inclusion of outages to those that were at least 3 days in duration and ranked in the top 60 percent in terms of recorded capacity offline for a refinery's market region (as defined by IIR). Thus, we do not include every single outage but we have a broad geographic range of the largest outages in the US.

Linkage data between refineries and cities they serve. The Baker & O'Brien data has the following limitations:

- They are quarterly estimates of product flows and costs. These data are intended to be reasonably reflective of actual product dispersion across the United States. However, in the course of our analysis we had to interpolate some missing data and to extrapolate our data beyond the end-points of the available data.

- The Baker & O'Brien data did not always contain complete data for the particular fuel that regulations required be used in that city. In some cases, seasonal variations in fuel requirements, such as RVP or oxygenate blending specifications, meant a precise match was not possible. However, in general, we were able to match the Baker & O'Brien fuel with these regulations.

Frequency of data. Except for our weekly wholesale gasoline price data, our other data were either monthly or quarterly, so we had to parse out the lower frequency observations accordingly.

Geographic level of analysis. Our analysis was performed at the city level, but some of the data we used were at a more aggregated geographic level. We used capacity utilization and inventory-sales ratio data at the PADD level. We did not have a measure of city-level sales data to determine the size of inventories relative to a local market, nor is there a relevant measure of capacity utilization at city-level, therefore, PADD-level data were used.[11],[12]

Economic indicators. Employment growth, personal income growth rate, and the unemployment rate were available at the state-level only.

Market concentration. Our measure of market concentration was an HHI measured using corporate refinery capacity at the spot market level. It is possible in some cases these measures were too highly aggregated and the control variables were less precise than would be ideal.

Number of outages. We did not take account of multiple outages at the same refinery on the same day–we simply established whether an outage

[11]State-level data were available, but we were concerned that these data were unsuitable for our purpose. In particular, state boundaries may not provide good measures of market boundaries, especially for cities located at the juncture of multiple states.

[12]Other researchers have found that inventories might have a significant impact on prices. However, in our analysis, the inventory-sales variable was not significant. This may reflect the fact that these data are measured at the PADD level, which does not adequately measure the impact of inventory-sales at the city level.

occurred in a particular week, at a particular refinery. Although the size of the outage determined whether it was included in our analysis, the impact is treated the same regardless of how large an impact on the refinery the outage had.

Effects of an outage over time. We did not attempt to include dynamic effects of outages on prices in our model. We assigned an effect of outage in the same time period (week), after which time our model implicitly assumed that the product was supplied from an alternate source.

Planned outages. We did not model planned outages in any detail. These planned events by definition, did not generally give rise to surprise reductions in product supply. Hence, vendors had the opportunity to plan ahead and make arrangements to receive alternative sources of product. However, we did estimate an analogous model to equation (1) and found no significant impact on prices.

Inventories. Inventories included those domestic and customs-cleared foreign stocks held at, or in transit to, refineries and bulk terminals, and stocks in pipelines.

Gasoline sold outside the city rack: Our analysis does not account for gasoline that is not sold at the city rack. It is possible that significant transactions occur elsewhere that may affect the general wholesale market for a particular city.

Examining wholesale prices, not retail prices. Our analysis is at the wholesale price level and the ramifications for retail prices are unclear. The effect on retail prices would depend upon the extent to which wholesale price changes are passed onto the retail sector.

Seasonal effects. Our model included of a set of time dummy variables, which account for variation in prices due to seasonal effects. A more complete model might have contained specific seasonal effects such as a set of monthly dummy variables, interacted with the outage effect, and also with each special fuel type. This would have allowed us to determine whether outages had a differential impact on prices, according to the time of year and the fuel type. However, data limitations precluded a comprehensive evaluation of such effects; specifically, this would have required us to include more than 200 additional explanatory variables (number of seasonal dummies times the number of special fuel types).

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

Frank Rusco, (202) 512-3841 or ruscof@gao.gov

Staff Acknowledgments

In addition to the individual named above, Shea Bader, Divya Bali, Benjamin Bolitzer, Dan Haas, Michael Kendix, Rob Marek, Michelle Munn, Alison O'Neill, Rebecca Sandulli, Benjamin Shouse, and Barbara Timmerman made key contributions to this report.

GAO's Mission

The Government Accountability Office, the audit, evaluation, and investigative arm of Congress, exists to support Congress in meeting its constitutional responsibilities and to help improve the performance and accountability of the federal government for the American people. GAO examines the use of public funds; evaluates federal programs and policies; and provides analyses, recommendations, and other assistance to help Congress make informed oversight, policy, and funding decisions. GAO's commitment to good government is reflected in its core values of accountability, integrity, and reliability.

Obtaining Copies of GAO Reports and Testimony

The fastest and easiest way to obtain copies of GAO documents at no cost is through GAO's Web site (www.gao.gov). Each weekday afternoon, GAO posts on its Web site newly released reports, testimony, and correspondence. To have GAO e-mail you a list of newly posted products, go to www.gao.gov and select "E-mail Updates."

Order by Phone

The price of each GAO publication reflects GAO's actual cost of production and distribution and depends on the number of pages in the publication and whether the publication is printed in color or black and white. Pricing and ordering information is posted on GAO's Web site, http://www.gao.gov/ordering.htm.

Place orders by calling (202) 512-6000, toll free (866) 801-7077, or TDD (202) 512-2537.

Orders may be paid for using American Express, Discover Card, MasterCard, Visa, check, or money order. Call for additional information.

To Report Fraud, Waste, and Abuse in Federal Programs

Contact:

Web site: www.gao.gov/fraudnet/fraudnet.htm
E-mail: fraudnet@gao.gov
Automated answering system: (800) 424-5454 or (202) 512-7470

Congressional Relations

Ralph Dawn, Managing Director, dawnr@gao.gov, (202) 512-4400
U.S. Government Accountability Office, 441 G Street NW, Room 7125
Washington, DC 20548

Public Affairs

Chuck Young, Managing Director, youngc1@gao.gov, (202) 512-4800
U.S. Government Accountability Office, 441 G Street NW, Room 7149
Washington, DC 20548