The role of content regulation on pricing and market power in regional retail and wholesale gasoline markets

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THE ROLE OF CONTENT REGULATION ON PRICING AND MARKET POWER IN REGIONAL RETAIL AND WHOLESALE GASOLINE MARKETS

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Abstract

Since 1999, regional retail and wholesale gasoline markets in the United States have experienced significant price volatility, both intertemporally and across geographic markets. This paper focuses on one potential explanation for regional variations in price levels and volatility, gasoline content regulation. Implemented regionally to address local mobile-source emissions, gasoline content regulations increase cost to refiners, transporters and distributors of gasoline, in addition to reducing the fungibility of gasoline across different regions. This paper first provides a summary of the regional gasoline content regulations and a primer on the refining industry. In addition, this paper specifies the costs regional content regulation imposes on refiners, transporters and distributors of gasoline and the role increasing heterogeneity of gasoline may play in regional price volatility. Finally, this paper surveys the previous literature looking at the effect of gasoline content regulation on prices and price volatility and suggests directions for future research.

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I. Introduction

Over the past several years, prices in US retail gasoline markets have fluctuated significantly, punctuated by regional prices spikes in the Midwest and California. The first of these regional spikes to receive significant attention occurred in Spring 2000 in Chicago and Milwaukee, where prices for reformulated gasoline rose from $1.85 and $1.74 on May 30, 2000 to $2.13 and $2.02 a gallon on June 20, 2000 before falling to $1.57 and $1.48 respectively by July 24, 2000.[2] In contrast, the national average price for reformulated gasoline over a similar period, which moved from $1.64 on May 29, 2000 to $1.73 on June 19, 2000 and to $1.66 on July 24, 2000.[3] A similar price spikes occurred in the Midwest in Spring of 2001, and have occurred periodically in California over the past several years.

These localized price spikes in US gasoline markets have created interest in understanding the factors underlying retail gasoline prices. In addition, there has also been interest in identifying whether or not a common cause for periodic regional gasoline price spikes exists. For instance, one cause of the high retail gasoline prices in Chicago and Milwaukee in Spring 2000 was a Citgo refinery fire which "made it difficult to supply major hubs like Chicago and Milwaukee with the special blends of reformulated gasoline that are required by law in those cities."[4] In fact, the Federal Trade Commission investigated the production difficulties associated with the Spring 2000 price spike, in an attempt to determine whether or not refineries able to produce reformulated gasoline were withholding capacity to manipulate retail prices.[5] In addition, a recent report by the Senate Subcommittee on Investigations investigates the potential effect of market structure and increasing concentration in many markets on price levels and volatility.[6]

A. What drives gasoline prices

As suggested by the investigations and analyses performed in response to gasoline prices spikes, many factors have the potential to contribute to the volatile nature of gasoline prices. Gasoline production costs, at a very basic level, are driven by input prices (predominately crude prices), the cost to refine that crude oil, and the cost to transport and distribute refined products to retail customers. Factors influencing any part of the production chain have the ability to influence costs of refiners, wholesale distributors and retail stations, and thus, have the ability to affect how the ultimate price of gasoline is set. Moreover, short-run gasoline demand is relatively inelastic. Although consumers are responsive to price competition

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[2] Final Report of the Federal Trade Commission on the Midwest Price Spikes, March 21, 2001, http://www.ftc.gov/os/2001/03/mwgasrpt.htm.

[3] EIA Motor Gasoline Watch; May 29, 2000; June 19, 2000; July 24, 2000. http://www.eia.doe.gov/oil_gas/petroleum/data_publications/wrgp/mogas_history.html.

[4] Barboza, D., "Gasoline Prices Jump in Midwest, Hinting of Wider Price Spike", New York Times, August 30, 2001.

[5] See Final Report of the Federal Trade Commission, Midwest Gasoline Price Investigation, March 29, 2001. http://www.ftc.gov/opa/2001/03/midwest.htm.

[6] See "Gas Prices – How Are They Really Set?", Majority Staff of the Permanent Subcommittee on Investigations, Released in Conjunction with the Permanent Subcommittee on Investigations' Hearings on April 30 and May 2, 2002. http://www.senate.gov/~gov_affairs/042902gasreport.htm.

between retail stations, overall demand for gasoline is not strongly affected by the price of gasoline.[7] As is the case with electricity consumption, this creates the potential for significant volatility in gasoline prices, either in response to fluctuations in production costs, low inventories caused by supply shocks, or market power by refiners and wholesale dealers.

Over the past twenty years, three significant trends may have contributed towards higher and more volatile gasoline prices. The first trend has been the general consolidation of the industry over the past decade. Large horizontal mergers in the petroleum industry include British Petroleum and Amoco in 1998, Exxon and Mobil in 1999 and BP/Amoco and Arco in 2000.[8] Although federal approval for the mergers required divestiture of overlapping refining assets in most cases, this important trend must be taken into account. In addition to industry consolidation, there has also been a trend toward decreasing reserve refining capacity over the past twenty years. In 1981, annual refinery production was 68% of operable refinery capacity. Since then, the utilization rate for refining capacity increased dramatically, as old refineries were closed, no new refineries were built and demand for petroleum products continued to rise.[9] Finally, the last trend has been one towards increased differentiation of gasoline products or "blends" via state and federal content regulation. Motivated by concerns about air pollution, the EPA and individual states have stipulated a variety of regulations aimed at reducing the emissions from gasoline-powered motor vehicles by specifying the gasoline content.

This paper focuses on the last of these trends, the trend toward greater regulation of gasoline content. Movement toward increasingly diverse "blends" of gasoline has important ramifications for several reasons. First, content criteria impose costs not only on refineries, but on transporters and distributors of petroleum products. In order to meet content regulations at the retail level, not only must gasoline be sufficiently refined to meet the content regulations, but it must be transported and stored without being intermixed with other "blends". Second, since some content regulations must be met though gasoline additives, gasoline supply becomes susceptible to supply shocks in additive markets. Finally, content regulation reduces the fungibility of gasoline, that is, fewer refiners produce gasoline for regions with specific regulations. This not only increases the potential for tacit collusion amongst the refiners of a specific blend, but also increases the impact of unexpected outages on the supply of particular blends. If only a small set of refineries are producing a particular blend of gasoline, an outage to any refinery in that set could lead to a large change in production capacity, if significant costs exist for refiners to switch production between blends. In addition, since content regulations reduce the substitutability of different "blends" of gasoline, it may be difficult to compensate for a drop in production capacity by reducing

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[7] Recent estimates cited in Sipes and Mendelsohn (2001) of short-run elasticities vary from -0.35 to -0.51 and of long-run elasticities vary from -0.73 to -0.87. In addition, Dahl and Sterner (1991) perform a meta-analysis across previous studies and calculated mean short-run price elasticities of -0.26 and mean long-run price elastiticities of -0.86 in studies with panel data.

[8] See "Gas Prices – How Are They Really Set?", Majority Staff of the Permanent Subcommittee on Investigations, Released in Conjunction with the Permanent Subcommittee on Investigations' Hearings on April 30 and May 2, 2002 at pg 3.

inventories. As a result, it comes as little surprise that the areas experiencing the most drastic prices changes in the past several years, namely Chicago, Milwaukee and California, also have some of the strictest regulations on gasoline content.

This paper first addresses, in Section II, the nature of refining, with an emphasis on those elements related to gasoline content regulation. Section III provides a summary of the history and implications of important federal and state regulations pertaining to gasoline content. In Section IV, the paper discusses the potential direct and indirect effects of content regulation, as mandated by federal and state governments, on the price levels and volatility of gasoline. Finally, Section V discusses the analyses performed to-date of the potential effect of content regulation on price levels, volatility and market power concerns. Section VI concludes.

II. **Refining Process**

To understand how gasoline content regulation affects the refining of crude oil, it is necessary to understand how refineries operate. At the most basic level, oil refineries process crude oil into a wide variety of petroleum products, from gasoline to industrial fuel to road tar. Crude oil is a mixture of hydrocarbons, with between 1 and 60 carbon atoms per molecule, and amounts of other compounds containing sulfur, nitrogen and other elements.[10] Generally, the number of carbon atoms in a molecule predispose a hydrocarbon to a particular application. For example, gasoline generally contains only "lighter" products, with between 4 and 12 carbon molecules, while industrial No 6 Fuel Oil is made up of "heavier" petroleum products, with more carbon atoms per molecule. The role of the refinery is threefold: (1) isolate "lighter" and "heavier" products, (2) remove impuries, such as sulfur, and (3) blend compounds together to create outputs with valuable properties.

It is important to note, though, that refiners have considerable flexibility when processing crude oil. Through choices of input crude and the method of refining, individual refiners can influence the acheivable output mix. This section first discusses how the choice of crude oil affects the output mix of a refiner and then addresses how the equipment at a refinery can affect the mix of final products.

A. **Choice of Crude Oil**

The choice of crude oil is the first way a refiner can influence output mix. For a refiner, crude oil from different locations is a heterogeneous good. Based on the chemical makeup of the crude oil, a particular refinery is limited in the blend of petroleum products it can produce. Two standard metrics for differentiating crude oil are the API gravity weight of the oil and the sulfur content.[11] The API gravity of oil is correlated to the relative proportion of shorter strings of hydrocarbons ("lighter" components) to long strings of hydrocarbons ("heavier" components). This relative proportion of light and heavy components

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[9] See Dazzo, N., Lidderdale, T., and N. Masterson, "U.S. Refining Capacity Utilization," Energy Information Administration, Petroleum Supply Monthly,

[10] An in-depth discussion of the components of crude oil and gasoline can be found at http://www.faqs.org/faqs/autos/gasoline-faq/part1/preamble.html.

dictates, at a basic level, what products a refinery can produce through simple distillation. For example, if a refinery distills heavy oil, it will produce a greater proportion of industrial products like fuel oil and coke than if a refinery distills light oil. Thus, depending on the desired mix of end products and the technology of the refinery (discussed in the next section), a refiner may choose to refine light or heavy oil based on forecasted market prices.

Not only do the characteristics of the crude oil matter to the proportions of the products produced, but the characteristics also effect the amount of processing that is required at the refinery to transform the oil into various products. Sulfur content, referred to in the market by whether crude is "sweet" (low-sulfur) or "sour" (high-sulfur), specifies how much sulfur a particular barrel of oil contains. Refining sour oil, oil with high sulfur content, may require additional processing to remove sulfur from end products to meet environmental or industry standards. An example is fuel oil sold for industrial use, which becomes more valuable as the sulfur content decreases.

B. Refinery Technology[12]

Technology at refineries also allows a refiner to influence the output mix. Most refineries have several different types of equipment that allow the refiner to separate, alter and purify the various components of crude oil. The basic operating unit at any refinery is the distillation tower. The distillation unit separates crude oil into component parts by heating the oil until the crude oil evaporates. The evaporated crude oil is piped to the distillation tower where the hot gas begins to rise through a series of filters, decreasing slowly temperature as it passes through each filter. Since "heavy" hydrocarbons condense at higher temperatures than "light" hydrocarbons, the "heavy" hydrocarbons condense after rising through only a few filters. The lighter the component, the cooler it condenses and the higher it rises in the tower. [13] By siphoning component at each of the different filters, a distillation tower roughly separates the crude oil into "light" components (removed at the top) and "heavier" components, removed towards the bottom. Depending on the technology of a particular distillation tower (whether a distillation unit is atmospheric or vacuum), a refiner is able to separate out all but the heaviest components, the residuum.

Although the weight of oil determines the petroleum products created through distillation, refineries also have equipment that can adjust and improve the mix of end products after distillation.[14] Three units are part of most large, modern refineries: (1) Catalytic Cracker, (2) Reformer and (3) Hydrotreater. The first of these, the cracking unit, adjusts the mix of outputs by "cracking" long chains of hydrocarbons into shorter ones. This changes heavier products, like fuel oil, into lighter (and more valuable) products like distillate and naphtha. Depending on the expected prices and blend of products that

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[11] Alternative metrics to API gravity degrees include specific gravity and density. See http://pump.net/thebasics/equivdegrees.htm for a table translating API gravity into alternative metrics.

[12] A primer on refining and refining technology can be found at http:/www.petrostrategies.org/LearningRefining.html

[13] Generally, components from lightest to heaviest are butanes, naphtha, kerosene, distillate, vacuum distillate and residua.

[14] www.chevron.com/about/learning_center/refinery.

can be produced from a particular kind of crude oil, a refiner can "crack" less valuable products into more valuable ones.

Unlike the cracking unit, which alters the proportions of the output mix, the reformer and hydrotreater improve the quality of petroleum products. The reformer changes the structure of naphtha molecules without changing the number of hydrocarbons. Reforming changes low-octane molecular structures into high-octane molecular structures (e.g. benzene), which can then be blended into gasoline to improve quality. Hydrotreating also improves products by removing impurities – in most cases sulfur – from a product. Since processing done by a refiner is linked to the quality of the distilled crude oil, many refineries were built with the intention of using a particular crude oil.

Thus, although the choice of crude oil drives what end products will be created, the technology at a refinery also provides the firm with flexibility to alter to a limited degree the final mix of products. For example, simply distilling a barrel of crude oil typically yields about 4/10 of a barrel of gasoline and 6/10 of a barrel of other petroleum products. Cracking and reforming, though, can typically allow a barrel of crude to be roughly transformed into 2/3 of a barrel of gasoline and 1/3 of a barrel of heating oil.[15] In addition, depending on which components of a barrel of crude oil are cracked, reformed or hydrotreated, a refinery can produce other output mixes depending on the expected prices it will receive for each of the finished components.

C. Production runs

While a refinery has considerable flexibility in manipulating and improving petroleum products, planning must occur prior to refining due to the interconnected nature of refining, cracking and reforming. In addition, the logistics for transporting and purchasing crude oil and for transporting finished products require preparation. Since it is costly to adjust inputs and output mixes on a day to day basis, refineries operate around “production runs”. Production runs are generally two to four weeks in length, during which consistent inputs and processing create a steady mix of finished products. Planning for a production run, begins two to three months in advance, with orders to purchase and transport the necessary crude oil.[16] In addition, based on preliminary price estimates, the refiner plans a production and processing schedule that yields as profitable an output mix as possible. As the production run gets closer, the refiner finalizes the inputs. Just prior to the run, engineers make any changes to output mix and production process, based on costs of inputs and updated expected prices of refined products. Soon after, production begins. At this point, any significant change to production requires the refinery to reduce production and reconfigure the system of distilling, cracking, reforming and hydrotreating. Thus, once a production run commences, a change to production becomes very costly until the completion of the run.

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[15] Refiners and marketers often refer to the 3:2:1 crack spread – three barrels of crude can be made into two barrels of gasoline and one barrel of heating oil.

[16] See Final Report of the Federal Trade Commission, Midwest Price Spike Investigation, March 29, 2001, sect. C.2. for more information about the refining process.

III. Environmental Regulation of Gasoline[17]

A. Mandate - Clean Air Act

The Environmental Protection Agency (EPA) regulates the chemical content of motor fuels through Section 211 of the Clean Air Act (CAA), passed as part of the Clean Air Act Amendment of 1990 (CAAA). These regulations define both what must be removed during the refining process and what can or must be added to the fuel, prior to its sale in the marketplace. Specifically, section 211 grants the EPA the power to "control or prohibit the manufacture, introduction into commerce, offering for sale, or sale of any fuel or fuel additive for use in a motor vehicle, motor vehicle engine or non-road engine or non-road vehicle" based on the emissions and health consequences caused by a particular fuel.[18] Section 211, thus, encompasses all regulations (1) limiting content of fuels, such as sulfur limits on diesel fuel, (2) prohibiting additives, such as restrictions on lead anti-knock agents in gasoline, and (3) mandating additives, such as the requirement to add detergents to motor gasoline.

Five regulations in Section 211 mandate specific requirements for motor gasoline: (1) limitation on lead-based antiknock agents, (2) mandated detergent additives, (3) limitations on the Reid Vapor Pressure, (4) mandated oxygen content, and (5) reformulated gasoline (RFG).[19] To understand the potential impact of each of these programs, a three-part taxonomy is helpful. The first element is the geographic scope of the program. Like many regulations, some content regulations apply nationally, while others apply only to particular regions. Regulations (1) and (2) apply nationally, while (4) and (5) apply, by law, only to specified non-attainment areas specified by the EPA. Program (3) contains both regional and national components, placing a national requirement for all gasoline, and in addition, mandating more stringent requirements for non-compliance areas. A second classification is the temporal scope of the program. Due to the influence of temperature and sunlight in the generation and formation of air emissions, certain programs apply seasonally, while others apply year-round. Specifically, (1), (2), and (5) are year-round programs, while (3) and (4) apply only seasonally. The final categorization is the method of implementation of the regulation; that is, whether the regulation necessitates a change by refiners or can be met with an additive added after the standard refining process is complete. Programs (1), (2) and (4) can be met by additives alone, while (3) and (5) require special refining. This taxonomy facilitates understanding, at least at a first pass, how the various motor gasoline regulations might effect the price levels, price volatility and market power in the refining industry.

This section discusses each of the regulations pertaining to motor gasoline in greater detail, including other important facets of the regulations such as the ability of states to place restrictions exceeding those set by the EPA.

B. National Programs

i. Prohibition on Leaded Anti-knock Agents

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[17] This section only addresses content regulation related to gasoline. In addition to these regulations, the Clear Air Act also places regulations on the volatility and sulfur content of diesel fuel.

[18] Clean Air Act, Section 211 (c)(1)

[19] Section 211 also mandates requirements for diesel fuel, such as sulfur limits.

The first, and perhaps the most well-known, national regulation of gasoline content is the prohibition on leaded anti-knock agents, imposed by the EPA starting January 1, 1986.[20] Since the 1920's, lead compounds were added to gasoline to increase the octane number and to reduce the tendency of gasoline to "knock", prematurely igniting when compressed in an engine. Citing the known health effects of lead-based anti-knock agents, the EPA, starting in 1973, began to compel refiners to use non-leaded anti-knock additives by slowly ratcheting down the lead content limits of gasoline. The process culminated in 1986, when the EPA standard placed a nation-wide limit of 0.1 gram per gallon on the amount of lead in gasoline, in contrast to the previous limit of 1.1 gram per gallon. This content regulation ended the sale of leaded gasoline in the United States.

ii. Detergents[21]

A second national program, mandated by the CAAA of 1990, is the requirement of refiners and marketers to add detergents to gasoline, beginning in January 1, 1995. Detergents limit deposit accumulation in engines and fuel systems, preventing decreases in the fuel efficiency and increases in emissions as cars age. Although the program is a national, year-round one, states have flexibility in the choice of detergent additives, so long as they meet or exceed the emissions standards defined by the EPA.

C. Regional Programs

In addition to the national regulations focused on phasing-out lead-based antiknock agents and limiting fuel system buildup in cars, the CAAA created three regional programs with the objective of limiting air emissions from gasoline-powered mobile sources. Each of these programs targets a subset of three emissions: Carbon Monoxide (CO), Nitrogen Oxides (NOx), and Volatile Organic Compounds (VOCs). Initially, the regulations (with the exception of the general Low Reid Vapor Pressure limit) applied only to areas of the country classified by the EPA as ozone or carbon monoxide non-attainment areas depending on the specific emissions targeted by a program. Two important allowances of the CAA contribute to the effect of each of these regional programs. First, states and regions not required to participate in regional programs can opt-in to a program and adopt the EPA requirements. This contributes to the geographic scope of some regional programs significantly.[22] Second, the CAA only mandates a minimum standard to which gasoline in non-attainment areas must conform. The CAA allows for cities and states to impose stricter or more complicated standards than this identified minimum.

i. Low Reid Vapor Pressure[23]

The first of these regional programs, focusing on reducing ground-level ozone pollution, is a limit on the Reid vapor pressure of gasoline. Reid vapor pressure measures the propensity of gasoline to evaporate, and increases with the amount of "light" petroleum chains (eg. benzene or butane) in gasoline. In order to lower the RVP of gasoline, it is necessary for refiners to filter out the lightest components,

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[20] "EPA Sets New Limits on Lead in Gasoline", EPA press release, March 4, 1986. http://www.epa.gov/history/topics/lead/01.htm

[21] Clear Air Act, Section 211(l)

[22] For example, populations of opt-in areas constitute over 1/3 of the total population of all areas mandating reformulated gasoline.

which have the lowest boiling point and evaporate most easily. Limitations on the reid vapor pressure of gasoline reduce the amount of "fueling" pollution, evaporation that occurs as a gas tank is filled. This causes a large subsequent reduction in VOCs and a smaller reduction in NOx, which both are precursors to ground-level ozone pollution.

Several important aspects of this regulation need special emphasis. The first important facet of this program is the geographic scope. Phase I, effective Summer 1989, mandated a regional limits varying from 10.5 psi to 9.0 psi based on the region of the country. Phase II, effective Summer 1992, places a national cap on the RVP of gasoline of 9.0 psi. Since the severity of ozone pollution differs greatly across areas, though, the RVP requirements for Phase II are more strict in ozone non-attainment areas. For non-attainment areas, Phase II requirement varies from 7.8 psi to 7.0 psi throughout the ozone season. In addition, in some locations it varies from month to month during the ozone season, depending on the severity of the ground-level ozone pollution. In addition, many areas have further tightened RVP requirements beyond those specified by the EPA. For example, Pheonix, Arizona has a state-placed limit of 7.0 psi and in addition, runs through September 30 each year, instead of the required September 15.[24]

Second, since ground-level ozone formation is positively affected by both temperature and sunlight, ozone formation is only a problem during the summer. Thus, the RVP program is a seasonal program, in contrast to the previous two national year-round programs. In most cases, the "ozone season" begins May 1 and ends September 15. It is only over this period that the refiners are required to limit the amount of benzene within gasoline.

The final note to make about Low RVP regulation is that reformulated gasoline also places a limit on the benzene content of gasoline (although not the RVP specifically). RFG regulations, thus, currently supersede Low RVP regulations in many metropolitan areas of the country. Thus, RVP regulations currently only apply to areas which do not participate in the reformulated gasoline program.[25]

ii. Oxygenation[26]

The second regional program, effective November 1992, is a regional to increase the oxygen content of gasoline sold to consumers. Whereas reducing RVP lowers evaporative emissions and hence VOC and NOx emissions, oxygenating gasoline enables an engine to burn gasoline more completely, reducing Carbon Monoxide (CO) emissions. Once again, the method of implementation, the temporal scope and geographic scope provide a starting point from which to understand the potential effects of this regulation.

With regard to method of implementation, unlike Low RVP requirements that can only be satified through additional refining, oxygenation can be achieved through additives. While the baseline EPA requirement calls for 2.7% oxygenation by weight, this requirement can be met by blending in one of

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[23] Clear Air Act, Section 211(h)

[24] US Environmental Protection Agency, Guide on Federal and State RVP Standards for Conventional Gasoline Only, EPA420-B-01-003, March 2001. http://www.epa.gov/otaq/fuels.htm#rvp.

[25] See US Environmental Protection Agency, Office of Mobile Sources, "Guidance on Use of Opt-in to RFG and Low RVP Requirements in Ozone SIPs," April 1, 1999.

several additives that increase oxygen content. The two most common, commercially viable oxygenates are methyl tertiary butyl ether (MTBE) and ethanol. In order to achieve the 2.7% baseline set by the CAA, refiners or distributors must either blend 15% MTBE, derived from natural gas, or 8% Ethanol, derived from renewable feedstocks such as corn stover or cellulose, into gasoline.

Like Low RVP regulation, baseline EPA requirements to oxygenate fuels have a seasonal component. Carbon Monoxide emissions from mobile sources are greatest during the winter, as cold cars (especially when starting) emit greater amounts of CO. In addition, ethanol increases the RVP of gasoline, and hence is detrimental to efforts focused on reducing summer ground-level ozone pollution. While CAA does not specify outright a seasonal schedule for oxygenation, simply mandating a minimum duration of 4 months per year, the EPA in all cases mandates winter oxygenation. Generally, refiners and distributors must oxygenate gasoline from November through February.[27]

The geographic scope of the regulation has two important facets: the areas required to participate and state-based regulations which drive how oxygenation requirements must be met. First, unlike Low RVP requirements, there is no national requirement for oxygenation – only regions with significant CO pollution must oxygenate gasoline. The CAA initially required oxygenated fuel for 39 areas in CO non-attainment for 1988 and 1989, as specified by the National Air Ambient Quality Standards (NAAQS). These initial 39 Non-attainment areas covered CMSAs containing 87.5 million people. As regions come into attainment, oxygenated gasoline is not longer required. Coming into CO attainment has resulted in a significant number of areas (totaling approximately 46.4 of the original 87.5 million people) "opting out" of oxygenated programs. In addition, any region that subsequently fails to attain the NAAQS standard for CO, must begin oxygenation during winter months specified by the EPA. Moreover, several areas in attainment, such as Portland, OR and Tuscon, AZ, voluntarily opted in through state-mandated programs, adding to the geographic scope.

The second geographic aspect to the oxygenation requirement is that while the EPA mandates a baseline on 2.7% oxygen by weight and specifies a seasonal duration of the program for each area, the areas themselves determine which oxygenate will be used and are able to impose more stringent requirements than those mandated by the EPA. In the case of oxygenation, additional regulation is much more pervasive than in other programs. While some areas have imposed more stringent oxygenation requirements (e.g. WA, NV, AZ all require 3.5% oxygen consistent with blending 10% ethanol with gasoline) and more stringent temporal requirements (MN requires year-round oxygenation), the greatest amount of differentiation between state programs is generated by requirements over the choice of

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[26] Clean Air Act, Section 211(m)

[27] For a comprehensive list of temporal requirements facing particular areas, see Lidderdale, Tancred; Areas Participating in the Oxygenated Gasoline Program; Energy Information Administration, July 1999, Short-Term Energy Outlook Special Report. http://www.eia.doe.gov/emeu/steo/pub/special/oxy2.html.

oxygenate. Due to the need for a renewable feedstock (generally corn stover) to produce ethanol, ethanol is used as an oxygenate in the Midwest while MTBE is used primarily in the Northeast and California.[28]

Finally, several other aspects of oxygenation programs deserve mention. First, like Low RVP regulations, reformulated gasoline has somewhat supplanted oxygenated gasoline. The basic RFG formula specified by the CAA requires 2% oxygen by weight, which in many areas is sufficient to meet NAAQS standards. Currently, only reformulated gasoline sold in New York City area must be oxygenated during the winter beyond RFG requirements. Also, CAA also grants the EPA the ability to provide a waiver from the 2.7% oxygen requirement for states where "the use of oxygenated gasoline would prevent or interfere with the attainment by the area of a national primary ambient air quality standard for any air pollutant other than carbon monoxide."[29] Due to the additional volatility of oxygenated gasoline which hampers efforts to reduce ground-level ozone, California restricts oxygen content to 1.8-2.2%.

iii. Reformulated Gasoline (RFG)[30]

The final regulation of gasoline content mandated by the CAA is reformulated gasoline. The most comprehensive legislation to control emissions through gasoline content, reformulated gasoline targets both NOx and VOC emissions (like Low RVP regulation) and CO emissions (like oxygenated gasoline). The method by which RFG reaches these goals is different than both oxygenate gasoline and Low RVP regulations. Low RVP and Oxygenation requirements stipulate explicit content criteria. While RFG regulations also stipulate content criteria, the regulations also specify "performance" standards, which are emissions-based measurements that refiners have flexibility in meeting. The content requirements are similar to those stipulated by the Low RVP regulation and oxygenation regulation - benzene is limited to 1% of total volume and oxygen content must be at least 2% of weight. Thus, the content requirements are essentially a combination of the Low RVP requirements and the oxygenation requirements. The three "performance" standards specify reductions of VOC emissions, NOx emissions and toxic air pollutants (TAPs) emissions that must be met by reformulated gasoline relative to the 1990 gasoline. Performance requirements may be met by refiners in the least-cost manner. RFG regulations also contain "anti-dumping" restrictions for refiners. These prevents refiners from simply shifting gasoline components that they would like to remove from reformulated gasoline to their conventional gasoline.

Like RVP regulation, RFG standards have phased in over time, with the performance standards becoming more strict in the second Phase. Phase I, effective January 1, 1995, necessitated refiners to meet 15% reductions in VOC and TAP emissions as part of the performance standards as well as the content standards for benzene and oxygenation. In addition, NOx emissions from reformulated gasoline cannot exceed those from the baseline 1990 gasoline. Phase II, effective January 1, 2000, requires 25% reductions

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[28] California plans to phase out MTBE by December 31, 2002 due to health concerns. California Executive Order D-5-99, March 25, 1999. http://www.energy.ca.gov/mtbe/index.html. In addition, twelve other states have passed legislation to reduce or eliminate the use of MTBE as an oxygenate. See "Gas Prices – How are they really set?" at 69.

[29] Clean Air Act, Section 211(m)(3)

[30] Clean Air Act, Section 211(k)

in VOC and TAP emissions in addition to the content standards. The NOx emissions is unchanged by Phase II. Thus, standards for reformulated gasoline have become more stringent over time.

Once again, the taxonomy helps identify how the content regulation may affect refining and distribution. RFG is a regional, year-round requirement - the act initially required sale of reformulated gasoline in the nine severe ozone nonattainment areas, with 1980 populations in excess of 250,000. These nine areas (including Baltimore, Chicago, Hartford, Houston, Los Angeles, Milwaukee, New York City, Philadelphia and San Diego) constitute over 63 million people, or 24% of the total US population. In addition to these nine cities, any area reclassified as severe nonattainment is required to shift from conventional to reformulated gasoline. For example, Sacramento was reclassified as in severe ozone nonattainment in the summer of 1995 and was required to use reformulated gasoline beginning January 1, 1996.

Like other content regulations, though, areas can opt-in to the reformulated gasoline program, adopting the content and performance requirements for gasoline. While opt-in increased participation to slightly for Low RVP regulation and oxygenation, RFG opt-in areas contribute greatly to the geographic scope of RFG regulation. Since 1995, regions containing approximately 35 million people have adopted the RFG content and performance regulations.[31]

While standards do not vary across different regions participating in the federal RFG program (California's program will be discussed in the next section), participating regions can and do stipulate the use of particular oxygenates. Consistent with the pattern of oxygenate use for oxygenated gasoline, reformulated gasoline in the Midwest is usually oxygenated with ethanol, while areas on the East and West coasts require oxygenation via MTBE.

iv. CARB Gasoline[32]

The final major regional gasoline content regulations are those promulgated by the California Air Resources Board regulating gasoline sold year-round in California. Beginning in 1992, California began a three phase state-run program regulating gasoline content. Phase I content regulation, effective January 1, 1992, was consistent with federal Low RVP and oxygenated gasoline programs at the time, with the exception that the oxygenated gasoline program mandated oxygen content of 1.8 - 2.2 percent by weight as opposed to the federal standard of at least 2.7 percent oxygen by weight. The California Air Resources Board designated control periods in the summer (for Low RVP gasoline) and in the winter (for oxygenated gasoline) for areas in ozone or CO nonattainment respectively, generally with control periods set by EPA for other nonattainment areas. Low RVP restrictions generally run from May 1 through September 30 while oxygenation is necessary, in general, from October 1 though February 29.

Phase II CARB gasoline replaced Phase I gasoline in 1996. In many ways, Phase II regulations were similar to the federal regulations for reformulated gasoline. First, like RFG regulation, most Phase II regulations were effective year-round (with the exception of the Low RVP limit), no longer containing any

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[31] For a comprehensive list of areas subject to RFG regulation, see http://www.epa.gov/otaq/rfgarea.htm.

[32] Title 13, California Code of Regulations, Sections 2250-2273.

seasonal components for oxygenation. Phase II regulations ratcheted down the RVP limit from 7.8 psi to 7.0 psi, limited benzene content to 1 percent by volume and mandated 1.8 to 2.2 percent oxygen content by volume. California regulations covered the entire state, essentially opting-in areas already in ozone and CO attainment (mainly Northern California). One significant difference, though, between the CARB requirements and EPA RFG requirements is a limitation placed on sulfur content of gasoline by CARB. CARB Phase II requirements stipulate a flat limit of 40 ppm sulfur on all gasoline. As discussed in the earlier section on refining, sulfur naturally occurs in crude oil and, when untreated, occurs generally at concentrations of approximately 250 ppm in gasoline. This sulfur limit requires either skimming off high-sulfur gasoline into the less valuable distillate pool or through hydrotreating the gasoline to remove sulfur during the refining process. In addition, CARB gasoline does not impose any “performance” standards like reformulated gasoline.

Phase III, going into effect for producers December 31, 2002 and for retailers March 31, 2003, tightens limits on sulfur content (to a flat limit of 20 ppm) and benzene content (to 0.8 percent by volume). In addition, phase III CARB gasoline also prohibits the use of oxygenates other than ethanol.[33] Citing fears of costly gasoline and additional volatility of ethanol, which leads to greater evaporative emissions of VOCs and NOx, Governor Davis has appealed to EPA to waive the oxygenation requirement for California's compliance with federal "minimum" RFG standards.[34]

D. From Gasoline to "Boutique Blends"

In 1991, gasoline across the country met similar content standards for lead and other metals. In the past 10 years, environmental regulation has significantly changed the substitutability of gasoline across different areas. Currently, there are fifteen “boutique fuels”, each satisfying content constraints for regional content requirements.[35] The trend toward differentiation began in 1992, when Phase II RVP limits lowered gasoline volatility nationwide. In addition, summer RVP limits were placed on gasoline sold in ozone nonattainment areas. That winter, oxygenation of gasoline was required in CO non-attainment areas. Like the RVP limits, required duration varied by noncompliance area. Some areas in compliance opted-in to each of these programs, increasing participation. In addition, various cities and states mandated stricter content requirements, specified the use of particular oxygenates and lengthened the period of compliance.

Starting January 1, 1995, year-long reformulated gasoline requirements supplanted seasonal RVP limits and oxygenation requirements for the nine metropolitan areas in severe ozone nonattainment. Once again, a significant number of areas in attainment chose to adopt reformulated gasoline requirements. With the exception of California, though, EPA requirements only provided regions the ability to mandate the use of particular oxygenates. While choice of oxygenates has little effect on refining when gasoline must only

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[33] California Executive Order D-5-99, March 25, 1999. http://www.energy.ca.gov/mtbe/index.html. In addition, twelve other states have passed legislation to reduce or eliminate the use of MTBE as an oxygenate. See “Gas Prices – How are they really set?” at 69.

[34] "Governor Davis Sues US EPA Over Gasoline Additive", August 13, 2001. http://www.arb.ca.gov/cbg/oxy/wav/oxywav.htm.

[35] Study of Unique Gasoline Fuel Blends, Effects on Fuel Supply and Distribution and Potential Improvements, US Environmental Protection Agency. Appendix D.

meet a minimum oxygen content, different oxygenates have different properties. In order to meet "performance requirements" for RFG, gasoline must be refined differently if it is going to be blended with ethanol or MTBE. Thus, although the requirements for RFG are consistent across program areas with the exception of California, choice of oxygenate has an impact on refining.

Effective March 1996, the California Air Resources Board tightened EPA requirements for reformulated gasoline, introducing both a summer RVP limit (on top of the benzene limit in RVP) and a limit on sulfur content as part of the Phase II CARB gasoline requirements. Sulfur limits necessitate hydrotreating to prevent downgrading high-sulfur gasoline to distillate, creating a sharp division between product that can be sold in California and outside California.

More strict standards for reformulated gasoline (Phase II RFG) went into effect January 1, 2000. In addition, Phase III CARB gasoline will further tighten its requirements starting December 31, 2002. Thus, in a under a decade, the US gasoline market has become considerably more differentiated. In summary, table 2 contains a breakdown of the various content requirements imposed by the EPA and state regulations. Table 3 details the geographic and temporal scope of reformulated gasoline, oxygenated gasoline and CARB gasoline programs.

IV. Costs imposed on production and distribution of gasoline by gasoline content regulation

Adherence to gasoline content regulation clearly increases the cost of gasoline directly. Costly additives raise the average cost of producing a gallon of gasoline. In addition, additives meant to reduce pollution dilute gasoline, lowering the energy content and reducing fuel efficiency of automobiles. Moreover, content regulations can affect production costs of gasoline in less direct ways. Some regulations force refiners to refine gasoline more than they otherwise would, increasing production costs. In addition, gasoline content regulation also imposes other costs on production and distribution of gasoline due to the inflexible nature of refining, storage and transportation of gasoline.

The goal of this section is to identify how gasoline content regulation could affect the price levels and price volatility of gasoline. This section first discusses the direct costs of additives and the impacts of regulations on fuel efficiency. After addressing these primary costs, potential costs imposed on refining, transportation and storage infrastructure are summarized for the major regional content regulations: RVP limits, oxygenation, RFG and CARB gasoline.

A. Direct costs of environmental regulation

i. Cost of oxygenation additives (Ethanol/MTBE)

The most direct cost imposed by content regulation is the cost of additives required to meet certain fuel specifications. Oxygenation standards drive the majority of this type of cost, since either 8 percent ethanol or roughly 15 percent MTBE must be blended into gasoline to meet the 2.7 percent oxygen by weight minimum for oxygenated gasoline. Since reformulated gasoline and CARB Phase II and III also stipulate a minimum oxygen content, albeit lower than that required for oxygenated gasoline, oxygenate costs also play a role in the prices for each of these types of gasoline.[36] Historically, gasoline prices on a per gallon basis have been lower than MTBE prices which have in turn been lower than ethanol prices. Hence, requiring oxygen be added to gasoline most directly affects production costs by increasing the average cost of the components constituting a gallon of gasoline.[37]

On top of the simple cost of oxygenates, mandating an oxygen content level also introduces an additional input subject to production disruptions into the production of gasoline. While MTBE is generally produced at refineries, ethanol plants located in the Midwest produce the vast majority of US ethanol. Depending on inventory levels of ethanol and transportation costs, unexpected outages of ethanol plants may affect the supply of ethanol and hence ethanol-blended gasoline. On top of the effect of unexpected outages, production of ethanol is even more concentrated than crude oil refining. Thus, stipulating an oxygen content level and especially stipulating a particular oxygenate could lead to higher and more volatile gasoline prices.

ii. Lower Fuel Efficiency

A less obvious effect of content regulation is an alteration of the energy content of gasoline. By limiting certain petroleum products and requiring certain additives, content regulation changes the amount of energy contained in a volume of gasoline, thereby affecting mileage of cars. The two requirements which substantively affect energy content are RVP limits and oxygenation. The RVP cap on gasoline limits the volume of volatile elements. Since these elements contain relative less energy, by volume, RVP limits increase energy density in gasoline. In addition, since less fuel is lost through evaporation when fueling, a 1 percent decrease in benzene levels roughly corresponds to a 0.25 percent increase in engine efficiency. Adding oxygenates to gasoline, on the other hand, dilutes the gasoline by adding lower energy density oxygenate. Due to the greater percentages of oxygenates used, meeting EPA oxygenated gasoline requirements leads to a 2 to 3 percent loss in engine efficiency. Reformulated and CARB gasoline, with oxygen content and volatility limits, fall somewhere in between, with 1 to 2 percent efficiency losses.[38]

It is important to note, though, that both of these also affect the volume of gasoline produced. For example, if gasoline is blended with ethanol, 100 gallons of gasoline and 8 gallons of ethanol create 108 gallons of oxygenated gasoline. Thus, although oxygenation reduces the energy content for each gallon of gasoline, the reduction in energy content per gallon is compensated for by increasing the total volume. Hence, the energy content of gasoline is not lost through oxygenation, but merely spread over a greater number of gallons. Unless significant costs are associated with filling gas tanks such that a 3-4% energy loss, and consequently an increase of similar magnitude in the frequency of filling tanks, is significant,

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[36] California sued the EPA over their application for a waiver for CARB Phase III gasoline from federal RFG minimum oxygen content requirements. http://www.arb.ca.gov/cbg/oxy/wav/oxywav.htm

[37] Gasoline blended with 10% ethanol (gasohol) is exempt from 5.4 cents of federal gasoline tax. In addition, this exemption is prorated for gasoline containing less than 10% ethanol. This translates into a 54 cent per gallon subsidy of the production and use of ethanol. Even with this subsidy, though, historical ethanol prices have been higher than MTBE prices.

reductions in energy content only need only be considered when comparing price levels of conventional gasoline with price levels of various gasoline blends.

B. Refining costs

The nature of crude oil refining drives how gasoline content regulation affects the refining industry. The primary effect of gasoline content regulation (specifically Low RVP, reformulated gasoline and CARB gasoline) is over-refinement of gasoline. That is, content regulation forces refiners to refine gasoline more than they otherwise would, in order to remove meet various standards.

Limits on the RVP of gasoline clearly impose costs on refiners, since RVP can only be reduced at the refinery level. Gasoline, like any petroleum product is made up of a blend of different elements. To lower the RVP, it is necessary to isolate and remove the components of gasoline which are the most volatile and hence most prone to evaporation. This increases refiner production costs, both through additional refining costs to remove these components, as well as processing costs of these and other components if the refiner wants to maintain the volume of gasoline.

Reformulated gasoline requirements also require additional refining to remove volatile components in gasoline. Although RFG requirements do not specify a particular RVP limit, they do constrain benzene levels at a maximum of 1 percent of total volume. In addition, the VOC and TAP performance standards force refiners to remove volatile elements of gasoline. This places a similar constraint on refiners to the constraint placed by a RVP limit, forcing refiners to separate benzene and other volatile elements from the gasoline.

Any regionally-imposed constraint of the choice of oxygenate places additional costs of meeting the benzene limit and performance standards, due to the differing chemical properties of ethanol and MTBE. The most significant difference from a refining perspective is the difference in volatility - ethanol has more than double the Reid vapor pressure of MTBE (18.0 psi versus 8.0 psi).[39] Thus, if MTBE and ethanol were added in equal proportion to gallons of gasoline, the ethanol/gasoline mix would have a higher vapor pressure than the MTBE/gasoline mix. Although ethanol's higher oxygen content allows for it to be blended in lesser proportion to gasoline to meet oxygen content requirements, it nonetheless increases the RVP of gasoline by about 1 psi when blended to satisfy the requirements of RFG. MTBE, on the other hand, increases the vapor pressure of gasoline very little when blended in since the vapor pressure of MTBE and the vapor pressure of Low RVP gasoline are close. This forces refiners, who intend to blend with ethanol, to remove more benzene and other volatile components to satisfy the performance standards for NOx and VOCs than they would if they had used MTBE.

CARB gasoline imposes both limits on the volatility of gasoline (through a cap on RVP) and mandates a minimum oxygen content, subjecting refiners to additional production costs similar to RFG. In

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[38] For more information about the effect of content regulation of efficiency, see Lidderdale, T., “Environmental Regulations and Changes in Petroleum Refining Operations”, Energy Information Administration, June 1998.

[39] See Gomez J., T. Brasil and N. Chan, "An Overview of the Use of Oxygenates in Gasoline", California Air Resources Board, September 1998. http://www.arb.ca.gov/cbg/oxy/oxy.htm.

addition, though, CARB gasoline also places a limit on the sulfur content of gasoline. This forces refiners to hydrotreat gasoline intended for use in California, removing sulfur to meet the limit.

To understand the effect of refining constraints imposed by content regulation, it is helpful to think about separating the effects into two categories: (1) those for which adjustments can be made during the next production run and (2) those which require investment by a refiner. For example, small adjustments in Reid vapor pressure can be easily made through changes in the refining process. For most large refineries, no major investment need occur to produce gasoline to be blended with MTBE to meet RFG requirements after producing Low RVP gasoline since the two have relatively close vapor pressures. Requirements for Phase II RFG produced with ethanol, though, do have some investment ramifications for many refiners, since ethanol's volatility requires it be blended with very low volatility gasoline. While these investments are not extremely costly, only refiners serving RFG markets requiring ethanol as an oxygenate made the investments prior to the start of Phase II RFG. Other refiners "have not made such facility changes because they have little reason to undertake these changes for the markets they traditionally serve."[40] Similarly, CARB gasoline requires refiners to be able to hydrotreat large quantities of gasoline to remove sulfur. While many refineries already can hydrotreat significant amounts of diesel fuel, many do not have the capacity to also hydrotreat large amounts of gasoline.

The effect of national and state-specific content regulation has been to separate the homogenous gasoline market of 1991 into smaller gasoline "islands", each of which is a small market for gasoline satisfying particular content requirements. Whether or not refiners can adjust their production process from one production run to the next determines the ability of the refining industry to adjust to production shocks in the sub-markets. In the case of ethanol blended RFG or CARB gasoline, refinery investment or substantial production costs limit the number of refiners not traditionally serving those markets that can respond to supply shocks within those markets. Due to the costs involved for refiners to produce either an RFG blend to be mixed with ethanol or CARB gasoline, California and Chicago/Milwaukee are recognized as the best examples of gasoline "islands".[41]

With a greater number of markets and fewer refiners fully committed to each market, content regulation has the potential to both increase industry vulnerability to refinery outages and increase the potential for refiners in a particular sub-market to exercise market power. In fact, both of these have been proposed as contributing factors to the gasoline price spikes in Chicago in 2000 and in California in 2001. With fewer refiners able to quickly adjust production to meet the specifications of particular gasoline blends, unplanned outages for maintenance should lead to greater price volatility. In addition, to the extent that certain refineries are more efficient than others, necessary investment may lead a less efficient refinery (say in Chicago) to produce in the event of a fire at a larger Midwest refinery when, but-for the content

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[40] Shore, J., "Supply of Chicago/Milwaukee Gasoline, Spring 2000", Energy Information Administration, Petroleum division; http://www.eia.doe.gov/oil_gas/petroleum/info_glance/gasoline.html.

[41] See Statement of John Cook, Director, Petroleum Division USDOE Energy Information Administration before the Committee on Energy and Commerce, Subcommittee on Energy and Air Quality, US House of Representatives, May 15, 2001. http://www.eia.doe.gov/oil_gas/petroleum/info_glance/gasoline.html.

regulation, a larger refinery in the Gulf Coast might have produced instead to cover the slack. In addition, as it becomes more difficult for refineries to easily move between the production of different blends, less competitive pressure is brought to bear on markets with relatively few refiners. Each of these problems only becomes more acute as reserve refinery capacity decreases over time, as it has been over the last 20 years.

In summary, content regulation has several distinct effects on refining that could increase gasoline price levels and volatility. The most direct method is from the cost of the additional refining necessary to meet to content standards of a particular blend. In a world in which adjusting refining process to meet different criteria was costless, this would be the end of the story. In actuality, though, significant costs exist, either from investment necessary to meet content standards or from the adjustment costs associated with altering the production plan in the midst of a production run. These costs lead to what are referred to as gasoline “islands”, smaller markets served by a small group of refineries. Since it is costly, in many cases, for refiners to switch from producing one blend to another, even at the end of a particular production run, content regulation also has the potential to influence price levels and volatility by magnifying the effects of an unexpected refinery outage or by reducing the competitive pressure on small groups of refiners producing a particular blend of gasoline.

C. Transportation costs

Content regulation for gasoline also has ramifications for the transportation of gasoline from refiners to wholesale terminals, after which the gasoline is distributed to retailers. Gasoline is transported to wholesale terminals either through pipeline or by barge depending on the locations of the refinery and terminal. In order to ensure that fuel meets specification both before and after transportation, different blends of gasoline must not mix to a great degree. This is relatively easy to do using barges, but becomes more difficult using a pipeline which must be full of product in order to operate. As is the case with different grades of gasoline, pipelines often must be filled with higher quality (lower emission) product first and lower quality (higher emission) product second. With many different refineries and many different locations requiring gasoline, transportation costs may increase as a result of content regulation.

On top of additional transportation costs incurred when transporting the gasoline, RFG, CARB and oxygenation regulation also necessitates transportation of additives. While refiners often produce and mix MTBE with gasoline at the refinery, refiners cannot do this when blending with ethanol for two reasons. First, ethanol is produced through sugar fermentation and distillation, which does not happen at the refinery. Also, and more importantly, ethanol is completely miscible in and has an affinity for water.[42] If ethanol mixed with gasoline comes into contact with water, the ethanol will separate from the gasoline and combine with the water. Since water can and does exist in gasoline pipelines, refiners cannot mix gasoline and ethanol at the refinery and then transport the blend. Instead, the operator of the wholesale terminals must blend ethanol with gasoline onsite. This requires ethanol to be transported to wholesale

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[42] See Gomez J., T. Brasil and N. Chan, "An Overview of the Use of Oxygenates in Gasoline", California Air Resources Board, September 1998 for chemical characteristics of oxygenates used in gasoline.

terminals rather than refiners. While in many cases this may be less costly, if only a few areas require ethanol-blended gasoline and the majority of the areas requiring ethanol are in close proximity to the ethanol plants, this becomes more costly as the number of areas requiring ethanol to be blended with gasoline increases. For example, California's prohibition on the use of MTBE as an oxygenate goes into effect December 31, 2002. Under the federal oxygen content regulations for RFG, California will need 660 million gallons of ethanol annually. With year to date US production averaging 128 thousand barrels per day, this amounts to roughly one-third of current US ethanol production.[43] Not only must this be produced, but it must also be transported to wholesale terminals in California and blended there.

Finally, content regulation may also affect transportation costs by altering transportation pattern in the event of unplanned maintenance to a particular unit. In the event of unplanned maintenance, refineries with the lowest cost to serve wholesale terminals affected by the outage would likely do so. Content regulation can only negatively affect this, since, at the very least, the same plant operates in lieu of a plant requiring maintenance.

D. Storage costs

The final way content regulation can affect the price level and volatility of gasoline via infrastructure is through additional storage costs. Depending on the specific regulation, several potential costs might exist. Clearly, additive-induced transportation costs imply analogous storage costs. Regardless of who blends the additives with the gasoline, storage must exist for the additives at that location as well as the machinery to blend additives into gasoline.[44] In addition, as is the case with different grades of gasoline, different content blends must be stored separately. For instance, if a wholesale terminal sells several "blends", it needs separate tanks to maintain content and "performance" requirements of the gasoline. Not only does this create costs for facilities that store several types of gasoline, but it also reduces regional storage capacity for either "blend" which potentially affects market response to supply shocks. Finally, storage costs can also arise due to the seasonal nature of some content regulations, since tanks must be either drained fully or filled several times before stored gasoline will meet specifications. As a result, both retailers and wholesale distributors draw down gasoline levels in storage tanks significantly prior to seasonal changes in gasoline content requirements. While this does not impose any storage costs, in itself, it does draw down inventories, making retail prices more susceptible to shocks.

V. Past Literature on the Effect of Gasoline Content Regulation

In August 2001, the head of the Environmental Protection Agency (EPA), Christie Whitman, suggested that "limiting the number of 'boutique blends' to three or four formulas could increase fuel

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[43] Energy Information Administration, EIA-819M, Monthly Oxygenate Telephone Report, Table B1, August 2002. http://www.eia.doe.gov/oil_gas/petroleum/data_publications/monthly_oxygenate_telephone_report/motr.html.

[44] California terminals' inability to store and blend large amounts of ethanol was noted in CARB report, "An Overview of the Use of Oxygenates in Gasoline". September 1998.

supplies and help prevent large spikes in the prices drivers see at the pump."[45] Despite recognition of the potential effects of content regulation on gasoline price levels and volatility, relatively little empirical work has assessed the effects of content regulation on prices and the ability of refiners and wholesalers to wield market power. No work was found to empirically address the effect of any form of content regulation on price volatility. Nor has any work looked at the effect of decreasing reserve refinery capacity. In addition, none of these analyses attempt to empirically identify which factors, as discussed in the previous section, increase or decrease price levels. This section summarizes the work looking at the effect of content regulation first on price levels and then looks at investigations of market power.

A. Literature on Price Levels

Papers evaluating the effect of content regulation on price level can be categorized into ex-ante estimates and ex-post analyses. Ex-ante estimates generally focus on the incremental costs to refiners from producing various blends of gasoline, and occasionally estimate the overall effect on prices. The ex-post analyses empirically quantify the actual effect of content regulation on retail or spot price levels.

i. Ex-ante estimates

EIA and EPA studies provide the majority of ex-ante estimates of the costs of various content regulations. Prior to the start of oxygenated gasoline regulations, EIA estimated the additional cost of oxygenates would lead to a three to five cent increase in the spot price of oxygenated gasoline relative to conventional gasoline.[46] In 1994, EIA performed a similar analysis for Phase I and Phase II reformulated gasoline. For Phase I RFG, EIA estimated up to a four cent differential between spot prices of conventional and wholesale gasoline.[47] For Phase II RFG, EIA estimated that compliance with Phase II regulations would not add to the price premium in the winter, but would add between 1 and 1.5 cents relative to Phase I RFG during the summer. This was based on the expectation that refiners would be able to comply more easily with Phase II regulations during the winter, when volatility was less of a concern. Based on these estimates and the observed wholesale price premium of 2.5 cents between Phase I RFG and conventional gasoline, EIA estimated a price premium of 2.5 cents during the winter months and 3.5 to 4 cents during the summer months.[48] The EIA estimates were roughly consistent with EPA estimates for Phase I RFG - the EPA initially estimated phase I reformulated gasoline would lead to additional costs of three cents per gallon. In addition, they estimated that CARB gasoline would create additional costs of eight to eleven cents per gallon.[49]

ii. Ex-post analyses

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[45] "EPA mulls limiting number of special gasoline blends", The Associated Press, 8/6/01

[46] Lidderdale, T., "Demand, Supply and Price Outlook for Oxygenated Gasoline," Energy Information Administration, Short-Term Energy Outlook, June 1992.

[47] Lidderdale, T., "Demand, Supply and Price Outlook for Reformulated Motor Gasoline 1995," Energy Information Administration, Short-Term Energy Outlook, July 1994.

[48] Bohn, A., and T. Lidderdale, "Demand and Price Outlook for Phase II Reformulated Gasoline, 2000," Energy Information Administration, Short-Term Energy Outlook Update, April 1999 to August 1999.

[49] US Environmental Protection Agency, "The Case for California Reformulated Gasoline – Adoption by the Northeast", Office of Policy, Planning and Evaluation, May 1993.

Several studies by the EPA and one academic article evaluate the ex-post effects of the first several years of content regulation. It is important to note, though, that no study attempts to isolate the effect of content regulation controlling for either increasing industry concentration or changes in refining reserve capacity. Since the time frame for each study is relatively small and prior to most significant industry consolidation, though, these issues are likely to be relatively small.

a. Energy Information Administration[50]

Lidderdale performs an ex-post analysis of the wholesale price premium for Low RVP gasoline, oxygenated gasoline and RFG at major supply and refining centers. Specifically, for each content regulation he averages spot or wholesale prices over the relevant season for each regulation on an annual basis. He uses this average as an estimate for the price premium in the wholesale market. In addition, for seasonal programs such as Low RVP regulation and oxygenated gasoline, Lidderdale begins his averaging window one month early to account for the transportation lag between spot markets and retail markets, where content specifications must ultimately be met.[51]

Lidderdale finds that for summer seasons from 1993 through 1998, waterborne Gulf Coast spot prices for 7.8 psi RVP unleaded regular gasoline annually averaged between 0.33 cents and 0.79 cents higher that 9.0 psi RVP gasoline at the same location. Using a similar methodology, Lidderdale finds that for the three winter seasons from 1992-1993 to 1994-1995, the price premium for wholesale, oxygenated gasoline at New York Harbor and the Gulf Coast annually averaged between 2.9 and 7.0 cents. The annual average reformulated gasoline price premium at the same locations from 1995 through 1998 varies between 1.9 cents and 3.5 cents. The price premia are, as expected, highly correlated with the price differential between MTBE and conventional gasoline. Lidderdale performs a similar analysis of wholesale price premia for CARB gasoline and finds that from January 1997 to December 1998, the average pipeline spot premium for CARB gasoline relative to conventional gasoline was 4.2 cents in Los Angeles and 4.3 cents in San Francisco.[52]

b. Vita, 2000[53]

Vita addresses the affect of divorcement regulation, preventing integration of refiners and retailers, on gasoline prices from 1995 through 1997. Using a panel of average monthly retail prices net of taxes for each state, he regresses price in a particular month for a particular state on demand variables, cost variables and regulatory variables, capturing whether or not a state had divorcement regulation. Included in his model specification as cost-shifting variables, though, are variables indicating the percentage of gasoline

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[50] Lidderdale, T., “Environmental Regulations and Changes in Petroleum Refining Operations”, Energy Information Administration, Short-Term Energy Outlook Special Report, November 1999.

[51] The averaging window for Low-RVP gasoline and oxygenated gasoline is April 1 through August 31 and October 1 through February 29 respectively in contrast to EPA mandate that generally requires Low RVP gasoline from May 1 through September 15 and oxygenated gasoline from November 1 through February 29.

[52] Bohn, A., and T. Lidderdale, “Demand and Price Outlook for Phase II Reformulated Gasoline, 2000,” Energy Information Administration, Short-Term Energy Outlook Update, April 1999 to August 1999.

[53] Vita, M., “Regulatory Restrictions on Vertical Integration and Control: The Competitive Impact of Gasoline Divorcement Policies”, Journal of Regulatory Economics, 18:3 217-233, 2000.

sold meeting oxygenated and RFG requirements. In addition, he includes a dummy variable for California after May 1, 1996, to capture the affect of CARB gasoline, and interacts it with a 1997 year-dummy to control if costs of producing CARB gasoline have fallen over time.

Depending on how his regression is specified, Vita estimates a retail price premium of 0.55 to 1.21 cents per gallon for a state required to oxygenate all of their gasoline relative to a state using strictly conventional gasoline. His estimates also imply a 1.52 to 2.18 cent retail premium for CARB gasoline, holding all else constant. Interestingly, the estimation of the effect of reformulated gasoline on price levels is the opposite of the expected effect. He estimates a state requiring reformulated gasoline pays 0.19 to 0.35 cents per gallon **less** than a state with conventional gasoline.

B. Price Spikes and Price Volatility

The gasoline "price spikes" of the last several years prompted three investigations into the behavior of refiners and market participants, an investigation by the FTC of the price spikes in the Midwest during 2000, a similar investigation by the FTC into gasoline pricing in Western States, and an report by the US Senate Subcommittee on Investigations. In addition, the DOJ is currently investigating antitrust concerns in the market for ethanol production. While the focus of each of these investigations is the whether or not antitrust law was violated (i.e. whether or not explicit collusion amongst participants occurred), each investigation discusses the role that content regulation may play in creating the price spikes.

i. FTC Midwest Price Spike Investigation[54]

After the retail gasoline price spikes in Chicago and Milwaukee during May and June 2000, the FTC began an investigation of the behavior of market participants leading up to the price spikes. The FTC found that while market participants may have unilaterally acted in their best interest, there was no evidence of explicit collusion by firms to manipulate the retail price, and hence no violation of antitrust statutes. Evidence suggested that "prices rose both because of factors beyond the industry's immediate control and because of conscious (but independent) choices by industry participants."[55] As part of the report, though, the FTC did identify three primary factors in the price spike, namely, refinery production problems, pipeline disruptions and inadequate inventories. Of the factors identified by the FTC, several can be traced to content regulation. First, content regulation complicated the production of Phase II RFG (especially that produced for Chicago and Milwaukee requiring ethanol), as refiners had difficulty meeting the new standards for Phase II. In addition, the requirement to use ethanol as an oxygenate in Chicago and Milwaukee reduced the ability of other refineries to substitute MTBE-blended Phase II RFG for the Chicago and Milwaukee blend. Finally, in order to meet the Phase II RFG standards, refiners and wholesale distributors needed to drain tanks to prevent Phase II compliant and non-phase II complaint gasoline from commingling. This led to low inventories, increasing the susceptibility of the industry to reduced pipeline availability and delays bringing refineries back from maintenance.

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[54] Final Report of the Federal Trade Commission, Midwest Gasoline Price Investigation, March 29, 2001.
[55] See Executive Summary of Final Report of the FTC.

ii. FTC Western Price Investigation[56]

In addition to the FTC investigation of the Midwest price spikes, the FTC also investigated the production and distribution practices of major refiners in the Western states of Arizona, California, Nevada, Oregon and Washington. Again, the FTC found no evidence of explicit collusion between refiners. Once again, though, the FTC investigation identified "unique product requirements, such as gasoline satisfying California Air Resources Board standards" as an important factor contributing to the differences in price between the gasoline market in the West and in the rest of the US.

iii. US Senate Subcommittee Investigation[57]

The final, and largest, investigation was a US Senate Subcommittee investigation addressing "whether the increased concentration has contributed to the price spikes and increases."[58] The goal of this investigation was not to ascertain whether or not explicit collusion had occurred, but rather to evaluate the factors underlying the retail price spikes of the last several years. The findings of the subcommittee identify both increasing concentration and declining reserve capacity as factors underlying the retail price spikes of the last several years. While they noted "the current gasoline production and distribution system is able provide adequate quantities of boutique fuels," these also remarked that "in the event of a supply disruption or shortage, it may be more difficult to bring in additional supply to an area that requires a boutique fuel rather than a conventional fuel, because fewer refiners may be readily capable of producing the required gasoline."[59] In addition, the investigation specifically identifies seasonal storage transition issues as a contributor to the Midwestern price spikes of 2000 and 2001. Thus, although the investigations of the FTC and Senate Subcommittee do not attempt to quantify the effect of content regulation, they do acknowledge that content regulation has played a role in recent price spikes.

VI. Conclusion

To address the increased volatility of gasoline prices over the past several years, three important industry trends must be incorporated into any analysis. First, over the past ten years, the industry has significantly consolidated. While consolidation was conditional on divestiture of overlapping refining and retailing assets, significant refining resources have been purchased and sold. While apriori the effect of consolidation with divestiture is ambiguous, this must be nonetheless incorporated into any analysis. Second, since the early 80's, refining capacity has not increased at the same rate as demand. As in the case of the electricity industry, reserve refining capacity provides backup refining in the case of unexpected refinery outages. Depending on the degree to which inventories and the transportation system are able to compensate for unexpected outages, this may or may not play a role in the high gasoline prices of the past

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[56] See Statement of Commissioners Anthony, Swindle and Leary Concerning Western States Gasoline Pricing Investigation. May 7, 2001. http://www.ftc.gov/os/2001/05/wsgpiswindle.htm.

[57] See "Gas Prices – How Are They Really Set?", Majority Staff of the Permanent Subcommittee on Investigations, Released in Conjunction with the Permanent Subcommittee on Investigations' Hearings on April 30 and May 2, 2002

[58] See "Gas Prices – How Are They Really Set?" at pg 17.

[59] See "Gas Prices – How Are They Really Set?" at pg 74-75.

several years. Thus, declining reserve refining capacity also must be taken into account in any analysis of gasoline pricing. Finally, federal and state regulations now mandate distinct blends of gasoline for different regions of the country. These regulations have the potential to impose significant costs on refineries, pipelines and storage terminals. Moreover, content regulations reduce the fungibility of gasoline across different, but often nearby, areas. This reduces the ability of refiners and marketers to substitute gasoline between locations in response to unforeseen supply and demand shocks. It is these regulations which at least at first glance, are the most directly related to price volatility since over the past several years, the two regions with the most volatile gasoline prices have both had a unique blend of gasoline.

The effects of each of these trends have clear policy implications. Almost 130 billion gallons of gasoline were sold at the wholesale level in the United States during 2000.[60] To the extent that any of these trends creates a cost that is avoidable, (i.e. through standardization of content regulation), large potential savings exist. In addition, if the goal of content regulation is to reduce air pollution in particular areas, it is also informative to determine whether content regulation represents a relative efficient or inefficient way of reaching that goal. A number of existing and potential policy tools, including fuel-economy regulation, vehicle emissions standards, emission-based registration fees, and premature vehicle retirement, could substitute as a policy tool for reducing air emissions. An important question, given the potential costs of content regulation is whether alternative policies provide a more cost-effective method of reducing local emissions.[61] Alternatively, if significant effects are traced to declining reserve capacity, other policy tools could potentially address those costs. The quantification of the effects and evaluation of the relative efficiencies of the policies provides a question and focus for future research.

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[60] EIA Petroleum Marketing Annual, 2000, Table 48.

[61] See Harrington, Walls and McConnell (1994) for estimates of the cost-effectiveness of various policies to reduce motor vehicle emissions.

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Table 1: Regulations Pertaining to Gasoline Additives

Regulation	Geographic Scope	Seasonality	Method of Compliance	Notes
Lead Anti-knock Agents	National	Full Year	Use of Other Antiknock Additives	
Detergents	National	Full Year	Additives	
Phase II Reid Vapor Pressure	National	Summer Ozone Season	Refining	National Component: 9.0 psi limit
Phase II Reid Vapor Pressure	Regional	Summer Ozone Season	Refining	Regional Component: 7.0 - 7.8 psi limit generally
Oxygenation	Regional	Winter	Additives	Period and Additives vary by location
Reformulated Gasoline	Regional	Full Year	Additives and Refining	
CARB Gasoline	California Only	Full Year	Additives and Refining	

Table 2: General Specifications of Gasoline Blends*

Specification	National RVP Limit	Low RVP Limit	Oxygenated Gasoline	RFG Phase I	RFG Phase II	CARB Phase I	CARB Phase II	CARB Phase III
Scope								
Retail Implementation Date	1-May-92	1-May-92	1-Nov-92	1-Jan-95	1-Jan-00	1-Jan-92	1-Mar-96	31-Mar-03
Temporal	May 1 - Sept 15	May 1 - Sept 15	Nov 1 - Feb 29	Year-Round	Year-Round	Summer/Winter**	Year-Round	Year-Round
Geographic	National	Regional	Regional	Regional	Regional	Parts of California	California	California
Content Regulation								
RVP	9.0	7.8	-	-	-	7.8	7.0	7.0
Oxygen Content (% weight)	-	-	2.7 % min	2.0 % min	2.0 % min	1.8 % - 2.2 %	1.8 % - 2.2 %	1.8 % - 2.2 %
Benzene Content (% volume)	-	-	-	1.0 % max	1.0 % max	-	1.0 % max	0.8 % max
Sulfur Content (ppm)	-	-	-	-	-	-	40.0	20.0
Performance Standards								
NOx Reduction	-	-	-	0.0%	0.0%	-	-	-
VOC Reduction	-	-	-	15.0%	25.0%	-	-	-
TAP Reduction	-	-	-	15.0%	25.0%	-	-	-

*Note: Some regional programs have more strict regulations or slightly different control periods.
** Oxygenation requirement must be met during the winter while RVP requirement must be met during the summer.

Table 3: Regional Gasoline Content Regulations*

				Annual Control Period		
Area	**Content Regulation**	**Date Effective**	**Redesignation/ Opt-out Date**	**Seasonal Start Date**	**Seasonal End Date**	**Area Specific Notes**
Albuquerque, NM	Oxygenated	1-Nov-92	13-Jun-96	Nov. 1	Feb. 29	
Albuquerque, NM	Oxygenated	13-Jun-96		Nov. 1	Feb. 29	State Mandated Program, currently requires ethanol oxygenation
Anchorage, AK	Oxygenated	1-Nov-92		Nov. 1	Feb. 29	Anchorage program suspended until 1999/2000 winter season, currently requires ethanol oxygena
Baltimore, MD	Oxygenated	1-Nov-92	31-Oct-95	Nov. 1	Feb. 29	
Boston-Lawrence-Salem, MA	Oxygenated	1-Nov-92	30-Jan-96	Nov. 1	Feb. 29	
Chico, CA	Oxygenated	1-Nov-92	31-Mar-98	Oct. 1	Jan. 31	1.8%-2.2% weight oxygen consistent with CARB Phase I, II, III
Cleveland-Akron-Lorain, OH	Oxygenated	1-Nov-92	4-Feb-94	Nov. 1	Feb. 29	
Colorado Springs, CO	Oxygenated	1-Nov-92	10-Mar-97	Nov. 1	Feb. 29	
Colorado Springs, CO	Oxygenated	10-Mar-97	1-Jun-98	Nov. 1	Feb. 14	
Colorado Springs, CO	Oxygenated	1-Jun-98	22-Dec-00	Nov. 1	Feb. 7	oxygenation made a contingency measure by SIP revision.
Denver-Boulder, CO	Oxygenated	1-Nov-92	10-Mar-97	Nov. 1	Feb. 29	
Denver-Boulder, CO	Oxygenated	10-Mar-97	1-Jun-98	Nov. 1	Feb. 14	Average 3.1% weight oxygen
Denver-Boulder, CO	Oxygenated	1-Jun-98		Nov. 1	Feb. 7	Currently requires ethanol oxygenation
Duluth, MN	Oxygenated	1-Nov-92	14-Apr-94	Oct. 1	Jan. 31	Minnesota currenly implements a year-round state program
El Paso, TX	Oxygenated	1-Nov-92	12-Sep-94	Nov. 1	Feb. 29	
El Paso, TX	Oxygenated	12-Sep-94		Oct. 1	Mar. 31	Currently requires ethanol oxygenation
Fairbanks, AK	Oxygenated	1-Nov-92		Nov. 1	Feb. 29	note: Fairbanks program suspended; 10% volume ethanol
Fort Collins-Loveland, CO	Oxygenated	1-Nov-92	10-Mar-97	Nov. 1	Feb. 29	
Fort Collins-Loveland, CO	Oxygenated	10-Mar-97	1-Jun-98	Nov. 1	Feb. 14	
Fort Collins-Loveland, CO	Oxygenated	1-Jun-98		Nov. 1	Feb. 7	Average 3.1% weight oxygen, currently requires ethanol oxygenation
Fresno, CA	Oxygenated	1-Nov-92	31-Mar-98	Oct. 1	Jan. 31	1.8%-2.2% weight oxygen consistent with CARB Phase I, II, III
Grants Pass, OR	Oxygenated	1-Nov-92		Nov. 1	Feb. 29	
Greensboro-Winston-Salem-High Point, NC	Oxygenated	1-Nov-92	21-Sep-94	Nov. 1	Feb. 29	
Hartford, CT	Oxygenated	1-Nov-92	31-Oct-95	Nov. 1	Feb. 29	
Klamath County, OR	Oxygenated	1-Nov-92		Nov. 1	Feb. 29	Currently requires ethanol oxygenation
Las Vegas, NV	Oxygenated	1-Nov-92	11-Dec-98	Oct. 1	Feb. 29	
Las Vegas, NV	Oxygenated	11-Dec-98		Oct. 1	Mar. 31	3.5% weight oxygen, currently requires ethanol oxygenation
Los Angeles-Anaheim-Riverside, CA	Oxygenated	1-Nov-92		Oct. 1	Feb. 29	1.8%-2.2% weight oxygen consistent with CARB Phase I, II, III
Medford, OR	Oxygenated	1-Nov-92		Nov. 1	Feb. 29	Currently requires ethanol oxygenation
Memphis, TN	Oxygenated	1-Nov-92	26-Jul-94	Nov. 1	Feb. 29	
Minneapolis-St. Paul, MN	Oxygenated	1-Nov-92	21-Feb-96	Oct. 1	Jan. 31	Minnesota currenly implements a year-round state program
Minnesota	Oxygenated	21-Feb-96		Jan. 1	Dec. 31	State Mandated Program
Missoula, MT	Oxygenated	1-Nov-92		Nov. 1	Feb. 29	
Modesto, CA	Oxygenated	1-Nov-92	31-Mar-98	Oct. 1	Jan. 31	1.8%-2.2% weight oxygen consistent with CARB Phase I, II, III
New York City, CT	Oxygenated	1-Nov-92	25-Jul-96	Oct. 1	Apr. 30	
New York City, CT	Oxygenated	25-Jul-96	1-Dec-99	Nov. 1	Feb. 29	SIP revisions removed oxygenation as control measure
New York City, NJ	Oxygenated	1-Nov-92	25-Jul-96	Oct. 1	Apr. 30	
New York City, NJ	Oxygenated	25-Jul-96	22-Nov-99	Nov. 1	Feb. 29	SIP revisions removed oxygenation as control measure
New York City, NY	Oxygenated	1-Nov-92	12-Feb-96	Oct. 1	Apr. 30	
New York City, NY	Oxygenated	12-Feb-96	19-Apr-00	Nov. 1	Feb. 29	SIP revisions removed oxygenation as control measure
Ogden, UT	Oxygenated	8-Nov-94	9-Mar-01	Nov. 1	Feb. 29	Oxygenation made a contingency measure by SIP revision.
Philadelphia-Wilmington-Trenton, NJ	Oxygenated	1-Nov-92	30-Jan-96	Nov. 1	Feb. 29	
Philadelphia-Wilmington-Trenton, PA	Oxygenated	1-Nov-92	30-Jan-96	Nov. 1	Feb. 29	
Phoenix, AZ	Oxygenated	1-Nov-92		Oct. 1	Feb. 29	3.5% weight oxygen, currently requires ethanol oxygenation
Portland, OR	Oxygenated	1-Nov-92	2-Sep-97	Nov. 1	Feb. 29	
Portland, OR	Oxygenated	2-Sep-97		Nov. 1	Feb. 29	State Mandated Program
Provo-Orem, UT	Oxygenated	1-Nov-92		Nov. 1	Feb. 29	3.1% weight oxygen content, requested revision to 2.7%, currently requires ethanol oxygenation
Raleigh-Durham, NC	Oxygenated	1-Nov-92	2-Aug-95	Nov. 1	Feb. 29	
Reno, NV	Oxygenated	1-Nov-92		Oct. 1	Jan. 31	Currently requires ethanol oxygenation
Sacramento, CA	Oxygenated	1-Nov-92	31-Mar-98	Oct. 1	Jan. 31	1.8%-2.2% weight oxygen consistent with CARB Phase I, II, III
Salt Lake City, UT	Oxygenated	8-Nov-94	21-Jan-99	Nov. 1	Feb. 29	

San Diego, CA	Oxygenated	1-Nov-92	31-Mar-98	Nov. 1	Feb. 29	1.8%-2.2% weight oxygen consistent with CARB Phase I, II, III
San Francisco, CA	Oxygenated	1-Nov-92	31-Mar-98	Oct. 1	Jan. 31	1.8%-2.2% weight oxygen consistent with CARB Phase I, II, III
Seattle-Tacoma, WA	Oxygenated	1-Nov-92	11-Oct-96	Nov. 1	Feb. 29	Oxygenation made a contingency measure by SIP revision.
Spokane, WA	Oxygenated	1-Nov-92		Sep. 1	Feb. 29	3.5% oxygen, currently requires 100% ethanol
Stockton, CA	Oxygenated	1-Nov-92	31-Mar-98	Oct. 1	Jan. 31	1.8%-2.2% weight oxygen consistent with CARB Phase I, II, III
Syracuse, NY	Oxygenated	1-Nov-92	29-Sep-93	Nov. 1	Feb. 29	
Tuscon, AZ	Oxygenated	1-Jan-96		Oct. 1	Mar. 31	State Mandated Program, 1.8% Weight Oxygen
Vancouver, WA	Oxygenated	1-Nov-92	21-Oct-96	Nov. 1	Feb. 29	
Washington, DC-MD-VA	Oxygenated	1-Nov-92	30-Jan-96	Nov. 1	Feb. 29	
Albany, NY	RFG	1-Jan-95	7-Aug-96	Jan. 1	Dec. 31	Opt-In to Federal RFG, Stay of RFG program granted 1/11/95
Allentown-Bethlehem-Easton,NJ	RFG	1-Jan-95		Jan. 1	Dec. 31	Opt-In to Federal RFG
Atlantic City, NJ	RFG	1-Jan-95		Jan. 1	Dec. 31	Opt-In to Federal RFG
Baltimore, MD	RFG	1-Jan-95		Jan. 1	Dec. 31	
Boston-Lawrence-Worcester MSA, NH	RFG	1-Jan-95		Jan. 1	Dec. 31	Opt-In to Federal RFG
Buffalo, NY	RFG	1-Jan-95	7-Aug-96	Jan. 1	Dec. 31	Opt-In to Federal RFG, Stay of RFG program granted 1/11/95
Chicago-Gary-Lake County, IL-IN-W	RFG	1-Jan-95		Jan. 1	Dec. 31	
Cincinnati-Hamilton, KY	RFG	1-Jan-95		Jan. 1	Dec. 31	Opt-In to Federal RFG
Dallas-Fort Worth, TX	RFG	1-Jan-95		Jan. 1	Dec. 31	Opt-In to Federal RFG
Essex, NY	RFG	1-Jan-95		Jan. 1	Dec. 31	Opt-In to Federal RFG
Hancock & Waldo Co., ME	RFG	1-Jan-95	7-Aug-96	Jan. 1	Dec. 31	Opt-In to Federal RFG, Stay of RFG program granted 1/11/95
Hartford, CT	RFG	1-Jan-95		Jan. 1	Dec. 31	
Houston-Galveston-Brazoria, TX	RFG	1-Jan-95		Jan. 1	Dec. 31	
Jefferson Co., NY	RFG	1-Jan-95	7-Aug-96	Jan. 1	Dec. 31	Opt-In to Federal RFG, Stay of RFG program granted 1/11/95
Kent & Queen Anne's Co., MD	RFG	1-Jan-95		Jan. 1	Dec. 31	Opt-In to Federal RFG
Knox-Lincoln, ME	RFG	1-Jan-95	10-Mar-99	Jan. 1	Dec. 31	Opt-In to Federal RFG
Lewiston-Auburn, ME	RFG	1-Jan-95	10-Mar-99	Jan. 1	Dec. 31	Opt-In to Federal RFG
Los Angeles-Anaheim-Riverside, CA	RFG	1-Jan-95	1-Mar-96	Jan. 1	Dec. 31	Supplemented by CARB gasoline program beginning 3/1/96
Louisville, KY	RFG	1-Jan-95		Jan. 1	Dec. 31	Opt-In to Federal RFG
Massachusetts	RFG	1-Jan-95		Jan. 1	Dec. 31	Opt-In to Federal RFG
Milwaukee-Racine, WI	RFG	1-Jan-95		Jan. 1	Dec. 31	
New York City, NY-NJ-CT	RFG	1-Jan-95		Jan. 1	Dec. 31	
Norfolk, VA	RFG	1-Jan-95		Jan. 1	Dec. 31	Opt-In to Federal RFG
Philadelphia, PA-NJ-DE-MD	RFG	1-Jan-95		Jan. 1	Dec. 31	
Phoenix, AZ	RFG	10-Jun-98		Jan. 1	Dec. 31	State Mandated Program, Gasoline Must Meet RFG or CARB Phase II standards
Phoenix, AZ	RFG	3-Jul-97	10-Jun-98	Jan. 1	Dec. 31	Opt-In to Federal RFG
Portland, ME	RFG	1-Jan-95	10-Mar-99	Jan. 1	Dec. 31	Opt-In to Federal RFG
Rest of CT	RFG	1-Jan-95		Jan. 1	Dec. 31	Opt-In to Federal RFG
Rhode Island	RFG	1-Jan-95		Jan. 1	Dec. 31	Opt-In to Federal RFG
Richmond, VA	RFG	1-Jan-95		Jan. 1	Dec. 31	Opt-In to Federal RFG
Sacramento, CA	RFG	1-Jun-96	1-Mar-96	Jan. 1	Dec. 31	Supplemented by CARB gasoline program beginning 3/1/96
San Diego, CA	RFG	1-Jan-95	1-Mar-96	Jan. 1	Dec. 31	Supplemented by CARB gasoline program beginning 3/1/96
St. Louis, MO	RFG	1-Jun-99		Jan. 1	Dec. 31	Opt-In to Federal RFG
Sussex Co, DE	RFG	1-Jan-95		Jan. 1	Dec. 31	Opt-In to Federal RFG
Warren Co, NJ	RFG	1-Jan-95		Jan. 1	Dec. 31	Opt-In to Federal RFG
Washington, DC	RFG	1-Jan-95		Jan. 1	Dec. 31	Opt-In to Federal RFG
Washington, MD	RFG	1-Jan-95		Jan. 1	Dec. 31	Opt-In to Federal RFG
Washington, VA	RFG	1-Jan-95		Jan. 1	Dec. 31	Opt-In to Federal RFG
Western Pennsylvania	RFG	1-Jan-95	7-Aug-96	Jan. 1	Dec. 31	Opt-In to Federal RFG, Stay of RFG program granted 1/11/95
California	RFG/Carb Phase II	1-Mar-96		Jan. 1	Dec. 31	State Mandated Program

* For sake of brevity, this table omits regional low-RVP regulations. For a list of Low-RVP regional regulations updated as of April 2002, see http://www.epa.gov/otaq/volatility.htm.