Market Structure and Price Adjustment in the U.S. wholesale gasoline markets*

Olusegun Oladunjoye
Department of Economics
University of Guelph,
Guelph, Ontario, Canada
N1G 2W1

E-mail: ooladunj@uoguelph.ca
Phone: 519-341-9126
Fax: 519-763-8497

June 29, 2006

Abstract

The perennial issue of sticky prices in the U.S. gasoline market is re-examined with a focus on the effect of market structure as measured by the increased market concentration as a result of the major mergers, acquisitions and joint ventures (hereafter mergers) and refining capacity utilization in the U.S. gasoline markets. Using daily data I test for structural break in the pattern of price adjustments and used an asymmetric error correction model to investigate market structure effects on speed of price adjustment based on the notion that increased market concentration and refinery capacity utilization leads to downward price stickiness as the industry becomes less responsive to negative crude price shocks.

I find that market concentration and refinery capacity utilization affects the asymmetric speed of price adjustment in the response of wholesale gasoline price changes to crude price shocks in the Gulf Coast and New York markets. This result is interesting because it isolates and tries to identify part of the asymmetric speed of price adjustments due to market structure effects as represented by capacity utilization and market concentration. Also, the notion that the speed of adjustment lead to immediate pass-through as markets becomes concentrated was refuted in the Los Angeles market. Overall, the results suggest that market structure affects the speed of price adjustment in the Gulf Coast and New York wholesale gasoline spot markets but not significant enough to warrant policy intervention.

Keywords: error correction model, gasoline price adjustment, symmetry

JEL classification: L11, Q40

*Thanks to Assoc. Prof. Henry Thille and Prof. Thanasis Stengos for their supervision and helpful comments. This paper will be included in my PhD dissertation, currently in progress.

1. Introduction

Through various refining activities, crude oil is transformed into many useful products and prominent among them is gasoline. In the United States of America (hereafter U.S.), refined petroleum products are stored in tanks at the refinery or moved to other distribution facilities, called wholesale terminals by either truck, rail, through pipelines or barges. Refined gasoline is bought by jobbers[1] who transport it from refiners and either distribute to gasoline retailers or sell directly to the public through their own retail stations. Thus, the economics of gasoline pricing depends on various factors ranging from the cost of the upstream[2] input, inventory management, market concentration, firms pricing policies, profit maximization objectives and refinery operation cost to the market price a refiner can obtain for the product.

The price of gasoline is the most visible energy statistic to consumers and many consumers are concerned about gasoline price changes. This is because gasoline prices are visible, volatile and directly impact economic activities. Persistent increases in gasoline prices along with increases in other products can push an economy into recession while threatening an economy in recovery. Downward price stickiness in gasoline prices create a burden on people with fixed incomes who depend on cars for their basic needs, and result in large wealth transfers from consumers to a few companies that refine and market gasoline. This has led to numerous complaints by consumers and politicians that oil companies may be engaging in anti-competitive practices which leads to the companies' faster response to crude oil price increase in comparison to their response to a decrease in crude oil price. Based on this observation and complaints, there have been various econometric analyses and government inquiries to determine the existence of this kind of pricing behaviour and proposals of policies, if needed, to regulate these practices.

[1]Jobbers purchase and transport gasoline from refiners and sell or distribute to retailers.
[2] The upstream is the segment of the oil industry that deals with the exploration, production and transportation of crude oil to refineries while the downstream segment includes the refining process and the distribution and marketing of the refined products.

Gasoline price changes may reflect crude oil price changes, changes in the degree of market concentration, firms' inventory management and accounting practices, refinery adjustment costs, costs of adjusting supply, consumer search costs, interaction of supply and demand, and the behaviour of mark-ups over the business cycle. These factors notwithstanding, the sharp increases and asymmetric adjustment in wholesale gasoline prices have mostly been attributed to refiners wielding their market power. The Connecticut attorney general, was quoted in the December 7, 1998 *Washington Post* as saying the Exxon-Mobil merger will face scrutiny from regulators because "gas prices go up a lot faster than they go down."[3] The Chairman of the Permanent Subcommittee on Investigations, Senator Carl Levin, in June 2001, directed the Majority Staff of the Subcommittee to investigate the reasons for price increases, and, in particular, whether the increased concentration within the refining industry has contributed to price spikes and price increases in the Midwest gasoline market.[4] On March 13, 2003, Governor Gray Davis of the state of California asked the California Energy Commission to investigate the causes of the rapid rise in gasoline and diesel prices in February and March 2003, and to provide a monthly progress update on the first day of each month.[5] In 2003, Senator Carl Levin, the Ranking Minority Member, Permanent Subcommittee on Investigations, Senate Committee on Governmental Affairs, asked the United States General Accounting Office (hereafter GAO) to examine the effect of the wave of mergers that occurred in the U.S. petroleum industry in the 1990s.[6]

[3] See U.S. DOE EIA publication "Price Changes in the Gasoline Market: Are Midwestern Gasoline Prices Downward Sticky?" (1999)
[4] See the U.S. Senate Permanent Subcommittee on Investigations Report (April 2002)
[5] See the June edition of the monthly update on price adjustments in the California gasoline markets, "Causes for Gasoline and Diesel Price Increases in California"
[6] See GAO (May 2004) report on "Effects of Mergers and Market Concentration in the U.S. Petroleum Industry"

2. Mergers, acquisitions and joint ventures in the U.S. oil industry

Mergers, acquisitions and joint ventures (hereafter, mergers) are some of the mechanisms that the U.S. oil companies have used to consolidate their downstream petroleum operations. A large number of mergers, acquisitions and joint ventures in the U.S. oil industry in recent years has led to a significant consolidation of refining assets.[7] Figure 1 shows the major mergers that created the present big firms occurred in the U.S. oil industry between 1998 and 2002.[8]

The wave of mergers has led to a general consolidation of assets within the refining industry over the past two decades. The mergers in the U.S. oil industry and the closing down of refineries due to asset consolidation over the last eight years have increased concentration in the refining industry which has led to the refining and marketing industry for gasoline in states like California to be highly concentrated compared to many other states where it is moderately concentrated. In 1981, 189 firms owned a total of 324 refineries, at 1997, 79 firms owned a total of 164 refineries in the U.S. which by April 2005 has reduced to 55 firms owning a total of 148 refineries, a decrease of about 71% in the number of firms and 54% in the number of refineries since 1981. These mergers have also led to the largest five oil refining companies controlling 51.24% of the national domestic refinery capacity compared to the 31.08% of the domestic refinery capacity they controlled as at 1997, with 6 firms controlling 51% of the refining capacity of the entire 6 states in the Gulf Coast and 81.5% of California's refining capacity[9] thus creating a handful of firms with significant share of the U.S. refining industry.

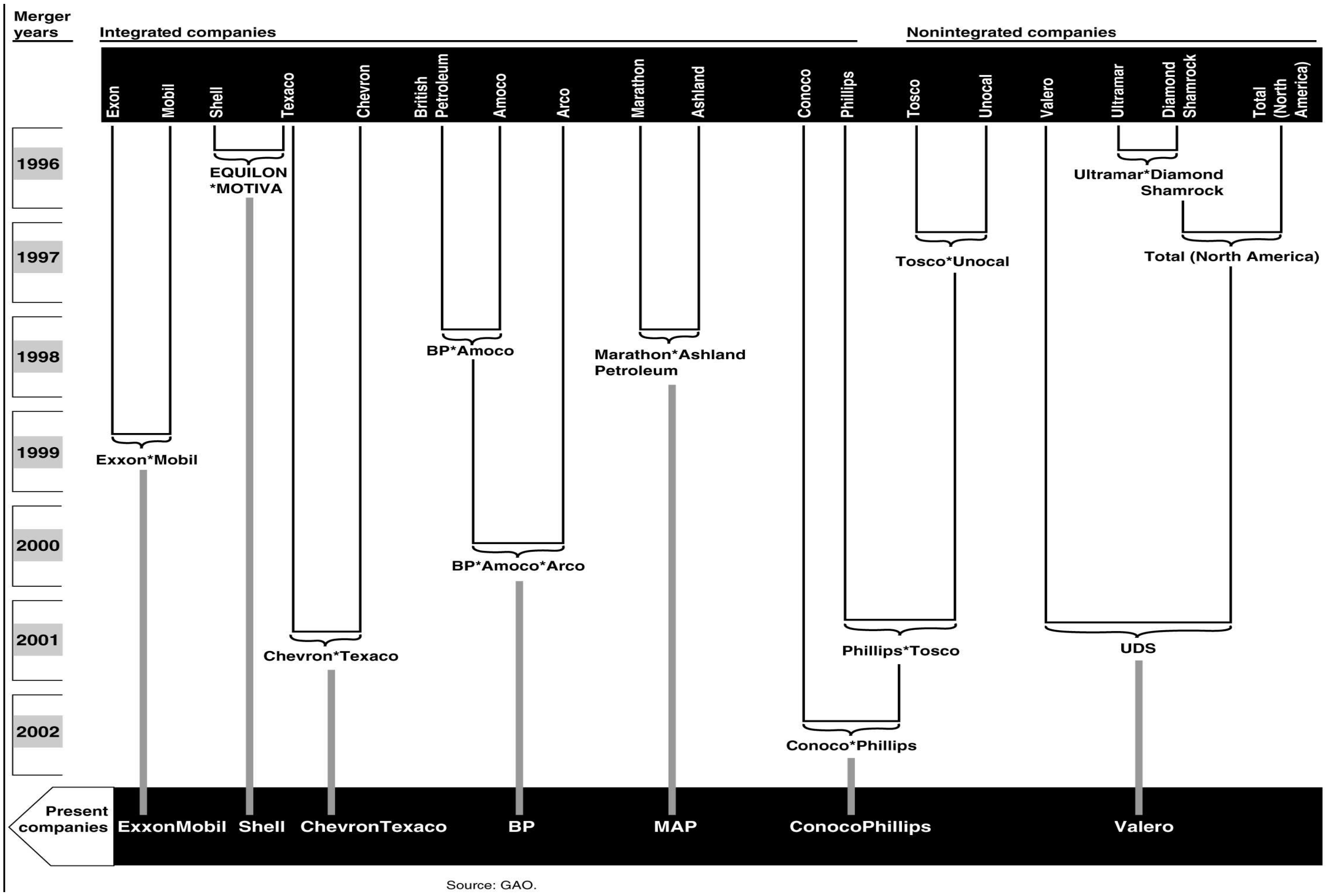
---

[7] For a detailed discussion of some of the major mergers in the U.S. oil industry, see U.S. GAO report of May 2004.

[8]The mergers depicted in figure 1involved firms in which one or both belonged to EIA's Financial Reporting System (FRS) companies at the time of the merger or became an FRS company after the merger occurred. FRS companies are U.S.-based major energy producers that report financial statistics to the EIA used by the agency to prepare its annual *Performance Profiles of Major Energy Producers.* According to EIA, as of 2002, criteria for selecting FRS companies include a company that accounts for (1) at least 1 percent of U.S. crude oil or natural gas liquids reserves or production, (2) at least 1 percent of U.S. natural gas reserves or production, or (3) at least 1 percent of U.S. crude oil distillation capacity. (Source: U.S. GAO report of May 2004).

[9] I estimated these refining capacities using information on each state in the Gulf Coast area and California. See the appendix for details of the firms operating refineries in each state.

Figure 1: Selected Major Petroleum Mergers (1996 - 2002)



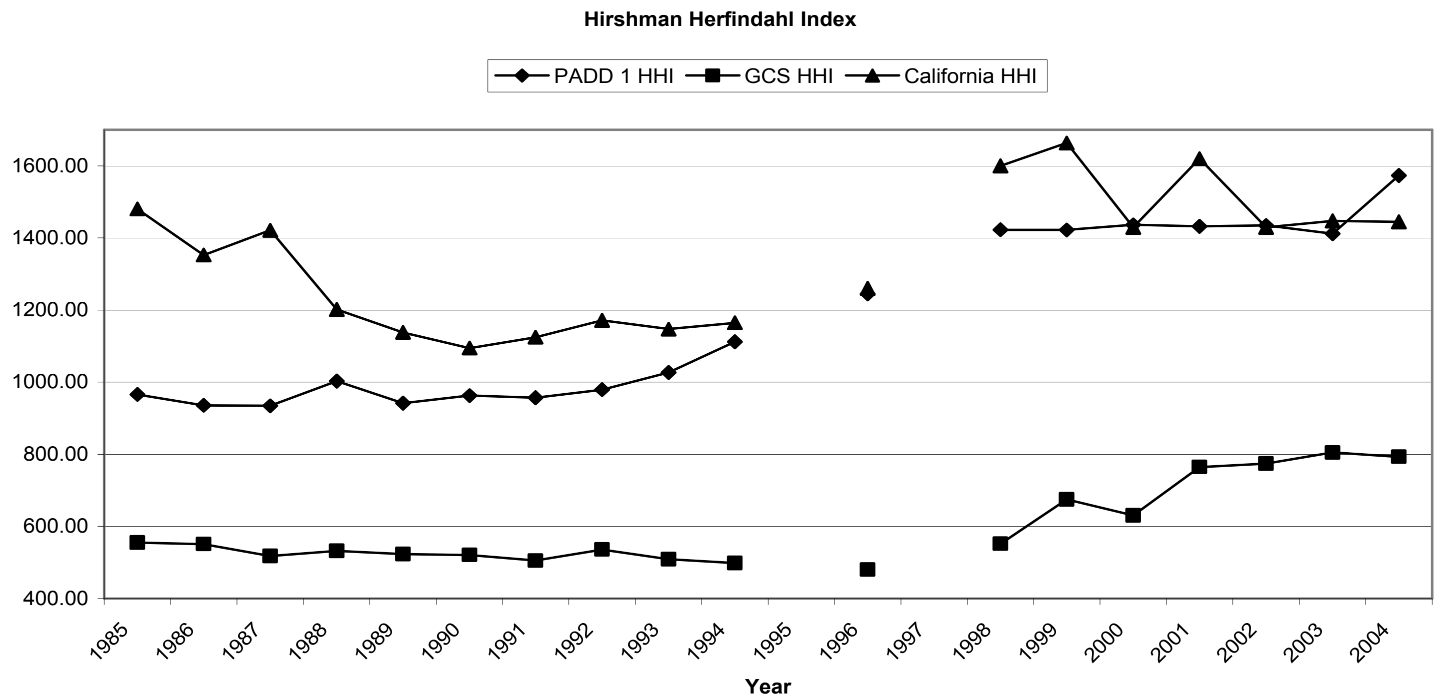
Source: GAO.

Figure 2 shows a plot of the Herfindahl-Hirschman Index (HHI) corresponding to the three spot markets being examined which are denoted NYSH, GCSH, and LASH for the New York, Gulf Coast and Los Angeles wholesale gasoline markets respectively.[10] The market concentration in PADD 1 corresponding to the HHI used in the New York market indicates a rising trend in concentration to becoming a moderately concentrated industry with HHI of 1573.40 at the end of 2004, while the Gulf coast market structure has always remained

[10] The HHI for PADD 1 (Crude oil allocation in the U.S. is divided into five Petroleum Administration for Defense Districts (PADD)) is associated with the New York wholesale gasoline market (NYSH) since there is no refinery in the New York and New York being in PADD 1 gets most of its supplies directly from PADD 1 refiners. The HHI for PADD 3 (also known as Gulf Coast) is associated with the Gulf Coast wholesale gasoline market (GCSH), while the HHI for California is associated with the Los Angeles wholesale gasoline market (LASH).

unconcentrated with a maximum HHI of 805.23 at the end of 2003 and an average HHI of 595.78 over the sample period.[11]

Figure 2: Plot of the Herfindahl-Hirschman Index[12]



The Los Angeles market concentration measured by California's HHI, indicates that the market has always been moderately concentrated with an average HHI of 1343.85 and a maximum HHI of 1662.88 in 1999. The monthly refinery capacity utilization for the three areas are unstable and volatile, with the Gulf Coast capacity utilization ranging between 77% and 102.1% with an average of 91.6%, while PADD 1 and PADD 5 capacity utilization ranges between 75% and 90% with an average capacity utilization of 88.7% for both PADDs. These fluctuating productive capacities could have an important implication for the speed of gasoline price adjustments in the wholesale gasoline markets.

[11] According to the merger guidelines jointly issued by DOJ and FTC, market concentration is ranked into three separate categories based on the HHI: a market with an HHI under 1,000 is considered to be unconcentrated; if the HHI is between 1,000 and 1,800 the market is considered moderately concentrated; and if the HHI is above 1,800, the market is considered highly concentrated. (GAO (May 2004))

[12] Data for the year 1995 and 1997 are missing. Details of how the HHI was generated are in the appendix.

3. Potential Price Effects of Mergers

Mergers provide companies with a way of reducing their costs by increasing their economies of scale or sharing assets and operations respectively. Mergers could promote anticompetitive behaviour and increase market power through increased market concentration which has the potential of increasing prices above competitive levels. It could enhance vertical integration and increase barriers to entry as a vertically integrated firm with considerable market power could influence gasoline price movements. Also, mergers can lead to efficiency gains through synergies and cost savings, which may be passed on to consumers in the form of lower prices. Thus, the ultimate impact of mergers on price adjustments depends on whether market power or efficiency gains dominate. In a highly concentrated market a few dominant firms may engage in tacit collusion which occurs when firms are able to coordinate their behaviour by observing and anticipating their rivals' pricing behaviour. This is made possible as firms recognize their mutual interdependence and the advantages of coordination, thus a firm could anticipate rivals matching any increase or stability in its price which establishes a course of action where firms raise or maintain their price in the knowledge that it is mutually beneficial if all firms adopt the same course of action. This leads to a greater degree of coordination and increased short run profits. Firms can also affect the price of gasoline by their decisions on the amount to supply, which can lead to price spikes and increases in gasoline prices.

According to GAO report of May 2004, market concentration, as measured by HHI, calculated by summing the squares of the market shares of all the firms within a given market, has increased substantially in the downstream segment of the U.S. petroleum industry since the 1990s. Market concentration in the wholesale gasoline[13] market increased substantially from the mid-1990s so that by 2002, some petroleum refining states had become moderately concentrated in wholesale gasoline markets.

[13] In this paper, wholesale gasoline market refers to the gasoline refining industry.

Since crude oil is a major input into gasoline production, the instability of its price over the years has created instability in the cost of producing gasoline at the refinery. In a perfectly competitive gasoline market, an increase in the crude oil price is a priori expected to lead to a rise in gasoline prices while a decrease in crude oil price is also expected to lead to a decrease in gasoline prices. The rate and degree of transmission of crude oil price changes to wholesale gasoline prices is also expected to be the same when there is an increase in crude oil price as when there is a decrease in crude oil price. The apparent lack of uniformity in this transmission begs the question of how competitive the gasoline market is and various studies discussed below have tried to investigate the existence of such asymmetric adjustment in price pass-through.[14] Price symmetry could be in form of *amount symmetry*, in which the magnitude of changes at the upstream and downstream levels are compared, or *pattern symmetry*, in which the change occurs at different rates between market levels depending on the direction of the upstream price change. Bacon (1991) referred to asymmetric pattern of adjustment as the “rockets and feathers” hypothesis, in which gasoline prices rise at a rocket’s speed following an increase in upstream prices and floats downward like feathers following a decrease in upstream prices. Usually, when price asymmetry is being investigated, the focus is on pattern asymmetry, which is the main source of concern to the stakeholders, especially the consumers, in gasoline markets**.**

4. Review of Literature

Different econometric studies[15]have either confirmed or refuted the rockets and feathers hypothesis, but there have been a few studies on the relationship between market structure and price inflexibility. Domberger (1979) empirically examine a set of price adjustment equations for a sample of industries by testing for a relationship between the rate of price adjustment and

---

[14] Price pass-through means changes in price at the refinery, or any intermediate sale downstream are expected to affect prices at each successive sale.

[15] Some of these studies include Bacon (1991), Borenstein, Cameron, and Gilbert (1997, hereafter BCG), Balke, Brown and Yucel (1998), Reilly and Witt (1998), Godby, Lintner, Stengos and Wandschneider (2000), Asplund, Eriksson and Friberg (2000), Galeotti, Lanza and Manera (2002), Bachmeier and Griffin (2002), Davis and Hamilton (2004) and Kaufmann and Laskowski (2005).

industrial structure measured by the HHI, using a symmetric partial adjustment model. He found that industrial concentration raises the speed with which firms react to cost increases. However, Winters (1981) commented that he neither specified nor estimated his concentration-adjustment link correctly, and that consequently he failed to realize that has no applicability within engineering industries, but Domberger (1981) replied by rejecting the inapplicability of the model to engineering industries as the econometric analyses were based on a model with inadequate theoretical justification. Dixon (1983) using a sample of industries included a production lag variable alongside a four firm concentration measure to investigate the relationship between industry structure and speed of price adjustment. Contrary to Domberger (1979)'s result, he found that the rate of price adjustment to prime costs is slower the more concentrated the industry and the longer the period of production the slower the speed of adjustment.

Bedrossian and Moschos (1988) argued that the influence of industrial structure upon the speed of adjustment of prices to cost changes can be decomposed into two opposing in nature effects; the leadership effect and the industry profitability effect. They noted that unless one can determine the relative significance of these factors, the size of the coefficient of a concentration index in an equation explaining price adjustment speed is not *a priori* predictable. The leadership effect: In a price game characterized by interfirm differences in profitability all the participants are aware that firms with the highest profitability are likely to dominate the game. Thus, if a concentrated industry is dominated by a single firm or a collusive group of firms it will be to the advantage of firms in the industry to avoid delays in the adjustment of prices to changes in costs. If, on the other hand, the industry is concentrated and there are more or less equally dominant and profitable rival firms, the already existing high profit margins could facilitate competition in the form of delays in adjusting prices, in contrast with fragmented industries with low profit margins where there is little or no room for interfirm competition. The profitability effect leads to a negative relationship between concentration and the speed of price adjustment as, *ceteris paribus*, the lower the profit margin at the industry level, the higher is likely to be the speed of price adjustment to a rise in costs.

The speed of adjustment as a function of the production period and industrial concentration is given by $\lambda = f(PLA, CR)$ (1)

where λ , is the speed of price adjustment, *PLA* is the length of the production period and *CR* is an index of industrial concentration. While $\partial\lambda/\partial PLA$ is expected to have a negative sign and the sign of $\partial\lambda/\partial CR$ cannot be determined *a priori*. The ambiguity concerning the direction of the effect of market concentration on price adjustment speed is reflected in the Domberger (1979) and Dixon (1983) empirical evidence. They noted that this is not unexpected as various aspects of industrial behaviour, such as the degree of competition among firms and the possibility of collusive behaviour are unobservable elements, as such, the net effect of these elements together with interfirm differences in profitability cannot be captured by relatively simple indicators of industrial structure. Bedrossian and Moschos used a two-step estimation procedure in which the first step involved fitting the set of price adjustment equations to quarterly time series data and obtaining the speed of price adjustment coefficients for a sample of industries in Greece. The second step examines the effects of industrial concentration and the length of the production period on the price adjustment speed by means of a cross-section analysis. They find that the length of production period and industrial concentration exert negative effects on the speed of price adjustment. In an attempt to examine the effect of market power on the adjustment of retail gasoline prices to cost shocks in 188 retail gasoline markets, Borenstein and Shepard (2002) used a Vector Autoregression for their analyses. They found that firms with market power adjust prices more slowly than do competitive firms, but found no evidence that the effect of market power on price adjustment is asymmetric. The U.S. General Accounting Office (2004) examined the effects of mergers and market concentration in the U.S. oil industry by examining data from the mid-1990s through 2000. They find that mergers and increased market concentration which reflects the cumulative effects of mergers and other competitive factors, generally led to higher wholesale gasoline prices.

The literature on market structure and the speed of adjustment have all assumed a symmetric speed of price adjustment to cost increases and decreases. However, Bedrossian and Moschos (1988) noted that the relationship between concentration and the speed of price adjustment is likely to be asymmetric with respect to cost increases and decreases. They predicted that in the event of a decrease in costs, price leadership analysis (effects) would imply that firms with relatively high profit margins are in a better position to delay the price adjustment process, since their high profit margins allow them to take this risk (downward price stickiness as a result of high profitability), while on the other hand, in the absence of interfirm differences in profitability, fierce price competition in the form of a relatively fast downward adjustment is most likely to take place in concentrated industries with high profitability. They also noted that to test for the degree of such asymmetry the availability of long enough time series on price-cost decreases as well as increases is required. All the empirical studies measure the speed of price adjustment as a function of market concentration and other variables as shown in equation (1).

Based on the result of Andrew (1993) test for structural change in the U.S. gasoline markets as a result of the major mergers, this paper incorporates a measure of concentration and refinery capacity utilization in an Engel-Granger asymmetric error correction model to test for the effect of the market structure on the speed of wholesale gasoline price adjustment to costs shocks as represented by crude oil price changes. I also empirically tested Bedrossian and Mochos (1988) prediction of slow price adjustment to cost decrease in a highly profitable[16] concentrated

[16] The refining industry has been known to be a profitable industry. This was noted in Chapter 3 of the EIA publication "Performance Profiles of Major Energy Producers 2004" that "The profitability of the U.S. refining/marketing operations of FRS companies reached an FRS all-time high during 2004 (dating back to 1977). The new all-time high of 18-percent return on investment (ROI) exceeded the previous all-time high, registered in 1989, by more than 3 percentage points and essentially doubled the 9-percent ROI of 2003. Finally, a new all-time high was reached in 2004 at 18.1 percent (with signs that 2005 may be characterized by an even greater level of profitability)..."
http://www.eia.doe.gov/emeu/perfpro/ch3sec4.html

market, and the notion that price adjustments can be effectively coordinated and industry equilibrium restored fairly rapidly as industrial concentration increases i.e. speed of price adjustment tend to rise and possibly lead to an immediate pass-through as markets become concentrated. It is worthy of note that most of the previous empirical papers in the literature on the U.S. gasoline market have used information and data that ends about the start of the series of major mergers in the U.S. oil industry. Thus making this paper also the first to investigate the effects of market structure as measured by the recent increased market concentration in the U.S. oil industry and the volatile refining capacity utilization, on the response patterns of wholesale gasoline prices to crude oil price shocks. The idea behind this is that market structure is determined in part by market concentration and firms could use their refining capacity utilization as a strategic oligopoly tool for influencing price adjustments in the presence of cost shocks to make short run profits.

Symmetric speed of adjustment of wholesale gasoline prices to crude oil price changes was rejected in the three wholesale gasoline spot markets examined. I find that market structure as measured by market concentration and refinery capacity utilization explained a small part of the asymmetric speed of price adjustment in the response of wholesale gasoline price changes to crude price shocks in the Gulf Coast and New York wholesale gasoline spot markets. This result confirms Bedrossian and Mochos (1988) prediction of slow price adjustment to cost decrease in a highly profitable concentrated market while the Los Angeles market result refutes the notion that the speed of adjustment lead to immediate pass-through as markets becomes concentrated. This result is interesting because it isolates part of the asymmetric speed of price adjustments due to market structure effects. The next section explains the data and specifies the econometric models used to test for price asymmetries. Section six presents and discusses the results of the econometric models and symmetry tests, while section seven summarizes and concludes the paper.

5. Data and Econometric model

I incorporate refinery capacity utilization and a measure of market concentration in an Engel-Granger asymmetric error correction model to check if market structure has an effect on the pattern of the speed of adjustments of wholesale gasoline price to a shock in the crude oil price in three different areas, using daily price series spanning a period of 17 years from 06/01/1987 to 12/30/2004 with 4377 observations. The price series investigated include the Cushing, Oklahoma West Texas Intermediate crude oil spot prices (WTIS) and each one of the wholesale conventional area regular spot gasoline prices for Gulf Coast (GCS), Los Angeles (LAS) and New York (NYS), with market concentration measured by annual Herfindahl-Hirschman Index (HHI) for the Gulf Coast, California (includes Los Angeles market) and PADD 1 (East Coast – includes New York market); and production efficiency measured by monthly refining capacity utilization rates (RCU) for the Gulf Coast, PADD 5 (includes Los Angeles market) and PADD 1 (East Coast – includes New York market). These data were all obtained from the Energy Information Administration (EIA). The three spot price series are measured in cents per gallon, with the capacity utilization rates measured in percentage. It is well known that market structure is slow to change and the effect of a structural change on behavior may be subject to some lags, as such the effect of a major merger may not be instantaneous at the date of merger announcement, but it may take a while before it actually changes firm's behavior in price change response pattern. However, interactions between firms before the mergers could also have affected firms' behavior even before the announcement of a merger. Therefore, the obvious and readily available measure of concentration was the annual HHI which has the advantage of taking into consideration the size distribution of competing firms (i.e. relative sizes) over just counting the number of firms in the industry, and also the advantages of not selecting an arbitrary number of firms in its estimation, but including all the firms in the industry without ignoring the structure of the smaller firms in the industry as does the concentration ratio.[17]

Given that crude oil price is the main input cost in wholesale gasoline prices, holding other costs constant, the long run equilibrium relation determinants of price is specified as:

$$Pg_t = \delta_0 + \delta_1 PC_t + \delta_2 HHI_t + \delta_3 RCU_t + \sum_{i=2}^{12} \gamma_i month_t + Z_t \qquad (2)$$

Where Pg_t is the wholesale gasoline price, δ_0 represents other costs, taxes and profits (held constant), PC_t is the crude oil price, and δ_1 is the proportion of the crude oil price that is passed through to the wholesale price in the long run, HHI_t is Herfindahl-Hirschman Index corresponding to the gasoline spot price location being examined, RCU_t is refinery capacity utilization corresponding to the gasoline spot price location being examined, $month_t$ are monthly dummies used to capture seasonal effects, Z_t is an IID error term and the subscript *t* denote days. A positive coefficient on HHI and/or RCU indicates a one unit increase in market concentration and/or a percentage increase in capacity utilization lead to δ_2 and/or δ_3 increase in wholesale gasoline price and vice versa. Bachmeier and Griffin, (2002) noted that the Granger Representation Theorem[18] shows that any cointegrated series will have an error correction representation and failure to include cointegrating relations implies model misspecification. The error correction process is a means of reconciling short run and long run price adjustment behaviors; as such I first estimate a basic asymmetric error correction model (ASECM) of the form:

[17] The national four-firm concentration ratio was also estimated and found to be highly correlated to the national annual HHI.
[18] For more on the Granger Representation Theorem see Engle and Granger (1987)

$$\Delta Pg_t = \sum_{i=1}^{k} \phi_i^+ (\Delta Pg_{t-i})^+ + \sum_{i=0}^{k} \beta_i^+ (\Delta PC_{t-i})^+ + \lambda^+ (Z_{t-1})^+$$
$$+ \sum_{i=1}^{k} \phi_i^- (\Delta Pg_{t-i})^- + \sum_{i=0}^{k} \beta_i^- (\Delta PC_{t-i})^- + \lambda^- (Z_{t-1})^- + \varepsilon_t \tag{3}$$

$(\Delta Pg_{t-i})^+ = \max\{0, \Delta Pg_{t-i}\}$, $(\Delta PC_{t-i})^+ = \max\{0, \Delta PC_{t-i}\}$ and $(Z_{t-1})^+ = \max\{0, Z_{t-1}\}$ are respectively, the positive changes in wholesale gasoline price, crude oil price and the lagged residuals of the long run relationship in equation (1), while $(\Delta Pg_{t-i})^- = \min\{0, \Delta Pg_{t-i}\}$, $(\Delta PC_{t-i})^- = \min\{0, \Delta PC_{t-i}\}$ and $(Z_{t-1})^- = \min\{0, Z_{t-1}\}$ are the negative changes in the downstream price, upstream price and the lagged residuals of the long run relationship in equation (2) respectively. k is the number of lags, β_i measure the short run impact of changes in crude oil price, ϕ_i coefficients measure the short run impact of lagged wholesale gasoline price changes, λ measures the speed of adjustment to long run equilibrium, Z_{t-1} is the lagged residual from equation (2) and is the error correction term which measures the long-run disequilibrium between the crude price and the wholesale gasoline price changes, which is a stationary process when the two price series are cointegrated, and ε_t is an error term that is serially uncorrelated with mean zero and variance σ^2, and is uncorrelated with all the regressors in the equation.

The Augmented Dickey Fuller (ADF) test for unit root which corrects for serial correlations in the disturbance terms was administered on each of the five spot prices and a null hypothesis of a unit root process with positive drift tested for in each of the variables.[19] Based on the critical values of Mackinnon (1991), the null hypothesis could not be rejected at 5% level of significance for all the price series, thus, all the price series were treated as first difference

[19] The lags used in the ADF test was chosen using the method proposed by Ng and Perron (1995) as described by Eric Zivot and Jiahui Wang in "Modelling Financial Time Series with Splus". The procedure states that if the absolute value of the t-statistic for testing the significance of the last lagged difference is greater than 1.6, set p = pmax (pmax=12*(n/100)^(1/4) Shwert (1989)) and perform the unit root test, otherwise, reduce the lag length by one and repeat the process. Then, do the ADF test starting with pmax and reducing one lag until the coefficient on the last lag is greater than 1.6 in absolute value.

stationary. The Engle Granger cointegration test was used on the crude oil prices and wholesale gasoline prices, where the residuals from the ordinary least square regression of equation (2) were tested using the Augmented Engle Granger cointegration test. The lags used for the test were chosen the same way the lags of the ADF unit root test were chosen to induce white noise process in the error terms. For all the relationships tested and, based on the critical values of Mackinnon (1991), the null hypothesis that the least squares residuals are not stationary was rejected, as such all the relationships examined were treated as cointegrated and the estimates of δ_1 in equation (2) are taken to be valid estimates of the long run equilibrium relationship between crude oil prices and wholesale gasoline prices. The number of lags included in each of the asymmetric error correction models was chosen based on the number of lags k chosen by Shwartz Information Criterion. An F-test of Granger causality conducted on changes, and positive and negative changes in crude oil price and wholesale gasoline prices under the null hypothesis that the lagged values of the upstream prices does not Granger cause the downstream prices was rejected at 5% level of significance.

The basic ASECM from (3) above was estimated and tested for stability using Andrews (1993) structural break test to determine the existence of an unknown change point during the period of major mergers, acquisitions and joint ventures. I tested for any structural change in price adjustment behavior that may have been initiated by the series of mergers that occurred between January 1, 1997 and December 31, 2002, and if there was any structural change that occurred after a lag of unknown length or before the series of mergers in anticipation of the mergers. I used the algorithm described in Bai & Perron (2003) as implemented in *R* econometric software, to extract the breakpoints corresponding to the breakdates of the structural breaks in the ASECM models. Dummy variables corresponding to these breakdates were created to capture the shifts in the parameter model estimates and estimated as in (4). This is to help determine if there was indeed a shift in the response pattern of gasoline price changes to crude price changes. If the coefficients on the dummies are significant and the response pattern of the speed of price adjustment changes, then there will be a basis for examining the cause of the structural change, if it was due to a change in market structure, else it will be an indication of no shift in the response pattern of gasoline price changes to crude oil price changes.

$$\Delta Pg_t = \sum_{i=1}^{k} \phi_i^+ (\Delta Pg_{t-i})^+ + \sum_{i=0}^{k} \beta_i^+ (\Delta PC_{t-i})^+ + \lambda^+ (Z_{t-1}^+) + \xi^+ (D_t * Z_{t-1}^+)$$
$$+ \sum_{i=1}^{k} \phi_i^- (\Delta Pg_{t-i})^- + \sum_{i=0}^{k} \beta_i^- (\Delta PC_{t-i})^- + \lambda^- (Z_{t-1}^-) + \xi^- (D_t * Z_{t-1}^-) + \varepsilon_t \qquad (4)$$

Where D_t is the dummy for days after the breakdate. In order to examine if market structure or capacity utilization has an effect on asymmetric speed of price adjustments, I incorporate the error correction term interacted with both HHI and RCU directly in the ASECM as shown in (5) to (9). The HHI and RCU are decomposed based on the signs of the error correction term as follows: If $Z_{t-1} > 0$, then $HHI_{t-1} > 0 \Rightarrow (Zh)_{t-1}^+$ and If $Z_{t-1} < 0$, then $HHI_{t-1} < 0 \Rightarrow (Zh)_{t-1}^-$ (5)

If $Z_{t-1} > 0$, then $RCU_{t-1} > 0 \Rightarrow (Zc)_{t-1}^+$ and If $Z_{t-1} < 0$, then $RCU_{t-1} < 0 \Rightarrow (Zc)_{t-1}^-$ (6)

where the market concentration index corresponding to the spot gasoline price being investigated is HHI_{t-1} and RCU_{t-1} is the lagged refinery capacity utilization. This allows for HHI_t and RCU_t to explain the pattern of adjustment based on the direction of the speed of adjustment. The following are the various models that were estimated and incorporating these variables:

$$\Delta Pg_t = \sum_{i=1}^{k} \phi_i^+ (\Delta Pg_{t-i})^+ + \sum_{i=0}^{k} \beta_i^+ (\Delta PC_{t-i})^+ + \lambda^+ Z_{t-1}^+ + \varphi^+ (Zc)_{t-1}^+ + \theta^+ (Zh)_{t-1}^+$$
$$+ \sum_{i=1}^{k} \phi_i^- (\Delta Pg_{t-i})^- + \sum_{i=0}^{k} \beta_i^- (\Delta PC_{t-i})^- + \lambda^- Z_{t-1}^- + \varphi^- (Zc)_{t-1}^- + \theta^- (Zh)_{t-1}^- + \varepsilon_t \qquad (7)$$

$$\Delta Pg_t = \sum_{i=1}^{k} \phi_i^+ (\Delta Pg_{t-i})^+ + \sum_{i=0}^{k} \beta_i^+ (\Delta PC_{t-i})^+ + \lambda^+ (Z_{t-1}^+) + \theta^+ (Zh)_{t-1}^+$$
$$+ \sum_{i=1}^{k} \phi_i^- (\Delta Pg_{t-i})^- + \sum_{i=0}^{k} \beta_i^- (\Delta PC_{t-i})^- + \lambda^- (Z_{t-1}^-) + \theta^- (Zh)_{t-1}^- + \varepsilon_t \qquad (8)$$

$$\Delta Pg_t = \sum_{i=1}^{k}\phi_i^{+}(\Delta Pg_{t-i})^{+} + \sum_{i=0}^{k}\beta_i^{+}(\Delta PC_{t-i})^{+} + \lambda^{+}(Z_{t-1}^{+}) + \varphi^{+}(Zc)_{t-1}^{+}$$
$$+ \sum_{i=1}^{k}\phi_i^{-}(\Delta Pg_{t-i})^{-} + \sum_{i=0}^{k}\beta_i^{-}(\Delta PC_{t-i})^{-} + \lambda^{-}(Z_{t-1}^{-}) + \varphi^{-}(Zc)_{t-1}^{-} + \varepsilon_t \qquad (9)$$

If the coefficients on HHI and/or RCU are significant and there is substantial change in the coefficients on the error correction terms from what is obtained in the estimation of the basic ASECM in (3), then market structure as measured by either market concentration and/or refinery capacity utilization could be said to be responsible for the difference in the response patterns of (3) compared to (7) - (9).

6. Presentation and discussion of results

From the estimated long run equilibrium relationships, equation (2),[20] the positive coefficient on the HHI corresponding to the Gulf Coast and Los Angeles shows that a 100 point increase in HHI leads to 0.7 cents and 1.2 cents increase in wholesale gasoline prices in the Gulf Coast and Los Angeles markets. This corroborates the established notion in the industrial organization literature that prices tend to increase as markets become more concentrated. In the New York market, a 100 point increase in HHI leads to a 0.1 cents decrease in gasoline prices. This could be attributed to the fact that the New York market is also supplied by imports from the Gulf Coast and Canada which poses a substantial competition to the local market. A 1 percent increase in refinery capacity utilization leads to 0.12 cents and 0.017 cents decrease in gasoline prices in the Gulf Coast and New York markets respectively. This suggests a competitive market exists in the two markets, hence the negative price effect of increased supply resulting from increased production. In the Los Angeles markets, a 1 percent increase in refinery capacity utilization leads to 0.014 cents increase in wholesale gasoline prices. This is interesting as it suggests that refiners could influence gasoline prices, hence passing on refinery adjustment costs

[20] The detailed results of the long run relationship are in Table A1 in the appendix.

to gasoline prices in the Los Angeles market where most refining capacity is concentrated in a few refiners' hands.

The asymmetric error correction models were estimated for the relationships between each of the wholesale gasoline prices and the crude oil price with or without HHI, RCU and breakdate dummies, as indicated in (3) to (9). Because of the potential endogeneity of the WTIS and the results of Hausman specification tests, the Europe Brent crude oil spot price (EBS) was used as an instrument because it reflects the world crude oil prices and is not subject to the local demand shocks within the U.S., as WTIS could be affected by local market factors which affects wholesale gasoline prices.[21] The positive and negative price changes in EBS were used as instruments for the corresponding positive and negative price changes in WTIS. This led to the estimation of the asymmetric error correction model by two stage least squares while the long run equilibrium relationship in equation (2) above was estimated by ordinary least squares as its estimated coefficients are superconsistent.

The results of the estimated speed of adjustment in the asymmetric error correction models in equations (3) to (9) are reported in Table 1. The coefficients on the breakdate dummies of equation (4) were not significant as such there was no basis for examining the cause of the structural change in the basic ASECM model, indicating that the structural break could be a model specification issue or the Andrews (1993) structural break test not suitable for the basic ASECM model. Thus, the analysis of equation (4) in line with structural break was discontinued.

The coefficient on the speed of adjustment towards the long run equilibrium when price is above or below the long run equilibrium is a priori expected to be negative. Thus, $|\lambda^{+}| < |\lambda^{-}|$, indicates a slower adjustment towards the long run equilibrium when wholesale gasoline price is above equilibrium and faster upward adjustment towards the long run equilibrium when wholesale gasoline price is below equilibrium.

[21] The levels data of EBS and the NYMEX four crude oil Futures prices were found to be highly correlated with the WTIS but only the positive and negative EBS price changes were found to be highly correlated with the positive and negative WTIS respectively, thus only the EBS was used as the instrument.

Table 1: Speed of Adjustment and Pattern Asymmetry*

Model	Gulf Coast Market			Los Angeles Market			New York Market		
	λ^+	λ^-	$(\lvert\lambda^+\rvert - \lvert\lambda^-\rvert)$	λ^+	λ^-	$(\lvert\lambda^+\rvert - \lvert\lambda^-\rvert)$	λ^+	λ^-	$(\lvert\lambda^+\rvert - \lvert\lambda^-\rvert)$
ASECM	-0.042	-0.054	**-0.012**	-0.043	-0.044	**-0.001**	-0.038	-0.051	**-0.012**
HHI	-0.047	-0.065	**-0.018**	-0.058	-0.046	**0.012**	-0.037	-0.061	**-0.024**
RCU	-0.046	-0.064	**-0.018**	-0.057	-0.046	**0.011**	-0.037	-0.064	**-0.026**
HHI & RCU	-0.048	-0.065	**-0.017**	-0.059	-0.046	**0.012**	-0.037	-0.063	**-0.026**

*ASECM, HHI, RCU and HHI & RCU correspond to equations (3), (7), (8) and (9) respectively

Cook et al (1998) noted that for any asymmetric error correction specification as in equation (3) to be valid, the coefficients λ^+ and λ^- must be significantly different from each other and individually significant simultaneously. These conditions were satisfied by all the coefficients λ^+ and λ^- corresponding to Z_{t-1}^+ and Z_{t-1}^- respectively. The prominence of the divergence between the point estimates as shown in Table 1 confirms the general perception that there could be widespread asymmetric speed of adjustment of wholesale gasoline price to crude price shocks.

6.1. Symmetry tests and Cumulative Adjustments[22]

The point estimates of long run equilibrium relationships between each wholesale gasoline spot price and crude price indicate full pass through. To confirm this observation, the question of whether refiners pass on 100% of the crude oil price change into wholesale gasoline price was tested by the null hypothesis of $H_0 : \delta_1 = 1$. This is a test of long run price pass-through. *A priori*, it is expected that there will be a full pass-through of a crude oil price change to a wholesale gasoline price change in the long run or lack of competition may lead to an asymmetric pass-through of either a positive or negative price change. If the null hypothesis is rejected and $\delta_1 > 1$, there is complete pass-through, but if $\delta_1 < 1$, there is incomplete pass-through.

[22]Detailed entries are of the estimated coefficients and their corresponding standard error of all the models considered are in Table A2 in the appendix.

Table 2: Symmetry test results

	GCS	LAS	NYS						
Model	***Amount Symmetry***$^{+}$								
Cointegrating Relationship	17.25	31.71	23.77						
	Adjustment Speed Symmetry[23]			***Short Run Symmetry***[24]			***Symmetric Specification***[25]		
	GCS	**LAS**	**NYS**	**GCS**	**LAS**	**NYS**	**GCS***	**LAS**	**NYS**
ASECM	-8.97	-10.12	-9.5	-10.43	-13.03	-42.41	-2.89	-10.93	-41.93
HHI	-6.95	-8.57	-6.8	-11.33	-22.87	-34.72	-0.99	-12.04	-32.97
RCU	-7.02	-8.54	-6.91	-9.87	-21.93	-35.08	-0.70	-12.29	-32.33
HHI & RCU	-6.97	-8.6	-6.83	-11.91	-23.18	-37.13	-0.47	-11.93	-33.96

*Is the only estimated statistics that is not significant at 5% level, all the others are significant at 5%

$^{+}$A *t*-test of the null hypothesis is $(\delta_1 - 1)/SE(\delta_1)$ in which *SE* is the standard error of δ_1

As seen in Table 2, for all the long run price relationships considered, the null hypothesis of amount symmetry was rejected with $\delta_1 > 1$, indicating a full pass-through in the long run. These results confirm *a priori* expectations, indicating that the refiners pass on the full amount of any crude oil price change to wholesale gasoline prices. To arrive at an estimate of the full adjustment path, I construct a cumulative adjustment function (CAF) for both increases and decreases in the upstream prices using BCG's methods.[26] Figures 4 show the cumulative adjustment functions of equations (3) and (9) for the Gulf Coast. The CAF takes into

---

[23]This is a test of the $H_0 : \lambda^{+} = \lambda^{-}$, which is a *t*-test of the significance of the coefficient of Z_{t-1} in the model: $\Delta Pg_t = \sum_{i=1}^{k} \phi_i^{+} (\Delta Pg_{t-i})^{+} + \sum_{i=0}^{k} \beta_i^{+} (\Delta PC_{t-i})^{+} + \lambda (Z_{t-1}) + \sum_{i=1}^{k} \phi_i^{-} (\Delta Pg_{t-i})^{-} + \sum_{i=0}^{k} \beta_i^{-} (\Delta PC_{t-i})^{-} + \varepsilon_t$

[24]This is a Wald test of the $H_0 : \beta_i^{+} = \beta_i^{-}$ for $i \in (0, k)$ with the restricted model under ASECM stated as:

$$\Delta Pg_t = \sum_{i=1}^{k} \phi_i^{+} (\Delta Pg_{t-i})^{+} + \sum_{i=1}^{k} \phi_i^{-} (\Delta Pg_{t-i})^{-} + \sum_{i=0}^{k} \beta_i (\Delta PC_{t-i}) + \lambda^{+} (Z_{t-1})^{+} + \lambda^{-} (Z_{t-1})^{-} + \varepsilon_t$$

[25]This is a Wald test of the null hypothesis that the symmetric specification best fits the data i.e. Symmetric Error Correction Model (SECM) vs ASECM, with the SECM being the restricted model stated as:

$$\Delta Pg_t = \sum_{i=1}^{k} \phi_i (\Delta Pg_{t-i}) + \sum_{i=0}^{k} \beta_i (\Delta PC_{t-i}) + \lambda (Z_{t-1}) + \varepsilon_t$$

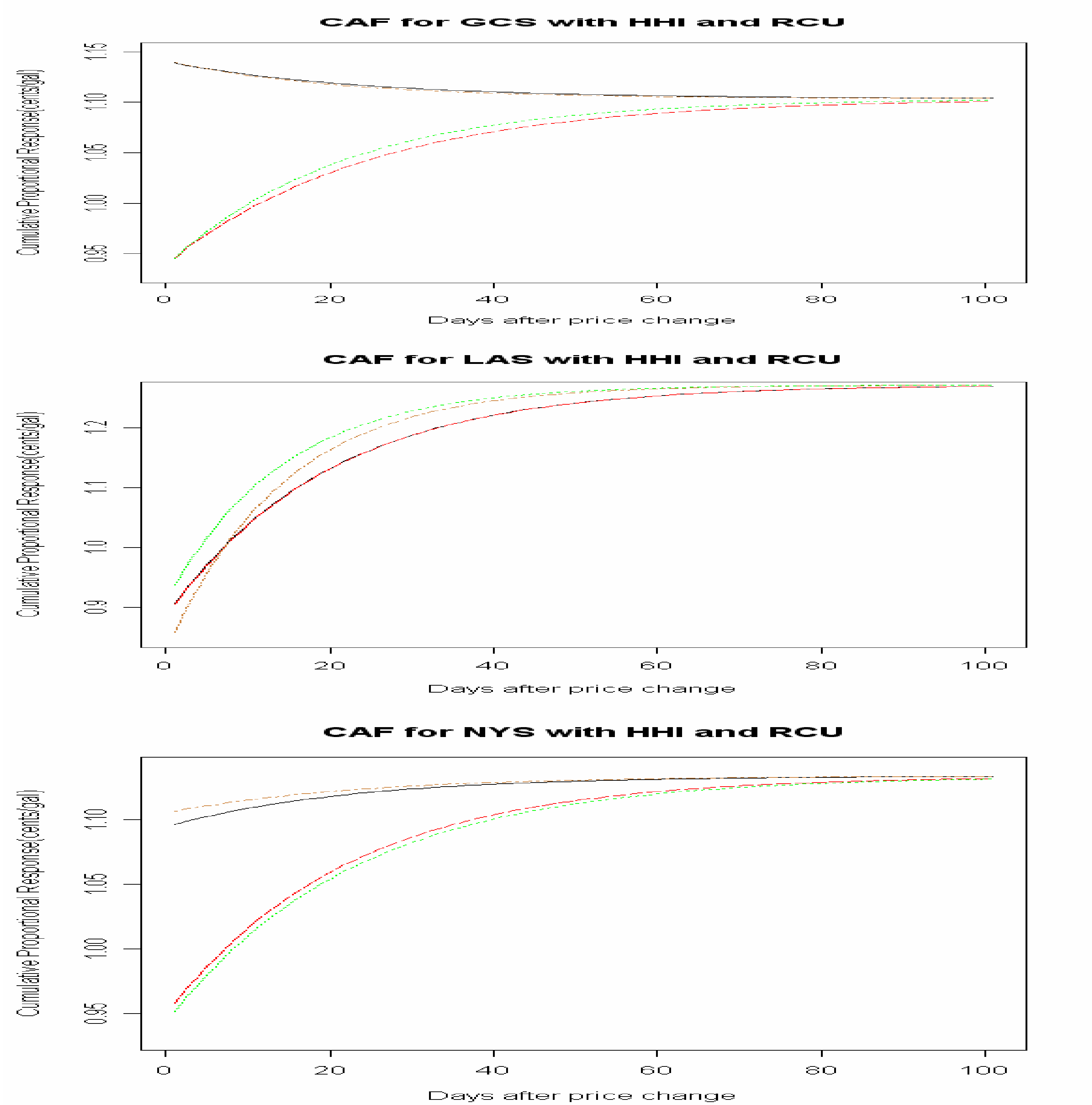
26 The cumulative adjustment function is a nonlinear function of the estimated parameters which measures the adjustment of the downstream prices to a unit change in the upstream prices. The cumulative adjustment in the *k*th period after a change in the upstream price is the sum of the estimated response parameter from the estimated equations ($\beta_k^{+} or \beta_k^{-}$), the effects of the resulting changes in downstream prices (ϕ_k^{+} or ϕ_k^{-}) and the speed of adjustment over the *k* days (λ^{+} or λ^{-}). Details of this method are in BCG (1997) consideration the indirect effects of lagged changes in the downstream price and the effect of the reversion toward the long-run equilibrium.

The cumulative adjustment functions show the estimated downstream price response, in cents per gallon, to a one-time one cent per gallon increase (decrease) in the upstream prices. As shown in Figure 4, the basic ASECM model, equation (3) for the Gulf Coast market, shows a one cent increase in crude price leads to an immediate increase of 1.139 cents in gasoline price a day after crude price changes while a one cent decrease in crude price leads to an immediate decrease of 0.945 cents in gasoline price a day after crude price change. Figure 4 also shows the cumulative adjustment functions for each of the three markets approach the estimated long run adjustment factor of 1.104 cents, 1.272 cents and 1.134 cents for the Gulf Coast, Los Angeles and New York wholesale gasoline markets respectively.[27]

Wald tests of symmetric versus asymmetric error correction model specification was carried out and the results, displayed in Table 2, suggest that the asymmetric error correction model suits the analysis of speed of price adjustment in the New York and Los Angeles markets while the symmetric model specification was not rejected in the Gulf Coast. Thus, all the three wholesale gasoline markets were analyzed using an asymmetric error correction model specification. The differences in the point estimates of the coefficients of Z_{t-1}^{+} and Z_{t-1}^{-} as shown in the basic ASECM results in Table 1 indicate the presence of an asymmetric adjustment in wholesale gasoline price to crude price shocks in the Gulf Coast spot and New York markets with the exception of the Los Angeles market which shows a negligible asymmetry in adjustments speeds. This observation calls for a test of equality between the positive and negative adjustment speed parameters in the estimated ASECM models.

[27]The long run equilibrium estimates are greater than 1 as expected. It is well known that crude oil prices are proportional to gasoline prices, this is corroborated by the EIA in her brochure called *"A Primer on Gasoline Prices"* where it was noted that "…about 47 barrels of gasoline are produced from every 100 barrels of crude oil processed at U.S. refineries" (EIA (2005)). A short proof of how the estimates could be greater than 1 is in the appendix.

Figure 4: Cumulative Adjustment Function of ASECM for the markets[28]



[28] In all the cumulative adjustment functions (CAF), the black lines (dashed red lines) represent the effect of 1 cent increase (decrease) in wholesale gasoline prices based on the basic ASECM, equation (18) superimposed on the CAF of each model as labeled on the plots, with the grey dot-dashed lines and green dot lines representing the effect of 1 cent increase and decrease in wholesale gasoline price respectively.

A rejection of the null hypothesis $H_0 : \lambda^+ = \lambda^-$ implies an asymmetric speed of adjustment to the long-run equilibrium. This is what the Rockets and Feathers hypothesis is about and this is what stakeholders easily observe as downstream price changes when there is a change in crude oil prices in the world market. Stakeholders are more concerned about this because they cannot easily compare the magnitude of changes in crude oil price with those of wholesale gasoline prices as a result of the interplay of various inexhaustible factors including level of competition in the market, demand conditions, adjustment costs, firm pricing policies, inventory management, refinery capacity utilization and a host of other factors that are not easily observable but pertinent to the successful pass-through of crude price shocks to wholesale gasoline prices. In a competitive market, it is expected that market clearing prices should incorporate all the available information quickly and lead to high speed of adjustment, thus refiners are expected to immediately pass on cost shocks through wholesale price adjustments.

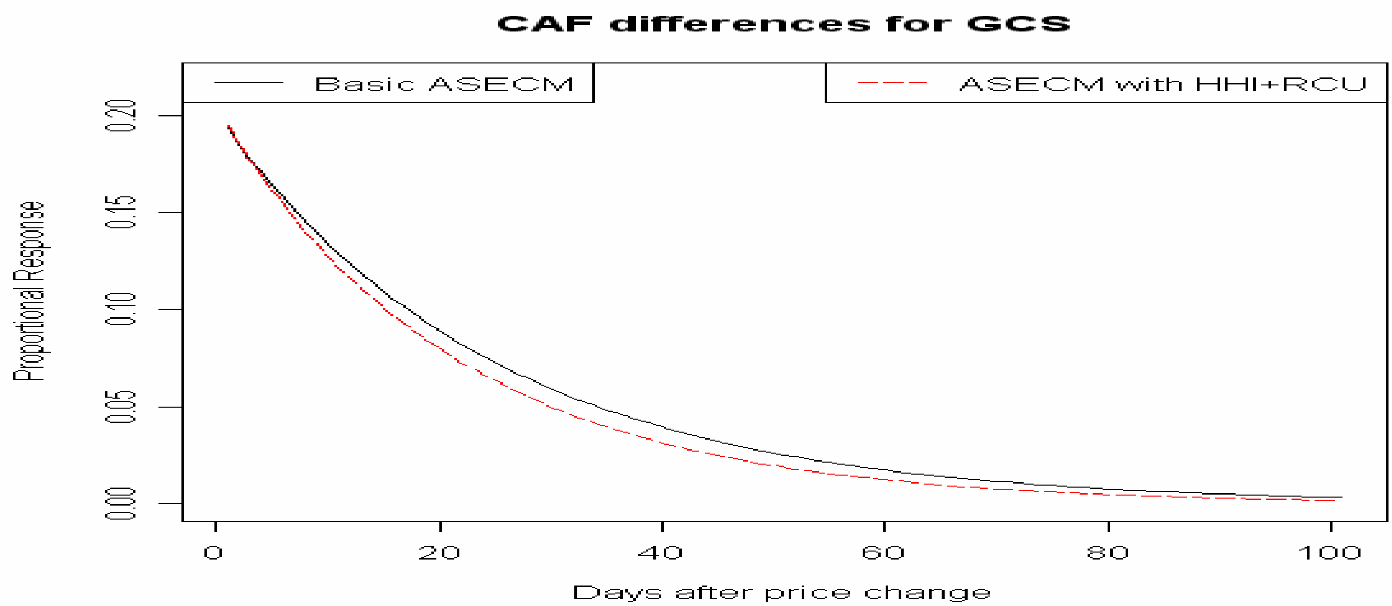
The results of the tests of the null hypothesis of symmetric speed of adjustment in Table 2 indicate that symmetry should be rejected in all the three wholesale gasoline markets, implying the existence of an asymmetric speed of adjustment in the markets, such that firms are more responsive to crude price increases and less responsive to crude price decreases in the three gasoline spot markets. As could be seen in Table 1, the ASECM model incorporating HHI and RCU, equation (9), explained the same proportion of the source of asymmetry in the markets in comparison as the other models with just either HHI or RCU. This shows that market structure as measured by market concentration and refinery capacity utilization did contribute to the pattern asymmetry as observed in the basic ASECM in the Gulf Coast and New York markets.

The point estimates difference, ($|\lambda^+| - |\lambda^-|$) in Table 1 show that market concentration and refinery capacity utilization have the same effect on the asymmetric speed of adjustment in the Gulf Coast while there seems to be no apparent asymmetry in the speed of adjustment in the Los Angeles market in the basic ASECM. The inclusion of the market concentration measure and refinery capacity utilization led to the display of asymmetry in the Los Angeles wholesale gasoline price changes to crude shocks. This is shown in Figure 4, where asymmetric adjustment could be seen in the model with HHI and RCU, equation (9). In the New York area, refinery capacity utilization made a bigger impact in the reduction of asymmetry compared to market concentration, with the point estimate difference for market concentration effect and refinery capacity utilization effect being -0.024 and -0.026 respectively. This could be because there is no refinery in New York and the wholesale gasoline sold in the New York market is imported from refiners in PADD 1, Gulf Coast and Canada.

Direct comparison of the point estimates on the short run adjustment parameters show that there seems to be a complete upward price adjustment a day after crude price increase and an incomplete downward price adjustment a day after crude price decrease in all the estimated models in all the wholesale gasoline markets except the Los Angeles market. This sharp contrast between the point estimates of the coefficients of ΔPC^{+}_{t-i} and ΔPC^{-}_{t-i} for $i \in (0,1)$, indicates a possible asymmetric short run price adjustment which was tested by the null $H_0 : \beta^{+}_{t-i} = \beta^{-}_{t-i}$ for $i \in (0,k)$. The results of a Wald test of this hypothesis did not reject short run asymmetric adjustment of wholesale gasoline prices to crude price shocks in the three markets.

Figure 5 shows the differences in the positive and negative estimates of the cumulative adjustment functions for the basic ASECM and the ASECM with both HHI and RCU, equation (9). From day 17 to day 37 after crude price change, the gap between positive and negative estimates of the cumulative adjustment function shows the Gulf Coast asymmetry reduced with the inclusion of market structure effects as represented by market concentration and refinery capacity utilization by 0.009 cents with an average gap of 0.005 cents over the entire adjustment period to long run equilibrium. This implies that market structure did contribute to price asymmetry in the Gulf Coast but by an economically insignificant amount.[29]

Figure 5: Cumulative Adjustment Function Difference for Gulf Coast



6.2. Explanations for Price Adjustments

A wholesaler can respond differently to crude oil shock, depending on her supply adjustment cost, refining capacity and carrying cost of inventory, as such an asymmetry in the speed with which they pass on these positive and negative price changes could be an indication of capacity constraints and inadequate market competition in the wholesale gasoline market.

Market Concentration:

Changes in technology, environmental regulations and firms' strategic objectives led to the wave of mergers that started in 1998 which led to the consolidation of assets within the U.S. oil industry leading to a drastic reduction in the number of refineries as well as independent refiners, as the big oil companies acquired most of them. This saw five oil firms controlling over

[29] The Gulf Coast is used as a representative market for the U.S. because of the consistency of available data on HHI and refinery capacity utilization for the area, and the fact that the Gulf Coast market is self contained in terms of crude oil and wholesale gasoline production. These ensure completely reliable estimates and analysis of the Gulf Coast market.

50% of the refining industry and over 61% of the retail gasoline market in the U.S. The refiner's market power was also increased by coordinated behaviour made possible by the inelasticity of gasoline demand and new refiner's entry limitations. Also, tacit collusion could be more easily exploited in the wholesale gasoline market as a result of firms' interaction with each other and anticipation of rivals' pricing behaviour. Contrary to expectations, the econometric analyses results suggest that market concentration contributes to the downward price stickiness in the three wholesale gasoline markets examined. This is not surprising as the Gulf Coast refining industry has the highest number of refiners as well as refineries in the U.S. with the New York and Los Angeles markets being moderately concentrated.

Refining capacity utilization:

Wholesale gasoline is imported from other states and Canada into New York; while 6 firms control 51% of the refining capacity of the entire 6 states in the Gulf Coast and 81.5% of California's refining capacity. This creates a tendency for refining capacity utilization to be used as an effective tool in oligopolistic strategies as it explained part of the asymmetric speed of adjustment in the Gulf Coast and New York wholesale gasoline markets. This could allow firms make supply adjustment decisions that will boost their profit maximizing strategies especially when their carrying cost of inventory is manageable.[30] The Gulf Coast is also known to have the highest number of refineries in the U.S. thus allowing for greater impact of capacity utilization on adjustment speed in the Gulf Coast and the Gulf Coast supply dependent New York market. Thus, when firms have excess capacity (i.e. less than 100% capacity utilization) for example, due either to insufficient demand faced by the refiners inducing them to restrict production to a level below capacity, due to shortage of some critical input (e.g., crude oil (or increase in crude prices)), or due to refinery outages which could be an aftermath of a natural

[30] It was noted in the March 2001 U.S. Federal Trade Commission Report that oil companies intentionally withheld supplies of gasoline from the market as a profit maximizing strategy. "The report states: "…A decision to limit supply does not violate the antitrust laws, absent some agreement among firms. Firms that withheld or delayed shipping additional supply in the face of a price spike did not violate the antitrust laws. In each instance, the firms chose strategies they thought would maximize their profits…"

disaster, refiners could continue to hold back production even when crude price falls or when there is sufficient demand for gasoline in order to gain short run profits.

The departure from symmetric speed of adjustment in the Los Angeles market when market concentration and/or refinery utilization is included in the basic ASECM confirms the uniqueness of the Los Angeles market. This could be attributed to the interplay of the effect of the market's well known tight balance between supply and demand and the fact that California's demand exceeds the growth of production capacity of the refineries producing the state's unique blend of gasoline coupled with California's high gasoline taxes.[31]

The rest of the asymmetry not captured by the market concentration and refinery capacity utilization parameters could be explained by the other reasons that have been enumerated in the empirical literature. These possible reasons for asymmetric adjustment speed include menu-cost interpretations (Davis and Hamilton (2004)), downstream oligopoly focal point pricing, midstream inventories, search in downstream markets (BCG (1997)) and threshold reasons, but market structure as measured by market concentration and refinery capacity utilization in the hands of a few dominant firms, can not be downplayed as a major contributor to wholesale gasoline price asymmetry.

7. Concluding Remarks

This paper has re-examined issue of price adjustment in the transmission of upstream price shocks to downstream gasoline prices by investigating how wholesale gasoline prices adjust to crude price shocks when market structure effects is taken into consideration. This isolates the response pattern of wholesale gasoline price changes to crude oil price changes as a result of market structure as represented by market concentration and refining capacity utilization. Relative to the approaches that have been used in the previous literature, this paper approached the question in a novel manner, by first examining the existence of any structural change in the

[31] Taxes in California are the third highest in the U.S.

pattern of price adjustment speed around the period of major mergers which could have been as a result of the series of major mergers in the oil industry. Structural break was found in the three markets around the period of major mergers, but the effect on speed of adjustment was insignificant and the idea that the series of mergers led to a change in pattern of adjustment speed was discarded.

From the literature, no formal theory relating market structure to asymmetric speed of adjustment has been empirically tested, also making this the first attempt to investigate the effects of market structure on price adjustment in the wholesale gasoline markets as there is much evidence of increased market concentration in the industry and volatile refining capacity utilization. This led to the incorporation of the HHI and refining capacity utilization in the basic ASECM to investigate the effect of market structure on the speed of price adjustments.

Symmetric speed of adjustment of wholesale gasoline prices to crude oil price changes was rejected in the three wholesale gasoline spot markets examined. These results are corroborated by the differences in the point estimates of the parameters of the model which point to the lack of uniformity in the speed of price adjustment when crude oil price rise or fall. In the Gulf Coast and New York spot markets, a small part of the downward price stickiness is explained by increased market concentration and refinery capacity utilization as the industry becomes less responsive to negative crude shocks, and firms exploit their market power through capacity utilization. But this effect is not economically significant, implying that market structure does not dramatically influence the speed of price adjustment in the wholesale gasoline markets. On the other hand, the result confirms Bedrossian and Mochos (1988) prediction of slow price adjustment to cost decrease in a profitable concentrated market and refutes the notion that price adjustments can be effectively coordinated and industry equilibrium restored fairly rapidly as industrial concentration increases. While the effect of market structure on adjustment pattern is not economically significant enough to warrant policy intervention, and as Brown and Yucel

(2000) have also noted, policy makers should watch for mergers, acquisitions and joint ventures that increase market concentration without much gains in economies of scale.

References

Andrews Donald W.K., "Tests for Parameter Instability and Structural Change With Unknown Change Point", *Econometrica* **61** (4) (July, 1993), 821-856.

Asplund Marcus, Eriksson Rickard, and Friberg Richard, "Price Adjustment by a Gasoline Retail Chain", *Scandinavian Journal of Economics* **102** (1) (2000), 101-121.

Bachmeier Lance J. and Griffin James M., "New Evidence on Asymmetric Gasoline Price Response", *Review of Economics and Statistics*, **85** (3) (August 2003), 772 - 776

Bacon, Robert W., "Rockets and Feathers: The Asymmetric Speed of Adjustment of U.K. Retail Gasoline Prices to Cost Changes", *Energy Economics* **13** (July 1991), 211-218.

Bai J., and Perron P., "Computation and Analysis of Multiple Structural Change Models", *Journal of Applied Econometrics* **18** (2003), 1-22.

Balke, Nathan S., Brown Stephen P.A., and Yucel Mine K., "Crude Oil and Gasoline Prices: An Asymmetric Relationship?", *Economic Review,* Federal Reserve Bank of Dallas (First quarter 1998), 1-11.

Bedrossian A. and Moschos D., "Industrial Structure, Concentration and the Speed of Price Adjustment", *The Journal of Industrial Economics* **36** (4) (June 1988), 459-475.

Borenstein Severin, Cameron Colin A., and Gilbert Richard "Do Gasoline Prices Respond Asymmetrically to Crude Oil Price Changes? ", *The Quarterly Journal of Economics* **112** (1), (Feb. 1997), 305-339.

Borenstein Severin and Shepard Andrea, "Sticky Prices, inventories, and market power in wholesale gasoline markets", *Rand Journal of Economics* **33**(1), (Spring 2002), 116-139.

Brown Stephen P.A. and Yucel Mine K., "Gasoline and Crude Oil Prices: Why the Asymmetric? ", *Economic and Financial Review,* Federal Reserve Bank of Dallas (Third quarter 2000), 1-7.

Cook S., "Nonsymmetric error correction revisited", *Applied Economic Letters* **6** (1999), 467-470.

Davis Micheal C. and Hamilton James D., "Why Are Prices Sticky? The Dynamics of Wholesale Gasoline Prices", *Journal of Money, Credit, and Banking* **36** (1) (2004), 17-37.

Dixon R., "Industry Structure and the Speed of Price Adjustment", *The Journal of Industrial Economics* **32** (1) (Sept. 1983), 25-37.

Domberger S., "Price Adjustment and Market Structure", *The Economic Journal* **89** (353) (March, 1979), 96-108.

Domberger S., “Price Adjustment and Market Structure: A Reply”, *The Economic Journal* **91** (364) (Dec., 1981), 1026-1030.

Engle, Robert F. and Clive W.J.Granger, “Co-integration and Error Correction: Representation, Estimation, and Testing”, *Econometrica* **55** (March 1987), 251-276.

Galeotti Marzio, Alessandro Lanza, and Matteo Manera, “Rockets and feathers revisited: An international comparison on European gasoline markets”. *Energy Economics* **25** (2003), 175-190

Geweke John, “Issues in the ‘Rockets and Feathers’ Gasoline Price Literature”, Report to Federal Trade Commission (May 16, 2004)

Godby Rob, Anastasia M Lintner, Thanasis Stengos, and Bo Wandschneider, “Testing for asymmetric pricing in the Canadian retail gasoline market”, *Energy Economics* **22** (2000), 349-368.

Kaufmann R.K. and Laskowski C., “Causes for an asymmetric relation between the price of crude oil and refined petroleum products”, *Energy Policy* **33** (2005), 1587-1596

Mackinnon J., “Critical Values for cointegration tests”, In: Engle, R.F., Granger, C.W.J. (Eds.), *Long-Run Economic Relationships: Readings in Cointegration* (1991), Oxford University Press, Oxford.

Oladunjoye Olusegun, “Rockets and Feathers Revisited: New Evidence on Symmetric Price Adjustments in U.S. Gasoline Markets” (2003), *Unpublished Masters degree project, University of Guelph, ON, Canada.*

Reilly Barry and Witt Robert, “Petrol price asymmetries revisited ”, *Energy Economics* **20**, (1998), 297-308.

State of California Energy Commission, *“Causes for Gasoline and Diesel Price Increases in California”*, June Monthly Update (June 1, 2003)

Shwert, G.W., “Tests for unit roots: A Monte Carlo investigation”, *Journal of Business and Economic Statistics* **7,** (1989), 147-159.

U.K. Monopolies and Mergers Commission, “Parallel Pricing – A Report on the General Effect on the Public Interest of the Practice of Parallel Pricing”, *Cmnd 5330. London: H.M.S.O.* (1973).

U.S. Department of Energy, Energy Information Administration, *“Price Changes in the Gasoline Market: Are Midwestern Gasoline Prices Downward Sticky?”*, (February 1999) http://www.eia.doe.gov/pub/oil_gas/petroleum/analysis_publications/price_changes_gas_market/pdf/price_change.pdf

U.S. General Accounting Office, *“Energy Market: Effects of Mergers and Market Concentration in the U.S. Petroleum Industry”* (May 2004), United States General Accounting Office Report to the Ranking Minority Member, Permanent Subcommittee on Investigations, Committee on Governmental Affairs, U.S. Senate http://www.gao.gov/new.items/d0496.pdf

U.S. Senate, "*Gas Prices: How Are They Really Set?"* Report prepared by the Majority Staff of the Permanent Subcommittee on Investigations, released in conjunction with the Permanent Subcommittee on Investigations' Hearings on April 30, 2002 and May 2, 2002.

Winters L.A., "Price Adjustment and Market Structure: A Comment", *The Economic Journal* **91** (364) (Dec., 1981), 1026-1030.

Appendix

HHI and RCU Data

I estimated the Refinery Capacity, market shares (based on aggregated capacity) of each firm owning a refinery, the refining industry HHI index and the 4 firm concentration ratio[32] from the Annual crude capacity (in million) barrels per calendar day data obtained from EIA[33]. The data were as at January 1st of each year from 1986 to 2005 with data at January 1st 1996 and 1998 missing. I took these data to be representative of the previous year information and used the information on refineries for 1994 and 1996 as substitutes for the years 1995 and 1997. I estimated the GCSH data using the Gulf Coast HHI data[34] and the LASH data is generated from the California HHI data. The NYSH corresponds to the PADD1 HHI estimated from the aggregated capacity of all refineries operating in PADD1, as there is no refinery in the New York and New York being in PADD 1 gets most of its supplies directly from PADD 1 refiners. These HHI data are annual and therefore exhibits no monthly variation.

The refinery capacity utilization data (RCU) is the Percent Utilization of Refinery Operable Capacity corresponding to PADD 3 (Gulf Coast), PADD 5 (West Coast – includes the Los Angeles market) and PADD 1 (East Coast – includes the New York market). This represents the utilization of the atmospheric crude oil distillation units. The rate is calculated by dividing the gross input to these units by the operable calendar day refining capacity of the units.

[32] The 4 firm concentration ratio is defined as the sum of the largest four market shares. This measure of concentration was also used in the U.S. Senate report, "*Gas Prices: How Are They Really Set?"* (2002) in its analysis.
[33] Thanks to Micheal Conner of EIA for providing the Annual crude capacity barrels per calendar day and the Annual crude capacity barrels per stream day data.
[34] The Gulf Coast is also referred to as PADD 3.

Long Run relationships

HHI and RCU were found to be significant in the long run equation for all the markets, as such it was included in the long run relationship estimation under alongside monthly dummies.

Table A1: Estimation Results of the Long Run equilibrium

	Gulf Coast Market		***Los Angeles Market***		***New York Market***	
	Estimate	**S.E.**	**Estimate**	**S.E.**	**Estimate**	**S.E.**
Intercept	8.085	1.287	-19.90	3.396	3.918	1.197
WTIS	**1.104**	0.006	**1.272**	0.009	**1.134**	0.006
(GC, P5, P1)HHI	**0.007**	0.001	**0.012**	0.001	**-0.001**	0.000
(GC, P5, P1)RCU	**-0.120**	0.015	**0.014**	0.039	**-0.017**	0.015
M2	0.975	0.386	6.173	0.708	1.305	0.400
M3	3.952	0.374	11.920	0.684	3.237	0.385
M4	8.353	0.387	11.990	0.710	6.409	0.394
M5	9.018	0.387	9.223	0.710	7.481	0.397
M6	5.268	0.379	8.431	0.697	4.502	0.400
M7	4.019	0.379	5.570	0.711	3.805	0.401
M8	4.077	0.376	8.796	0.711	4.608	0.393
M9	1.192	0.379	5.381	0.708	2.819	0.396
M10	-0.459	0.370	1.069	0.677	0.938	0.382
M11	-1.306	0.381	-1.338	0.693	1.081	0.392
M12	-3.107	0.380	-3.018	0.694	-1.714	0.389
Adjusted R-Squared		*0.937*		*0.858*		*0.933*

Table A2: Detailed model estimation results[35]

	Gulf Coast Market							
	ASECM		**HHI**		**RCU**		**HHI & RCU**	
	Estimate	**S.E.**	**Estimate**	**S.E.**	**Estimate**	**S.E.**	**Estimate**	**S.E.**
dp1	-0.053	0.038	-0.053	0.038	-0.053	0.038	-0.054	0.039
dcsap	-0.042	0.008	-0.047	0.009	-0.046	0.009	-0.048	0.009
dn1	0.007	0.033	0.006	0.033	0.006	0.033	0.007	0.033
dcsan	-0.054	0.010	-0.065	0.013	-0.064	0.013	-0.065	0.013
wp	**1.139**	0.054	**1.141**	0.057	**1.142**	0.056	**1.140**	0.057
wp1	-0.076	0.081	-0.074	0.081	-0.071	0.081	-0.075	0.081
wn	**0.945**	0.043	**0.945**	0.044	**0.944**	0.044	**0.945**	0.044
wn1	0.076	0.061	0.075	0.062	0.074	0.062	0.075	0.062

[35] In this result, *dp, dp1, dsap, wp, wp1, rp, re and D1* denote respectively, positive downstream price change, 1 period lagged positive downstream price change, positive error correction term, positive upstream price change, 1 period lagged positive upstream price change, positive HHI, positive refinery capacity utilization and positive error correction term interacted with a dummy, while their corresponding negative variables are denoted as *dn, dn1, dsan, wn, wn1, rn, rw and D3 respectively.*

rnp			**0.709**	1.066			**3.317**	3.409
rnn			**-1.015**	1.038			**-0.594**	3.181
rne					**0.028**	0.065	**-0.169**	0.210
rnw					**-0.066**	0.064	**-0.025**	0.196
Adjusted R-Squared		*0.411*		*0.411*		*0.411*		*0.411*
Los Angeles Market								
	ASECM		**HHI**		**RCU**		**HHI & RCU**	
	Estimate	**S.E.**	**Estimate**	**S.E.**	**Estimate**	**S.E.**	**Estimate**	**S.E.**
dp1	0.135	0.026	0.131	0.026	0.133	0.026	0.130	0.026
dcsap	-0.043	0.006	-0.058	0.008	-0.057	0.007	-0.059	0.008
dn1	0.125	0.028	0.133	0.027	0.130	0.027	0.134	0.028
dcsan	-0.044	0.009	-0.046	0.012	-0.046	0.012	-0.046	0.012
wp	**0.906**	0.083	**0.861**	0.087	**0.866**	0.087	**0.859**	0.087
wp1	-0.113	0.088	-0.171	0.090	-0.166	0.090	-0.172	0.090
wn	**0.905**	0.067	**0.936**	0.068	**0.933**	0.068	**0.938**	0.068
wn1	0.033	0.072	0.071	0.074	0.069	0.074	0.071	0.074
rnp			**2.643**	0.721			**5.212**	3.165
rnn			**0.619**	0.722			**0.209**	2.665
rne					**0.355**	0.105	**-0.381**	0.459
rnw					**0.082**	0.104	**0.064**	0.387
Adjusted R-Squared		*0.119*		*0.119*		*0.118*		*0.118*
New York Market								
	ASECM		**HHI**		**RCU**		**HHI & RCU**	
	Estimate	**S.E.**	**Estimate**	**S.E.**	**Estimate**	**S.E.**	**Estimate**	**S.E.**
dp1	0.129	0.041	0.131	0.041	0.131	0.041	0.131	0.041
dcsap	-0.038	0.007	-0.037	0.008	-0.037	0.008	-0.037	0.008
dn1	0.059	0.038	0.056	0.038	0.056	0.038	0.057	0.038
dcsan	-0.051	0.009	-0.061	0.012	-0.064	0.012	-0.063	0.012
wp	**1.096**	0.049	**1.111**	0.052	**1.110**	0.052	**1.107**	0.053
wp1	-0.223	0.079	-0.206	0.079	-0.206	0.079	-0.211	0.079
wn	**0.958**	0.039	**0.949**	0.041	**0.949**	0.040	**0.952**	0.041
wn1	0.023	0.064	0.013	0.064	0.014	0.064	0.016	0.064
rnp			**-0.384**	0.462			**-0.675**	1.744
rnn			**-0.690**	0.454			**1.426**	1.527
Rne					**-0.048**	0.063	**0.052**	0.241
Rnw					**-0.110**	0.059	**-0.292**	0.200
Adjusted R-Squared		*0.426*		*0.427*		*0.427*		*0.426*

Proof that long run equilibrium factor is greater than 1

In a fixed proportions wholesale gasoline production technology, crude oil and other inputs are assumed to be used in gasoline refining in fixed proportion. Thus giving a production function of the form:

$$x_g = Min[ax_c, \overline{y}], \ 0 < a < 1 \tag{A1}$$

Where x_g is gasoline production x_c is crude oil input, a is a strictly positive term and $\overline{y}$ is all other factors of production, assumed to be fixed. The total cost function is given as:

$$C(x_g, P_c) = P_c x_c + \kappa \overline{y} \tag{A2}$$

Where $0 < \kappa < 1$ and $x_g = ax_c$. $C(x_g, P_c) = \frac{1}{a} P_c x_g + \kappa \overline{y}$ (A3)

In perfect competition, marginal cost pricing => $MC = P_g$ => $MC = \frac{1}{a} P_c$, therefore $\frac{1}{a} > 1$

This implies that the long run equilibrium adjustment factor of gasoline prices to crude price changes $\frac{1}{a}$, i.e. the coefficient on crude oil price should be greater than 1. Estimates of $\frac{1}{a}$ for PADD 1, 3 and 5 are obtained from the ratio of crude oil input into refineries over finished motor gasoline production. These estimates are based on the time series data for the three PADDs from January 7, 1994 to December 30, 2004. The average estimates of $\frac{1}{a}$ from the data are 2, 1.86 and 1.53 for PADD 1, 3 and 5 respectively.