ECONOMIC ANALYSIS GROUP
DISCUSSION PAPER

An Empirical Investigation of the Determinants of Asymmetric Pricing

By

Marc Remer*

EAG 12-10 November 2012

----

*Economic Analysis Group, U.S. Department of Justice. Email: marc.remer@usdoj.gov. The views expressed in this article are entirely those of the author and are not purported to reflect those of the U.S. Department of Justice. I am grateful to Joe Harrington for advice throughout this project. I also thank Mitsukuni Nishida, Stephen Shore, Guofang Huang, Gloria Sheu, Nathan Miller, and participants at the Johns Hopkins Empirical Microeconomics seminar, the Eastern Economics Association Meetings, and the International Industrial Organization Conference. All remaining errors are my own.

Abstract

This article empirically investigates the cause of asymmetric pricing: retail prices responding faster to cost increases than decreases. Using daily price data for over 11,000 retail gasoline stations, I find that prices fall more slowly than they rise as a consequence of firms extracting informational rents from consumers with positive search costs. Premium gasoline prices are shown to fall more slowly than regular fuel prices but rise at the same pace, and this pricing pattern supports theories based upon competition with consumer search. Further testing also rejects focal price collusion as an important determinant of asymmetric pricing.

1 Introduction

A robust body of economic literature has focused on the retail gasoline industry. The attention stems from the market being influenced by factors rigorously studied by microeconomic theorists: search costs, spatial differentiation, tacit collusion, and Edgeworth cycles to name a few. The primary focus of this article is asymmetric pricing: the tendency for firms to adjust retail prices more quickly in response to cost increases than decreases. In particular, I verify the existence of the phenomenon using a new, high-frequency, micro-level data set. Perhaps more importantly, I provide new empirical insight into asymmetric pricing's underlying cause, and in doing so establish empirical regularities of gasoline price adjustments that have yet to be documented at a micro-level across a large number of markets.

Bacon (1991) was the first to demonstrate that firms respond with greater speed to cost increases than decreases, while also coining the phrase "rockets and feathers" to describe the phenomenon. Supporting the hypothesis that gasoline prices shoot up like rockets but fall like feathers are the findings of Borenstein, Cameron, and Gilbert[1] (1997), whose empirical model has served as the foundation for identifying asymmetric price adjustments. Building on the work of BCG, rockets and feathers has been identified in retail gasoline markets in Canada, the United States, Chile, and a host of European countries. Asymmetric pricing, however, is not confined to the retail gasoline industry; Peltzman (2000) examines 242 diverse product markets and confirms rockets and feathers to be a common pricing phenomenon in more than two thirds of the markets.

These empirical findings, until recently, were unexplained by economic theory, and even now there exists a lack of consensus as to asymmetric pricing's underlying cause. One of the first explanations to gain traction was that asymmetry is a precipitant of focal price collusion.[2] A number of recent studies have theoretically derived asymmetric pricing as a consequence of consumer search costs. In particular, Lewis (2011), Tappata (2009), Yang and Ye (2008), and Cabral and Fishman (2008) each find that firms extract informational rents from consumers unaware of input cost changes and therefore exhibit price asymmetry.

This article presents evidence in favor of the consumer search-based theories posited in Yang and Ye (2008) and Tappata (2009), and finds no support for focal price collusion. First, Yang and Ye (2008) show that the price of products whose consumers are less likely to shop for the lowest price are slower to adjust downwards following a negative cost shock, but increase at the same rate following a cost increase. This implication is confirmed by examining the dynamic properties of firms' markup of premium over regular unleaded fuel. Specifically, the gap increases following a cost decrease but remains constant following a cost increase; premium prices, therefore, fall more slowly

[1] Hereafter referred to as BCG.

[2] BCG (1997) and Lewis (2011) both discuss this possibility.

than regular prices, but rise at the same speed. I argue that there is a systematic difference in the search costs of consumers who purchase either premium or regular gasoline, and as such confirm the prediction of Yang and Ye (2008).

By studying the markup of premium over regular, I isolate how specific firms price products purchased by distinctly different consumers. The value added by this approach to a study such as Peltzman (2000) is that it measures not only the relative asymmetry of different products, but also how the same firm prices two different goods that are subject to nearly identical cost shocks. Thus, many important determinants of the dynamic price behavior of the two products are controlled for, except the type of consumers buying the goods. The unique pricing patterns of premium and regular gasoline is, therefore, partially attributable to differences between the two products' consumers.

Additional empirical analysis supports search-based theories of asymmetric pricing, undermines collusion as a meaningful cause of the pricing pattern, and provides new insight into the relationship between the speed of price adjustment, firm price levels, and market structure. The large amount of variation in firm prices and market concentration present in the data allow, for example, the relationship between asymmetric pricing and the Herfindahl-Hirschman Index (HHI) to be estimated. While finding that HHI is inversely related to the degree of asymmetry stands as evidence against collusion as a meaningful determinant of the pricing phenomenon, viewed independently of theoretical motivations, the result still improves our understanding of firm pricing behavior. Similarly, analysis of price dispersion, price-levels, and their relationship to the speed of price adjustment further evidences the underlying cause of asymmetric pricing and demonstrates a new empirical trait of dynamic pricing behavior.

A host of empirical studies have verified the presence of asymmetric pricing in the gasoline industry.[3] BCG (1997) uses price data on four distinct links of the gasoline supply chain – crude oil, spot wholesale, local rack, and retail[4] – and finds evidence of asymmetry at every link except for the transmission from spot to local rack. It is more typical in the literature, however, to test the speed at which spot crude oil or spot wholesale prices are incorporated into final retail prices.[5] For example, Verlinda (2008) and Lewis (2011) both analyze the speed at which spot wholesale prices are transmitted to retail prices and find evidence of asymmetry. Chen et al. (2005) finds asymmetry in the response of retail prices to changes in both the spot price of crude oil and wholesale gasoline. There are, however, studies that fail to find evidence of asymmetry; for example, Godby et al. (2000) finds no crude to retail price asymmetry in thirteen Canadian cities and neither Bachmeier and Griffin (2003) nor Chen et al. (2005) find asymmetry in the response of spot wholesale prices

[3]Geweke (2004) offers a detailed summary of the asymmetric pricing literature.

[4]Generally speaking, these prices are listed from upstream to downstream. See, BCG for a more detailed explanation.

[5]The reliance upon either crude or spot over rack as a measure of cost is due to crude and spot prices being publicly available, while rack prices are proprietary.

to changes in spot crude oil prices.

A reason for the disparity in results in the asymmetric pricing literature is that different studies utilize data that covers unique geographic regions and is subject to different levels of aggregation. A large share of the literature uses price data that is averaged over large geographic areas, such as cities (BCG (1997), Eckert (2002), Chesnes (2010)), states (Deltas (2008)), or countries (Galeotti et al. (2003)). Also, much of the previous analysis has relied upon data that is either averaged over time (Bacon (1991) and Hosken et al. (2008))[6] or are sampled at regular temporal intervals (both Verlinda (2008) and Lewis (2011) employ data that was collected once per week). Bachmeier and Griffin (2003) and Remer (2010) find that temporal aggregation may lead to biased estimates of asymmetric pricing.

In this article, I employ one year of daily retail gasoline price observations for more than 11,000 gas stations, and find strong evidence in support of asymmetric pricing. In establishing the existence of asymmetric pricing with data disaggregated to the daily-firm level, I estimate its magnitude with a high degree of precision and find that five days after an initial change to the spot price of unleaded gasoline firms incorporate 46% of a positive change into their final price, but only 24% of a negative change; the difference in the speed of retail price adjustment persists for more than ten days. While there exists a plethora research into the existence of rockets and feathers, there has been little empirical sifting of the various theoretical explanations. To the best of my knowledge, other than Lewis (2011), no other paper has been able to empirically verify or discredit a specific theory of rockets and feathers. Having data disaggregated to the firm-level across a plethora of markets allows me to both delve deeper into the causes of asymmetric pricing and to more generally describe the relationship between the pricing phenomenon and local market characteristics.

The outline of the article is as follows; Section 2 discusses the data and its general properties, Section 3 introduces the econometric model and presents new evidence of rockets and feathers, Section 4 tests search-based theories of price asymmetry, Section 5 examines focal price collusion, and Section 6 concludes.

2 Data and Summary Statistics

The econometric analysis in this article is buoyed by a richly detailed data set consisting of daily, firm-level price observations from July 30th, 2008 through July 29th, 2009. Included in the data are observations for most gas stations in the states of New Jersey, Maryland, Virginia, Washington, as well as the Philadelphia, PA and Washington, DC metro areas. This amounts to over 11,000 unique stations. The data was culled from the website gasprices.mapquest.com whose information is provided by the Oil Price Information Service (OPIS). According to its website, OPIS collects

[6]Each of the papers listed as using geographically averaged prices also use temporally averaged data.

data "through exclusive relationships with credit card companies, direct feeds, and other survey methods," and therefore price observations are measured with a high degree of accuracy. While mapquest was scraped at daily intervals, the website did not report a new price for each station on every day. On average, they posted new price observations for 72% of stations on weekdays and 48% on weekends.[7]

Daily gasoline spot prices listed on the New York Mercantile Exchange (NYMEX) are employed as the cost variable. Reformulated gasoline delivered from the New York and Los Angeles Harbors are used for firms located in the eastern and western states, respectively. In reality, retail stations purchase gasoline at the rack price posted at local terminals, who in turn purchase their product on the spot market. BCG note, however, that terminal prices react symmetrically and almost immediately to changes in spot prices. Thus, spot prices should be highly correlated with terminal prices and suitable for use in the subsequent analysis.

Another potential concern is which day's spot price to use for a given day's retail price. Even though wholesale costs change daily, gas stations do not receive a new shipment of gasoline every day. Thus, lagged values of cost reflect the price paid by firms that do not replenish their inventory on a given day. However, the concurrent day's spot price reflects the opportunity cost of holding inventory and is generally the index by which stations set their price.[8] Therefore, in accordance with the literature, I match retail prices with the same day's spot price.[9]

The spatial makeup of individual markets plays an important role in the econometric analysis.[10] In particular, the number of competing stations within given distances of the firm of interest is incorporated into each test. To calculate this, I first geocoded[11] the data using software provided by USC's Department of Geography, which were then cross referenced with coordinates determined by Yahoo maps. Any coordinates that did not match or were unable to be determined with sufficient precision were then geocoded by hand using the Google maps API. Then, the distance between all pairs of firms was calculated using the Euclidean distance measure.

Table 1 reports summary statistics for pertinent station and market characteristics that are at times included as additional controls in the empirical analysis. Also reported in the table are the results of regressing regular unleaded retail price on those traits. In step with previous studies, such as Eckert and West (2004) and Hosken et al. (2008), independent brand retailers are found to charge significantly lower prices than majors. Additionally, prices increase with the distance

[7]These numbers are consistent with those reported in previous studies whose data is directly obtained from OPIS.

[8]The Association for Convenience and Petroleum Retailing, a lobbying group for gas stations, explains in their 2009 Gas Price Kit that firms set their retail price based on the "replacement cost" of gasoline: the current wholesale price.

[9]Chandra and Tappata (2011), Lewis (2008), and Verlinda (2008) also use this approach.

[10]Houde (2011) finds that both market structure and the commuter paths of consumers significantly impact retail price dynamics.

[11]Geocoding is the process of converting street addresses into longitude and latitude coordinates.

to the closest competitor, which indicates that firms are able to exploit available market power. The number of competing firms within .1 miles is positively related to price levels, likely reflecting high demand in such areas and/or the ability to collude. The number of competitors within other distances does not have an economically meaningful effect on price levels. This is a consequence of two counteracting effects; the number of firms within a given distance positively correlates with the degree of competition, which decreases price levels, but also serves as a proxy for demand, which positively correlates with price levels. Acting as a better representation of local competition, Table 1 indicates that prices decrease if more competitors are not major brands. Previous studies find that these independent retailers are more likely to undercut their rivals' prices, thereby increasing market competition.[12] Thus, the basic statistics are consistent with the existing literature.

The time over which I analyze data was a particularly volatile period in the gasoline industry; the price of oil peaked at just over \$126 per barrel and fell to a low of \$31. Figure 1 plots the wholesale and average retail price for regular unleaded gasoline over this time period, and Table 2 presents summary statistics for the average daily prices of premium, regular, and wholesale gasoline. The most striking feature of Figure 1 is the rapid decline in gas prices during the autumn of 2008, which coincides with a financial crisis and worldwide slowdown of production. A primary concern, given the lengthy downward trend, is that the price and cost series may not be stationary in first differences. However, augmented Dickey-Fuller tests (Said and Dickey, 1984) assure that both price and cost are stationary in first differences.

At first glance, retail prices in Figure 1 appear to drop simultaneously with wholesale costs, yet upon close inspection there exist many instances when costs drop suddenly and retail prices slowly (or never) follow suit. Around mid-December 2008 and again during mid-July 2009, for example, there are sharp declines in cost, but retail prices exhibit only a gradual decline. Also consistent with asymmetric pricing is the noticeably higher retail margins during the large decline in wholesale prices from mid-September to the end of December. In total, it is not obvious whether retail prices adjust faster to price increases than decreases, and a more careful analysis is needed.

3 Testing for the Presence of Asymmetric Pricing

3.1 A Model of Asymmetric Pricing

To estimate the degree of price asymmetry, I rely upon the econometric model specified in BCG (1997) and further modified in Bachmeier and Griffin (2003), which has become standard in the asymmetric pricing literature. The model is a straightforward extension of the error-correction

[12]See Eckert and West (2004) and Noel (2007) for empirical evidence and Eckert (2002) for a theoretical justification.

model derived in Engle and Granger (1987). The error-correction model, specified in equation (1), was developed to estimate time-series data that are cointegrated:[13]

$$\Delta R_t = \sum_{j=0}^{n} \beta_j \Delta C_{t-j} + \sum_{j=1}^{n} \gamma_j \Delta R_{t-j} + \vartheta_1 (R_{t-1} - \phi_1 C_{t-1} - \phi_0) + \epsilon_t. \tag{1}$$

Here, R_t and C_t are retail price and wholesale cost, respectively, at time t, $\Delta X_t = X_t - X_{t-1}$ is defined for any variable of interest X, and ϵ_t is a zero-mean, normally distributed iid error term. The model implicitly assumes a long-run linear relationship between retail price and wholesale costs:

$$R_t = \phi_0 + \phi_1 C_t + \epsilon_t, \tag{2}$$

and thereby $R_{t-1} - \phi_1 C_{t-1} - \phi_0$ in equation (1) captures the extent to which retail prices and wholesale costs were out of their long-run equilibrium.[14] Consequently, equation (1) separately identifies the effect on retail prices of short-run changes in cost and own-price (β_j and γ_j, respectively) from the pressure for retail prices to return to their long-run relationship with cost (ϑ_1).

To test for the presence of asymmetric pricing, equation (1) must be generalized to allow for positive and negative cost changes to differentially affect retail prices. In an extension of the model proposed in BCG, Bachmeier and Griffin (2003) propose the following estimable equation:

$$\begin{aligned}\Delta R_t = &\sum_{j=0}^{n} (\beta_j^+ \Delta C_{t-j}^+ + \beta_j^- \Delta C_{t-j}^-) \; + \; \sum_{j=1}^{n} (\gamma_j^+ \Delta R_{t-j}^+ + \gamma_j^- \Delta R_{t-j}^-) \\ &+ \vartheta_1^+ (R_{t-1} - \phi_1 C_{t-1} - \phi_0)^+ + \vartheta_1^- (R_{t-1} - \phi_1 C_{t-1} - \phi_0)^- + \epsilon_t. \end{aligned} \tag{3}$$

Here, ΔC_{t-j}^+ takes the value of ΔC_{t-j} if it is positive, and zero otherwise, ΔC_{t-j}^- takes the value of ΔC_{t-j} if it is negative, and zero otherwise; lagged retail price changes and the error-correction term are analogously defined. Therefore, equation (3) allows for positive and negative cost changes to have a unique effect on current retail prices. Similarly, past changes in retail price and the error-correction term are allowed to asymmetrically affect current retail prices. In general, if $\beta_j^+ > \beta_j^-$ then rockets and feathers exists.

To rigorously assess the existence of asymmetric pricing, however, the entire lag structure must be taken into account. Thus, as suggested in BCG, the parameters of equation (3) are used to construct *cumulative response functions* (CRF's), which map the adjustment of retail price over time in response to a one time, one cent change in wholesale cost. After an initial one cent increase

[13] In the following subsection, I test for asymmetry in the pricing of regular unleaded gasoline. Augmented Dickey-Fuller tests confirm that the retail price of regular gasoline and the cost series are cointegrated and stationary in first differences.

[14] $R_{t-1} - \phi_1 C_{t-1} - \phi_0$ is referred to as the "error-correction" term, as it is the lagged residual from equation (2).

to costs at $t = 1$, the period k change in retail price, B_k^+, is determined by:

$$\begin{aligned} B_k^+ =& B_{k-1}^+ + \beta_k^+ + \vartheta_1^+ \max\{B_{k-1} - \phi_1, 0\} + \vartheta_1^- \min\{0, B_{k-1} - \phi_1\} \\ &+ \sum_{i=1}^{k} (\gamma_i^+ \max\{0, B_{k-i} - B_{k-i-1}\} + \gamma_i^- \min\{0, B_{k-i} - B_{k-i-1}\}). \end{aligned} \tag{4}$$

Then, the CRF is a recursive function which sums n equations, where n is the number of periods it takes retail prices to completely respond to a one time change in cost, and the period $k \in \{1, ..., n\}$ cumulative adjustment is as stated in equation (4). The CRF detailing the response to a cost decrease is defined analogously to equation (4). Thus, rockets and feathers pricing exists at any point in time if the value of the positive CRF is greater than the negative CRF.

3.2 Estimating the Magnitude of Retail Price Asymmetry

Prior to empirically evaluating specific theories of asymmetric pricing, I first establish its presence in the data. To the best of my knowledge, no previous study of rockets and feathers has documented the phenomenon with daily firm-level data for such a large number of geographically diverse firms. Previous firm-level studies of asymmetric pricing utilized data detailing only a single metropolitan area. Furthermore, analysis presented in Remer (2010) illustrates that aggregating data to even weekly averages can contaminate parameter estimates. Therefore, verifying the phenomenon's existence with temporally disaggregated data for firms located in rural and urban markets on both coasts of the USA serves as an important contribution to the literature.

To ascertain if retail gasoline firms react more quickly to cost increases than decreases, I estimate equation (3) as recommended in Engle and Granger (1987). That is, I first estimate equation (2) using OLS, then substitute the parameter values into equation (3) and estimate that equation again using OLS. This procedure is appropriate due to the stationarity of the regressors in equation (3), which enables standard significance tests of both the parameters and functions of multiple parameters.[15] Because quantifying the degree of price asymmetry involves constructing response functions from multiple parameters, estimating the error-correction model using this two-step procedure ensures that I am constructing appropriate confidence intervals to test for asymmetry.

Previous literature has discussed the possible endogeneity of upstream prices due to lagged changes in cost being affected by unobserved demand shocks. To assess this possibility, I ran a specification using lagged changes in Brent crude oil spot price (the primary index for crude prices in Europe) and Singapore conventional gasoline prices as instruments; both price series are

[15] As retail prices and costs are cointegrated, estimates of ϕ_0 and ϕ_1 are superconsistent. Therefore, it is appropriate to substitute the residuals of the estimated equation (2) into equation (3) in place of $R_{t-1} - \phi_1 C_{t-1} - \phi_0$, as superconsistency allows the econometrician to act as though ϕ_0 and ϕ_1 were truly known.

determined on the world market and highly correlated with wholesale gasoline costs, but should be unaffected by local demand shocks in the United States. Although this alternative specification did yield estimates qualitatively similar to the two-step OLS method, Hansen overidentification tests rejected the validity of the instruments with more than 99% confidence. In light of Bachmeier and Griffin (2003) and Galeotti et al. (2008), wherein the potential bias of estimating equation (3) in one step using instrumental variable regression is demonstrated, I err on the side of caution by following the procedure originally posited in Engle and Granger (1987), whose properties have been widely studied.

Before proceeding with the estimation, a host of controls are included to account for differences in local market conditions and firm specific traits. First, station fixed effects are added to equation (2) to allow for the possibility that individual firms employ different long-run markups or consistently purchase wholesale gasoline at relatively high or low prices. Additionally, to control for the effect that local competition, demand conditions, and firm traits may have on short-run adjustments, equation (3) is augmented by each variable listed in Table 1.[16] Finally, day of the week dummies are included in the second step of the econometric procedure to control for predictable changes in demand conditions over the course of the week.[17]

Regression results are reported in Table 3 with standard errors clustered by station and corrected for heteroscedasticity.[18] The regression produces economically plausible results consistent with the existence rockets and feathers. The coefficients for being above or below the long-run equilibrium retail price, ϑ_1^+ and ϑ_1^- respectively, are both negative. This implies that when retail prices are above (below) their long-run equilibrium value there exists downward (upward) pressure guiding retail prices towards their long-run equilibrium relationship with cost. Also, the estimated value for the long-run relationship between retail prices and wholesale costs, ϕ_1 in equation (2), is 1.04. Previous literature, such as BCG and Verlinda (2008), has argued that in the retail gasoline industry there should be full pass-through of an industry-wide cost shock (i.e. $\phi_1 = 1$).[19]

Supporting the existence of rockets and feathers is that the coefficient on current period positive cost changes, .08, is significantly greater than for negative cost changes, -.003. Thus, on the day

[16]Population data is either the 2007 projections by the United States Census Bureau, or when the projections are unavailable, the 2000 census measure. I classify Exxon/Mobil, Shell, BP, Texaco, Chevron, Citgo, Amoco, Sunoco, Lukoil, Getty, 76, and Conoco Phillips stations as major brand, and all others as non-majors. The results are robust to changes in the classification.

[17]Generally demand is higher during weekdays when there are a greater number of drivers commuting to work. Also, weekend drivers may be less informed about the market price distribution because they are not necessarily traveling along their usual commuter routes.

[18]Standard errors are clustered by station to control for correlation in the error term across time for a given station; results are nearly identical without clustering. For this regression, and all subsequent analysis, the lag lengths for cost and retail price changes are set to nine.

[19]If industry demand is linear, marginal costs are constant, and there is free entry and exit then long-run pass-through is one. In general Bertand models of differentiated products, however, there is no a priori reason to expect an industry pass-through rate of one.

of a 10¢ positive cost shock retail prices increase by .8¢, but are essentially unchange following a negative shock. This, however, is not proof of asymmetric pricing beyond the first day of a cost change. To more completely describe the magnitude of asymmetry, I use the parameter estimates and substitute them into the CRF specified in equation (4).

Figure 2 plots the CRF's and 95% confidence intervals[20] corresponding to the regression in Table 3, and it is clear that the existence of rockets and feathers is a widespread phenomenon in the retail gasoline industry. Here, the vertical axis plots the percentage of the total cost shock that has been incorporated into the final retail price. For just over ten days following a one time cost shock, the cumulative response is significantly greater for positive than negative shocks. Therefore, rockets and feathers is found to be a general pricing pattern found across a large number of diverse firms and markets; as such, the data provide an ideal context within which to examine both the underlying cause of asymmetric price adjustments and it's interaction with general market characteristics.

4 Consumer Search Costs and Asymmetric Pricing

4.1 Theoretical Background and Testable Hypothesis

Until recently, rockets and feathers was unexplained by microeconomic theory. Informal models of focal price collusion were conjectured as the cause, but no rigorous theory or empirical support has surfaced. On the other hand, formal models of asymmetric pricing as a consequence of consumer search costs have recently been developed. Interestingly, asymmetry has often been detected at the retail level, where search costs may be quite high, but frequently rejected at the wholesale level, where search costs are likely much lower. In this section, I empirically analyze the testable implications of the search theory developed in Yang and Ye (2008) and Tappata (2009); the two studies offer unique models with qualitatively similar results.

Both models rely upon the assumption that consumers do not observe firms' marginal cost of production, but may learn this cost through market search and purchase decisions; firms face the same marginal cost, which evolves according to a Markov process and exhibits persistence.[21] In equilibrium firms use mixed strategies to set prices,[22] and both studies prove that there exists more price dispersion when costs are low. Consumers with nonzero search costs have a greater incentive to search when prices are more dispersed, as the expected gain from obtaining additional price quotes is higher when the distribution of prices has greater spread. Therefore, consumers search more

[20]Throughout the article, I use the estimated variance-covariance matrix from the initial regression to obtain bootstrap confidence intervals for the CRF's.

[21]In the two point cost distribution considered in both theories, persistence is defined as the probability of costs remaining the same next period being greater than $\frac{1}{2}$.

[22]Empirically testing the assumption of mixed strategies is beyond the scope of this article. Hosken et al. (2008), Wang (2009), and Chandra and Tappata (2011) all find evidence that retail gasoline stations play mixed strategies.

intensely when they believe marginal costs to be low, and both Yang and Ye (2008) and Tappata (2009) demonstrate that these asymmetric search incentives result in consumers being less informed about cost decreases than increases. Consequently, firms have a lower incentive to decrease price following cost decrease than to increase price following a cost increase, which leads to asymmetric price adjustments.

Yang and Ye (2008) and Tappata (2009) offer testable predictions, two of which I address in the following subsections. First, Yang and Ye (2008) prove that if the proportion of "shoppers," consumers that face zero search costs, increases then retail prices will adjust downward more slowly in response to a negative cost shock, but rise at the same speed following a cost increase.[23] Intuitively, if the number of shoppers in a market decrease then there is less equilibrium search. Therefore, consumers are generally less informed when costs drop, and consequently, retail prices fall more slowly. A second verifiable consequence of search-based theory is that greater expected gains from search result in a lower magnitude of price asymmetry. This is true as larger gains from search incentivize more equilibrium search, and thereby, consumers are better informed. Firms are then less able to take advantage of unknowledgable buyers, and prices descend more quickly. In the following two subsections, I carefully test these implications of theories based upon competition with consumer search.

4.2 When Consumers Search Less – The Case of Premium Fuel

To empirically examine the consequences of search-based price asymmetry, I rely upon the differences in consumers who purchase regular versus premium unleaded gasoline. Premium gasoline has a higher octane rating than regular fuel, and in my data set, sold for, on average, 26¢ more per gallon. While a higher octane rating used to lead to less engine knocking, in cars manufactured since the early 1990's almost all engines have been designed to automatically correct engine knocking, thereby rendering the performance advantage of premium gasoline negligible (Ford 2008).[24] In spite of this fact, many luxury vehicles' warranties may be voided if anything but premium fuel is put into the tank. Thus, drivers of more expensive cars are more likely to purchase premium gasoline than owners of less expensive automobiles. Luxury car owners tend to have higher incomes, and Barron et al. (2000) presents convincing evidence that high income consumers that purchase premium fuel are typified by greater search costs. Consumers that are not required by warranty to purchase premium fuel pay a large markup for a product that offers almost no perceptible benefit over regular fuel. Healey (2003) notes, "engineers, scientists and the federal government say there's little need for premium." Consequently, consumers not bound by contract to purchase high octane fuel, but still choose to do so, are ill informed. Consumers that do not acquire information pertaining to

[23]This claim is explicitly stated and proved in *Proposition 8* of Yang and Ye (2008).
[24]Also, premium gasoline neither increases fuel efficiency nor reduces harmful emissions.

product quality can accurately be described as having a high cost of search for such information. Any correlation between consumers' search cost for obtaining product quality information and price information translates into purchasers of premium gasoline having a high cost of price search. In comparing the patterns of price dispersion between premium and regular gasoline, Chandra and Tappata (2011) find evidence consistent premium consumers having higher search costs. Finally, Manzan and Zerom (2009) find that consumers of premium gasoline are exceedingly more demand inelastic than regular buyers across all price levels.

Given that consumers of premium gasoline generally earn higher incomes, are far less price sensitive, and possibly less informed than consumers of regular fuel it appears safe to assume that premium customers are (i) typified by higher search costs and (ii) less likely to be a "shopper" for the lowest possible price.[25] Assumptions (i) and (ii) in conjunction with Yang and Ye's (2008) prediction that a lower proportion of shoppers increases price asymmetry allows the following hypothesis to be tested.

Hypothesis 1 *Firms price premium gasoline with a greater magnitude of asymmetry than regular fuel, and the increased asymmetry is entirely a result of slower adjustment to cost decreases.*

Before undertaking the analysis, an issue in the data must be dealt with; the data set only contains new premium fuel price observations for, on average, 12% of stations each day. Consequently, if empirical testing is performed on the station-level at daily intervals then a majority of the data will be dropped from the analysis.[26] To ameliorate the problem and maximize the amount of information extracted from the data, the analysis in this subsection is performed at the daily *market*-level. It is more prudent to spatially aggregate the data than to average it across time because results presented in Remer (2010) convey that temporally aggregating data can severely bias results, but little is changed by spatial aggregation. Defining a market in the retail gasoline industry can be difficult; firms one mile apart may compete with each other, but the total set of competitors that each faces may not be the same. Essentially the retail gasoline industry consists of a large number of overlapping markets, of which each firm may belong to more than one. This caveat is addressed in the same fashion as Chandra and Tappata (2011) and Lewis (2008); each firm is specified to be operating in a unique market of which they are located at the center. Then, I define a market to be a 1.5 mile radius around each firm.[27]

To test hypothesis 1, I first create a new market-level price series:

$$D_{it} = P_{it} - R_{it}. \tag{5}$$

[25] Here, "shopper" is defined as in the previous subsection: a consumer with zero search cost.

[26] When lag lengths are set to nine a firm needs to have a run of ten consecutive price observations to be included in the regression.

[27] Lee (2009) finds that stations compete most heavily with competitors within one mile. I extend the market radius an extra half mile to ensure that I capture all pertinent competitive dynamics.

Here, P_{it} and R_{it} are the premium and regular prices, respectively, set in market i during time period t, and D_{it} represents the markup of premium over regular gasoline. D_{it} then acts as the price variable in equations (2) and (3). The spot price of WTI crude oil traded on NYMEX is used instead of wholesale regular unleaded fuel to ensure that the cost measure is common to both types of fuel and reflects movement in the cost component shared by both types of fuel. If wholesale regular fuel were employed as the cost data then cost changes may reflect shocks to regular unleaded fuel that are unrelated to premium gasoline.[28]

I first estimate equation (2) and obtain economically plausible results. The relationship between the markup of premium over regular fuel and cost (ϕ_1) is found to be .005 and the constant (ϕ_0) is 26.3, both estimated with more than 99% confidence. Thus, the long-run markup of premium fuel over regular gasoline is nearly constant at 26.3¢; it only increases by .5¢ for every dollar increase in the per gallon price of oil. These coefficients are then substituted into equation (3), and the results of estimating the equation are listed in Table 4 and the corresponding CRF's are plotted in Figure 3. The most striking feature of the CRF's plotted in Figure 3 is the distinct negative proportional response to a negative cost shock. This translates into D_{it}, the gap between premium and regular prices, *increasing* when costs *decrease*; thereby, premium prices fall more slowly than regular prices following a cost decrease. The reaction to positive cost shocks is another story. The cumulative response of the markup to a positive cost change is never greater than .03; therefore, the markup of premium over regular increases by only .03¢ in response to a 1¢ cost increase. That the markup is largely invariant in response to a positive shock is highlighted in Table 4 where the only price and cost variables that are not significantly different from zero are those pertaining to lagged positive cost changes. A markup unaffected by positive cost changes implies that premium and regular fuel prices rise at the same speed. In sum, these estimates confirm hypothesis 1 and support consumer search costs as the mechanism driving rockets and feathers.

There are potentially two alternative explanations of the results in this subsection. First, to the extent that cost changes are correlated with income shocks, marginal consumers may switch between regular and premium gasoline. This explanation may explain why premium gasoline prices fall slower than regular, as demand for premium could increase when costs fall. However, substitution between premium and regular cannot explain why the gap remains constant after a cost increase, as it would predict the gap to decrease. Furthermore, Manzan and Zerom (2009) note that regular gasoline consumers are much more demand elastic than premium; thus a cost decrease is likely to cause regular gasoline consumers to increase consumption relative to premium gasoline consumers, which may more than account for the decreased regular demand from consumers that switched to

[28]When the model is estimated with wholesale regular unleaded instead of spot oil as the cost measure the results are largely similar. However, consistent with cost changes being more correlated with regular retail prices than premium prices, the markup increases slightly more in response to a negative shock and slightly decreases (as opposed to remaining unchanged) in response to a positive shock.

premium. Second, premium gasoline includes octane enhancers and detergents, which are additional costly inputs that are not included in regular gasoline. For the results of this section to be a relic of movements in the price of unobserved inputs the unobserved prices would have to increase immediately following oil price decreases and remain unchanged after increases in oil prices – there is no evidence to suggest that this is the case.

4.3 Price Dispersion and the Magnitude of Asymmetry

This subsection presents, to the best of my knowledge, the first document of the relationship between price dispersion and the magnitude of asymmetric pricing. I argue that the results are consistent with the predictions of and provide support for search-based asymmetric pricing theory. In formulating their theory of rockets and feathers, Tappata (2009) and Yang and Ye (2008) both find that when prices are expected to be more dispersed consumers increase their search intensity. And, as proven in both studies, a more intensively searching consumer-base implies less price asymmetry.

Hypothesis 2 *Markets with greater price dispersion exhibit less price asymmetry.*

The assumption underlying hypothesis 2 is that markets with more dispersed prices cause consumers to increase their intensity of search; however, a higher degree of search may also drive down price-cost margins, leading to less price dispersion. Therefore, it is not entirely clear whether markets with low price dispersion discourage consumer search, or exhibit low dispersion as a direct result of intensely searching consumers. At the end of this subsection, I present evidence that the market structure of high dispersion markets is consistent with low search costs, which provides support for the explanatory power of hypothesis 2. Still, note that a direct consequence of search-based theory is that exogenous price dispersion negatively correlates with the magnitude of market price asymmetry.

The econometric tests in this and subsequent subsections will follow the same pattern: (i) define a characteristic that partitions the firms in the data and (ii) separately estimate the magnitude of asymmetry for the partitioned firms. To carry out this procedure, a dummy variable that partitions the data is defined and then interacted with each independent variable in equation (3). Finally, the estimated parameters are used to construct CRF's for the separate groups of firms.

In this subsection, as a proxy for the gains from search, I separately estimate the degree of asymmetry[29] for firms located in markets[30] with low or high price dispersion. As a measure of price

[29]For the remainder of the article, the analysis is undertaken using firm-level regular fuel retail prices and the spot price of regular unleaded fuel as the measure of cost.

[30]As in the previous subsection and throughout the remainder of the article, a market is defined as the 1.5 mile radius surrounding each firm.

dispersion, I calculate the average difference between the maximum and minimum price for regular unleaded fuel in each firm's market over the course of the data. This statistic captures, on average, the most a consumer can save by visiting each firm in the market. I then divide the average price range distribution into quintiles and accordingly partition the set of firms.

Figure 4 plots the estimated CRF's for firms that fall in either the first or fifth quintile, and the magnitude of asymmetry is greater for markets with a low average price range.[31] The average price range of markets in the first quintile is 3.73¢ compared to 21.9¢ for markets in the fifth quintile. Thus, consumers have a much stronger incentive to search in markets belonging to the upper quintile as apposed to the lower quintile. And, in accordance with search-based theory, there is a greater degree of asymmetry (1.6¢ cumulative difference[32] twenty days after a one cent cost shock) in markets with a lower incentive to search.[33] The difference in the magnitude of asymmetry between the two types of markets grows for more than twenty days after a cost change. Therefore, as predicted by the search theory, there is a significantly negative relationship between search incentives and the magnitude of price asymmetry.

As mentioned above, hypothesis 2 assumes that markets with greater price dispersion are populated by consumers with lower search costs. While the endogeneity of search intensity is not controlled for in the analysis, there is some evidence that high dispersion markets typically have lower search costs. In particular, markets with high dispersion have significantly more firms per square mile than markets with low price dispersion. Therefore, to the extent that the traveling distance between firms is correlated with search costs, high dispersion markets present consumers with a lower marginal cost of search and thereby should have more intensely searching consumers. Admittedly, this fact does not completely reconcile the endogeneity of search intensity. Still, the expansive data set used to estimate the relationship between price dispersion and asymmetry suggests the result is generalizable and may provide guidance to future research. Thus, any theory that seeks to explain the existence of rockets and feathers should predict an inverse relationship between the degree of asymmetry and price dispersion.

5 Focal Price Collusion

5.1 Theoretical Background

In this subsection, I present empirical evidence that contradicts a common explanation for rockets and feathers: focal price collusion. BCG offered a stylized version of the collusion model developed in Green and Porter (1984) as a motivation for the rockets and feathers phenomenon, wherein

[31] Qualitatively identical results are obtained when average market price variance is used as a measure of dispersion.
[32] Cumulative asymmetry is calculated by taking the integral of the positive CRF minus the negative CRF.
[33] This is true at the 95% confidence level.

firms use the previous period's retail price as a focal point for collusion. If costs drop then the previous period's price is maintained until a firm cheats on the agreement and triggers a price war. Conversely, if costs increase then firms raise their price to maintain a positive margin and/or not be viewed as cheating on the collusive agreement. In sum, market prices adjust slower to cost decreases than increases. While this variant of focal price collusion generates price asymmetry, BCG only conjecture it to be the cause of the phenomenon and provide no formal model. Despite the lack of a formal theory deriving focal price collusion as a profit maximizing strategy, it has become a common explanation for asymmetric pricing, and Lewis (2011) does provide some supporting empirical evidence.

5.2 Empirical Tests of Focal Price Collusion

5.2.1 Price levels and Asymmetry

I now present evidence that firms in the data that most likely acted collusively do not exhibit more price asymmetry than firms that almost certainly did not collude. In doing so, I more generally demonstrate that there is no robust connection between firm price levels and asymmetry.

Hypothesis 3 *Pairs of closely located firms that consistently price above the market average exhibit more asymmetry than firms that price below the average.*

Hypothesis 3 is constructed to isolate firms in the data that were most likely to have acted collusively, and then determine if they price with more asymmetry than firms that almost certainly did not collude. In general, the ability to maintain collusion decreases in the number of firms entered in the agreement, increases in the ability to monitor behavior, and decreases in the degree of product differentiation.[34] Thus, I restrict the data to include only firms that have exactly one competitor within .1 miles; such firms have a single rival whose price is costlessly observable, faces nearly identical demand conditions, and is minimally geographically differentiated.

Within this subset of firms, I then separately estimate the degree of asymmetry for high and low priced firms. "High" ("low") priced firms are defined as those who consistently price above (below) their market's average price, as this helps to control for the influence of consumer demand and other pertinent market characteristics over retail prices. Note, however, that firms that generally price above the market average may do so because they offer a higher quality product. Therefore, the power of the subsequent test of collusion is dependent upon the extent to which collusion influences price-cost margins relative to other factors, such as product quality. Yet, if focal price collusion substantially increases prices and is the driving force of rockets and feathers then hypothesis 3 will be upheld.

[34]See Ivaldi et al. (2003) for an in depth explanation.

To precisely define high and low priced firms, I first define the following dummy variable:

$$d_{pt} = \begin{cases} 1 & \text{if } p_{ft} - p_{kt} > 0 \\ 0 & \text{otherwise} \end{cases} . \tag{6}$$

Here, p_{ft} is the average price of the two firms located within .1 miles of each other, p_{ft} is the average price of all other firms within 1.5 miles, and d_{pt} takes a value of one if and only if the average price of the two firms is greater than the market average on day t. Then, the statistic, S, is generated to determine the percentage of days such that the average price of the two closely located firms is greater than other firms firms in the market:

$$S = \sum_{t \in T_j} \frac{d_{pt}}{|T_j|}. \tag{7}$$

Here, T_j is the set of days for which I have available price data for the firms in market j. Therefore, S allows for a distinction to be made between firms who regularly price above, or below, their competitors. After partitioning the distribution of S values into quintiles, I estimate CRF's for firms located in the upper and lower quintile. Firms in the lower quintile price above the market average between 0% and 14% of the time and firms in the upper quintile price above the market average between 72% and 100% of the days. Figure 5 plots the CRF's for pairs of firms that consistently price above or below their market's average, and there is no significant difference in the speed of adjustment between high and low priced firms. Therefore, firms in the data that have the highest potential for collusion and consistently price above their competitors do not price more asymmetrically than firms that regularly price below the competition, which undermines collusion as a major determinant of rockets and feathers.

I find qualitatively identical results when the connection between local market prices and asymmetry is more generally analyzed. To do this, equation (2) is estimating using local market average prices and a market specific fixed effect term, FE_i, is included in the regression. FE_i captures the extent to which a market's retail price varies, on average, from the price predicted by the long-run relationship between price and cost. Estimating the degree of asymmetry for firms located in markets in the upper and lower quintile of the FE_i distribution reveals no significant relationship between asymmetric pricing.[35] Viewing this result in the context of focal-price collusion further demonstrates that collusion is not a predominant cause of asymmetric pricing. More generally, there does not appear to be a strong relationship between price-levels and the speed of price adjustments. Therefore, the results in this section suggest that the magnitude of price asymmetry does not explain price levels within or across markets.

[35] Results available on the authors website, https://sites.google.com/site/marcjremer.

5.2.2 Branding, Number of firms, and Asymmetry

Branding is a primary source of product differentiation in the retail gasoline market. Also, gasoline stations of the same brand are contractually obligated to sell gasoline from the same supplier and are subject to the same brand-specific supply and demand shocks. It follows that retail gasoline stations of the same brand can more easily coordinate prices. Therefore, if there are a sufficient number of firms in the market (i.e. two) and asymmetric price adjustments are a consequence of collusion then the following hypothesis follows.

Hypothesis 4 *Markets with a fewer number gasoline stations and more gasoline stations of the same brand will exhibit more price asymmetry.*

To test this hypothesis, I estimate the relationship between the magnitude of asymmetry and the Herfindahl-Hirschman index (HHI), where the share of a brand is simply the percentage of firms of a given brand in the market. This metric is increasing in brand concentration and decreasing in the number of firms in the market. To increase the likelihood that the analysis excludes gas stations with strong monopoly power and includes firms that are potentially colluding, the regressions are restricted to only include markets with at least three firms within the 1.5 mile radius.[36]

The CRF's for firms located markets in the lower and upper quintile of the HHI distribution are plotted in Figure 6, and the results contradict collusion as a determinant of asymmetry; firms in less concentrated markets price significantly more asymmetrically.[37] As a robustness check and to isolate the effect of brand concentration, as opposed to the number of firms in the market, I further restrict the sample to only include markets with 7-10 firms,[38] and find qualitatively identical results. Thus, no evidence in favor of collusion as a determinant of rockets and feathers is discovered. More generally, this result suggests that greater local market power does not imply more asymmetry.

6 Conclusion

In this article, I identify the existence of rockets and feathers in the retail gasoline industry, but more importantly, provide sound evidence in support of consumer search costs as the underlying cause. By examining the markup of premium over regular fuel, I find that individual firms price premium gasoline with more asymmetry than regular, and the increased asymmetry is entirely a result of premium prices falling more slowly. As premium consumers are typified by greater search costs, this result supports the theories presented in Tappata (2009) and Yang and Ye (2008). Moreover,

[36]Results are robust to including markets with only two firms.

[37]This is true with 90% confidence for more than 5 days following a cost change.

[38]Results are robust to other similar restrictions on the number of firms in the market.

the relationship between measures of price dispersion and rockets and feathers is consistent with search-based theory.

Conversely, I find little evidence in favor of focal price collusion as a consequential determinant of asymmetric pricing. Firms with the highest probability of being engaged in a collusive agreement price with no more asymmetry than firms that almost certainly are not colluding. This is not to say, however, that collusion is absent from the retail gasoline industry; it only shows that the chosen method of collusion does not generate asymmetric pricing.

Finally, the richness of data used throughout the empirical investigation affords the opportunity to generalize results. The data set includes daily price observations for over 11,000 stations located in the east and west coasts, and in both rural and urban areas. Thus, the findings in the this article can be viewed as results typical of the retail gasoline market, and not relics of a unique market.

References

[1] Bachmeier, L.J. and J.M. Griffin (2003), "New Evidence on Asymmetric Gasoline Price Responses", *Review of Economics and Statistics*, Vol. 85, pp. 772-776.

[2] Bacon, R. (1991), "The Asymmetric Speed of Adjustment of UK Retail Gasoline Prices to Cost Changes", *Energy Economics*, Vol. 13, pp. 211-218.

[3] Barron, J.M., B.A. Taylor, and J.R. Umbeck (2000), "A Theory of Quality-Related Differences in Retail Margins: Why there is a "Premium" on Premium Gasoline", *Economic Inquiry*, vol. 38, pp. 550-569.

[4] Barron, J.M., B.A. Taylor, and J.R. Umbeck (2004), "Number of Sellers, Average Prices, and Price Dispersion", *International Journal of Industrial Organization*, Vol. 22, pp. 1041-1066.

[5] Borenstein, S., A.C. Cameron, and E. Gilbert (1997), "Do Gasoline Prices Respond Asymmetrically to Crude Oil Price Changes?", *The Quarterly Journal of Economics*, Vol. 112, pp. 305-339.

[6] Borenstein, S., and A. Shepard (1996), "Dynamic Pricing in Retail Gasoline Markets", *The RAND Journal of Economics*, Vol. 27, pp. 429-451.

[7] Cabral, L. and A. Fishman (2008), "Business as Usual: A Consumer Search Theory of Sticky Prices and Asymmetric Price Adjustment", Working Paper, New York University.

[8] Chandra, A. and M.E. Tappata (2011), "Consumer Search and Dynamic Price Dispersion: An Application to Gasoline Markets", *RAND Journal of Economics*, Forthcoming.

[9] Chen, L.H., M. Finney, and K.S. Lai (2005), "A Threshold Cointegration Analysis of Asymmetric Price Transmission From Crude Oil to Gasoline Prices,", *Economics Letters*, Vol. 89, pp. 233-239.

[10] Chesnes, M. (2010), "Asymmetric Pass-Through In U.S. Gasoline Markets", Working Paper, Federal Trade Commission.

[11] Deltas, George (2008), "Retail Gasoline Price Dynamics and Local Market Power", *The Journal of Industrial Economics*, vol. 57, pp. 613-628.

[12] Eckert, A. (2002), "Retail Price Cycles and Response Asymmetry", *Canadian Journal of Economics*, Vol. 35, pp. 52-78.

[13] Eckert, A. and D.S. West (2004), "Retail Gasoline Price Cycles Across Spatially Dispersed Gasoline Stations", *The Journal of Law and Economics*, Vol. 7, pp. 245-273.

[14] Engle, R. and C.W.J. Granger (1987), "Co-Integration and Error Correction: Representation, Estimation, and Testing", *Econometrica*, Vol. 55(2), pp. 251-276.

[15] Ford, D. "Premium Required? Not Necessarily", *The New York Times* 3 August 2008.

[16] Foros, O. and F. Steen (2008), "Gasoline Prices Jump Up on Mondays: An Outcome of Aggressive Competition?", Discussion Paper NHH SAM.

[17] Galeotti, M., A. Lanza, and M. Manera (2003), "Rockets and Feathers Revisited: An International Comparison on European Gasoline Markets", *Energy Economics*, Vol. 25, pp. 175-190.

[18] Geweke, J.F. (1978), "Temporal Aggregation in the Multiple Regression Model", *Econometrica*, Vol. 46, pp. 643-661.

[19] Geweke, J.F. (2004), "Issues in the Rockets and Feathers Gasoline Price Literature", Report to the Federal Trade Commission, University of Iowa.

[20] Godby, R., A.M. Lintner, T, Stengos, and B. Wandschneider (2000), "Testing for Asymmetric Pricing in the Canadian Retail Gasoline Market," *Energy Economics*, Vol. 22, pp. 349-368.

[21] Green, E., and R. Porter (1984), "Non-cooperative Collusion Under Imperfect Price Information", *Econometrica* vol. 52, pp. 87-100.

[22] Healey, J.R., "Why Use Premium When Regular Will Do?", *USA Today*, 30 July 2003.

[23] Hosken, D.S., R.S. McMillan, and C.T. Taylor (2008), "Retail Gasoline Pricing: What Do We Know?", *International Journal of Industrial Organization*, Vol. 29, pp. 1425-1436.

[24] Houde, J.F. (2011), “Spatial Differentiation and Vertical Contracts in Retail Markets for Gasoline”, forthcoming, *American Economic Review.*

[25] Ivaldi, M., B. Jullien, P. Rey, P. Seabright, and J. Tirole (2003), “The Economics of Tacit Collusion”, Final Report for DG Competition, European Commission.

[26] Lee, S.Y. (2009), “Spatial Competition in the Retail Gasoline Market: An Equilibrium Approach Using SAR Models”, Working Paper, San Francisco State University.

[27] Lewis, M.S. (2008), “Price Dispersion and Competition With Differentiated Sellers”, *The Journal of Industrial Economics*, Vol. 57, pp. 654-678.

[28] Lewis, M.S. (2011), “Asymmetric Price Adjustment and Consumer Search: An Examination of the Retail Gasoline Market”, *Journal of Economics and Management Strategy*, vol. 20.2, 409-449.

[29] Manzan, S. and D. Zerom (2009), “A Semiparametric Analysis of Gasoline Demand in the US: Re-examining the Impact of Price”, *Econometric Reviews*, Forthcoming.

[30] Maskin, E. and J, Tirole (1988), “A Theory of Dynamic Oligopoly II: Price Competition, Kinked Demand Curves and Edgeworth Cycles”, *Econometrica*, vol. 56, pp. 571-599.

[31] National Association of Convenience Stores, “The 2009 Gas Price Kit” www.nacsonline.com, 12 September 2009.

[32] Noel, M. (2007), “Edgeworth Price Cycles: Evidence From the Toronto Retail Gasoline Market”, *Journal of Industrial Economics*, vol. 55, pp. 69-92.

[33] Noel, M. (2009), “Do Retail Gasoline Prices Respond Asymmetrically to Cost Shocks? The Influence of Edgeworth Cycles”, *RAND Journal of Economics*, vol. 40, pp. 582-595.

[34] Peltzman, S. (2000), “Prices Rise Faster Than They Fall”, *Journal of Political Economy*, vol. 108, pp. 466-502.

[35] Remer, M. (2010), “Empirical Regularities of Asymmetric Pricing in the Gasoline Industry”, Working Paper, Johns Hopkins University.

[36] Said, Said E., and D. A. Dickey, “Testing for Unit Roots in Autoregressive-Moving Average Models of Unknown Order”, *Biometrika*, vol. 71, pp. 599-607.

[37] Slade, M.E. (1992) “ Vancouver’s Gasoline-Price Wars: An Empirical Exercise in Uncovering Supergame Strategies”, *Review of Economic Studies*, Vol. 59, pp. 257-276.

[38] Tappata, M. (2009), “Rockets and Feathers. Understanding Asymmetric Pricing”, *RAND Journal of Economics*, vol. 40, pp. 673-687.

[39] Verlinda, J.A. (2008) “Faster Rockets and Slower Feathers With Local Market Power“, *The Journal of Industrial Economics*, Vol. 57, pp. 581-612.

[40] Wang, Z. (2009) “(Mixed) Strategy in Oligopoly Pricing: Evidence From Gasoline Price Cycles Before and Under a Timing Regulation”, *Journal of Political Economy*, Vol. 117, pp. 987-1030.

[41] Yang, H. and L. Ye (2008), “Search With Learning: Understanding Aymmetric Price Adjustments”, *RAND Journal of Economics*, Vol. 39, pp. 547-564.

7 Tables

Table 1: Summary Statistics and Results of Regressing Retail Price on Characteristic and Day of Week Controls.

	Mean	Std. Dev.	Coef.	Std. Err.
Miles to closest competitor	0.65	1.30	0.53***	0.05
# firms $\leq$ .1 miles	0.34	0.63	0.58***	0.08
# firms $>$ .1 miles and $\leq$ 1.5 miles	6.29	5.23	0.03**	0.01
# firms $>$ 1.5 miles and $\leq$ 5 miles	41.26	37.97	-0.04***	0.002
Independent brand indicator	0.33	0.47	-7.50***	0.10
% independent competitors $<$ 0.1 miles	0.31	0.44	-1.93***	0.19
% independent competitors $<$ 0.1 miles and $\leq$ 1.5 miles	0.34	0.27	-5.26***	0.19
% independent competitors $<$ 1.5 miles and $\leq$ 5 miles	0.33	0.19	-11.65***	0.27
Log of population	10.26	1.91	0.71***	0.03

Notes: Before regressing retail price on station characteristics all taxes are removed. For the mean and standard deviation of *% independent competitors $\leq$ .1 miles*, only stations with at least one competitor within .1 miles are considered. This analogously holds for the subsequent two statistics. Significant at 1% = ***, significant at 5% = **, significant at 10% = *.

Table 2: Summary Statistics

	Regular Price	Premium Price	Wholesale Cost
Mean	201.6	227.8	173.1
Std. Dev.	68.8	68.8	62.8
# Increases	157	162	166
Avg. Increase Size	0.97	0.96	3.62
# Decrease	207	202	198
Avg Decrease Size	-1.43	-1.49	-3.67

Notes: Units are in cents per gallon. Cost data is a daily weighted-average of the closing spot price of reformulated gasoline shipped from the Los Angeles, CA and New York, NY harbors; the weights used to average the cost data reflect the proportion of gas stations in the data set located in the west or east coast of the United States.

Table 3: Asymmetric Response Individual Station Daily Prices

Coefficient	Estimate	Coefficient	Estimate	Coefficient	Estimate
ΔC_t^+	8.10***	ΔC_{t-9}^-	1.19***	ϑ_1^+	-7.13***
	(0.32)		(0.18)		(0.11)
ΔC_{t-1}^+	6.94***	ΔR_{t-1}^+	-34.71***	ϑ_1^-	-7.71***
	(0.30)		(1.32)		(0.11)
ΔC_{t-2}^+	3.74***	ΔR_{t-2}^+	-6.98***	# firms$\leq$ 0.1 miles	-0.92
	(0.24)		(0.58)		(0.74)
ΔC_{t-3}^+	2.38***	ΔR_{t-3}^+	-0.60	0.1 miles <# firms$\leq$ 1.5 miles	0.20*
	(0.24)		(0.54)		(0.10)
ΔC_{t-4}^+	3.49***	ΔR_{t-4}^+	1.01**	1.5 miles < # firms $\leq$ 5 miles	0.01
	(0.21)		(0.43)		(0.01)
ΔC_{t-5}^+	2.72***	ΔR_{t-5}^+	1.01**	Independent Brand	.05***
	(0.19)		(0.44)		(0.01)
ΔC_{t-6}^+	-0.54***	ΔR_{t-6}^+	0.92**	independent competitors $\leq$0.1 miles	-0.00
	(0.19)		(0.44)		(0.02)
ΔC_{t-7}^+	-2.33***	ΔR_{t-7}^+	4.89***	0.1 miles < % independent competitors $\leq$ 1.5 miles	0.04**
	(0.18)		(0.42)		(0.01)
ΔC_{t-8}^+	-1.17***	ΔR_{t-8}^+	5.93***	1.5 miles < % independent competitors $\leq$5 miles	-0.03
	(0.16)		(0.34)		(0.02)
ΔC_{t-9}^+	-0.55***	ΔR_{t-9}^+	5.44***	Closest competitor	-0.23
	(0.16)		(0.42)		(0.79)
ΔC_t^-	-3.8*	ΔR_{t-1}^-	-17.16***	Log of population	-0.02***
	(0.23)		(0.66)		(0.00)
ΔC_{t-1}^-	-4.53***	ΔR_{t-2}^-	-5.66***	Monday	-0.09***
	(0.24)		(0.45)		(0.02)
ΔC_{t-2}^-	-0.18	ΔR_{t-3}^-	-0.25	Tuesday	-0.03
	(0.22)		(0.36)		(0.02)
ΔC_{t-3}^-	0.59***	ΔR_{t-4}^-	2.87***	Wednesday	-0.12***
	(0.21)		(0.43)		(0.02)
ΔC_{t-4}^-	-0.90***	ΔR_{t-5}^-	2.78***	Thursday	-0.31***
	(0.21)		(0.39)		(0.02)
ΔC_{t-5}^-	2.29***	ΔR_{t-6}^-	6.29***	Friday	-0.23***
	(0.20)		(0.34)		(0.02)
ΔC_{t-6}^-	3.88***	ΔR_{t-7}^-	10.76***	Saturday	-0.09***
	(0.21)		(0.45)		(0.02)
ΔC_{t-7}^-	4.18***	ΔR_{t-8}^-	6.72***		
	(0.19)		(0.37)		
ΔC_{t-8}^-	2.74***	ΔR_{t-9}^-	2.29***		
	(0.19)		(0.37)		

Notes: Observations = 609,669. All price, cost, # of firm, and closest competitor coefficients and standard errors are multiplied by 100 for ease of reading. Standard errors are listed in parenthesis below the estimate, clustered by station, and robust to heteroscedasticity.

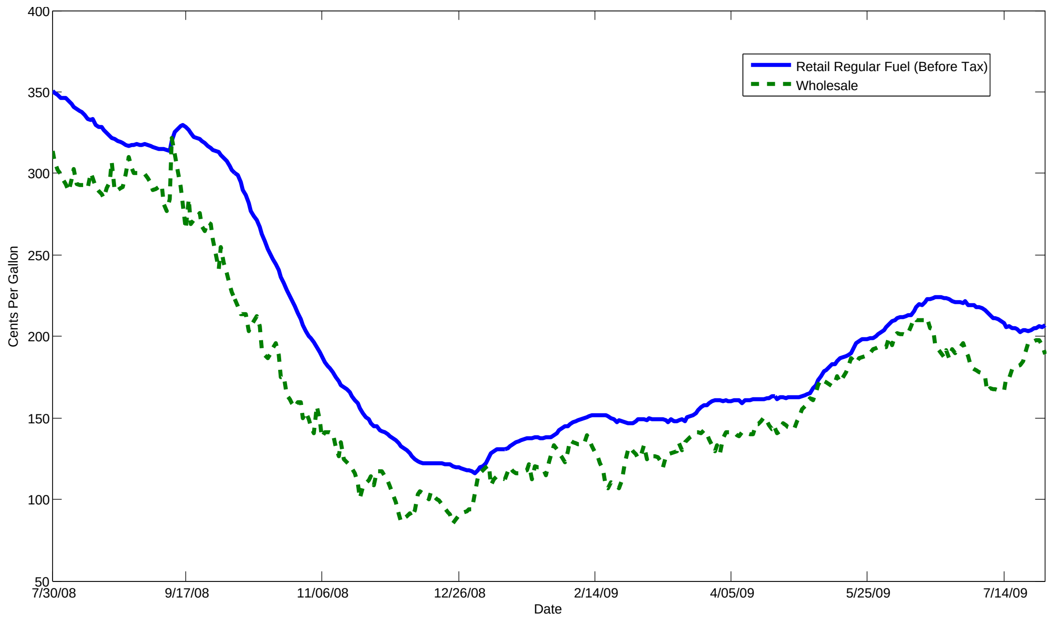
Table 4: Premium Markup Over Regular Response

Coefficient	Estimate	Coefficient	Estimate	Coefficient	Estimate
ΔC_t^+	-0.01	ΔC_{t-7}^-	-3.85***	ΔR_{t-6}^-	-23.26***
	(0.35)		(0.29)		(0.45)
ΔC_{t-1}^+	1.54***	ΔC_{t-8}^-	-1.88***	ΔR_{t-7}^-	-13.94***
	(0.33)		(0.31)		(0.46)
ΔC_{t-2}^+	0.75**	ΔC_{t-9}^-	-2.04***	ΔR_{t-8}^-	-9.50***
	(0.36)		(0.29)		(0.40)
ΔC_{t-3}^+	0.42	ΔR_{t-1}^+	-68.49***	ΔR_{t-9}^-	-2.94***
	(0.37)		(0.48)		(0.32)
ΔC_{t-4}^+	-1.12***	ΔR_{t-2}^+	-56.20***	ϑ_1^+	-18.72***
	(0.35)		(0.51)		(0.51)
ΔC_{t-5}^+	1.17***	ΔR_{t-3}^+	-47.46***	ϑ_1^-	-17.49***
	(0.34)		(0.57)		(0.65)
ΔC_{t-6}^+	-0.44	ΔR_{t-4}^+	-38.04***	# firms$\leq$ 1.5 miles	-32.62***
	(0.33)		(0.52)		(12.62)
ΔC_{t-7}^+	-0.25	ΔR_{t-5}^+	-30.16***	1.5 miles $<$ # firms $\leq$ 5 miles	0.05**
	(0.37)		(0.50)		(0.02)
ΔC_{t-8}^+	-0.14	ΔR_{t-6}^+	-23.37***	$\frac{\text{independents}}{\text{firms}} \leq$ 1.5 miles	-0.22***
	(0.35)		(0.52)		(0.03)
ΔC_{t-9}^+	-2.66***	ΔR_{t-7}^+	-13.45***	1.5 miles $< \frac{\text{independents}}{\text{firms}} \leq$ 5 miles	-0.20***
	(0.35)		(0.46)		(0.04)
ΔC_t^-	-3.16***	ΔR_{t-8}^+	-7.09***	Log of population	0.00
	(0.32)		(0.41)		(0.00)
ΔC_{t-1}^-	-2.04***	ΔR_{t-9}^+	-5.34***	Monday	-0.41***
	(0.33)		(0.38)		(0.05)
ΔC_{t-2}^-	-3.88***	ΔR_{t-1}^-	-65.45***	Tuesday	-0.44***
	(0.34)		(0.57)		(0.04)
ΔC_{t-3}^-	-3.22***	ΔR_{t-2}^-	-55.00***	Wednesday	-0.40***
	(0.31)		(0.59)		(0.04)
ΔC_{t-4}^-	-2.47***	ΔR_{t-3}^-	-46.25***	Thursday	-0.31***
	(0.31)		(0.56)		(0.05)
ΔC_{t-5}^-	-4.92***	ΔR_{t-4}^-	-37.36***	Friday	-0.35***
	(0.29)		(0.54)		(0.05)
ΔC_{t-6}^-	-2.43***	ΔR_{t-5}^-	-30.30***	Saturday	-0.07
	(0.28)		(0.51)		(0.04)
Observations		429,046			

Notes: All price, cost, # of firm, and closest competitor coefficients and standard errors are multiplied by 100 for ease of reading. Standard errors are listed in parenthesis below the estimate, clustered by station, and robust to heteroscedasticity.

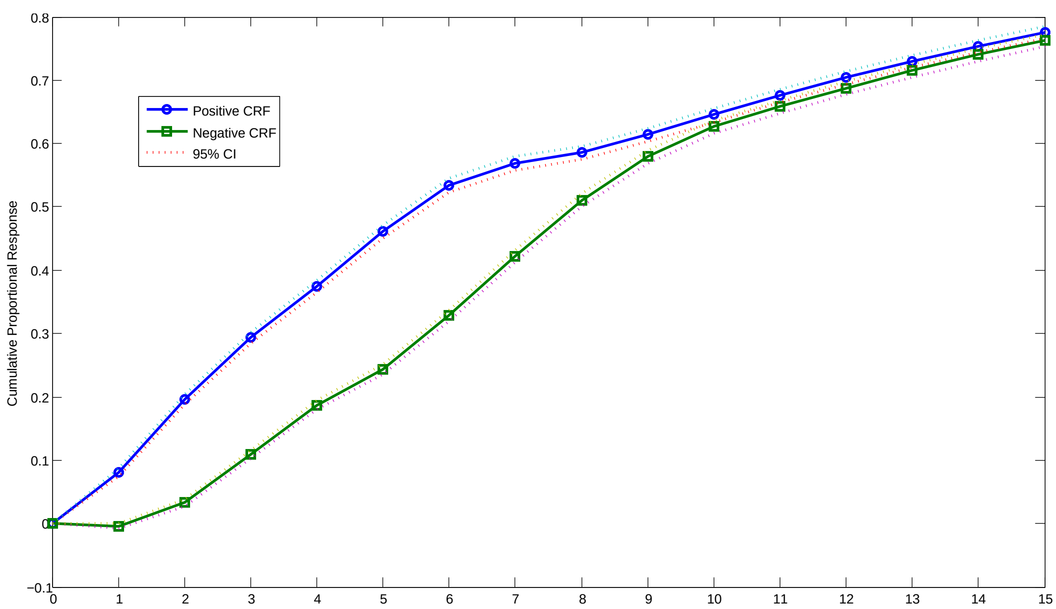
8 Figures

Figure 1: Average Daily Prices



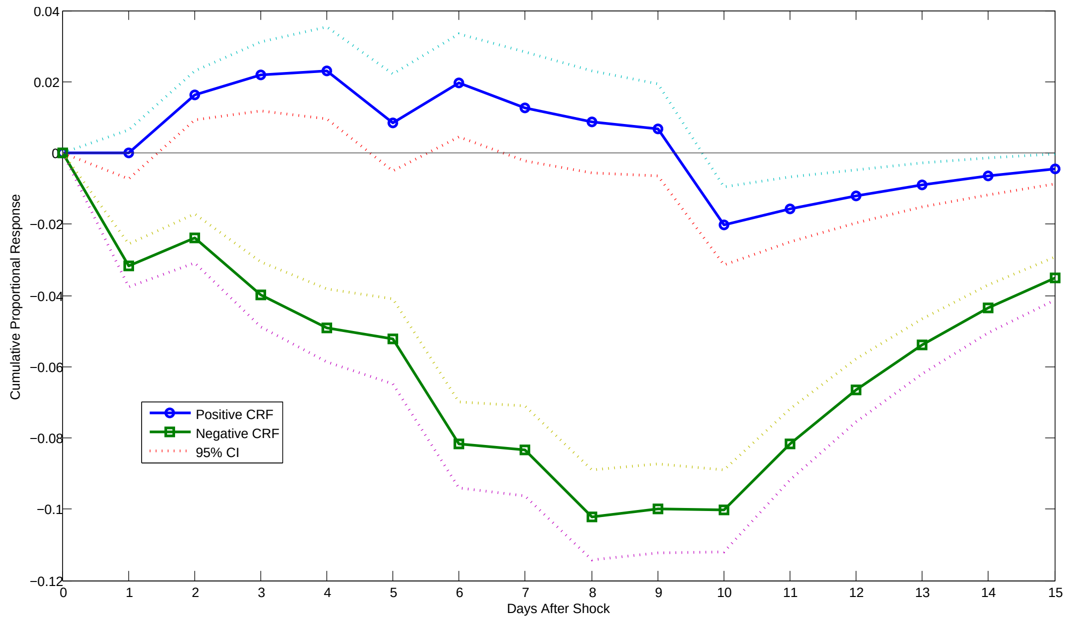
Notes: Retail price is the daily average price for regular unleaded fuel for all firms in the data set. Wholesale is a daily weighted-average of the closing spot price of reformulated gasoline shipped from the Los Angeles, CA and NY, NY Harbors; the weights used to average the cost data reflect the proportion of gas stations in the data set located in the west or east coast of the United States.

Figure 2: Cumulative Response: Regular Fuel Prices



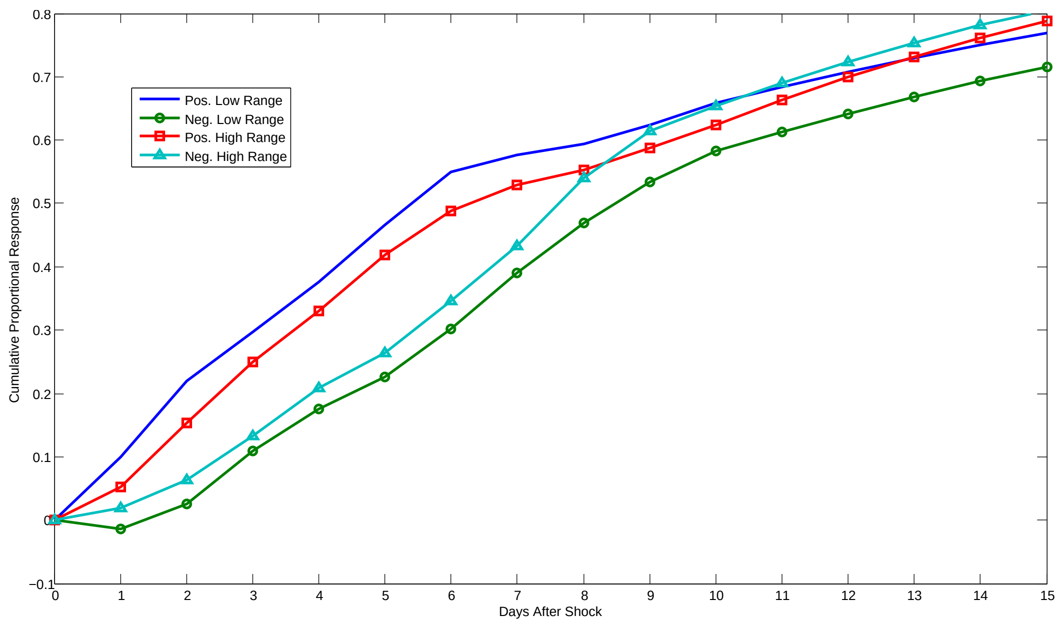
Notes: CRF's are constructed from the parameters estimated in Table 3. The positive (negative) cumulative response function measures, on each day, the proportion of a one unit positive (negative) cost shock at $t = 1$ that has been incorporated into a firm's retail price.

Figure 3: Cumulative Response: Premium Markup Over Regular



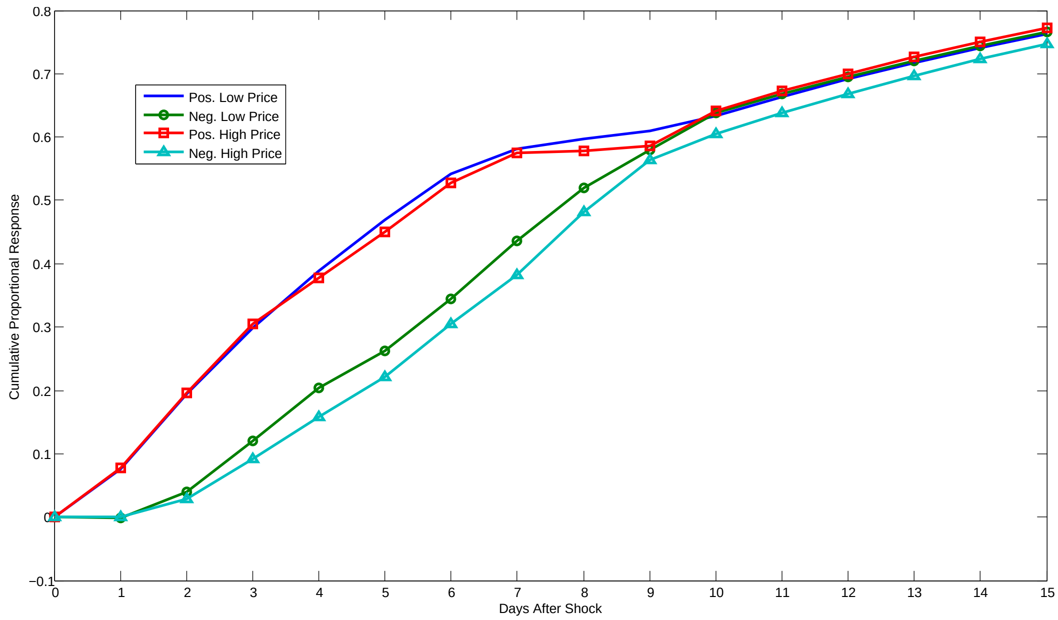
Notes: Parameters Table 4 are used to estimate the CRF's, which track the response of the markup of premium over regular gasoline to positive and negative cost shocks.

Figure 4: Cumulative Response: Sorted by Market Price Dispersion



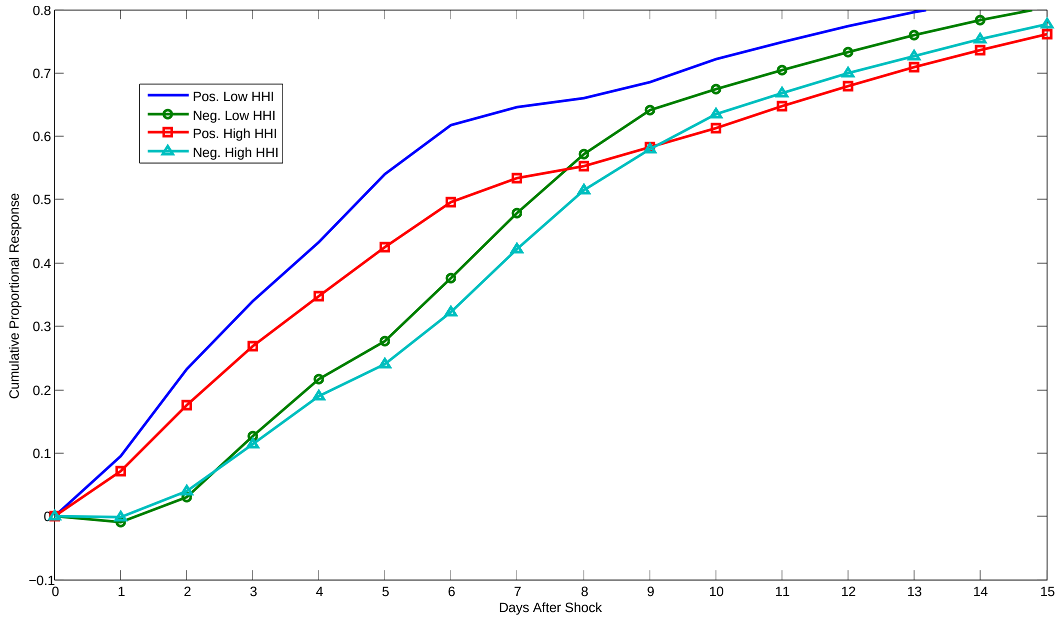
Notes: CRF's are estimated for firms located in markets with an average price range in the lower or upper quintile of average price range distribution.

Figure 5: Cumulative Response: Sorted by Relative Prices



Notes: CRF's are graphed for firms located within .1 miles of each other that generally price above or below their market's average price ("high" and "low", respectively).

Figure 6: Cumulative Response: Sorted by HHI



Notes: CRF's are estimated for firms in markets whose concentration of brands is in the top or lower quintile of the HHI distribution ("High HHI" and "Low HHI", respectively).