Market Fragmentation and Gasoline Price Shocks: An Investigation

*By Barry Posner**

During the summers of 2000 and 2001 the price of gasoline reached historically high levels in many parts of the United States, most notably in the Midwest. The Clean Air Act Amendments of 1990 mandated the use of different types of gasoline in geographically proximate regions, which has led to the existence of 24 different "fuel islands" in the United States, areas which use different gasoline formulations than the surrounding areas. Many feel this market fragmentation has been a cause of the price spikes.

I analyzed price data from 36 U.S. gasoline markets, and calculated the portion of the price added by the refining, transportation and marketing functions. I compared the price in each market, and in each week, to the price in the same market in the four previous years and delineated the percentage increase in markups. This was done for the years 1998-2001. This markup percentage was used to define whether or not a price shock existed. For each market, I calculated the population of the "island" in which the market was contained.

I examined the geographical extent of each price shock, and regressed the number of shocks versus the population of each island. It was hypothesized that markets in small islands would be more prone to shocks than markets in large islands. I discovered that no significant relationship between island size and number of shocks existed using the present data set. Indeed, a weak positive correlation between number of shocks and market size existed.

Shocks were shown to be primarily regional, and typically affected markets of all sizes and of all types of gasoline in a given region. No shocks existed in 1998 or 1999, but a large number did in 2000 and 2001. This leads me to hypothesize that ever-tighter production capacity constraints combined with stochastic occurrences of regional pipeline and refinery outages may be the root cause of the price shocks. I shall address this theory in future research.

Introduction

In the past two summers, there was great outcry in the Midwest concerning the price of gasoline. The price spiked up to over $2.00 per gallon in some areas - unprecedented high nominal prices. Congressional investigations were undertaken, and the results loudly trumpeted that the problem was with "boutique fuels," special blends of gasoline specific to each market. Legislation was thought to have created a balkanization of the gasoline market, and exacerbated supply crunches that occurred in the high driving season. This idea has an intuitive appeal: when the gasoline market was largely homogeneous, price differences in geographically proximate regions presented arbitrage opportunities that were seized by local distributors, thus quickly correcting regional market imbalances. Given that presently the gasoline in a certain city may not be the same as that in surrounding counties, it is more difficult for regional distributors to move to take advantage of these opportunities, and thus the arbitrage opportunities will have to be larger in order to attract movement of supply, and will take longer to correct. Therefore, local suppliers will be able to charge a premium that represents the transportation cost between the specified gasoline "island" and the closest similar "island" or producer.

This paper will examine the hypothesis that such balkanization was correlated with the price shocks observed in the summers of 2000 and 2001. I will start by listing the pertinent details of cleaner burning gasoline laws. I will define the markup component of prices - that is, the price after the cost of crude has been taken out, and before taxes added in - the net value added by the refining, distribution and retail functions of the gasoline market, and compare this markup during the past two summers with markups in 1998 and 1999. I will then define the market conditions that constitute a "price shock", and examine whether the size of the isolated gasoline "island" is correlated with the presence and persistence of price shocks.

Cleaner-Burning Gasoline Laws

As a reaction to the chronic incidences of poor air quality in many American urban areas, several pieces of legislation, both federal and state, have been passed. The most important laws governing mobile source (automobile) pollution were introduced in the 1990 Amendments to the Clean Air Act (CAA)(1). Three main clean gasoline programs exist.

Low RVP gasoline

The volatility of gasoline refers to its tendency to flash from a liquid to gaseous form. The Reid Vapor Pressure (RVP) is a measure of volatility. The lower the RVP, typically measured in pounds per square inch (psi), the less prone a gasoline is to flashing. Vaporized gasoline components react with oxides of nitrogen in the presence of sunlight to form ozone and photochemical oxidants (smog precursors). Volatility increases as temperature rises, so the U.S. Environmental Protection Agency (EPA) mandated the introduction of low RVP summer gasoline. The first phase of low RVP gasoline predates the CAA, having been introduced by the EPA in 1989 (2). Phase 2 RVP requirements were issued in 1990, revised to conform to the CAA in 1991 (3), and took effect in May 1992. Before introduction of these regulations, gasoline typically had an RVP of 11.5 psi. Under Phase II of the summer volatility program, the RVP is now 9.0 in the Northern United States, and all ozone attainment areas, and 7.8 in Southern ozone nonattainment areas. A total of 57 federally defined areas are currently in some state of ozone non-attainment, a drop from the count of 101 observed in 1989 (4).

RVP reduction is typically performed by reducing the amount of butanes in gasoline. Butanes (four-carbon molecules) are desirable for their low cost and high blending octane number, but as light ends they are very volatile. Butanes have to be replaced by higher-value high-octane components, thus increasing the cost of gasoline. The effects of the summer volatility program on refinery operation and gasoline costs are detailed by Lidderdale (5). Low RVP gasolines are mandated from June 1 to September 15.

Oxygenated Gasoline

Carbon monoxide (CO) is a colorless, odorless gas that

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(1) See references at end of text.

is very stable in the lower atmosphere, having a lifespan of two to four months (6). High ground-level concentrations exist in cold climates due to the inefficient operation of cold automobile engines coupled with thermal inversions, which trap the air at ground-level. CO is a poisonous inhalant that causes impairment and discomfort at concentrations as low as 30 ppm, and is fatal at 750 ppm. One way to combat CO formation is through the use of oxygen-containing gasolines. The oxygen in the fuel promotes more complete combustion, and reduction of tailpipe concentrations of CO. Section 211(m) of the CAA requires that gasoline containing at least 2.7 percent oxygen by weight is to be used in the wintertime in those areas of the county that exceed the CO National Ambient Air Quality Standard (NAAQS). At implementation of the winter oxyfuels program on November 1, 1992, 39 regions were designated as non-attainment areas. This number has since shrunk to 18, as of July 1, 1999, with seven more areas having filed redesignation plans. Depending upon the region, the winter oxyfuels program is typically in effect from October 1 or November 1 to February 29. Further details of the winter oxyfuels program can be found at the Energy Information Administration website (7)

Reformulated Gasoline

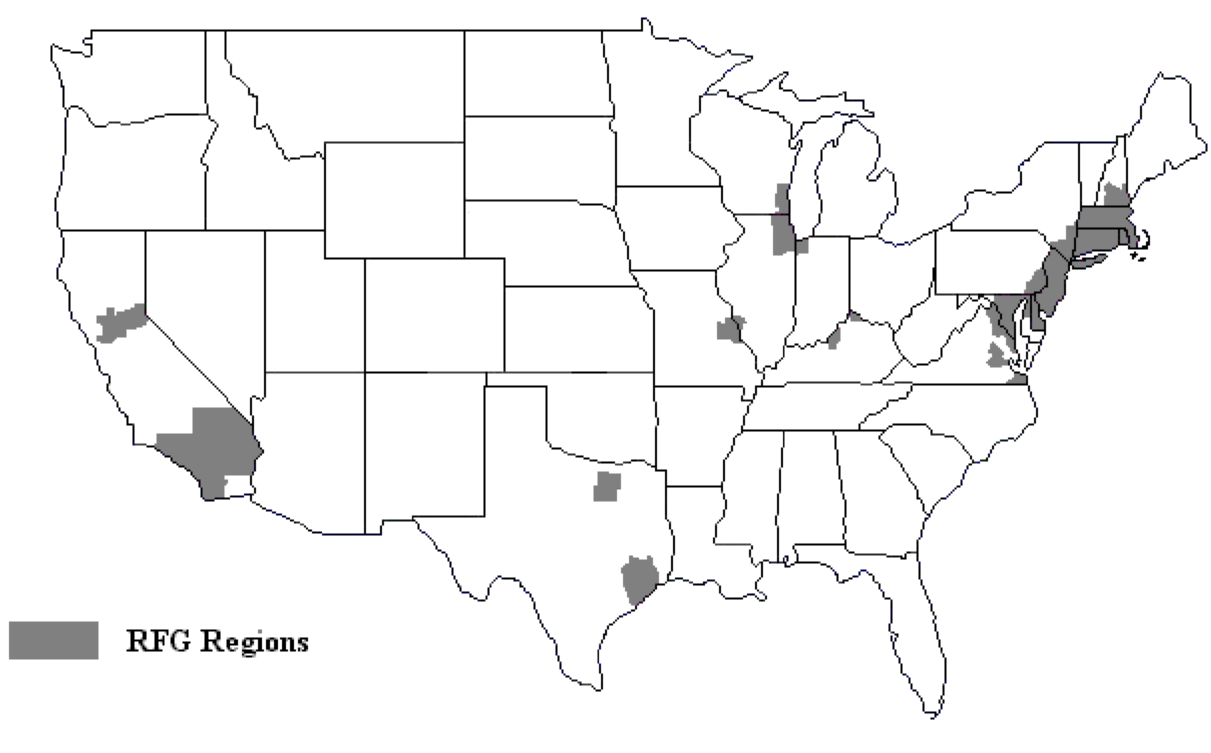
Section107(d) of the CAA requires all areas of the country to be classified according to non-attainment of the NAAQS for ozone. The classifications were marginal, moderate, serious, severe or extreme. One area, Los Angeles, was classified as extreme, and eight more were considered severe: Baltimore, Chicago, Hartford, Houston, Milwaukee, New York City, Philadelphia, and San Diego. In 1995 Sacramento, California was reclassified from serious to severe. These regions were mandated to adopt use of reformulated gasoline (RFG). Several other regions opted in to the RFG program, including Phoenix (which has since switched to more stringent California standard gasoline), Louisville, St. Louis, Dallas-Fort Worth, and almost all of the Eastern Seaboard from Massachusetts to mid-Virginia. These areas are shown in Figure 1.

RFG is manufactured according to a complex set of technical specifications designed to lower the tailpipe emissions of volatile organic compounds, oxides of nitrogen, CO, and other toxic pollutants, by significant amounts - over 20% below 1990 levels.

RFG specifications were introduced in two phases. Phase I ran from January 1, 1995 to December 31, 1999. The more stringent Phase II specifications took effect January 1, 2000. The detailed specifications can be found in the Code of Federal Regulations (8).

Specific requirements call for a reduction in benzene, a mandated oxygen content of 2.0% by weight, and low RVP requirements for the summer. Thus, the RFG program subsumes the oxygenate and low volatility requirements into a more rigorous set of requirements. For the refiner, this creates a much more stringently defined product. Gasoline will increase in cost due to the displacement of benzene, a common and cheap source of octane, of butane, as mentioned above, the addition of oxygenate, and the requirement for lower-polluting fuel in general. This entails more extensive preparation and modification of the crude feed, with ensuing increases in energy input and capital expenditure. More details of the RFG program can be found at the EIA website (9). It was anticipated that the implementation of the RFG provisions of the CAA would have economic impacts on gasoline consumers. Two cost issues were addressed by the EPA. First, a broad-based analysis of program implementation costs was undertaken (10), addressing the expected price rise from an industry cost perspective. Second, a study of the

Figure 1
Federal Reformulated Gasoline Areas



efficiency losses due to increased fuel consumption was performed (11). However, a third avenue of negative cost effect appears to have been unanticipated: exposure of the consumer to a cost increase due to balkanization of gasoline markets.

Midwest Price Spikes and RFG

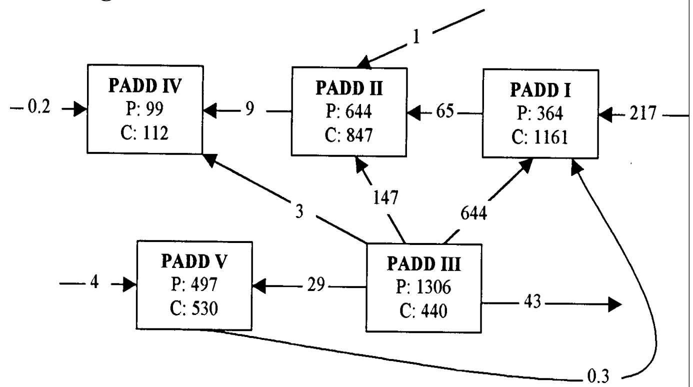
The summers of 2000 and 2001 saw drastic spikes in the prices of gasoline, most noticeably in the Chicago and Milwaukee areas, where retail prices reached as high as $2.75 per gallon. This attracted the attention of politicians and regulators. Both the Congressional Research Office (12) and the Federal Trade Commission (13) published reports about the price spikes. Neither report found any evidence of illegal behavior, but both mentioned the prevalence of boutique gasolines as a contributing factor: with the various combinations of winter oxygenate, summer volatility and RFG requirements, it has been estimated that there are as many as 38 mandated varieties of gasoline for sale at any time in the United States. This is a drastic change from the pre-CAA days, when gasoline was largely a homogeneous commodity, with variations for altitude and seasonality being the only differentiating factors. This meant that a shortage in one area could be easily addressed by transferring supply from a geographically proximate area. Stated in economic terms, there were low transaction costs to moving gasoline. The new laws have changed this. For example, if a shortage of reformulated gasoline crops up in Louisville, it is not possible to simply ship in gasoline from rural Kentucky or Cincinnati or Memphis, which use conventional gasoline, but instead supplies must come from St Louis or Chicago, and those markets may be encountering similar supply crunches. Therefore, the supply shortfall must be remedied by custom-ordered production increases in refining centers, such as the Gulf Coast, which must then be shipped long distances via pipeline and barge. Transaction costs have been greatly increased, as have transfer times, and thus it is hypothesized that shocks will persist for longer periods, and will be more severe. The EPA has issued two reports about boutique fuels, addressing blending and feedstock concerns, and transitional difficulties (14, 15). These reports do not mention market fragmentation.

The Regional Structure of the U.S. Gasoline Market

Figure 2 displays the production, consumption and inter-regional trade in gasoline in the USA. The five blocks labeled PADD I through V refer to the Petroleum Administration for Defense Districts, as defined by the Department of Energy for analysis purposes (and distribution in the case of national emergencies). The "P" term inside each block refers to gasoline produced in that PADD, and the "C" term refers to consumption in that region. The numbers overlying the arrows define the net flows between PAD districts and net imports from other countries. All amounts are in millions of barrels. Data are for the year 2000, and were downloaded from the 2001 Petroleum Supply Annual (16), published by the EIA.

As can be seen, PADD III (Gulf Coast) is the prime refining region in the country, supplying large shares of the Midwest and East Coast markets. PADD I imports about 15% of its consumption from overseas, and supplies PADD II with about 8% of its consumption. PADD V (the West Coast) is

Figure 2
Regional Structure of the U.S. Gasoline Market



remote from the rest of the system: there are very few linkages between this district and the rest of the country, either by pipeline or other mode of transport. Price behavior in PADD V is largely independent of that in the other districts, and as such it is typically treated as a separate country for purposes of analysis. This practice has been adopted for this report: henceforth, only market behavior in PADD's I-IV will be examined.

The Economic Model

Classical microeconomic theory tells us that in a perfect market, a large number of suppliers will behave as price-takers, and will drive prices down to the long-run average cost (LRAC). As markets become smaller, and the number of suppliers decreases, suppliers begin to develop market power, or the ability to charge prices above LRAC. The CAA gasoline provisions have fractured the U.S. gasoline market from one largely homogeneous market to several smaller, differentiated ones. At the same time, the number of refiners in the United States is shrinking. According to the above theory, these conditions should combine to increase price above LRAC. How can market power be modeled in this context?

The price of gasoline is strongly affected by the price of crude oil. A quick analysis of the spot market prices of crude oil (17) and regular-grade conventional gasoline (18) reveals that crude typically represents about 70-80% of the refiner's cost of gasoline, and is by far the most price-volatile of all inputs. A simple regression of gasoline spot price on crude spot price (from June 1986 through December 2001) reveals a relationship of the form: Gasoline Price = 4.2 + 1.12 x Crude Price, where prices are in cents per gallon. This equation has an R^2 value of 0.86, reflecting a high degree of correlation between the two prices. It is more revealing to look at the difference between crude prices and gasoline prices. The price of crude oil and the taxes levied on gasoline do not change with demand, and thus are assumed to be exogenous. We wish to examine the endogenous part of the cost of gasoline - the price with crude costs and taxes excluded.

I refer to this difference as the gasoline markup, which is the main focus of this study. The markup must cover a wide variety of costs. The *Oil and Gas Journal* (OGJ) tracks refiner and retailer margins, and Spletter and Starr, in the OGJ (19) have identified the following cost components:

Refiner costs: crude oil transportation (FOB location to refinery); crude oil inventory and storage; chemicals and catalysts; blending component purchase and storage costs; energy inputs (natural gas, electricity); labor costs; marketing costs; corporate taxes; refiner profit.

Distributor costs: transportation (refinery to terminal); terminal operations expenses (labor, energy, rent, income taxes); inventory and storage costs; additive costs (methanol); blending costs; distributor profit.

Retail costs: transportation (terminal to retailer); storage; labor; energy costs; rent; maintenance; retailer profit.

Clearly, many costs must be borne by the margin between crude cost and tax-out retail price. Of the above components, many are fixed in the short run: there are no significant short run changes in chemical and catalyst prices, equipment costs, rents or wages. Energy and transportation costs can vary according to the price of crude, but it is hypothesized that the swings in the markup are created by firms with market power exercising that asset: the markup goes up as demand increases and supply decreases.

Gasoline has a low short-run price elasticity of demand. Several authors, including Archibald and Gillingham (20), Puller and Greening (21), Molly (22), Kayser (23) and Rao (24) have shown that the short run elasticity is between -0.01 and -0.08. Assuming a median value of -0.04, this means that a 10% increase in the price of gasoline will result in reduced demand of 0.4%, or that a doubling of price will lead to a consumption drop of only 4%. This fact is well established and guides refiner and retailer behavior: they know that price increases related to demand increases will not invalidate those demand increases: a stable equilibrium arises at a higher priced supply-demand intersection.

It is hypothesized that the price of gasoline, net of taxes and crude prices, should be correlated to market power, and market power will be proxied by the size of a given gasoline market. This study shall attempt to define whether price shocks, which are assumed to be exercises of market power, are correlated with the size of the market. That is, has the balkanization of the national gasoline market led to a meaningful increase in market power?

The Econometric Model

Markets and Periods Studied

Weekly tax-out price data for 36 U.S. markets were recorded from the *Oil and Gas Journal* (25) for the eight-year period spanning 1994-2001. The markets are listed in Table 1, sorted by PAD District. These data are collected once per week by OGJ staff, and reflect an average price for regular unleaded gasoline over several urban and suburban gas stations in each market.

The Dependent Variable

Gasoline prices exhibit hysteresis when measured against crude prices. That is, the price of gasoline rises on news of crude price rises quicker than it falls in response to crude price drops. This is known as "downward sticky" behavior, and has been examined by, among others, Borenstein, et al. (26). It has been observed that crude price increases are almost instantaneously passed through to gasoline prices, but crude price drops typically lag by 4-8 weeks. Retailers are forward looking: when crude goes up, the retailer can expect to pay a higher price to replace his existing stock, and thus will raise the price of his current stock to his expected next purchase price. However, when crude prices drop the retailer is in possession of gasoline that was purchased at a higher price than that which will be available in the near future. Thus, the retailer keeps his price high enough to recoup costs of his existing inventory, and will only drop prices when new, lower cost inventory is obtained. Prices begin to come down when some retailer in a market exhausts his inventory of high-price gasoline and obtains a new, lower-cost shipment. Thus, gasoline prices are typically correlated to the maximum price of crude oil over some lagged period.

Table 1: Markets of Study

PADD I	PADD II	PADD III	PADD IV
Atlanta	Chicago	Albuquerque	Cheyenne
Baltimore	Cleveland	Birmingham	Denver
Boston	Des Moines	Dallas-Fort Worth	Salt Lake
Buffalo	Detroit	Houston	
Miami	Indianapolis	Little Rock	
Newark	Kansas City	New Orleans	
New York	Louisville	San Antonio	
Norfolk	Memphis		
Philadelphia	Milwaukee		
Pittsburgh	Minneapolis		
Washington, DC	Oklahoma City		
	Omaha		
	St. Louis		
	Tulsa		
	Wichita		

To take the hysteresis effect into consideration markup was modeled as the difference between current gasoline prices and the maximum cost of crude in the past six weeks. Symbolically,

$$MU_{i,t} = PG_{i,t} - \text{Max}\ \{PC_{t-5}, PC_{t-4}, PC_{t-3}, PC_{t-2}, PC_{t-1}, PC_t\} \quad \text{(i)}$$

where $MU_{i,t}$ is the markup in market i at time t, in cents per gallon,

PC_t is the Cushing, OK spot price of crude at time t, in cents per gallon,

$PG_{i,t}$ is the tax-out retail price of gasoline in market i at time t, in cents per gallon.

The markups were then inflation-adjusted using the monthly Bureau of Labor Statistics Transportation Cost Index (27), with January 1994 as the base period. They were sorted into annual bins for each of the 36 markets, and then a "Shock Index" for each week in the years 1998-2001 was calculated. This is defined as follows:

$$S_{i,w,y} = 100\frac{4 \times MU_{i,w,y}}{\sum_{j=1}^{4} MU_{i,w,(y-j)}} - 100 \quad \text{(ii)}$$

where $S_{i,w,y}$ = "shock index" in market i, week w and year y, in percent

$MU_{i,w,(y-j)}$ = markup in market i, week w and year y, cents per gallon

Thus, the shock index is simply this year's markup divided by the average markup in the same market, and same week of the year, over the previous four years. A market was assumed to be under gasoline price shock conditions if the value of "S" was greater than 50%, that is, if the gasoline markup was more than 50% higher than the four-year average price in the given period. Clearly, this is an arbitrary definition, but I assumed that if the combined real take of the refiner, transporter and merchant was over one and a half times his expected take based on the previous four years, it can be safely assumed that market power is being exercised.

The number of weekly occurrences of shocks were then tabulated and summed over the four-year period of study for the 36 markets in question. This sum is the dependent variable in this model: the number of weeks under shock conditions.

The Independent Variable

The size of each individual market is the independent variable in this model. Ideally, sales for each region would be used as the variable, but sales data by county, and hence by region, are unavailable in the public domain. The greatest degree of disaggregation reported by the EIA is by state (spatially) and by month (temporally). For this reason, I decided to use population as a proxy for sales, primarily because population data to match the exact boundaries of the different gasoline regions are available. The one nuance that is lost by this method is that different regions have different sales patterns, for example, farm-intensive regions have much greater seasonal variations, as do cold-weather regions. Year 2000 population data for each county in the United States were obtained from the U.S. Census Bureau (28). For each county in PAD Districts I-IV, the type of gasoline sold in the summer was listed. The different types of clean gasoline, reformulated, low RVP or oxygenated, were then arranged into contiguous regions, with each region forming an "island". The "sea" surrounding these islands consists of all of the areas selling conventional gasoline. The population was summed over each county within each contiguous region. This population of the region in which each of the 36 study markets falls into, measured in million of people, is the independent variable. Thus, the regression estimated in this study is:

$$\Sigma S_i = \beta_0 + \beta_1(P_i) + \varepsilon_I \qquad \text{(iii)}$$

Where ΣS_i = number of weeks under shock conditions in market i

P_i = Year 2000 population of region in which market i is contained

β_0, β_1 = empirically derived parameters

Data Conditioning Results

Price Shock Data

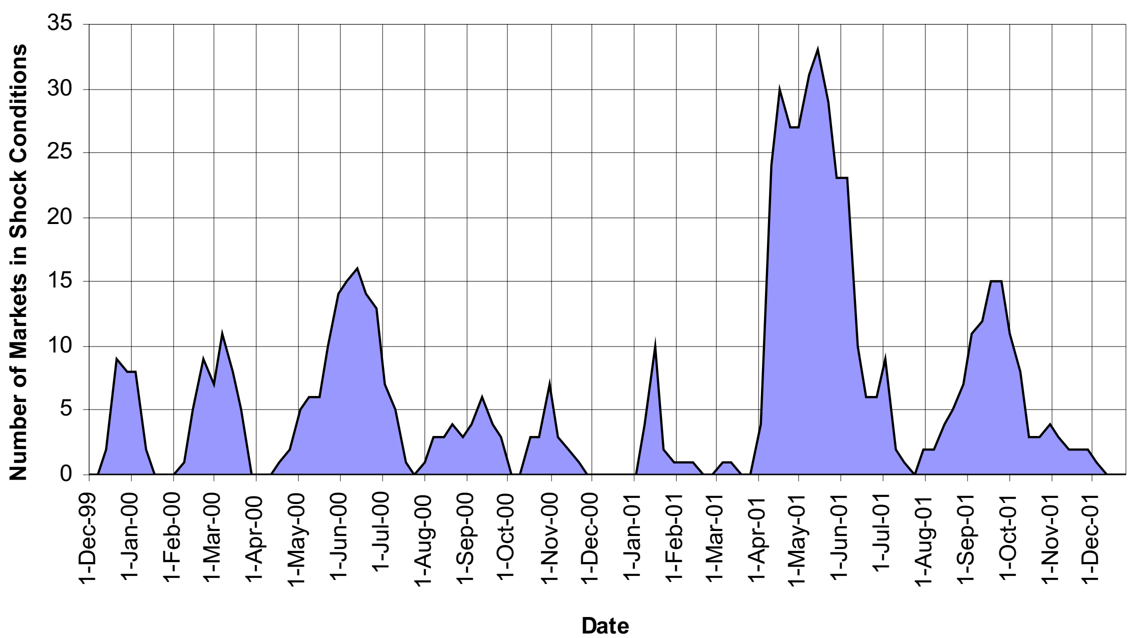
The sales price data were manipulated as described above, and the total number of weeks in the four-year period under shock conditions were calculated. The results are shown in Table 2. The number of markets under shock conditions for each week of this study is shown in Figure 3. There were no meaningful shocks in 1998 or through most of 1999 - any disturbances were limited to one or two markets, and were corrected in one or two weeks. Figure 3 begins at December 1999 and runs through December 2001. As can be seen, there are eight distinct "peaks", each corresponding to a shock that affected at least six markets and lasted for at least four weeks. These shocks will henceforth be labeled as shocks 1 through 8, and each will be described individually. The characteristics of each shock are detailed in Table 3.

Shock 1 was broadly dispersed, and was observed in Cleveland, Detroit, Kansas City, Oklahoma City, Wichita, Albuquerque, New Orleans, Cheyenne and Salt Lake City. This shock is hard to quantify: it is not concentrated in any particular region, and is broadly dispersed.

Shock 2 is confined to the central and southern regions of PADD I and PADD II. It does not reach as far north as Chicago or as far as Texas, but is fairly continuous over a "heartland" belt stretching from Atlanta to Wichita.

Shock 3 was the first shock to generate widespread attention. This took in almost all of PADD II, and existed in a less durable fashion through most of PADD III and the southern regions of PADD I. It did not reach the Northeast or PADD IV. While the price effect was publicized mostly in Chicago, the percent increase over normal markups was greatest in the small cities of the Corn Belt, sometimes reaching double previous levels.

Figure 3
Gasoline Price Shock Occurrences



Shock 4 was a small follow-on to shock 3. It occurred primarily in the central regions of PADD III and Atlanta. Oddly it was also felt in Philadelphia, but no other Northeast city.

Table 2
Number of Weeks Under Gasoline Price Shock Conditions

Market	PADD	Number of "Shock" Weeks
Atlanta	I	51
Baltimore	I	15
Boston	I	14
Buffalo	I	9
Miami	I	6
Newark	I	18
New York	I	7
Norfolk	I	9
Philadelphia	I	27
Pittsburgh	I	5
Washington, DC	I	8
Chicago	II	19
Cleveland	II	33
Des Moines	II	34
Detroit	II	36
Indianapolis	II	17
Kansas City	II	19
Louisville	II	15
Memphis	II	6
Milwaukee	II	21
Minneapolis-St. Paul	II	23
Oklahoma City	II	37
Omaha	II	27
St. Louis	II	20
Tulsa	II	27
Wichita	II	23
Albuquerque	III	5
Birmingham	III	15
Dallas-Fort Worth	III	20
Houston	III	38
Little Rock	III	24
New Orleans	III	7
San Antonio	III	2
Cheyenne	IV	10
Denver	IV	33
Salt Lake City	IV	4

Shock 5 was widely dispersed, like shock 1. It mildly affected markets as diverse as Boston and Wichita, but persisted for over a month in Dallas and Houston.

Shock 6 was another small mid-winter event. It occurred in cold climates, ranging from Buffalo to Cheyenne. It only persisted for any length of time in Des Moines.

Shock 7 was the successor to the big shock of 2000. This event was felt in every region, and every city except New Orleans and Salt Lake City (and was barely visible in San Antonio and Albuquerque). It was also accompanied by the most severe price rises in many cities, and persisted for months in the Northeast and Central areas.

Shock 8 was basically a continuation of shock 7 centered mostly in the Northeast and northern Midwest, but it also spread as far southwest as Tulsa.

Gasoline Island Definition

The results of the calculation of region definition are shown in Table 4. As can be seen from Table 4, regions 1 to 24 comprise the "islands" in the sea that is defined by region 25.

Table 3
Details of Gasoline Price Shocks

Shock No.	Onset	Length (weeks)	Peak Spread (markets)
1	December 1999	5	9
2	February 2000	7	11
3	April 2000	14	16
4	August 2000	9	6
5	October 2000	6	7
6	January 2001	6	10
7	April 2001	16	33
8	August 2001	19	15

Table 4
Gasoline Regions

No.	Region Name	Study Markets in Region	Fuel Type	Population
1	Atlanta	Atlanta	Low RVP	3,634,702
2	Birmingham	Birmingham	Low RVP	818,021
3	Charlotte	None	Low RVP	876,988
4	Chicago	Chicago, Milwaukee	RFG	10,528,712
5	Covington	None	RFG	324,273
6	Detroit	Detroit	Low RVP	4,879,448
7	Dallas	Dallas-Fort Worth	RFG	4,478,706
8	Houston	Houston	RFG	4,674,814
9	Jacksonville	None	Low RVP	781,055
10	Kansas City	Kansas City	Low RVP	1,526,544
11	Louisville	Louisville	RFG	735,608
12	Maine	None	Low RVP	1,274,915
13	Memphis	Memphis	Low RVP	905,755
14	Miami	Miami	Low RVP	5,034,956
15	Minnesota	Minneapolis-St. Paul	Oxygenated	4,919,436
16	Nashville	None	Low RVP	1,076,684
17	New Orleans	New Orleans	Low RVP	2,460,800
18	Northeast	Boston, New York, Newark, Philadelphia, Baltimore, Washington	RFG	45,250,379
19	Pittsburgh	Pittsburgh	Low RVP	2,461,874
20	Central NC	None	Low RVP	1,779,414
21	Salt Lake	Salt Lake City	Low RVP	1,336,938
22	St. Louis	St. Louis	RFG	2,505,842
23	Tampa	None	Low RVP	1,923,843
24	Norfolk	Norfolk	RFG	1,513,949
25	Rest of PADD I- IV	Buffalo, Cleveland, Des Moines, Indianapolis, Oklahoma City, Omaha, Tulsa, Wichita, Little Rock, San Antonio, Cheyenne, Albuquerque, Denver	Conventional	123,562,238

Regression Results

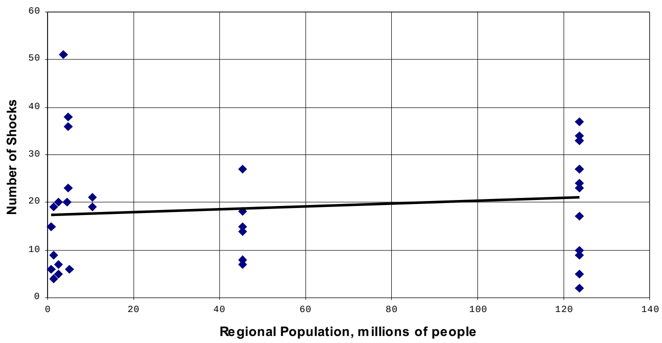
Figure 4 shows the sums of shocks per market (as defined in Table 2) plotted versus the population of each market's home region population, as well as the best-fit line. The shocks were regressed against the population, with the following results (standard error in parentheses):

$$\Sigma S_i = \underset{(2.78)}{17.36} + \underset{(0.036)}{0.030}\ P_i$$

The t-statistic the slope parameter is 0.832, and the R^2 for this regression is 0.020.

If one expects that arbitrage opportunities will persist mostly in small markets, then one would expect a larger number of shocks in these markets, and we would thus expect the regression to have a negative slope. In other words, a best-fit line will slope downwards. The hypothesis is formally framed as follows:

Figure 4
Number of Shocks versus Regional Population, All Markets



Null hypothesis: H_o: $\beta_1 < 0$
Alternate hypothesis: H_a: $\beta_1 \geq 0$

Given examination of the t-statistic of β_1, as well as the extremely low R^2 value, and the positive slope of best-fit line in Figure 4, we can safely reject the null hypothesis, and state that given the evidence at hand, there is no reason to believe that the slope of the best fit line is significantly different to zero, and thus no structural relationship between market size and number of shocks exists in the current data samples.

We may choose to look at only the data for small-markets, that is, reject the data for the "Rest of PADD I-IV" and the Northeast, and look at the relationship in smaller markets. These data, and the best-fit line, are plotted in Figure 5. The results for this regression are as follows:

$$\Sigma S_i = \underset{(5.05)}{13.76} + \underset{(1.073)}{1.295}\ P_i$$

The t-statistic the slope parameter is 1.21, and the R^2 for this regression is 0.089. The t-statistic and R^2 have improved, but not to levels that could be considered significant, and the slope is still positive.

Analysis

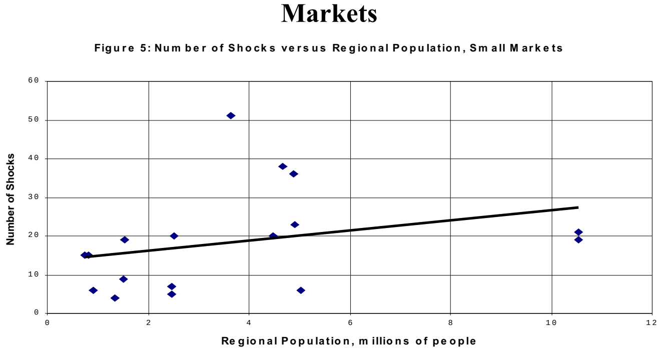
Based on both econometric estimation and descriptive analysis of the price shocks, it is clear that market size is not a determining factor, at least from the perspective of arbitrage opportunities being more prevalent in small markets. The large shocks were regional in nature, and equally affected both large and small markets and both reformulated and conventional gasoline markets. The largest shocks affected more than one PAD District, and this is not surprising given the inter-regional dependencies shown in Figure 2.

A refinery outage in PADD III will have effects on PADD I, II and III, with PADD IV being more immune to shocks than the other regions. A production interruption that is native to PADD I or II may only affect the home region, but if the shortfall is significant enough then demand-driven price pressure may extend back to PADD III. What is obvious is that price shocks seldom affect any region in isolation. This explains why the higher arbitrage theorem may be invalid: when an upset occurs in a market, then to seize this arbitrage opportunity an entrepreneur will want to ship product from the closest possible "same-product" market. However, if the shock has spread to that market, then no arbitrage opportunity exists, and one has to go further afield to find an unaffected market to capitalize upon. The further away the unaffected market, then the greater the transportation cost, and the longer the time required to deliver the product. Both of those factors will exacerbate the size and duration of shocks in the affected markets.

We must also consider that the possibility that the larger the affected market, the larger the arbitrage opportunity, and thus the larger the shock. This is in direct contradiction to the hypothesis upon which this paper is based. However, once again the largest markets, in the Northeast and the upper Midwest, are the furthest away from the refining hub in the Gulf, so it takes longer to get relief product into those markets, and a greater volume of product is required to satisfy demand in those markets.

One unexplained observation is the fact that minimal shocks were observed in 1998 and 1999, but many severe ones were in 2000 and 2001. On the surface, little is different between these two periods: Low-RVP gasoline requirements were the same in all markets, and reformulated gasolines were required in both periods. There was a shift from Phase I to Phase II RFG on January 1, 2000, but this did not effect market differentiation in any way. One explanation, contained in the FTC Investigation (13) is that unexpected pipeline and refinery shutdowns, coupled with capacity constraints, caused regional upsets which rapidly propagated through the entire PADD II region in 2000 and the entire nation in 2001.

Figure 5
Number of Shocks versus Regional Population, Small Markets



Conclusions and Recommendations for Further Work

As discussed above, the model as specified does a poor job of demonstrating that regional population is a significant and meaningful predictor of the presence of gasoline price shocks. The next stage in the development of this model is the incorporation of capacity constraint effects. These appear to be strongly non-linear, and as such an appropriate non-linear specification must be devised. Additionally, a better measure of market size may be helpful. Using a static value of population does little to capture seasonal shifts in demand that may have an effect on price, and differences in regional consumption patterns are not elaborated.

A better definition of market power can be established by looking at the links between specific refineries and markets: how many refineries serve each market, how close to peak market demand is the capacity of those refineries, and how easy are alternative supplies to find in the presence of unexpected refinery or pipeline outages?

I have also largely overlooked competition in the retail sector in this report. One might be better able to model the price response of this sector given more information about the number of major oil companies in each market, the number of independent retailers, and the ease of availability of branded gasolines in the various markets.

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Applications should be accompanied by a brief explanation as to why the applicant considers him/her self worthy of the award together with a letter of recommendation from the student's advisor (in confidence if desired) – two separate letters are needed. Applications will close 21 October 2002 and awards will be announced by 29 November 2002.

Applications for scholarships should be mailed or emailed to:

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