Experimental Gasoline Markets [*]

Cary A. Deck
Department of Economics
Walton College of Business
The University of Arkansas
Fayetteville, AR 72701
Phone: (479) 575-6226
Fax: (479) 575-3241
E-mail: *cdeck@walton.uark.edu*

Bart J. Wilson[**]
Interdisciplinary Center for Economic Science
George Mason University
4400 University Drive, MSN 1B2
Fairfax, VA 22030-4444
Phone: (703) 993-4845
Fax: (703) 993-4851
E-mail: *bwilson3@gmu.edu*

August 2003

Abstract: Zone pricing in wholesale gasoline markets is a contentious topic in the public policy debate. Refiners contend that they use zone pricing to be competitive with local rivals. Critics claim that zone pricing benefits the oil industry and harms consumers. With a controlled experiment, we investigate the competitive effects of zone pricing on consumers, retail stations, and refiners vis-à-vis the proposed policy prescription of uniform wholesale pricing to retailers. We also examine the issue of divorcement and the "rockets and feathers" phenomenon. The former is the legal restriction that refiners and retailers cannot be vertically integrated, and the latter is the perception that retail gasoline prices rise faster than they fall in response to random walk movements in the world price for oil.

JEL Classifications: C9, D4, L2, L4, L9

Keywords: gasoline industry, zone pricing, vertical integration, asymmetric price adjustment, experimental economics

---

[*] This paper has benefited from conversations with Charissa Wellford, Jeffrey Fischer, David Meyer, Mary Coleman, David Scheffman, Christopher Taylor, Michelle Burtis, and the anonymous reviewers for the FTC Working Paper Series. We thank Jeffrey Kirchner for writing the software for the experiments. The authors gratefully acknowledge financial support from the Federal Trade Commission and the National Science Foundation. This report reflects the opinions of the authors and does not necessarily reflect the position of the Federal Trade Commission or any individual Commissioner.
[**] Corresponding author.

1. Introduction

Few industries evoke such strong sentiments by consumers, retailers, wholesalers, and policy makers as gasoline. The structure of the gasoline industry is extremely complex, making the impact of common practices unclear and thus the focus of much public scrutiny. The practice of zone pricing has been a particularly contentious topic in the public policy debate for the past several years.[1] Zone pricing is the industry term to describe the practice of refiners setting different wholesale prices for retail gasoline stations that operate in different geographic areas or zones. Refiners contend, as Chevron does on its website, that they employ zone pricing to "price our wholesale gasoline to our dealers at prices that will allow them to be competitive in relation to their nearby competition."[2] However, state legislators and attorneys general propose legislation to ban zone pricing claiming that it "only benefits the oil industry, to the detriment of consumers."[3]

Another controversial issue that is debated in the gasoline industry is divorcement, the legal restriction that refiners and retailers cannot be vertically integrated. Maryland was the first state to pass such legislation in 1974 with a handful of other states following suit. A 2000 report from Bill Lockyer, the Attorney General for the State of California, states that "members of the Task Force believe the key to enhancing competition at the retail level is to eliminate vertical integration by petroleum companies (p. 33)." However, in a prepared statement made before a subcommittee of the U.S. Senate, Hastings (2002a) testified that "Divorcement will not lead to lower prices, and may increase inefficiency (p. 7)."

The objective of our study is to design an environment that captures the essential components of wholesale and retail gasoline markets and to use a controlled experiment to test these opposing viewpoints. Within the confines of the laboratory, the impact of zone pricing and divorcement can be evaluated while holding the geographic markets, production and delivery costs, and the associated consumer demographics constant.[4] Additionally, we can also preclude

---

[1] For example, Maryland set up The Governor's Task Force on Gasoline Zone pricing in 2000. The task force's report in September of 2001 promotes a prohibition on zone pricing. See Isaac, Oaxaca, and Reynolds (1998) for a detailed discussion of retail price differentials in Arizona.

[2] http://www.chevron.com/about/currentissues/gasoline/pricing_qanda/gasoline_pricing_qa.shtm#7. This view is also supported by Comanor and Riddle (2003) who examine the California market in the late 1990s.

[3] See "Testimony of Connecticut Attorney General Richard Blumenthal Before the House Judiciary Committee," http://www.house.gov/judiciary/blum0407.htm, April 7, 2000. The California State Assembly recently considered banning zone pricing (see Douglas (2003)).

[4] Smith (1994) lists evaluation of policy proposals as one reason to conduct experiments.

entry at the retail level, thus setting a condition most unfavorable to zone pricing in terms of its potential harm to consumers. Experimental economics is an ideal tool for addressing zone pricing. Currently, gasoline wholesalers are free, as Shepard (1993, p. 63) notes, to charge "station-specific" wholesale prices. In an experiment, we can control the extent, if any, to which zone pricing can be employed in situations where explicit collusion among the wholesalers is not possible. Allowing zone pricing in one treatment serves as a benchmark for evaluating the complementary treatment, banning zone pricing by mandating uniform wholesale prices. Such a comparison affords a direct examination of the welfare effects of the proposed legislation on consumers, retailers, and wholesalers. Similarly, we can vary the degree of vertical integration to assess the impact of divorcement. A chief advantage of a controlled laboratory study is that we can precisely measure buyer welfare, which cannot be done in naturally occurring gasoline markets because consumer preferences are not observable. With an experiment we also have precise data on the actual transaction prices paid by consumers as opposed to just posted prices at retail stations.

With our data set, we also explore the phenomenon that retail gasoline prices adjust asymmetrically to cost shocks, yet another topic that has led to much public outcry. Several papers have found that gasoline prices rise more rapidly than they fall (see Johnson, 2002; Reilly and Witt, 1998; Borenstein et al., 1997; Castanias and Johnson, 1993; and Bacon, 1991).[5] Even though the data suggest that the asymmetry is relatively short lived (see Johnson, 2002), when prices climb quickly, the popular press is filled with stories about price gouging, exploitation of market power and the possibility of collusion. Of course, there are less pejorative explanations as well. One such gasoline spike occurred in the Midwest during the spring of 2000. Bulow, Fischer, Creswell, and Taylor (2003) study this period and determine that the price response was due to supply interruptions and argue against the possibility of collusive explanations. Further, they conclude that such episodes are likely to occur with increasing frequency as more and more

[5] As Peltzman (2000) reports, this phenomenon is not unique to gasoline. It thus remains unclear why consumers respond so strongly to changes in gasoline prices. One potential explanation is that unlike other products, consumers process a large volume of gasoline price information daily even when they are not considering a purchase due to the prominence of posted pricing in this market. Conspicuous price information for an extensively used product may make it easier for people to detect price changes when retailer cost changes are less obvious.

localities place constraints on gasoline blends.[6] Chouinard and Perloff (2002) find that the price of crude oil is the only major factor explaining the recent movement of gasoline prices.

Other explanations for asymmetric responses include inventory costs, menu costs, trigger pricing strategies, and consumer search costs (see Johnson 2002, Castanias and Johnson 1993 and references therein). Using weekly gasoline prices from Los Angeles between 1968 and 1971, Castanias and Johnson (1993) argue that the data closely match the predictions of Maskin and Tirole's (1988) adjustment model. Johnson (2002) argues that empirical data from the mid to late 1990s are consistent with a search cost model. This search cost hypothesis asserts that when prices are falling consumers have less incentive to search out new retailers, making it less attractive for rivals to lower prices. To explore the impact of search costs, Johnson compares unleaded price responses to the responses of diesel prices with the underlying assumption that consumers in diesel markets such as trucking companies engage in more search. Our laboratory investigation allows direct empirical evidence to be collected on asymmetric price responses and their indicatives of anticompetitive behavior, while explicitly controlling factors such as buyer search and menu costs.

2. Industry Background

The first step in the production and delivery of gasoline is the extraction of crude oil. Oil is then traded in a global market and transported to refineries. At the refinery, oil is converted into gasoline and other products including diesel fuel, asphalt and jet fuel. Gasoline is then piped to various distribution terminals. In the U.S., these terminals are located throughout the country near most major metropolitan areas. At this point in the process, gasoline is a pure commodity in that the supplier is indistinguishable and, in fact, pipe lines carry gasoline from multiple suppliers. At the terminal, gasoline is collected in large holding tanks by the various wholesalers operating in the proximity. At this point in the process brand specific additives are inserted.[7] The price of gasoline from these holding facilities is referred to as the rack price. The gasoline is then shipped by tanker truck to individual retail locations.

[6] The Midwest gas spike of 2000 centered on the implementation of a new standard for cleaner burning reformulated gasoline.

[7] Unbranded gasoline is gasoline with no branded additives. Special gasoline blends such as the CARB gasoline required for California are produced at the refinery.

Recently the industry has experienced considerable consolidation with the merging of large integrated companies such as BP and Amoco and Exxon and Mobil. Using simulations Manuszak (2001) investigates refiner mergers.[8] His model predicts that the merged wholesaler will increase its price but its rivals will not alter behavior significantly. As stations are not expected to change their mark-ups, retail prices would remain unchanged except at stations affiliated with the merged refiner, which simply pass the higher prices on to the final consumer.

Not only can consolidation change the number of competitors, it can also change the degree of vertical integration present in a given geographic market as there are several different contractual arrangements between retail outlets and refiners. Branded stations must sell the specified brand of gasoline. Some branded stations are company operated, meaning that the refiner owns the retail outlet and sets retail prices. Alternatively, a branded station can be either a lessee dealer or a dealer owned station in which case the retail outlet sets the retail price but it is obligated to buy the refiner's brand of gas. The difference between a lessee dealer and a dealer owned station pertains to the ownership of the retail facility. The price of gasoline delivered to a station is referred to as a Dealer Tank Wagon (DTW) price. In practice, refiners can engage in zone pricing by setting the DTW price to reflect market conditions in very specific geographic locations, possibly as small as a single station. Under these types of arrangements, the stations can either be supplied directly by the refiner or can purchase gas from a branded jobber. The term jobber refers to an intermediary that delivers gas from the rack to the retail location.[9] A fourth category of retailer is the independent station. Independent stations typically sell unbranded gasoline. They are also free to set their own retail prices and can acquire gas directly from the terminal or via a jobber with the constraint that only a branded jobber can deliver branded gasoline.[10] While a small percentage of independent stations are dealer supplied, most are supplied by jobbers.

Hastings (2002b) uses ARCO's acquisition of the independent chain Thrifty in southern California to examine the impact of a reduction in the number of non-integrated independent

[8] Manuszak (2001) uses data from two Hawaiian islands where vertical integration is limited.
[9] Like refiners, jobbers can also set station-specific prices.
[10] During rack inversions, a situation in which branded rack prices are below unbranded rack prices, wholesalers of branded gasoline can place limits on the quantity jobbers acquire at the terminal effectively preventing independent stations from acquiring the cheaper branded gasoline. In addition, in times of shortages, unbranded stations are typically supplied last.

retailers in the market.[11] Comparing prices before and after ARCO's branding of Thrifty outlets, Hastings finds that retailers who had competed against the independent chain raised prices relative to retailers who had not been competing directly with Thrifty. One should be careful to note that the welfare effects of such a merger are unclear. While prices rose in some locations, consumers in these locations now have an additional brand of gasoline. If consumers have a preference for the branded gasoline, then this situation actually could generate additional utility.

Hastings also observes no retail price differential due to the new ARCO store being either a company operated or dealer operated station. This finding argues against the divorcement proposals issued by several communities that would force wholesalers and retailers of branded gasoline to be separate. In the event that the retailers have market power,[12] forcing retailers to be independent of the wholesaler could lead to a double marginalization problem, resulting in higher retail prices for non-integrated outlets. Barron and Umbeck (1984) and Vita (2000) find support for this hypothesis.

While vertical separation may have unfavorable price implications for consumers, the situations in which such separation will be observed are less clear. In a study comparing outlet ownership structure and the non-gasoline aspects of the outlet, Shepard (1993) finds that stations where monitoring is relatively more straightforward tend to be company operated and vice versa. An alternative explanation for vertical integration is risk sharing between the retailer and the wholesaler. However, Lafontaine and Slade (1997) do not find support for this explanation in their data. Slade (1998) examines a principle agent problem explanation as well as strategic motives for separation.[13] She argues that separation is a dominant strategy and points to agency costs as the reason some stations remain integrated. Using 1983 gasoline data from Vancouver, Slade does find that in situations where the gains from separation are predicted to be the largest, the ownership is more likely to be separated.[14]

Given the complexity of the gasoline industry and the incompleteness of naturally occurring field data, it is not surprising that there is ambiguity about the effects of certain actions. For example, the estimation results of Slade (1998) are based upon a linear demand

[11] Hastings (2002b) also investigates the impact of a reduction in the overall number of competitors but concludes that the elimination of a competitor is not responsible for the observed 5 cents per gallon price increase.
[12] Hastings (2002b, p. 6) notes that "Borenstein, Cameron, and Gilbert (1997), Borenstein and Shepard (1996), and Slade (1992) provide empirical evidence consistent with local retail market power."
[13] The basis of the strategic motives for vertical separation is a theoretical paper by Rey and Stiglitz (1995).
[14] The predicted profitability of the ownership structure is based upon estimates of own price and cross price elasticities.

curve which "facilitates testing in the absence of reliable data on marginal cost (p. 92)." Further, many factors change simultaneously thus making the process of disentangling effects difficult. Hastings (2002b) compares prices pre- and post-merger. The underlying assumption is that changes in local market characteristics are the same across the local markets. Thus changes pre- and post-merger are attributable to either city wide trends or ownership structure. Additionally, Hastings faces a potential endogeneity problem in identifying the effects of (a) acquiring the chain and (b) changing the ownership structure of specific stations. Both were not random choices, but were part of the profit-maximizing decision by ARCO to acquire Thrifty in the first place. Also, there is a lack of information about consumer behavior including preferences and search patterns. Many of the empirical studies discussed above are based upon assumptions about buyer behavior. For example, Johnson (2002) hypothesizes that gasoline consumers search relatively infrequently. Hastings (2002b) proposes two alternative structures of consumer preferences to guide her analysis. In contrast, the laboratory provides an environment in which factors such as buyer preferences and search patterns can be held constant. By exogenously manipulating the strategic capabilities of wholesalers, policies such as zone pricing and divorcement can be directly evaluated. Further, in the laboratory direct evidence can be gathered about responsiveness of the retail prices to supply shocks including changes in crude oil prices and the impact of changes in the number or composition of competitors. Beyond profits and retail prices, laboratory studies can also evaluate social welfare which is not possible in the field as data are not available as to the value consumers receive from purchasing gasoline.

3. A Vertical Model of Gasoline Markets

Our model of the gasoline industry consists of N refiners who compete to sell branded[15] gasoline to R gasoline retailers,[16] who in turn compete to sell gasoline to final consumers. Only refiner i can sell its branded gasoline b_i. The cost per unit to refiner i for supplying gasoline of type b_i is c_i. Based upon the types of contracts that exist in the retail gasoline market, each retail station is constrained to sell a specific brand of gasoline at an exogenously determined location on a grid. The location of outlet ρ is given by an integer pair, (s, a) where $s \in \{1, 2, \ldots, S\}$ and a

[15] As the primary focus of this paper is on zone pricing, divorcement, and asymmetric price responses, the environment is simplified by only considering branded gasoline. The impact of branded versus unbranded gasoline is beyond the scope of this paper.

[16] R and r are used to denote retail level players and the Greek versions, P and ρ of these letters denote the retail outlets. These groups are not isomorphic as a retailer can operate multiple outlets.

$\in \{1, 2,\ldots, A\}$. Thus each station $\rho^r_{(s,a),b_i}$ is indexed by location, brand, and retailer identity $r \in R$. Note that identifying the location and the retailer is not redundant as multiple outlets can operate at the same location. It is quite common for two stations to be located on opposite sides of the street at the same intersection. Further, the retailer identity and the brand type are not redundant as there could be multiple retailers selling the same brand, as would occur in a market with both company operated and lessee dealer stations. The per unit price charged to a consumer by a retail outlet is $p_{\rho^r_{(s,a),b_i}}$.

Each buyer has a value v for one unit of gasoline. Buyers in the market are characterized by brand preference and location. A fraction ω_{b_i} of the buyers have a preference for brand b_i, meaning that these buyers gain additional utility $\beta_{b_i} > 0$ if they consume brand b_i. The fraction of consumers who do not have a brand preference is defined as ω_{b_0} with $\omega_{b_0} = 1 - \sum_{n=1}^{N} \omega_{b_n}$. For customers with no brand preference we define $\beta_{b_0} \equiv 0$. To distinguish the location of a consumer from the location of a retailer, the buyer's location is denoted by the pair (σ, α) where $\sigma \in \{1, 2,\ldots, S\}$ and $\alpha \in \{1, 2,\ldots, A\}$. The percentage of buyers at a particular location is determined by the density function $f(\cdot)$ defined over the $S \times A$ possible locations with $\sum_s \sum_a f(s,a) = 1$. Buyers incur a travel cost $d(\cdot)$ which is increasing and convex in the distance traveled. In this model, distance is defined by the norm $\|(s,a),(\sigma,\alpha)\| = |s-\sigma| + |a-\alpha|$ which gives the number intersections a buyer located at (σ, α) must travel to reach the retail station $\rho^r_{(s,a),b_i}$.[17]

In naturally occurring economies, gasoline retailers must first acquire inventory from the refiner before selling the gasoline to the consumer. This sequencing puts the refiners that are not vertically integrated in a theoretically advantageous position relative to their stations, but generates the typical double marginalization problem. In the downstream market, retailers maximize their profits conditioned on upstream prices. The upstream refiners are able to incorporate retailer reaction when setting DTW prices.[18]

[17] As the retailers and consumers are located on a grid, this taxi cab metric provides a more natural notion of distance than does the standard Euclidian metric.
[18] In what follows we use the terms wholesale price and DTW price interchangeably.

A buyer with a preference for brand j attempts to

$$\max_{\rho^r_{(s,a),b_i} \in \mathrm{P}} v + \varsigma_{j\rho^r_{(s,a),b_i}} \beta_{b_j} - p_{\rho^r_{(s,a),b_i}} - d(\|(\mathrm{s},\mathrm{a}),(\sigma,\alpha)\|)$$

subject to $v + \varsigma_{j\rho^r_{(s,a),b_i}} \beta_{b_j} - p_{\rho^r_{(s,a),b_i}} - d(\|(\mathrm{s},\mathrm{a}),(\sigma,\alpha)\|) \geq 0$

where $\varsigma_{j\rho}$ is an indicator function that takes on the value 1 if station $\rho^r_{(s,a),b_i}$ sells brand j and is 0 otherwise.[19] The problem is similar for buyers with no brand preference. If the consumer cannot achieve a nonnegative utility from buying from any retailer, then the consumer does not purchase gasoline and receives a utility of 0. In the event that two stations offer the same total utility to a buyer, a buyer with a preference for b_i selects an outlet selling this brand over an outlet selling any other brand. Otherwise such ties are broken randomly.

A retailer's problem is to set prices at the retail outlets it operates so as to maximize its expected profit. Let $w_{\rho^r_{(s,a),b_i}}$ denote the per unit price charged by refiner i to a retail outlet $\rho^r_{(s,a),b_i}$ for gasoline of type i. In addition to the cost of gasoline, a retailer incurs an additional cost of $e_{\rho^r_{(s,a),b_i}}$.[20] This cost is interpretable as an effort cost or as the cost associated with operating service bays or convenience stores. Refiner i's problem is to set $w_{\rho^r_{(s,a),b_i}}$ for all $\rho^r_{(s,a),b_i} \in P$ to maximize profits. The equilibrium solution is a set of optimal prices for the refiners and the retailers.[21]

In the gasoline industry, gasoline is delivered to retailers by tanker trucks. The retailer then holds this gasoline in its inventory and sells the product to consumers over some period of time. To incorporate this into the model, we suppose that when a retailer sells out of gasoline, a tanker delivers K units of gasoline at a per unit price determined as described above. Each

---

[19] To include search costs, the buyer's problem becomes one of maximizing expected benefits net of search costs based upon the buyer's beliefs about the distribution of prices. Again, as the primary focus of this paper is on zone pricing, divorcement, and asymmetric price responses, we simplify the environment by not incorporating search costs.

[20] For simplicity, the role of the jobber has been suppressed in this model. The price charged by each retailer can be considered to include delivery or this additional cost could be thought of as a separate jobber fee.

[21] The specified model is a generalization of the spatial model originally due to Hotelling (1929) and subsequently extended by numerous researchers, see e.g., Salop (1979), Scholer (1993), Vandenbosch and Weinberg (1995), Veendorp and Anjum (1995), Irmen and Thisse (1998), and Heywood, Monaco and Rothschild (2001). For equilibrium solution techniques the reader is referred to these works and papers cited therein. In these models, retailers only compete against their nearest rivals. Not only does a spatial model intuitively capture the gasoline market quite well, use of such a model is further justified by the results of Pinkse, Slade and Brett (2002) who conclude that retail gasoline competition is in fact very localized.

period, one buyer enters the market at a randomly chosen location and considers purchasing a single unit of gasoline. A retailer only refills its tanks once it sells K units.

Before discussing our experimental design we briefly comment on the objective of this section. This section constructs a model of wholesale and retail gasoline markets that captures the essential features of naturally occurring markets. In particular, we chose those elements (agents, variables, and actions) that are necessary to generate data to address the questions posed in Sections 1 and 2. Our methodological objective for the experiment on which the model is based is heuristic or exploratory in nature (Smith, 1982), and hence we are more interested in the richness of the strategic interactions in these markets than in sharply defined predictions of a model. If out of this complexity emerges a distinct order of outcomes in the experiment, theory would play a critical role in summarizing the statement of the observed behavioral regularities. But that is beyond the scope of this paper.

4. Experimental Design and Procedures

Our laboratory gasoline markets consist of N = 4 refiners that each produce branded gasoline and R = 4 retailers who each operate 2 locations on a 7 × 7 grid. To the subjects, each brand is distinguished by its color: b_1 = blue, b_2 = pink, b_3 = green, and b_4 = red. Figure 1 depicts the location and brand for each retail station.[22]

Buyers are assumed to be uniformly distributed over the grid, $f(s,a)=\frac{1}{49}$. Further, the likelihood that a buyer prefers brand i is $\omega_{b_i}=0.20$ and the benefit a buyer who prefers brand i received from purchasing it is $\beta_{b_i}=25$. As each buyer has an inelastic demand for 1 unit valued at v = 240 and has an insignificant impact upon the market, truthfully revealing robots serve as the final consumers. With the market shown in Figure 1, there is a "center" area at (s, a) = (4, 4) where each of the four branded retailers are "clustered". Each retailer also operates an outlet in a relatively "isolated" area in the "corner" of the grid. These two types of areas are meant to address the claim of refiners that they use zone pricing to be competitive with their local rivals.[23]

The cost of traveling is $d(x)=4x^2$ for x = 0, 1, …, 12. Given that $\beta_{b_i}+v=265$, no consumer is willing to travel further than 8 blocks to purchase gasoline and would only be

[22] The information was presented graphically to the subjects.
[23] See footnote 2.

willing to travel 7 intersections to a non-preferred brand outlet. The buyers have complete information about current retail prices.[24] Each laboratory session lasts 1200 periods. In each period, which is every 1.7 seconds, a robot buyer from a randomly drawn location enters the market, observes retail prices and makes a purchase decision.

We consider three experimental treatments to identify the impact of banning zone pricing and limiting vertical integration in retail gasoline markets. In the zone pricing (or baseline) treatment, refiners have the ability to set $w_{\rho^r_{(s,a),b_i}}$ for each $\rho^r_{(s,a),b_i} \in P$, as described in the preceding section. In this treatment, each retailer observes two location specific wholesale prices but could not shift inventory between locations.[25] Our uniform pricing treatment represents the environment after legislation banning zone pricing is enacted. In terms of the model described above, the uniform pricing treatment imposes the restriction that $w_{\rho^r_{(s,a),b_i}} = w_i$ for every station selling b_i. It is important to note that uniform pricing at the wholesale level does not imply uniform retail prices. In both the zone pricing and uniform pricing treatments, refiners are able to change wholesale prices throughout the 1200 periods. We measure the effects of divorcement by comparing the baseline treatment with a company operated (company-op) treatment. In the company-op treatment all of the retail stations are vertically integrated, which essentially removes the intermediary and eliminates double marginalization. This is operationalized by automatically setting $w_{\rho^r_{(s,a),b_i}} = c_i$.[26] In all three treatments, the non-gasoline expenses of each retailer are $e_{\rho^r_{(s,a),b_i}} = 10$.

For the first 600 periods, $c_{b_i} = 100\ \forall i$. In the remaining 600 periods, the refiners' costs follow a random walk to simulate changes in price for crude oil on the world market. The stochastic shocks are distributed as $N(0, 15)$. The number of periods until the next permanent shock are distributed as $U[20, 35]$. This means that the refiners' costs change every 34 to 60 seconds. The subjects are not given this information on the nature of the cost shocks. To reduce intersession variation, we hold the set of cost realizations constant across all sessions.

---

[24] This assumption could be relaxed; however, a priori one would expect that search costs could have the same price increasing effect in both the zone pricing and the uniform pricing treatments.
[25] Generally, stations are contractually prohibited from shifting inventory in natural contexts.
[26] The price setting role of the refiner is eliminated in the company-op treatment and hence no subjects are placed in the role of refiner in these sessions.

Retailer r sets $p_{\rho^r_{(s,a),b_i}}$ and could adjust this price at any time during the 1200 periods. Retailers and refiners observe all current retail prices including those set by rival outlets. However, the current DTW prices are known only by the refiner and the associated retailer. At the beginning of sessions in the zone and uniform treatments, refiners set initial wholesale prices, which the branded retailers are forced to accept for the initial inventory of $K = 10$ units. Once a location stocks out, the retailer completely replenishes its inventory of $K = 10$ units at the current wholesale price. In the event that wholesale prices fall, it is possible that a retail outlet has gas in its inventory that cost more than current rival retail prices. To avoid the retailer having to fully absorb losses, the refiners can offer rebates to the retailers for unsold units in inventory.

We conducted a total of twelve laboratory sessions, four in each treatment. Each session lasted no longer than 90 minutes and consisted of 8 subjects in the zone and uniform treatments and 4 subjects in the company-op treatment, who were recruited from undergraduate classes in economics, management, and engineering at George Mason University. In each session subjects were randomly assigned a role.[27] Prior to beginning the actual experiment, subjects were given ample opportunity to ask questions. Each subject only participated in one session and received US$1 for every 800 of experimental profit. The average payoff across all subjects was $18.25, including $5 for showing up on time. Subjects received their payments in private at the conclusion of the session.

5. Experiment Findings

In what follows we present the results of our experiment as a series of nine findings. We break down the discussion of the results into two subsections. The first subsection covers the results from the first 600 periods with stable wholesale costs. We control for learning effects by focusing our attention on the last half these periods (301-600). For this set of periods we first estimate the comparative static effects of the zone and uniform pricing treatments and the

[27] To avoid the potentially loaded terms associated with gasoline markets, the refiners and station owners were referred to as suppliers and store owners, respectively, who were buying and selling a fictitious product. A copy of the instructions is available from the authors upon request. In an attempt to aid comprehension of the environment, prior to beginning the experiment, each subject experienced the opposite role for 300 periods (except in the company-op treatment for which there is only one role). That is, a refiner (retailer) first read the instructions and participated as a retailer (refiner) for 300 periods, before reading the instructions as a refiner (retailer) and participating for 1200 periods as a refiner (retailer).

location effect of corner and center stations. Then we consider the effects of divorcement by estimating the comparative static effects of lessee dealers with zone pricing versus vertically integrated, company-owned stations. The second subsection analyzes the dynamic adjustment of station prices when the wholesale costs are nonstationary in periods 601-1200.

5.1 Comparative Static Effects with Constant Wholesale Costs

5.1.1 Zone versus Uniform Pricing

As an introduction, consider the qualitative results reported in Figures 2 and 3. Figure 2 displays average wholesale prices for the four sessions in each of the two treatments. It is evident that the refiners have endogenously adopted zone pricing to the retail stations when permitted. The average wholesale price to the corner stations is 174 versus 147 to the center stations. When the refiners are forced to charge uniform prices, the average wholesale price is 151, but it is unclear how meaningful this average is considering that there is a large variation in refiner prices across and within sessions. Wholesale prices in two of the uniform pricing sessions are as high as the average corner station wholesale prices under zone pricing. In another uniform pricing session, wholesale prices are approximately equal to average center wholesale prices under zone pricing. Average wholesale prices in the remaining uniform pricing session are below the average center wholesale prices with zone pricing.

Figure 3, which contains histograms of all of the posted retail prices, reveals that consumers do not see lower retail prices with uniform wholesale pricing. The mode for the corner stations is 200 in both the zone and uniform treatments. The posted prices are slightly higher in the uniform treatment, as there is considerably more mass distributed across the 210-230 bins in the uniform treatment. The effect of a uniform pricing policy on retail prices is considerably more striking at the central stations. The entire distribution of posted prices shifts to the right under uniform wholesale pricing. The mode in the uniform treatment is 190, whereas the mode is only 150 with zone pricing.

We first assess the effect of zone and uniform pricing on the transaction prices in each market. Unlike field studies which rely on posted prices, our dataset contains the actual prices paid by each buyer. The quantitative results are derived by analyzing the data with a linear mixed-effects model for repeated measures.[28] The treatment effect (*Zone* vs. *Uniform* wholesale

[28] See Longford (1993) for a description of this technique commonly employed in experimental sciences.

pricing) and location effect (*Center* vs. *Corner* station) and an interaction effect are modeled as zero-one fixed effects, while the 8 independent sessions and the 4 subjects within each session are modeled as random effects, e_i and ζ_{ir}, respectively. Specifically, we estimate the model

$$Price_{ir\ell t} = \mu + e_i + \zeta_{ir} + \beta_1 Uniform_i + \beta_2 Corner_\ell + \beta_3 Uniform_i \times Corner_\ell + \varepsilon_{ir\ell t},$$

where $e_i \sim N(0,\sigma_1^2)$, $\zeta_{ir} \sim N(0,\sigma_2^2)$, and $\varepsilon_{ir\ell t} \sim N(0,\sigma_{3,i}^2)$. The sessions are indexed by *i*; the subjects acting as retailers within each session are indexed by *r* = 1, 2, 3, 4; and the repeated periods are indexed by *t* (e.g., *t* = 301, 302, …, 600). $Corner_\ell = 0$ if $\ell = (s, a) = (4, 4)$ and 1 otherwise. The dependent variable $Price_{ir\ell t}$ is the transaction price received by subject *r* in session *i* at station location ℓ in period *t*. We also accommodate heteroskedastic errors by session when estimating the model via maximum likelihood.

Estimates of the treatment and location effects are easy to compute with this specification. The intercept μ is the expected price in the zone pricing treatment at the center location, $\mu + \beta_1$ is the expected price in the uniform pricing treatment at a center location, $\mu + \beta_2$ is the expected price in the zone pricing treatment at the corner location, and $\mu + \beta_1 + \beta_2 + \beta_3$ is the expected price in the uniform pricing treatment at a corner location.

Finding 1: *Retail transaction prices are statistically higher in the isolated areas than in the clustered area. Uniform pricing in the wholesale market increases retail transaction prices in the clustered area, but has no significant effect on transaction prices in the isolated areas.*

Evidence: The mixed effects estimation results presented in Table 1 provide the quantitative support for this finding. The average retail transaction price with zone pricing at the wholesale level is $\hat{\mu}$ = 149.98 at a station in the clustered area and $\hat{\mu} + \hat{\beta}_2$ = 191.58 in an isolated area, a 27.7% increase. This effect of location is highly significant ($\hat{\beta}_2$ = 41.60, *p*-value = 0.0000). With uniform pricing in the wholesale market, the average retail transaction price is $\hat{\mu} + \hat{\beta}_1$ = 166.38 at a station in the center and $\hat{\mu} + \hat{\beta}_1 + \hat{\beta}_2 + \hat{\beta}_3$=195.87 in the corner. Again the effect of location is highly significant ($\hat{\beta}_2 + \hat{\beta}_3$ = 29.49, *p*-value=0.0000). The uniform pricing treatment effect of $\hat{\beta}_1$ = 16.40 at center stations is statistically significant (*p*-value = 0.0311) and nontrivial in economic terms—uniform pricing at the wholesale level increases retail transaction prices in the clustered area by 10.9%. Transaction prices in the isolated stations are slightly higher with uniform pricing than with zone pricing ($\hat{\beta}_1 + \hat{\beta}_3$ = 4.29), but this effect is statistically insignificant (p-value = 0.4926). ■

Given the data generated by our experiment we are able to determine that high retail prices in the isolated areas are not the *result* of high wholesale prices with zone pricing, but rather the *cause* of high wholesale prices. Figure 4 plots average wholesale prices and average posted retail prices by location for the first 300 periods when subjects are learning about the competitive pressures or lack thereof. Notice that, unlike Figure 2, wholesale prices to corner stations have a noticeable upward trend in the zone pricing treatment. Over the first 100 periods, corner station retail prices are very high. As the refiners recognize that these isolated stations are very profitable at those prices, the refiners use zone pricing to capture some of the rents from the corner stations. The clustered area stands in rather marked contrast. As station prices tumble due to the competition, wholesale prices also fall as the refiners use zone pricing to be more competitive. Only after station prices stabilize around period 250 do wholesale prices start to rise as refiners attempt to capture the retailer profits in the clustered area. Ultimately, the refiners capture more of the profits with zone pricing, but not to the detriment of consumers.

Also, we are able to gain insight as to why uniform pricing in the wholesale market actually increases transaction prices for consumers in the clustered area. Fundamentally, the reason is that uniform wholesale pricing forces the refiner to forgo profits in the corner to be competitive in the center. Thus refiners forced to sell at a uniform price have an incentive to keep wholesale prices elevated relative to the central wholesale prices with zone pricing. This is demonstrated in Figure 5, which plots the red refiner's wholesale price and red retailer's posted price for the center red branded station and the average decision by their counterparts for one session. At the beginning of the session, the red refiner's price quickly plummets from 231 to 120 and the red center station (s, a) = (4, 4) eventually follows suit. The refiner observes that there are substantial profits accruing at the red corner station (s, a) = (6, 6) and in period 176 raises the wholesale price to 200. When in period 190 the red center station restocks at the new wholesale price of 200, the station owner is forced to raise the center station's retail price. The red retailer maintains a high price at the center location because it cannot compete with the other central stations which have average retail prices below the red retailer's wholesale price. As the red station will not sell these higher-cost units, competition in the center is weakened and gradually the prices of the other refiners and stations drift upwards. The end result is that uniform pricing at the wholesale level stymies retail competition in the clustered center. Moreover, we note that it only takes one refiner's unilateral action to initiate this process of mitigating competition.

Our second finding considers the effect of mandating uniform wholesale pricing on buyer utility. The ability to collect direct measures of consumer welfare and conduct this analysis is another major benefit of a laboratory study over a field study where such measures cannot be collected. Again, we use a linear mixed-effects model to estimate the quantitative effects of the treatment (*Zone* vs. *Uniform* Pricing) on buyer utility. We classify each buyer as one of three types: interior, equidistant, and periphery. Interior buyers are those closest to the center stations. These buyers originate at one of the following intersections: (4, 3), (4, 4), (4, 5), (3, 4), or (5, 4). A buyer is equidistant from the center stations and at least one corner station if it originates at (4, 1), (4, 2), (4, 6), (4, 7), (1, 4), (2, 4), (6, 4), (7, 4), (3, 3), (3, 5), (5, 3) or (5, 5). All other buyers are relatively isolated, being located closer to a corner station, and are categorized as periphery buyers. The treatment effect, buyer types (*Interior*, *Equidistant*, and *Periphery*) and interaction effects are modeled as zero-one fixed effects. The sessions are again treated as random effects, e_i, so that the model we estimate is

$$\begin{aligned} BuyerUtility_{it} = \mu + e_i + \beta_1 Uniform_i + \beta_2 Equidistant_t + \beta_3 Periphery_t + \\ \beta_4 Uniform_i \times Equidistant_t + \beta_5 Uniform_i \times Periphery_t + \varepsilon_{it} \end{aligned}$$

where $e_i \sim N(0, \sigma_1^2)$ and $\varepsilon_{it} \sim N(0, \sigma_{2,i}^2)$. The sessions are indexed by i and the repeated periods by t (e.g., t = 301, 302, …, 600). $BuyerUtility_{it}$ is the utility that the buyer achieved in the market. We also include heteroskedastic errors by session in the maximum likelihood estimation of the model.

Finding 2: *Uniform pricing in the wholesale market decreases buyer welfare for the interior and equidistant buyers, but has no significant effect on periphery buyers.*

Evidence: Table 2 reports the quantitative support for this finding. The average buyer utility for interior buyers with zone pricing is $\hat{\mu}$ = 101.58 but with uniform wholesale pricing, buyer welfare drops by $-\hat{\beta}_1$ = 17.15, a 16.9% decrease that is statistically significant (p-value = 0.0491). With zone pricing, equidistant buyers are worse off than interior buyers because they have further to travel to the lower-price center stations ($\hat{\beta}_2 = -17.45$, p-value = 0.0000). However, with uniform wholesale pricing, the welfare for these buyers is even lower than equidistant buyers in the zone pricing treatment ($\hat{\beta}_1 + \hat{\beta}_4 = -15.01$, p-value = 0.0549). The point estimates indicate that periphery buyers are harmed by uniform pricing ($\hat{\beta}_1 + \hat{\beta}_5 = -10.05$), but this effect is statistically insignificant (p-value = 0.1555). ■

These first two findings directly counter the claims that zone pricing harms consumers and that uniform pricing would benefit consumers. Uniform pricing in the wholesale market raises the actual prices that consumers pay and reduces the welfare to all buyers except those on the periphery. Our next finding reports the impact of uniform wholesale pricing on station and refiner profits.

Finding 3: *Uniform pricing significantly increases station profits, but has no effect on refiner profits.*

Evidence: Figure 6 provides the qualitative support for this finding. Each marker represents the profits for one station owner from both the center and corner stations plotted against the associated refiner's profits. It is clear from the figure that station owner profits increase substantially with uniform wholesale pricing. The average station owner earns profits of 801 with zone pricing and 2304 with uniform pricing. For the quantitative support for this finding, we use a Wilcoxon rank sum test to compare the total station owner profits of the four zone pricing sessions with the total station owner profits of the four uniform sessions. We reject the null hypothesis of equal station owner profits with a two-sided test ($W = 26$, $n = 4$, $m = 4$, p-value = 0.0286). Average refiner profits are slightly lower with uniform pricing, 2616 versus 3006 with zone pricing, but a Wilcoxon rank sum test indicates that this difference is not statistically significant ($W = 17$, $n = 4$, $m = 4$, p-value = 0.8857). ■

In sum, we find that uniform wholesale pricing (a) reduces consumer welfare by increasing the prices that buyers pay at the clustered stations, relative to retail prices under zone pricing, (b) has no statistical effect on consumer welfare and prices for buyers that are in isolated areas, (c) increases station owner profits, and (d) has no statistical effect on refiner profits.

5.1.2 Zone Pricing (Lessee Dealers) versus Company-owned Stations

The effects of vertical integration are also rather striking. Figure 7 displays histograms of the posted retail prices. The mode for the corner stations is 200 in both the zone and company-owned treatments; however, there is considerably more mass in the left tail of the company-owned treatments. The effect of vertical integration on retail prices is considerably more conspicuous at the center stations. The entire distribution of posted prices shifts to the left with company-owned stations. The mode with lessee dealers is only 120, whereas the mode is 150 under zone pricing with lessee dealers.

For our quantitative analysis, we estimate a linear mixed effects for transaction prices. The treatment effect (*Lessee Dealers with Zone Pricing* vs. *Company-Owned Stations*) and location effect (*Center* vs. *Corner* station) and an interaction effect are modeled as zero-one fixed effects, while the 8 independent sessions and the 4 retailers within each session are modeled as random effects.

Finding 4: *Retail transaction prices with company-owned stations are statistically lower in both the clustered area and the isolated areas than in the zone pricing treatment.*

Evidence: The mixed effects estimation results presented in Table 3 provide the quantitative support for this finding. With company-owned stations, the average retail transaction price is $\hat{\mu} + \hat{\beta}_1$ = 130.22 at a station in the center, which is 13.2% lower than transaction prices with lessee dealers ($\hat{\mu}$ = 149.97). This effect is statistically significant ($\hat{\beta}_1$ = -19.75, *p*-value = 0.0157). In isolated areas, transaction prices with company-owned stations are -($\hat{\beta}_1 + \hat{\beta}_3$) = 31.53 less than transaction prices with lessee dealers. This effect is also statistically significant (*p*-value = 0.0022), reducing transaction prices by 16.5% from a level of $\hat{\mu}_1 + \hat{\beta}_2$ = 191.58 with lessee dealers to $\hat{\mu}_1 + \hat{\beta}_1 + \hat{\beta}_2 + \hat{\beta}_3$ = 160.04 with company-owned stations. ■

Finding 4 reports the extent to which a double markup by refiners and stations raises the prices that consumers pay vis-à-vis a single markup by company-owned stations. This finding complements the field studies of Barron and Umbeck (1984) and Vita (2000) and a laboratory study by Durham (2000), which also find that prices are lower with vertical integration than without. Our next finding quantifies the additional utility buyers receive from eliminating the double markup with company-owned stations.

Finding 5: *Relative to the zone pricing treatment, pricing with company-owned stations increases buyer welfare for all types of buyers: interior, equidistant, and periphery.*

Evidence: Table 4 reports that with company-owned stations the utility of interior and equidistant buyers increases by $\hat{\beta}_1$ = 20.45 (p-value = 0.0241). (The point estimate for equidistant buyers, $\hat{\beta}_4$, is small and highly insignificant.) The utility of periphery buyers increases by $\hat{\beta}_1 + \hat{\beta}_5$ = 25.94 (p-value = 0.0084). These absolute increases in buyer welfare translate into percentage increases of 20.1%, 24.4%, and 50.6% in buyer welfare for the interior, equidistant, and periphery buyers, respectively. ■

5.2 Dynamic Adjustments with Nonstationary Wholesale Costs

We now turn our attention to how prices dynamically adjust to nonstationary costs. Figure 8 depicts wholesale costs, average retail prices, and average retailer costs (net of $e_{\rho^r_{(s,a),b_i}} = 10$) for the selling a unit from inventory in period t. It is clear that retail prices more closely follow the station's cost of gasoline than the wholesale costs. The noticeable lagged response of retail prices to changes in wholesale costs is presumably due to the inventories of the stations. In this subsection we investigate how retail prices adjust to changes in station costs. In particular, we investigate whether station prices respond symmetrically or adjust faster to cost increases than to decreases.

As a first step, we must determine whether a long run relationship exists between station prices p_t and costs c_t (wholesale prices).[29] If both p_t and c_t are nonstationary with a unit root, i.e., integrated of order 1, $I(1)$, then we can operationalize the hypothesis of a long run (equilibrium) relationship between p_t and c_t using the concept of cointegration developed by Engle and Granger (1987). Station prices and costs are said to be cointegrated if a linear combination of the two series is stationary, $I(0)$. If p_t and c_t have a long run equilibrium relationship, then the short run dynamics of the cointegrated system also have an error-correction representation. An error-

[29] For ease of exposition we are dropping the location, retailer identity, and brand subscripts from per period prices and costs.

correction model of the first differences (Δp_t and Δc_t) includes a term that reflects the current "error" in the levels of p_t and c_t in achieving long-run equilibrium. To test whether prices adjust asymmetrically or symmetrically to changes in cost, we follow Granger and Lee (1989) in estimating a non-symmetric error correction model, namely,

$$\Delta p_t = \alpha_1 \Delta c_{t-1} + \alpha_2 \Delta p_{t-1} + \phi_1 z_{t-1} + \phi_2 z_{t-1}^{+} + \xi_t ,$$

where $\xi_t \sim N(0,\sigma^2)$, z_{t-1} is the error-correction term, and $z_{t-1}^{+} = \max(z_{t-1}, 0)$. If prices adjust symmetrically, the speed of the adjustment to the long run equilibrium is captured by $-1 < \phi_1 < 0$, with $\phi_2 = 0$. If prices respond faster to cost increases than decreases, then $-1 < \phi_1 < 0$ and $\phi_2 > 0$.

We begin this analysis by considering station prices and costs averaged across all sessions and subjects for each station location (corner and center) and treatment (zone, uniform, and company-owned), as depicted in Figure 8. Augmented Dickey-Fuller tests fail to reject the null hypothesis for all series. Given that the each of series are found to be $I(1)$, we now consider whether a long run equilibrium exists between prices and costs for each location in each treatment. This is our sixth finding.

Finding 6: *With zone wholesale pricing and company-owned retail pricing, a long run relationship exists between station prices and station costs for both center and corner stations; however no such relationships exist with uniform pricing.*

Evidence: Table 5 reports the results of Johansen cointegration tests, which serve as the qualitative support for this finding.[30] Likelihood ratio (LR) tests of the number of cointegrating equations indicate that there is 1 cointegrating equation at the 1% level of significance for both corner and center stations with zone wholesale pricing and that there is 1 cointegrating equation at the 5% level of significance for both corner and center stations with company-owned retail pricing. However, the LR tests reject any cointegration with uniform pricing at the 5% level of significance for either locale. ■

Finding 6 indicates that a long run equilibrium between station prices and costs with zone wholesale pricing and with company-owned retail pricing. Shocks to costs, both positive and

[30] Schwarz criteria indicate that a one period lag is superior to any other lag specification from two to thirty. The test assumption also assumes no deterministic trend in the data since none was included in the induced wholesale costs.

negative, are passed-through to customers via changes in station prices according to a stable long run relationship between the two series. In contrast, we find that uniform wholesale pricing breaks down the long run relationship between costs and prices at both center and corner stations. This means that any relationship implied by a regression of prices on costs in levels is spurious. Changes in costs still may lead to changes in prices, as Figure 8 faintly shows, but there is no short run adjustment of prices toward a long run relationship with costs when costs experience a shock. Uniform pricing purges the responsiveness of retail prices to cost changes, the negative implication being that when wholesale costs fall, retail prices do not follow. This also means that retail prices are insulated to increases in wholesale costs, but we also observe in Finding 2 that uniform wholesale pricing generates high retail prices in the clustered area.

Our seventh finding addresses the "rockets and feathers" phenomenon in the retail gasoline industry with zone wholesale pricing (7a) and company-owned retail pricing (7b), where a long run equilibrium relationship exists.

***Finding 7a*:** *Station prices in the clustered area adjust quickly and asymmetrically to changes in costs with zone pricing. Station prices in isolated areas adjust more slowly, but symmetrically to changes in costs.*

Evidence: Table 6 and Figure 9 provide the support for this finding. Table 6 reports the estimates of the error-correction model for the average station prices and costs across all sessions and subjects by treatment. The error-correction term is highly significant and is largely responsible for explaining the adjustment of prices (p-value < 0.0001 for both center and corner stations). When the error-correction term is positive (i.e., costs are lower relative to what is specified in the long run equilibrium given prices), the speed of adjustment for center stations is considerably slower ($\hat{\phi}_1 + \hat{\phi}_2$ = -0.176 + 0.128 = -.048) than when error-correction term is negative ($\hat{\phi}_1$ = -0.176). Figure 9 plots the adjustment of prices to positive and negative cost shocks of 10 experimental dollars. For the center stations, over 90% of an increase in costs is reflected in the price in just 11 periods (or just 18.7 seconds of experiment time), but in the same amount of time only 40% of a decrease in costs is passed-through. In fact, it takes 45 periods (or 76.5 seconds) for 90% of a cost decrease to be reflected in the price at center stations. The speed of adjustment for corner stations is slower than for center stations ($\hat{\phi}_1$ = -0.047) and is symmetric ($\hat{\phi}_2$ is statistically insignificant with a p-value = 0.1650). ■

Finding 7b: *With company-owned retail pricing, station prices adjust symmetrically and much more slowly to changes in station costs.*

Evidence: As reported in Table 6, the error-correction term $\hat{\phi}_1$ is significant for both center and corner stations (p-value = 0.0001 and 0.0353, respectively), but $\hat{\phi}_2$ is statistically insignificant (p-values = 0.9522 and 0.7719). Figure 9 indicates that the adjustment of prices to positive and negative cost shocks is rather slow. For the center stations, 90% of an increase in costs is reflected in the price in 123 periods, and at corner stations it takes 152 periods for 90% of a cost increase to be reflected in the price. ■

Having found at an aggregate level that prices adjust asymmetrically at the center stations with zone wholesale pricing, we continue to exploit our dataset to investigate asymmetric price responses to costs. First, we estimate error-correction models for the center stations at the session level and then for each individual station owner in each of the four zone pricing sessions.[31] In the interest of brevity, we focus on the estimates at the session level but only classify the individual station owners by whether $\hat{\phi}_2$ is (a) statistically positive, (b) statistically not different than zero, (c) statistically negative, or by (d) not having cointegrated prices and costs.

Finding 8: *At the session level, station prices in the clustered area adjust asymmetrically to changes in costs with zone pricing. Individual station owners are predominantly and equally classified as one of two behavioral types: asymmetric and symmetric adjusters.*

Evidence: Table 8 reports that prices rise faster than they fall in response to cost changes in three of the four sessions ($\hat{\phi}_2 > 0$ with p-values = 0.0051, 0.0740, and 0.0000). In the fourth session, prices actually fall faster than they rise ($\hat{\phi}_2 < 0$ with p-value = 0.0107). The sessions that adjust faster to cost increases contain at least one station owner who is classified as an asymmetric adjuster with $\hat{\phi}_2$ statistically greater than 0, as reported in Table 8. The fourth session contains three symmetric adjusters and one station owner who decreases prices faster than he increases

[31] Augmented Dickey-Fuller tests for all series fail to reject the null hypothesis of a unit root, and unless otherwise noted, Johansen cointegration tests indicate that all pairs of price and cost series are cointegrated. The Schwarz criteria also continue to indicate that 1 lag is superior to any other lag specification.

them in response to cost changes. Of the 16 station owners, 6 respond faster to cost increases than to decreases and 6 respond symmetrically. ■

Finding 8 begs the question as to whether there are any reasons why some station owners adjust asymmetrically while others adjust symmetrically. Using a meta-analysis of several industries, Peltzman (2000) uncovers a stylized fact that more volatile input prices are correlated with less price asymmetries. In our laboratory experiment we can directly test whether the volatility of wholesale prices set by refiners affects the price adjustment behavior of station owners. This comprises our final finding.

Finding 9: *The volatility of wholesale prices is uncorrelated with whether or not a station owner adjusts prices asymmetrically or symmetrically. However, during regimes of increasing wholesale costs, more volatile wholesale prices are correlated with station owners who respond more quickly to wholesale price increases than to wholesale price decreases.*

Evidence: Using a Wilcoxon rank sum statistic we test whether the variance of the change in wholesale prices is correlated with a station owner being classified as an asymmetric ($\hat{\phi}_2 > 0$) or symmetric ($\hat{\phi}_2 = 0$) price adjuster. Specifically, we compare the variance of wholesale price changes for periods 601-1200 for the 6 asymmetric price adjusters to the 6 symmetric price adjusters and find that there is no statistical difference ($W = 43$, $n = 6$, $m = 6$, p-value = 0.5887). However, if we separately measure the variance of price changes when wholesale costs are rising (periods 778-853 and 1053-1200), volatility of wholesale prices is larger for the asymmetric price adjusters than for symmetric price adjusters ($W = 27$, $n = 6$, $m = 6$, p-value = 0.0649). When wholesale costs are falling in periods 601-777 and 854-1052, there is no statistical difference in the volatility of wholesale prices for the different retail types ($W = 43$, $n = 6$, $m = 6$, p-value = 0.5887). ■

The implication of Finding 9 is that refiners who have greater volatility in wholesale prices during periods of rising crude oil costs cause their station owners to increases their prices more quickly than these same individuals decrease their retail prices when wholesale prices and oil prices are falling.

6. Conclusion

The gasoline industry is an intricate system, making the implications of policies such as prohibiting zone pricing and vertical integration unclear from anecdotal evidence alone. However, such topics are regularly debated in the political arena. Consumers and media routinely scrutinize retail gasoline prices looking for evidence of anticompetitive behavior. The sheer magnitude and social interest in this market has led numerous research studies of the industry. Unfortunately, this field research must rely on incomplete information. In this study we detail a laboratory investigation of the gasoline industry, focusing specifically on uniform pricing at the wholesale level, divorcement, and asymmetric retail price responses to cost shocks.

Our study provides a series of insights into the effect of zone pricing. In many situations our results provide support for hypotheses formalized by previous researchers. First, prices in relatively isolated areas are higher than prices in areas with a clustering of stations. Contrary to the claims expressed by proponents of uniform pricing legislation, uniform wholesale pricing actually increases prices in the more competitive area and simultaneously does not alter prices in more isolated geographic areas that are less competitive. Due to this behavior, uniform pricing actually reduces the welfare of buyers who are closest to the center area, as well as those who are on the border of the center and isolated areas. The buyer losses are not the refiners' gains. In fact we find that refiners' profits are unaffected by the uniform pricing. Instead, it is the retailers that are extracting surplus from the consumers. The data offer a simple explanation for this result. Under uniform pricing, the refiners offer a price that is above the center area zone wholesale price and below the isolated area zone wholesale price. These refiners are balancing extracting economic rents from the isolated stations and remaining viable in the competitive, center area. Thus, a refiner's gains in the center area, due to higher wholesale prices, are offset by reduced earnings in the isolated markets where wholesale prices have decreased and profits are unchanged. With uniform pricing the retailers do not gain a profit margin in the center area but do receive a larger margin in the isolated regions where retail prices are unchanged but wholesale prices have declined.

On the issue of divorcement we find that company-owned stations eliminate the double markup of prices. From this we can conclude that divorcement legislation harms consumers. All buyers, in clustered or isolated areas, pay lower prices and have substantially higher utility when stations are company-owned. This price finding in the laboratory (buyer utility cannot be directly measured in field studies) affirms the results from field studies, lending credence to our other findings.

Numerous studies have demonstrated an asymmetry in gasoline price responses. In the laboratory we are able to investigate this pattern while controlling for collusion, menu costs, and buyer search. With zone pricing, the practice in place when previous studies evaluated asymmetric price responses, we find that retail prices and retail costs are cointegrated, i.e., a long term equilibrium relationship exists between the two series. Our data indicate that prices in the center area adjust more quickly to costs increases than to cost decreases, but we find that in isolated areas price responses are symmetric. At the market (session) level we find that responses are influenced by the idiosyncrasies of individual retailers, some of whom respond symmetrically and some of whom respond asymmetrically. Further, a retailer's type is not correlated with the volatility of its wholesaler's prices. However, retailers who observe more volatile wholesale prices during periods of increasing wholesale costs (or world oil prices) are more likely to respond asymmetrically. With company-owned stations, prices adjust symmetrically to cost shocks. Further, this response is substantially slower in the company-owned treatment than with zone pricing.

In addition to benefiting retailers at the expense of consumers, another effect of uniform pricing is the destruction of the long term relationship between retail prices and costs. Formally, we find that with uniform wholesale pricing, retail costs and prices are not cointegrated and therefore any reduction in wholesale costs, say due to changes in the world price for oil, would not necessarily be reflected in retail prices.

As with any empirical study, the inherent specificity of a data set is determined by such details as the environment and institution, and raises the typical issues of inferring broader implications from the results. Further research would be useful in examining how the exogenous location and number of stations, as well as endogenous and costly entry and exit, affect our findings. Along the lines of Shepard (1993), it would also be useful to explore the endogenous formation of vertical relationships in laboratory markets.

References

Bacon, Robert W., "Rockets and Feathers: The Asymmetric Speed of Adjustment of UK Retail Gasoline Prices to Cost Changes." *Energy Economics* v13, 1991, pp. 211-8.

Barron, John M. and Umbeck, John R., "The Effects of Different Contractual Arrangements: The Case of Retail Gasoline Markets." *Journal of Law and Economics* v27, 1984, pp. 313-28.

Borenstein, Severin and Shepard, Andrea, "Dynamic Pricing in Retail Gasoline Markets." *RAND Journal of Economics* v27, 1996, pp. 429-51.

Borenstein, Severin; Cameron, A. Colin and Gilbert, Richard, "Do Gasoline Prices Respond Asymmetrically to Crude Oil Price Changes?" *Quarterly Journal of Economics* v112, 1997, pp. 305-39.

Bulow, Jeremy; Fischer, Jeffrey; Creswell, Jay and Taylor, Christopher, "U.S. Midwest Gasoline Pricing and the Spring 2000 Price Spike." *The Energy Journal*, v24 (3), 2003, pp. 121-149.

Castanias, Rick and Johnson, Herb, "Gas Wars: Retail Gasoline Fluctuations." *Review of Economics and Statistics* v75, 1993, pp. 171-74

Chouinard, Hayley and Perloff, Jeffrey M., "Gasoline Price Differences: Taxes, Pollution Regulations, Mergers, Market Power, and Market Conditions." Working Paper, University of California at Berkeley, 2001.

Comanor, William and Riddle, Jon, "The Costs of Regulation: Branded Open Supply and Uniform Pricing of Gasoline." *International Journal of the Economics of Business*, v10 (2), 2003, pp. 123-144.

Douglas, Elizabeth, "Station Owners Pump Fists at Oil Companies," *L. A. Times*, May 7, 2003.

Durham, Yvonne, "An Experimental Examination of Double Marginalization and Vertical Relationships." *Journal of Economic Behavior and Organization*, v42 (2), 2000, pp.207-229.

Engle, Robert and Granger, Clive, "Co-integration and Error Correction: Representation, Estimation, and Testing." *Econometrica* v55, 1987, pp. 251-76

Granger, Clive and Lee, T. H., "Investigation of Production, Sales and Inventory Relationships Using Multicointegration and Non-symmetric Error Correction Models." *Journal of Applied Econometrics* v4, December 1989, pp. S145-59.

Hastings, Justine, "Prepared Statement Before the Committee on Governmental Affairs," Permanent Subcommittee on Investigations, United States Senate, May 2, 2002a.

Hastings, Justine, “Vertical Relationships and Competition in Retail Gasoline Markets.” Working Paper, Dartmouth University, 2002b.

Heywood, John S.; Monaco, Kristen, and Rothschild, R., “Spatial Price Discrimination and Merger: The N-Firm Case.” *Southern Economic Journal* v67 2001, pp. 672-84.

Hotelling, Harold, “Stability in Competition.” *Economic Journal* v39, 1929, pp. 41-57.

Irmen, Andreas and Thisse Jacques-Fracois, “Competition in Multi-Characteristic Space: Hotelling Was Almost Right.” *Journal of Economic Theory* v78, 1998, pp. 76-102.

Isaac, Mark; Oaxaca, Ronald and Reynolds, Stanley, “Competition and Pricing in the Arizona Gasoline Market.” working paper, University of Arizona, 1998.

Johnson, Ronald, “Search Costs, Lags, and Prices at the Pump.” *Review of Industrial Organization* v20, 2002, pp. 33-50.

Lafontaine, Francine and Slade, Margaret E., “Retail Contracting: Theory and Practice.” *Journal of Industrial Economics* v45, 1997, pp. 1-25.

Lockyer, Bill. “Report on Gasoline Pricing in California.” Office of the Attorney General of the State of California, May 2000.

Longford, N. T., Random Coefficient Models. New York: Oxford University Press, 1993.

Manuszak, Mark, “The Impact of Upstream Mergers on Retail Gasoline Markets.” working paper, Carnegie Mellon University, 2001.

Maskin, Eric and Tirole, Jean, “A Theory of Dynamic Oligopoly, II: Price Competition, Kinked Demand Curves, and Edgeworth Cycles.” *Econometrica* v56, 1988, pp. 571-99.

Peltzman, Sam, “Prices Rise Faster Than They Fall.” *Journal of Political Economy* v108, 2000, pp. 466-502.

Pinkse, Joris; Slade, Margaret E., and Brett, Craig, “Spatial Price Competition: A Semiparametric Approach.” *Econometrica* v70, 2002, pp. 1111-53.

Reilly, Barry and Witt, Robert, “Petrol Price Asymmetries Revisited.” *Energy Economics* v20, 1998, pp. 297-308.

Rey, Patrick and Stiglitz, Joseph. “The Role of Exclusive Territories in Producers' Competition.” *RAND Journal of Economics* v26, 1995, pp. 431-51.

Salop, S., “Monopolistic Competition With Outside Goods,” *Bell Journal of Economics* v10, 1979, pp. 141-156.

Scholer, Klaus, "Consistent Conjectural Variations in a Two-Dimensional Spatial Market." *Regional Science and Urban Economics* v23, 1993, pp. 765-78.

Shepard, Andrea, "Contractual Form, Retail Price, and Asset Characteristics in Gasoline Retailing." *RAND Journal of Economics* v24, 1993, pp. 58-77.

Slade, Margaret E., "Vancouver's Gasoline-Price Wars: An Empirical Exercise in Uncovering Supergame Strategies." *Review of Economic Studies* v59, 1992, pp. 257-76.

Slade, Margaret E., "Strategic Motives for Vertical Separation: Evidence from Retail Gasoline Markets." *Journal of Law, Economics, and Organization* v14, 1998, pp. 84-113.

Smith, Vernon L., "Microeconomic Systems as an Experimental Science," *American Economic Review* v72, 1982, pp. 923-55.

Smith, Vernon L., "Economics in the Laboratory." *Journal of Economic Perspectives* v8, 1994, pp. 113-31.

Vandenbosch, Mark and Charles Weinberg, "Product and Price Competition in a Two-Dimensional Vertical Differentiation Model." *Marketing Science* v14, 1995, pp. 224-49.

Veendorp, E. and Majeed Anjum, "Differentiation in a Two-Dimensional Market." *Regional Science and Urban Economics* v25, 1995, pp. 75-83.

Vita, Michael G., "Regulatory Restrictions on Vertical Integration and Control: The Competitive Impact of Gasoline Divorcement Policies." *Journal of Regulatory Economics* v18, 2000, pp. 217-33.

Table 1. Estimates of the Linear Mixed-Effects Model for Transaction Prices: Zone vs. Uniform Pricing

	Estimate	Std. Error	Degrees of Freedom*	t-statistic	p-value
μ	149.98	4.13	2305	36.30	0.0000
Uniform (β_1)	16.40	5.85	6	2.80	0.0311
Corner (β_2)	41.60	0.75	2305	55.40	0.0000†
Uniform × *Corner* (β_3)	-12.11	1.05	2305	-11.56	0.0000
			2339 Obs.		
				H_a: $\beta_1 + \beta_3 \neq 0$	0.4926
				H_a: $\beta_2 + \beta_3 > 0$	0.0000†

*N.B. The linear mixed effects model for repeated measures treats each session as one degree of freedom with respect to the treatments. Hence, with two treatment parameters, there are 6 degrees of freedom for the estimates of the treatment fixed effect (8 sessions – 2 parameters).

†One-sided test.

Note: The linear mixed-effects model is estimated by maximum likelihood. For brevity, the session and subject random effects are not included in this table or any others.

Table 2. Estimates of the Linear Mixed-Effects Model for Buyer Utility: Zone vs. Uniform Pricing

	Estimate	Std. Error	Degrees of Freedom*	t-statistic	p-value
μ	101.58	4.68	2388	21.72	0.0000
Uniform (β_1)	-17.15	6.57	6	-2.61	0.0401
Equidistant (β_2)	-17.45	2.11	2388	-8.25	0.0000†
Periphery (β_3)	-50.31	1.90	2388	-26.45	0.0000†
Uniform × *Equidistant* (β_4)	2.14	2.86	2388	0.75	0.4543
Uniform × *Periphery* (β_5)	7.10	2.57	2388	2.76	0.0058
			2400 Obs.		
				H_a: $\beta_1 + \beta_4 \neq 0$	0.0549
				H_a: $\beta_1 + \beta_5 \neq 0$	0.1555

†One-sided test.

Table 3. Estimates of the Linear Mixed-Effects Model for Transaction Prices: Zone Pricing with Lessee Dealers vs. Company-Owned Stations

	Estimate	Std. Error	Degrees of Freedom	t-statistic	p-value
μ	149.97	4.99	2340	30.08	0.0000
Company-owned (β_1)	-19.75	7.06	6	-2.80	0.0157†
Corner (β_2)	41.60	0.75	2340	55.40	0.0000†
Company-owned × *Corner* (β_3)	-11.78	1.20	2340	-9.81	0.0000
			2374 Obs.		
				H_a: $\beta_1 + \beta_3 < 0$	0.0022†
				H_a: $\beta_2 + \beta_3 > 0$	0.0000†

†One-sided test.

Table 4. Estimates of the Linear Mixed-Effects Model for Buyer Utility: Zone Pricing with Lessee Dealers vs. Company-Owned Stations

	Estimate	Std. Error	Degrees of Freedom*	t-statistic	p-value
μ	101.59	5.82	2388	17.44	0.0000
Company-owned (β_1)	20.45	8.26	6	2.47	0.0241†
Equidistant (β_2)	-17.45	2.11	2388	-8.25	0.0000†
Periphery (β_3)	-50.32	1.90	2388	-26.44	0.0000†
Company-owned × *Equidistant* (β_4)	0.05	3.11	2388	0.02	0.4940†
Company-owned × *Periphery* (β_5)	5.49	2.81	2388	1.96	0.0253†
			2400 Obs.		
				H_a: $\beta_1 + \beta_4 > 0$	0.0216†
				H_a: $\beta_1 + \beta_5 > 0$	0.0084†

†One-sided test.

Table 5. Johansen Cointegration Tests of the Equation: $p_t = \beta_0 + \beta_1 c_t$

Treatment and Location	Eigenvalue	LR statistic	5% Critical Value	1% Critical Value	No. of Cointegrating Equations
Zone Pricing, Center Stations	0.087171	55.27	19.96	24.60	0**
	0.001219	0.73	9.24	12.97	1
Zone Pricing, Corner Stations	0.054853	35.43	19.96	24.60	0**
	0.002834	1.70	9.24	12.97	1
Uniform Pricing, Center Stations	0.027930	18.03	19.96	24.60	0
	0.001816	1.09	9.24	12.97	1
Uniform Pricing, Corner Stations	0.016531	10.91	19.96	24.60	0
	0.001572	0.94	9.24	12.97	1
Company-Owned, Center Stations	0.042158	26.86	19.96	24.60	0*
	0.001847	1.11	9.24	12.97	1
Company-Owned, Corner Stations	0.036239	22.91	19.96	24.60	0*
	0.001403	0.84	9.24	12.97	1

* Denotes rejection of the hypothesis at 5% significance level.
** Denotes rejection of the hypothesis at 1% significance level.

Table 6. Estimates of Error-Correction Model for Δp_t

	Estimate	Std. Error	*t*-statistic	*p*-value
Zone Pricing				
All Center Stations				
Δc_{t-1}	-0.098	0.052	-1.87	0.0620
Δp_{t-1}	0.009	0.039	0.23	0.8182
z_{t-1}	-0.176	0.026	-6.82	0.0000
z^{+}_{t-1}	0.128	0.035	3.67	0.0003
				$\overline{R}^2 = 0.10$
Zone Pricing				
All Corner Stations				
Δc_{t-1}	0.022	0.044	0.49	0.6243
Δp_{t-1}	-0.001	0.040	-0.23	0.8182
z_{t-1}	-0.047	0.010	-4.60	0.0000
z^{+}_{t-1}	0.020	0.014	1.39	0.1650
				$\overline{R}^2 = 0.06$
Company-Owned				
All Center Stations				
Δc_{t-1}	0.052	0.066	0.79	0.4298
Δp_{t-1}	0.092	0.040	2.28	0.0230
z_{t-1}	-0.065	0.016	-3.98	0.0001
z^{+}_{t-1}	-0.002	0.026	-0.06	0.9522
				$\overline{R}^2 = 0.05$
Company-Owned				
All Corner Stations				
Δc_{t-1}	-0.006	0.066	-0.09	0.9283
Δp_{t-1}	0.038	0.041	0.92	0.3579
z_{t-1}	-0.039	0.018	-2.11	0.0353
z^{+}_{t-1}	0.007	0.025	0.29	0.7719
				$\overline{R}^2 = 0.01$

Table 7. Estimates of Error-Correction Model for Δp_t by Session for Center Stations

	Estimate	Std. Error	t-statistic	p-value
Session 1				
Δc_{t-1}	-0.048	0.047	-1.01	0.3129
Δp_{t-1}	0.008	0.040	0.20	0.8415
z_{t-1}	-0.152	0.027	-5.65	0.0000
z_{t-1}^{+}	0.101	0.036	2.81	0.0051
				$\overline{R}^2 = 0.07$
Session 2				
Δc_{t-1}	-0.177	0.069	-2.55	0.0110
Δp_{t-1}	-0.042	0.040	-1.05	0.2941
z_{t-1}	-0.086	0.026	-3.32	0.0010
z_{t-1}^{+}	0.061	0.034	1.79	0.0740
				$\overline{R}^2 = 0.04$
Session 3				
Δc_{t-1}	-0.174	0.051	-3.41	0.0007
Δp_{t-1}	0.015	0.039	0.38	0.7041
z_{t-1}	-0.244	0.029	-8.49	0.0000
z_{t-1}^{+}	0.178	0.041	4.37	0.0000
				$\overline{R}^2 = 0.13$
Session 4				
Δc_{t-1}	-0.127	0.047	-2.68	0.0076
Δp_{t-1}	0.002	0.038	0.04	0.9681
z_{t-1}	-0.086	0.014	-6.19	0.0000
z_{t-1}^{+}	-0.062	0.024	-2.56	0.0107
				$\overline{R}^2 = 0.10$

Table 8. Types of Station Owners

	Asymmetric $\hat{\phi}_2 > 0$	Symmetric $\hat{\phi}_2 = 0$	Asymmetric $\hat{\phi}_2 < 0$	p_t and c_t are not cointegrated
Session 1	X*			
No. Subjects	3	1		
Session 2	X			
No. Subjects	1	1		2**
Session 3	X			
No. Subjects	2	1	1	
Session 4			X	
No. Subjects		3	1	
Totals	6	6	2	2

*See Table 7 for estimates.

**The refiners for these station owners maintained somewhat high prices that did not vary much over time.

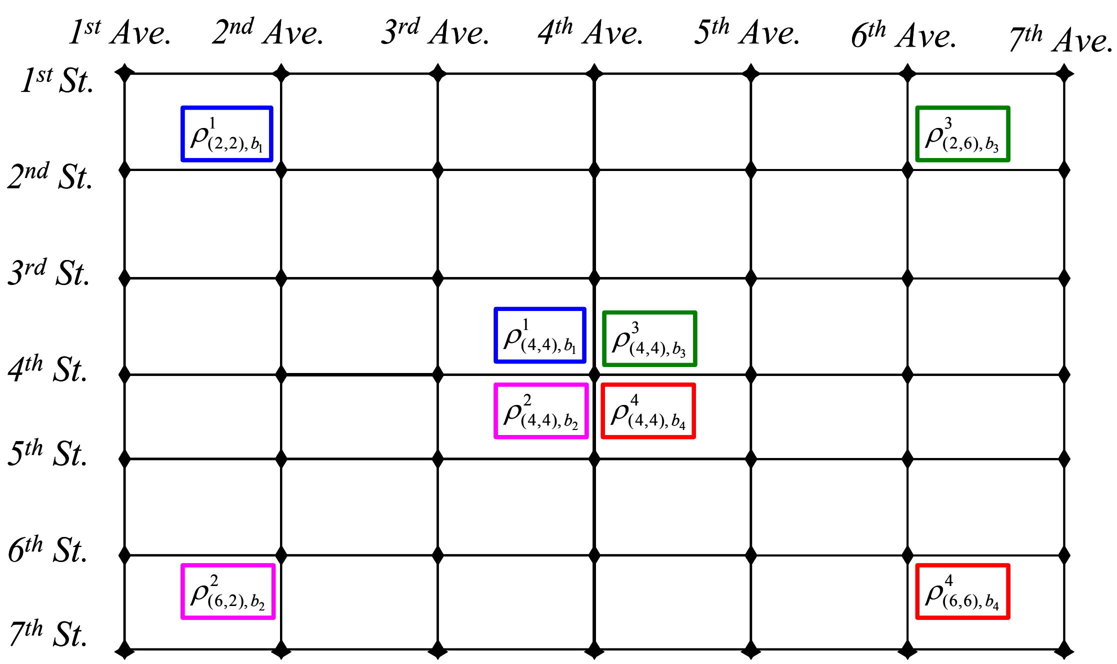


Figure 1. Geographic Depiction of the Laboratory Retail Gasoline Market

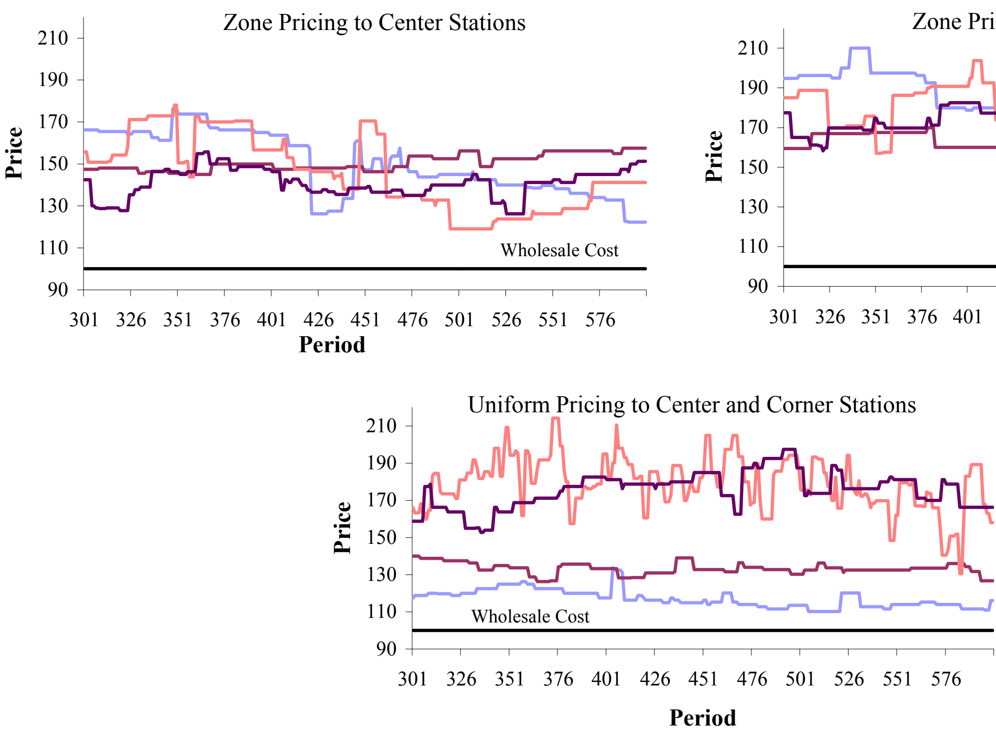


Figure 2. Average Wholesale Prices by Session

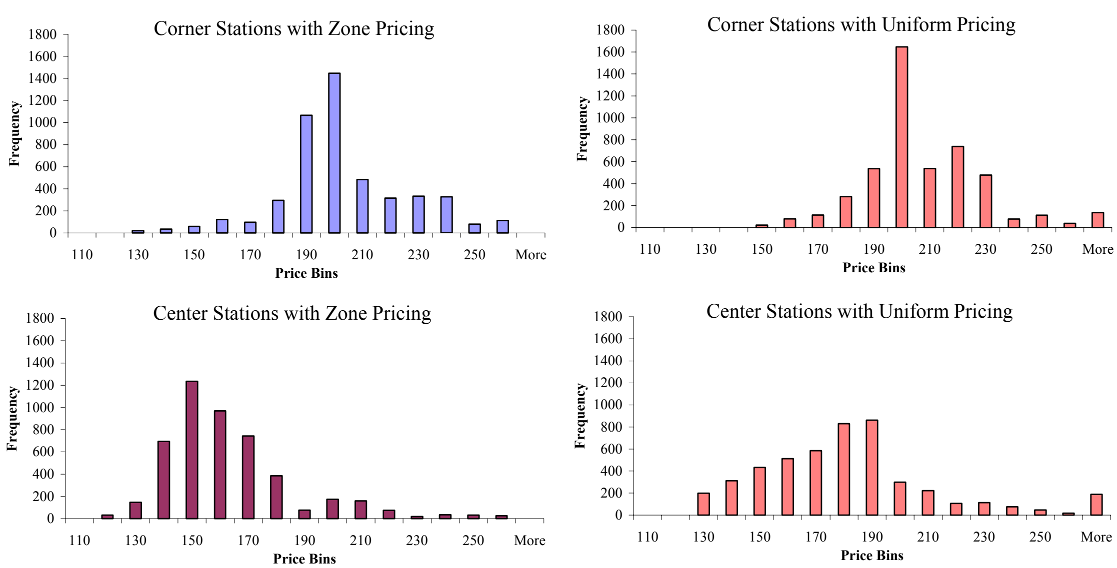


Figure 3. Histograms of Station Posted Prices: Zone vs. Uniform Pricing

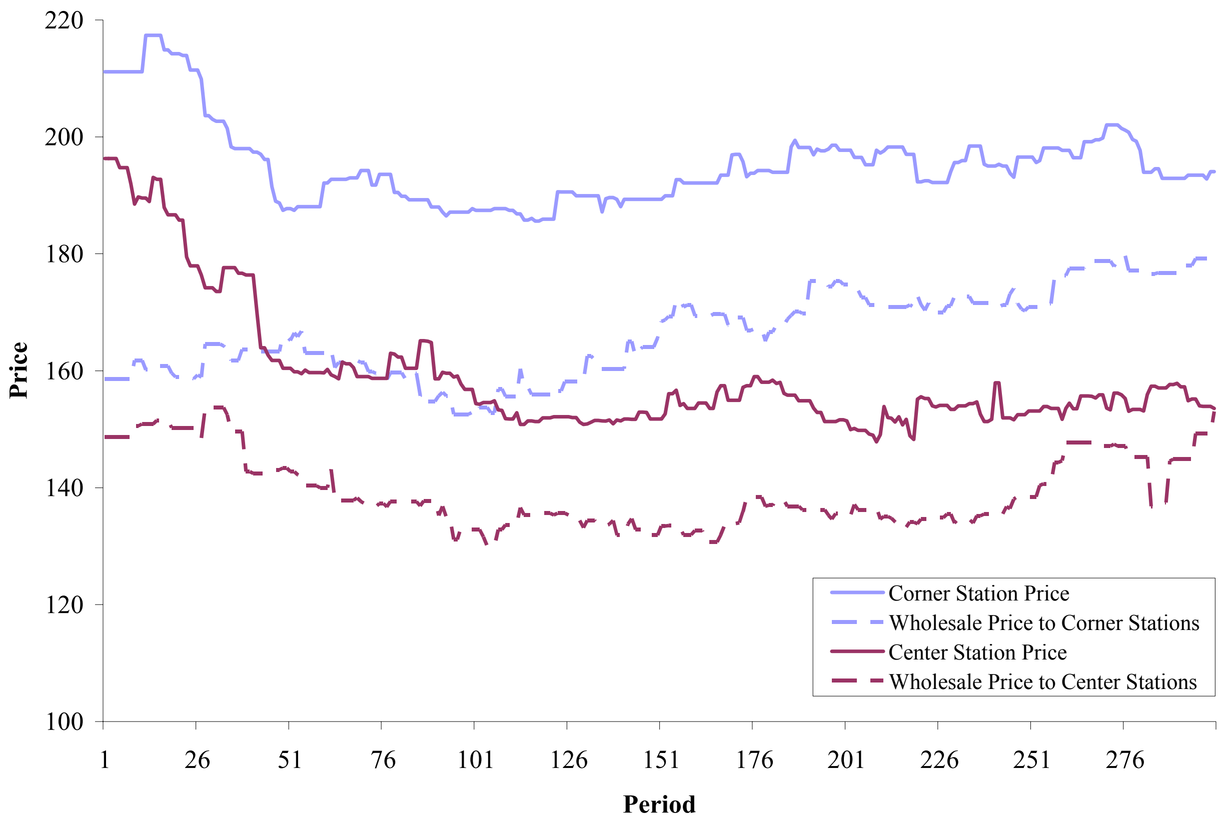


Figure 4. Average Wholesale and Station Prices with Zone Pricing in Periods 1-300

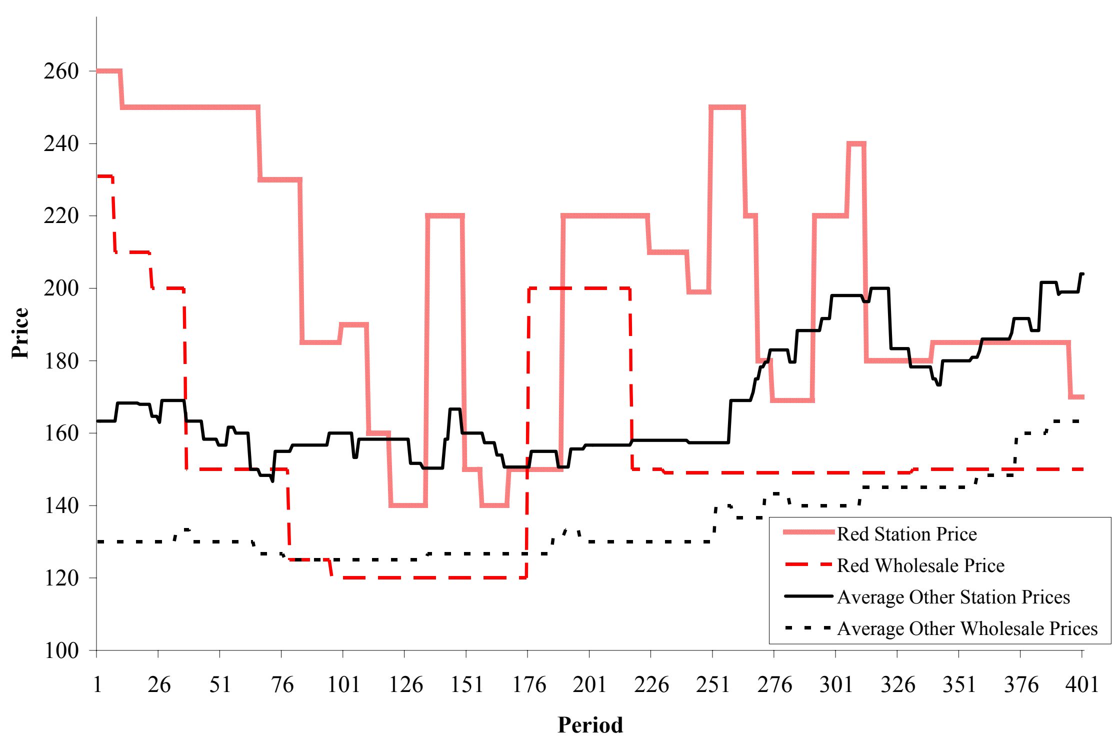


Figure 5. Example of How High Prices Arise in the Center with Uniform Wholesale Prices

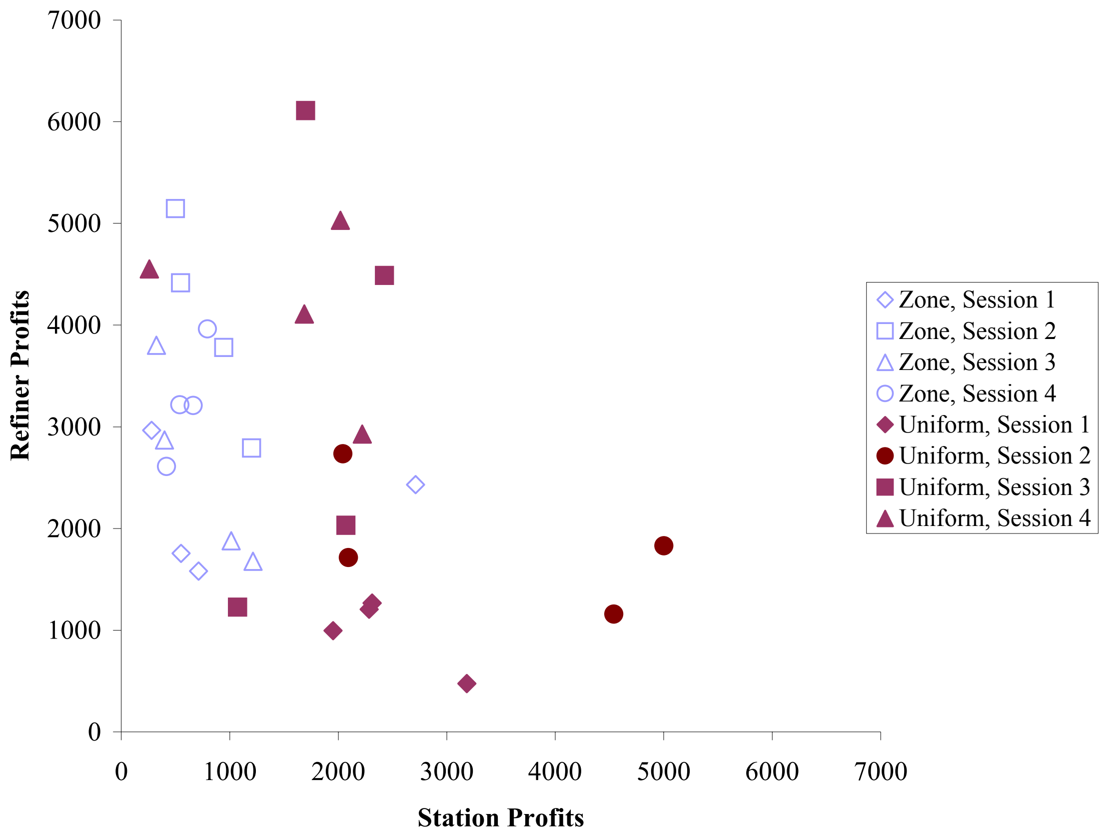


Figure 6. Station vs. Refiner Profits for Periods 301-600

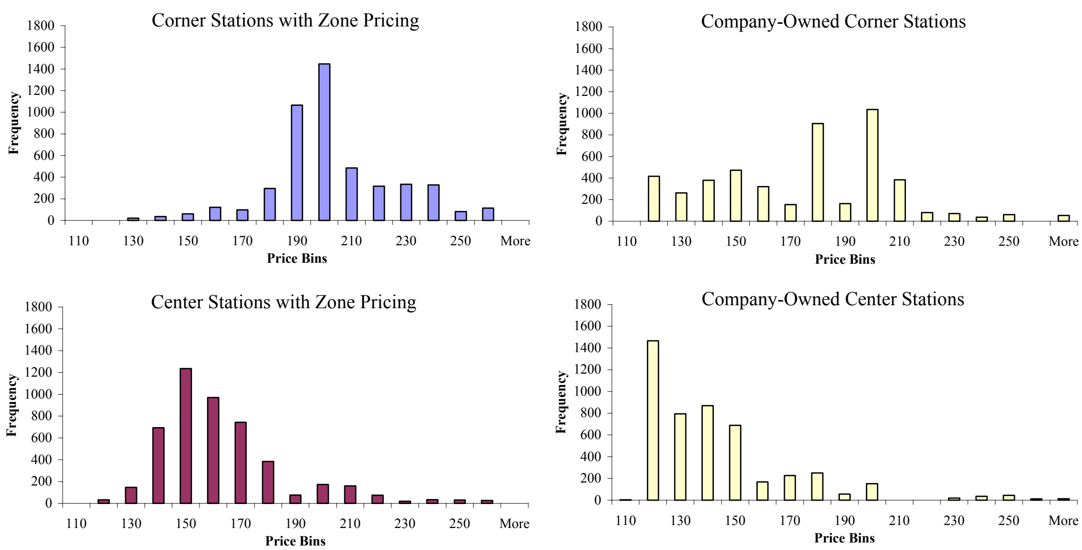


Figure 7. Histograms of Station Posted Prices: Zone Pricing (Lessee Dealer) vs. Company-Owned Stations

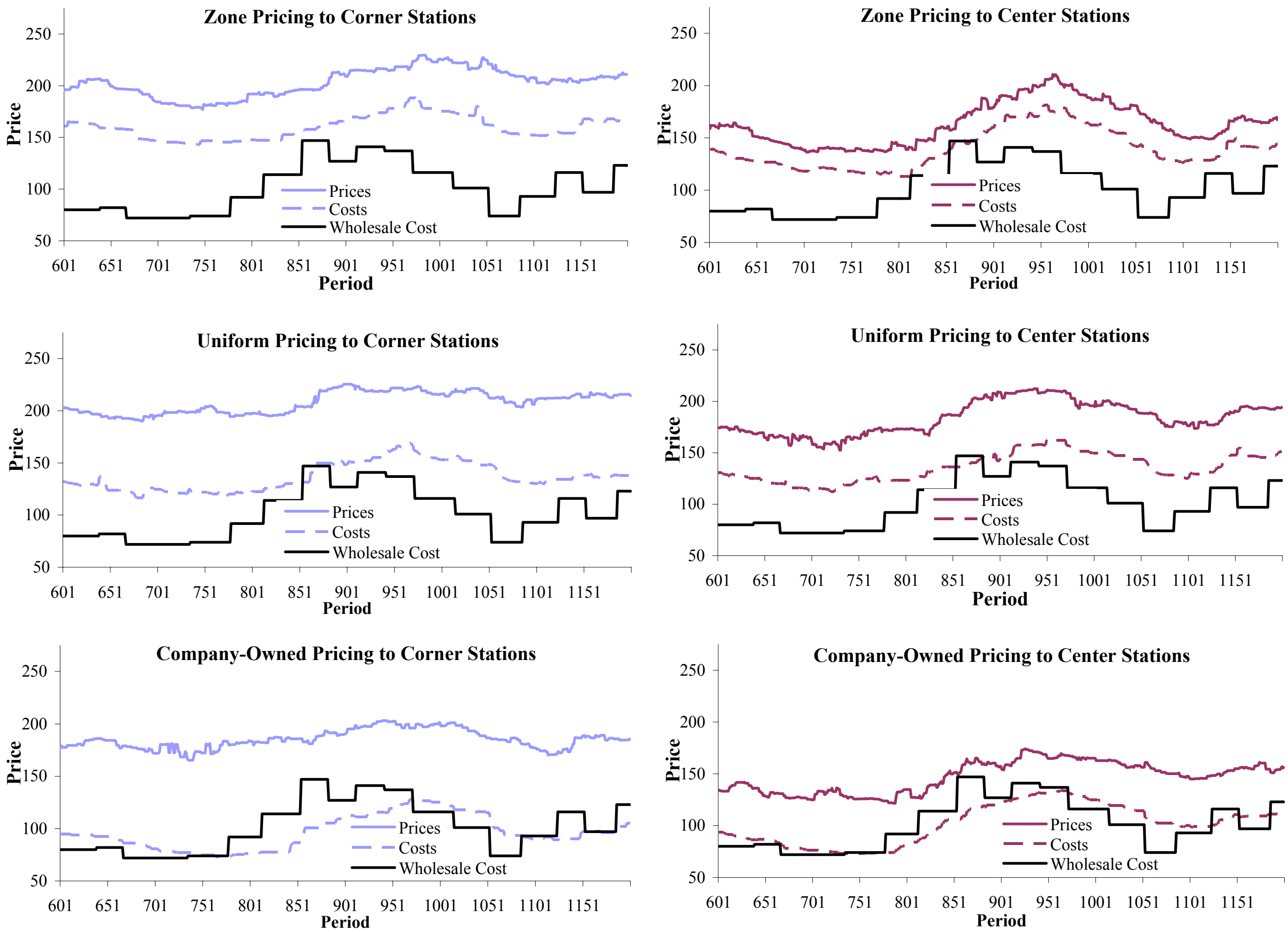
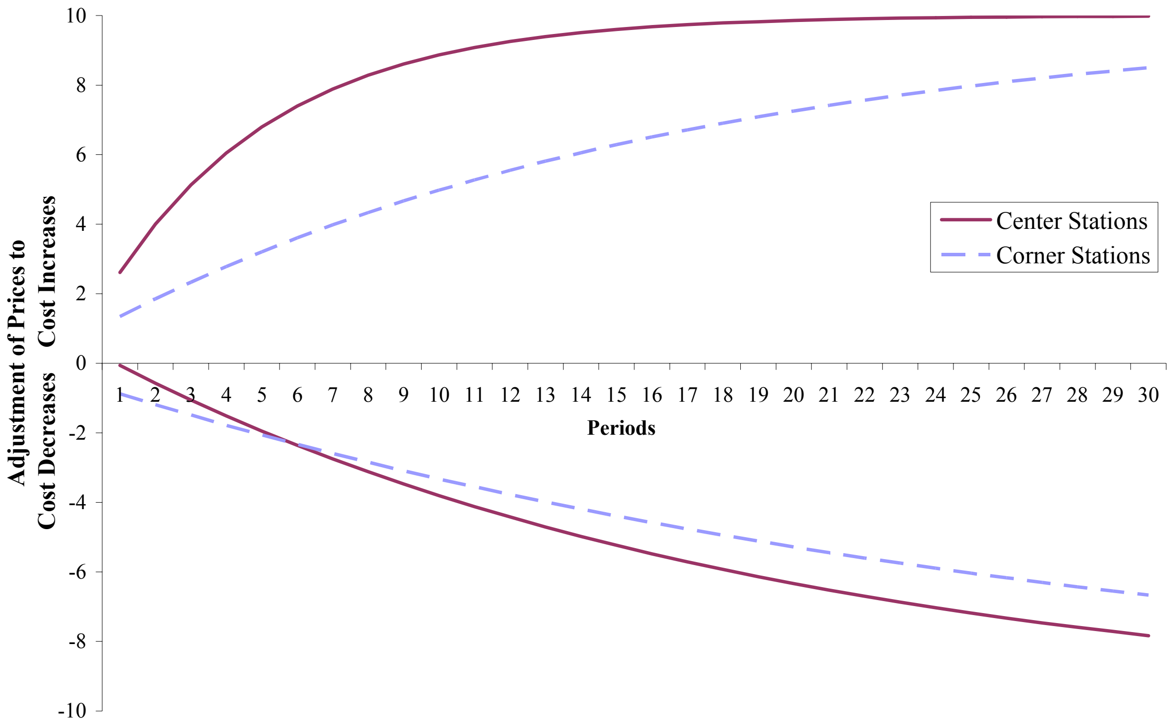
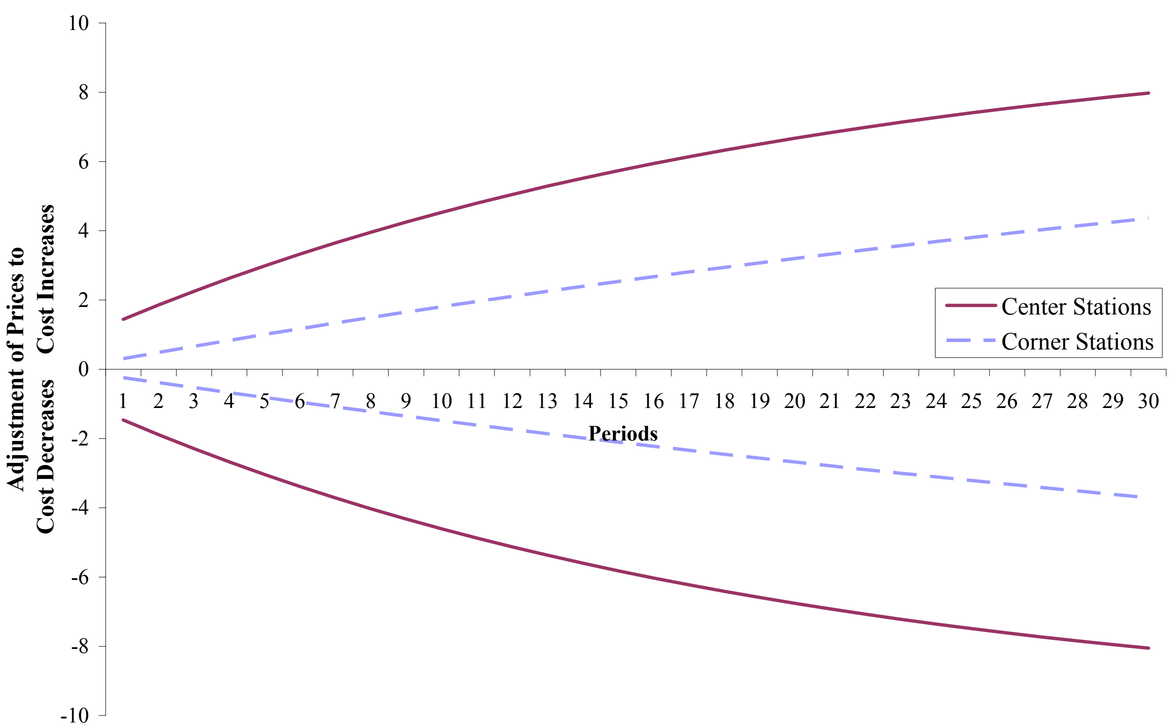


Figure 8. Station Prices and Costs in Periods 601-1200



Zone Pricing Treatment



Company-Owned Treatment

Figure 9. Adjustment of Station Prices to a 10 Experimental Dollar Innovation in Cost