DYNAMIC PRICING IN RETAIL
GASOLINE MARKETS

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ABSTRACT

This paper tests for price patterns in retail gasoline markets consistent with those predicted by models of implicit collusion among firms. Recent supergame models show that the highest supportable collusive price is a function of today's profit relative to expected future profit: collusive prices are higher when predictable changes in demand or cost lead firms to expect that collusive profits are increasing rather than declining. *Ceteris paribus*, collusive profits will be expected to increase when demand is expected to increase and/or costs are expected to decline. Using panel data on sales volume, and retail and wholesale prices in 59 cities over 72 months, we find results consistent with these predictions. Controlling for *current* demand and input price, the elasticity of current retail margins with respect to expected next-month demand is about 0.37. The elasticity of current margins with respect to next-month wholesale price is about -0.37. The results are inconsistent with inventory effects.

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I. Introduction

In recent years, economists have developed numerous models to distinguish empirically between collusive and non-collusive pricing behaviors.[1] Most studies have focused on industries that could be characterized as tight oligopolies, the U.S. auto industry and 19th century U.S. railroads for example. With one exception discussed below, these studies have attempted to uncover collusive behavior by estimating relationships among contemporaneous observations of output, cost and price. This study uses a test based on the relationship between current price and expected future demand and cost conditions to diagnose collusion in a market with many, differentiated firms.[2]

Our investigation of collusive pricing exploits the insights from game-theoretic models of self-enforcing collusive agreements that rely on future behavior to maintain collusion. In these models, future expected cost and demand conditions affect the ability to sustain collusion. More specifically, our test is based on the work of Rotemberg and Saloner (1987) and the extension of that model by Haltiwanger and Harrington (1991). The intuition in these models is that self-enforcing collusion depends on the gain from defection being less than the anticipated loss from the punishment triggered by defection. The gain from defection is greater when *current* collusive profits are higher; the expected loss from punishment is greater when expected, *future* collusive profits are higher. Holding cost constant, collusive profit increases with demand. Rotemberg and Saloner show that

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[1] These include Porter (1983 and 1985), Bresnahan (1987), Lambson and Richardson (1992), Ellison (1993) and Hajivassiliou (1989). Bresnahan (1989) provides a comprehensive review.

[2] Throughout this paper, we use "collusion" to mean implicit collusion supported by repeated interaction. This does not imply that firms in these markets are earning excess profits. Nor do we suggest that these firms engage in activities that violate U.S. antitrust laws.

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when current demand is high (low) relative to expected future demand, collusion is more (less) difficult to sustain. In the Haltiwanger and Harrington reformulation, the analogous prediction is that controlling for current demand, collusion is more difficult to sustain when demand is declining than when it is increasing. If firms are colluding, then, current margins should be positively correlated with anticipated changes in demand.

Although these models explicitly address only changes in demand, both works note that an analogous argument can be made for anticipated changes in cost. Higher input cost (holding demand constant) implies lower collusive profit. Lower expected collusive profit next period reduces the expected loss from the punishment phase and therefore requires lower collusive prices this period. Current collusive margins, therefore, should be negatively correlated with anticipated changes in input prices.

Our work is most closely related to Ellison's (1993) test of Rotemberg and Saloner using data on railroad prices and outputs during the era of the Joint Executive Committee cartel. Ellison models the collusive price as a function of the ratio of current to expected future demand. He finds no evidence of an effect on current margins, but notes that the explicit railroad cartel might not be an environment in which to expect a Rotemberg-Saloner effect. Hajivassiliou (1989) also tests for a Rotemberg-Saloner effect in the Joint Executive Committee cartel, but relies on contemporaneous price and quantity data only. He finds little support for the prediction that collusion is less likely when current demand is high.

We test these hypotheses in the retail gasoline market. In some respects, this is a natural setting for the test. The Rotemberg-Saloner and Haltiwanger-Harrington models rely upon predictable changes in market conditions, and retail gasoline experiences predictable changes in both de-

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mand and input price. There are substantial seasonal fluctuations in the demand for gasoline. The regularity of movements in gasoline demand means that decisionmakers have fairly precise predictions about the future state of demand. The size of the demand shifts (average daily consumption changes by approximately 20% from trough to peak of the seasonal cycle in our sample) means that the effect of demand changes on margins should be observable if it exists. Input cost movements are less regular, but prior studies have demonstrated that there are fairly long lags in the response of wholesale gasoline prices to crude oil shocks. As a result, some of the movement in wholesale prices is a predictable response to past shocks. The magnitude of the changes in crude oil prices also suggests that any margin response should be observable: over half of the month-to-month changes in crude oil prices are greater than 5% in absolute value and almost one-quarter exceed 10%.

Alternative explanations suggested for a linkage between today's margins and expected future changes are not applicable to the retail gasoline industry or can be distinguished from a Rotemberg-Saloner effect. Because consumer switching costs are fairly low, models based on capturing consumers with low prices today in order to have a large customer base next period are not compelling. Inventory effects also are unlikely to mimic a Rotemberg-Saloner effect. There are no constraints on the supply of gasoline from refiners, so inventory models based on the probability of stockouts at the retail level are not appropriate. Inventory effects based on anticipated price movements may be present, but we argue that they can be distinguished from the Rotemberg-Saloner effect.

While cost and demand structures suggest retail gasoline markets are a good place to test these models, the structure of the industry appears

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to argue against finding any evidence of cooperative pricing. At both the wholesale and the station level, there are more than the "few" firms assumed in oligopoly models. A typical metropolitan area will have more than 10 firms selling gasoline wholesale and many more selling gasoline to final consumers.[3] On the other hand, these firms sell a differentiated product. Gasoline is differentiated by brand, and stations are further differentiated by location and service. The number of firms operating in a metropolitan area, then, may not be a good indicator of the number of effective competitors in any actual retail market.

Further, prior research has shown that pricing in retail gasoline markets is not well characterized by standard competitive models. Slade (1986a) presents evidence from a single retail market in Vancouver that station demand is not perfectly elastic and rejects the hypothesis of competitive pricing. Borenstein (1991) and Shepard (1991) argue that U.S. gasoline stations have sufficient local market power to implement price discrimination across gasoline grades or service levels. Slade (1987) concludes that pricing in the Vancouver market is characterized by implicit collusion in which periods of cooperation alternate with price wars triggered by demand shocks. While the structure of the market makes it very unlikely that the firms are able to come close to achieving the monopoly price in a supergame equilibrium, these results suggest that the possibility of less perfect tacit collusive pricing cannot be rejected a priori.

The results of our analysis are consistent with the collusive pricing models. Controlling for current demand and wholesale price, we find that current margins increase in expected, one-period changes in demand and

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[3] See Henly, Potter and Town (1992) for information on wholesale market structures and Borenstein and Gilbert (1993) for information on retail market structure.

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decline in expected, one-period changes in the wholesale price. The magnitudes of these effects are not large in absolute value: increasing expected, next-period demand by 10% reduces the current margin, which averages slightly more than ten cents, by about 0.4 cents. Reducing the expected wholesale price of gasoline by ten cents increases current margins by about 0.6 cents. These finding suggest that some degree of cooperative pricing may be more common than is suggested by studies focusing solely on oligopolistic industries.

In the following section we describe the models on which the empirical work is based. In Section III, we describe how they might be applied to the retail gasoline market and discuss inventory effects. The data and the empirical model are discussed in Section IV, followed by presentation of the results in Section V. Some concluding comments are offered in Section VI.

II. Models of Price Dynamics

Bresnahan (1989) and others have pointed out that diagnosing collusive pricing from only contemporaneous price, cost, and demand data is difficult. The fact that non-cooperative behavior is consistent with a variety of pricing patterns poses a major problem in these endeavors. For example, non-cooperative prices may increase or decrease in response to positive demand shocks, depending on the cost structure and whether the shock changes the composition of demand as well as its level. As a result, such efforts to distinguish collusive from non-cooperative behavior generally have relied upon restrictive assumptions about the functional forms of demand and cost. Recent models of collusion, however, have implications for dynamic pricing that more easily distinguish the behavior consistent with these specific models from non-cooperative outcomes. In particular, some of these models predict that current prices will respond to expected,

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future demand and cost conditions. Whatever the price response to current demand and cost conditions might be, prices are generally unaffected by anticipated conditions in the absence of collusion.

Rotemberg and Saloner suggest that firms colluding implicitly on price will respond to anticipated demand conditions. In their model, very high demand periods are outlying realizations of an independently and identically distributed demand shock. In these periods, an individual firm has a relatively large incentive to deviate from the collusive price because it is able to capture a share of an unusually large market by doing so. Current deviations would be punished by lower prices next period. If deviation is to be prevented, the potential loss earned by the firm in the punishment phase must be greater than the potential gain earned by deviating in the current period. The punishment loss anticipated by a deviating firm is the present value of the difference between the profits it expects to earn while colluding and those it expects to earn under the lower, punishment prices. If demand is i.i.d., current demand realizations have no effect on expectations of future demand, and the expected loss remains constant. In high demand periods, then, collusion can be sustained only by reducing the gains to deviation. The highest sustainable collusive margin will therefore be lower in high demand periods than in low demand periods.

Haltiwanger and Harrington reformulate this model in the context of a deterministic demand cycle. In this environment, it is possible to distinguish the *level* of demand from the expected *change* in demand.[4] To understand their model, it is easier to reverse the thought experiment and hold constant the gain from deviating. Consider a simple model with con-

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[4] In the Rotemberg-Saloner model, the distinction between level and derivative cannot be made. A high demand necessarily implies a negative expected derivative and a low demand implies a positive expected derivative.

stant marginal cost and linear demand where the monopoly price would be procyclical. Figure 1 graphs the monopoly price as demand increases and then falls over the cycle. The level of current demand is equal at t_1 and t_2. If the monopoly price were sustained by collusion, the gain to a single firm from deviating would be equal at these two points. However, the loss from punishment will be more severe at t_1 because the near-term periods are higher demand periods, and it is these that are weighted more heavily in evaluating the present value of the loss from punishment. The highest sustainable collusive margin will therefore be lower at t_2 than at t_1. If colluding firms are never able to sustain the monopoly price, as is probably the case in retail gasoline markets, the Haltiwanger-Harrington result implies that the difference between the monopoly price and the sustainable collusive price will be greater at t_2 than at t_1.

Because gasoline demand follows a clear seasonal cycle, our empirical test of the Rotemberg-Saloner effect follows the Haltiwanger-Harrington formulation. For gasoline markets, their model suggests margins will be higher as demand rises toward the seasonal peak than as it declines away from it. More generally, controlling for current demand, margins will be positively correlated with expected, near-term changes in demand.

Both of these models explicitly hold marginal cost constant over time. But if changes in input prices create predictable shifts in marginal cost, it is straightforward to show that the models imply that retail margins also will be affected by expectations about future marginal cost. For simplicity, suppose demand does not change over time and marginal cost is invariant to output. Then if input prices are expected to rise next period, the expected increase in marginal cost will cause expected profits to decline. This will reduce the potential loss from future punishment. The effect of expected

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cost on collusive margins is therefore analogous to the effect of expected demand: holding constant current marginal cost, current margins will be *negatively* correlated with expected, near-term changes in marginal cost.

These predictions distinguish collusive from non-cooperative outcomes for which expected, future values have no effect on current pricing decisions. They also distinguish a Rotemberg-Saloner effect from a simple inventory effect, but to see this requires taking into account some institutional detail about the gasoline distribution network. We present this information in the next section and then return to the issue of inventories.

III. Gasoline Distribution and Inventories

The structure of gasoline distribution affects the implementation of the test for behavior consistent with a Rotemberg-Saloner effect. In particular, it affects how "margin" is defined and how inventory effects might link current and future conditions.

Since our test examines the relationship between margins and expected cost and demand conditions, it is important to have a clear understanding of what the retail margin is. One part of the definition is straightforward: the price is the retail price of gasoline charged to consumers at the pump. Defining the appropriate "cost" is more difficult.

We represent marginal cost by the wholesale price of gasoline. Choosing the appropriate "wholesale" gasoline price to use for marginal cost is complicated in principle by the structure of gasoline distribution and in fact by observability. The distribution structure for gasoline is illustrated in Figure 2. Market prices can be observed at several levels in the vertical structure. Prices for crude oil are readily observable. There also are observable prices for refined products, including gasoline. All these prices,

however, are substantially upstream from the marginal cost relevant for the retail market.

The relevant input price for a retail market is the "wholesale price" of gasoline at a given location. Wholesale markets are defined by terminal locations. Most larger cities (and all those in our sample) have a city terminal supplied by pipeline or barge. Gasoline is distributed by truck from the terminal to gasoline stations by wholesalers. At this wholesale level, distribution can be separated into a refiner network and an independent distributor network.

Approximately 55% of the retail gasoline sold in the U.S. is distributed to stations by independent wholesalers (called "jobbers" in the gasoline industry).[5] Jobbers are charged a posted, fob price set by refiners on a terminal-by-terminal basis. This is called the "terminal" price. Jobbers own and operate some of the stations they supply. For gasoline sold at these stations there is no additional wholesale market transaction. At stations jobbers supply but do not operate, there is a market transaction between the jobber and station operator, but the price at this transaction is not publicly available.

The remainder of gasoline sold is trucked to stations by the refiner. As is the case in the jobber network, there is no additional wholesale transaction at stations owned by the refiner. At independently operated stations supplied by a refiner, refiners sell gasoline to the station at the "dealer tankwagon price" (DTW). The DTW price is posted at the terminal. Slightly less than 30% of the gasoline sold by U.S. refiners is sold at refiner-supplied, but independent, stations.[6]

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[5] Temple, Barker and Sloan, Inc, 1988.

[6] *Petroleum Marketing Monthly,* 1988

For our purposes, the terminal price is the best proxy for marginal cost. For jobbers, it is the only observable wholesale price. It is also the opportunity cost of all gasoline sold through refiner-supplied stations. Finally, unlike the DTW price, the terminal price is subject to very little discounting, according to people familiar with the industry. Refiners and station operators report that there is widespread discounting off posted DTW prices.[7] Unobservable discounts are particularly troublesome here because their depth and prevalence probably varies over time with the refiner's perception of the changing nature of competition in a particular market at a particular time.

Because we use terminal price as the input cost, our analysis of the response of margins to changes in demand and input prices refers to the margin between the terminal price and the retail price of gasoline sold to consumers. This margin is influenced by both the supplier (jobber or refiner) and the station operator when there is an independent dealer. At stations operated by the supplier, the margin reflects only the decisions of the refiner or jobber. At independent stations, the retail price is set by the station operator, but her/his decision may be affected by quantity forcing and non-linear pricing in the delivered price.[8] Without further information, it is impossible to determine whether the patterns we observe in retail margins reflect primarily the response of refiners and jobbers or of station operators.

Because future conditions can affect the value of inventories, inven-

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[7] One person employed by a major refiner to set its DTW prices reported that a substantial portion of his division's effort was expended trying to infer rivals' actual delivered prices from their posted DTW prices.

[8] For a more complete discussion of how retail prices are set, see Shepard (1993) and Borenstein and Gilbert.

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tories may, in principle, link today's margins with expected future conditions. Inventories play an important role in upstream petroleum markets, but these effects will be reflected in the terminal price and will not affect our analysis of the retail margin. For inventory effects to be important for retail margins, inventories must be held by station suppliers or station operators. Station operators do not hold significant inventory; they accept new deliveries every few days. Any inventory effects, then, must come from suppliers.

It is difficult, however, to argue that supplier inventories will link current margins and expected future demand in retail gasoline markets. Assume for simplicity that marginal costs are constant, but demand is expected to increase next period. If increased demand leads to increased margins in the next period, a sale next period is (in expectation) more valuable than a sale this period. If there is some probability that suppliers will be unable to purchase sufficient supplies next period to meet demand, the cost of a sale this period is affected by the expected difference in price across the periods multiplied by the probability of stockout. If this difference is high enough to outweigh holding costs, suppliers will increase current prices to preserve inventory for the next period. However, there is no time during our sample in which wholesale purchases were constrained; the probability of stockout is effectively zero.

Links between current margins and expected future input prices are more plausible, but imply an effect with an opposite sign from that predicted by Rotemberg and Saloner. If suppliers believe the terminal price will increase next period, they have an incentive to increase inventories this period. But this will have no effect on the opportunity cost of marginal purchases. The opportunity cost is the market price. Arbitraging over time

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with inventories may increase profits, but it should have no effect on the optimal current retail price. If, however, the possibility of holding inventories leads buyers to transact only infrequently,[9] then the opportunity cost would be determined by the terminal price expected for the next transaction date. In that case, higher expected terminal prices could cause suppliers to increase the price they charge to station operators who will, in turn, pass at least some of the increase into the retail price. But this would lead to higher, not lower, current observed margins. The true economic margin would be today's retail price minus the expected future terminal price, but the observed margin would be today's retail price minus today's terminal price. Note that this correlation has the opposite sign of the Rotemberg-Saloner effect: holding inventories suggests that current observed margins may be *positively* correlated with changes in expected, future terminal prices.

IV. The Empirical Model

The estimation strategy is designed to isolate the effect of expected changes in future demand and wholesale price on retail margins. The basic estimating equation regresses margin on estimates of demand and terminal price expectations and other variables that affect current margin. Because the strategy is constrained by data availability, we start by describing the data. Descriptive statistics appear in Table 1. Next we discuss the structure of the estimating equation and our approach to handling endogeneity. We then describe the procedure used to construct the variables for expected changes in volume and terminal price.

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[9] This might be the case if, for example, there is a fixed cost to making a purchase that is higher than the cost of carrying inventory.

Table 1: Descriptive Statistics

(3838 observations)

Variable	Mean	Std Dev	Min	Max
$RETAIL$ (cents/gal)	72.83	12.41	43.18	126.57
$TERM$ (cents/gal)	62.28	11.82	36.00	111.88
$CRUDE$ (cents/gal)	46.38	10.77	25.83	87.98
$MARGIN$ (cents/gal)	10.57	5.12	-8.91	34.90
$VOLUME$ (00,000 gal/day)	10.43	10.48	0.38	38.12
$NVOLUME$	1.005	0.087	0.570	1.617
$TNVOLUME$, $\hat{\eta} = -0.1$	1.005	0.090	0.554	1.614
$TNVOLUME$, $\hat{\eta} = -0.2$	1.005	0.096	0.538	1.611
$TNVOLUME$, $\hat{\eta} = -0.3$	1.005	0.105	0.524	1.607
$EXP\ VOLCHG$, $\hat{\eta} = 0.0$	0.000	0.050	-0.406	0.288
$EXP\ VOLCHG$, $\hat{\eta} = -0.1$	0.000	0.050	-0.403	0.287
$EXP\ VOLCHG$, $\hat{\eta} = -0.2$	0.000	0.051	-0.400	0.286
$EXP\ VOLCHG$, $\hat{\eta} = -0.3$	0.000	0.053	-0.397	0.285
$EXP\ TERMCHG$	0.139	4.172	-17.313	13.959

The Data

The sample period, 1986 to 1991, is determined by the available retail price and gasoline volume data.[10] For retail prices ($RETAIL$ in Table 1), we use the average price for unleaded, 87 octane, self-service gasoline in each of 59 cities. These averages are reported by Lundberg Survey based

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[10] We have gasoline price data for 1986-1992, and volume data for 1982-1991.

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on a monthly survey in each city.[11] Lundberg reports the survey date and the average price in the city for that date. The surveys always occur on a Friday, and the stations sampled change infrequently. The prices have been adjusted to exclude all sales and excise taxes. As is the case for all prices used in the study, retail prices are in current dollars.

The terminal price ($TERM$) is the average price for branded, unleaded, 87 octane gasoline posted at the city terminal as reported by Lundberg. Lundberg reports average terminal prices for each Friday. We can therefore match the terminal and retail prices exactly. The retail margin ($MARGIN$) is simply $RETAIL - TERM$ for a given city at a point in time.

Figure 3 shows the monthly movement in retail, terminal and crude oil prices.[12] A large share of the volatility in terminal prices (and, therefore in retail prices) is the result of shocks to the price of crude oil. The effect of the Gulf War in 1990-91, for example, is quite clear in the data. Borenstein, Cameron and Gilbert (1993) report that about 50% of the variation in national average terminal price is explained by contemporaneous and lagged changes in crude oil price and lagged changes in average terminal price. Because lagged price movements heavily influence terminal price changes, decisionmakers have information from which to form time-varying expectations about future terminal prices. In the econometric model, we exploit this relationship to predict expected terminal prices.

The data on the volume of gasoline consumed are from the Federal Highway Administration, which reports the total volume of gasoline sold in

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[11] This is the best data series on retail prices. Other sources, such as *Oil and Gas Journal*, estimate retail prices from wholesale prices.

[12] The retail and terminal price series in Figure 3 are average monthly prices for the 59 cities. The crude oil price series is the gulf coast spot price for West Texas Intermediate crude oil.

each state in each month. These data are tied to payment of the Federal excise tax on gasoline. For each city, we use the volume data for the state in which the city is located. Our 59 cities are drawn from 43 states, so there is some duplication of the volume data across cities.

The movements in quantity of gasoline consumed per day, as shown in Figure 4, are much more regular than the movements in price.[13] Gasoline demand follows a clear seasonal pattern in the U.S.: demand is higher in the summer months with the annual peak in August and the trough in January. On average, the August peak consumption is 20% above the January trough. There is also long-run movement in consumption – annual volumes rise over the first half of the 1986-1991 period and then decline again – but this is swamped by the seasonal movement.

The annual cycle in volume is largely caused by seasonal demand shifts as consumers change their driving patterns. Conventional wisdom in the oil industry is that higher summer demand results from vacation and weekend travel. Regardless of the source of the shifts, it is clear from the data that the pattern is not induced primarily by changes in the retail price of gasoline. The industry demand for gasoline is fairly inelastic in the short run, with estimates ranging from −0.1 to −0.2 (Dahl and Sterner, 1991). To generate the observed movements in demand, retail prices would need to change by 100-200% over the cycle. As shown in Figure 3, retail price changes are not this large. Further, the temporal pattern in prices is not consistent with the regular seasonal pattern evident in demand.

The volume data record the cumulative volume for the month while the price data record the average price on a single day in the month. The

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[13] The data for Figure 4 are average daily consumption for the 59 cities in our sample. They are not from the interpolated series described below, but interpolation would have no substantive effect on the graph.

difference in timing raises the question of how best to match the price and volume data. The daily volume for the first Friday in April, for example, is probably best approximated by some combination of the average daily volume in March and in April. We address this problem by interpolating the volume data. We first construct estimates of daily consumption by dividing cumulative volume by the number of days in the month. We then apply a linear interpolation scheme to construct a weighted average of the daily volumes in adjacent months. The weighting scheme assigns a weight of one to the jth month's average daily volume if the observation happened to record prices on the middle day of that month. The weight on the current month declines linearly with movement away from the middle day. If, for example, prices happened to have been recorded for the first day of the month, the weighting scheme would apply a weight of one half to the average daily volumes of months j and $j - 1$.[14] The interpolated daily average is $VOLUME$.

The Estimating Equation

The critical variables for testing the Rotemberg-Saloner theory are the expected changes in volume and terminal price between the observation period and future periods. The number of relevant future periods depends on the length of the punishment period and the discount rate. Both the Rotemberg-Saloner and Haltiwanger-Harrington models use infinite pun-

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[14] Let v_j be the average daily volume for month j which has n_j days. Let d_{ij} be the day on which retail price is observed. Then the interpolated volume on the day price is observed, $\hat{v}_{ij}$, is given by:

$$\hat{v}_{ij} = \begin{cases} v_j(\frac{1}{2} + \frac{d_{ij}}{n_j}) + v_{j-1}(\frac{1}{2} - \frac{d_{ij}}{n_j}) & \text{if } d_{ij} \leq \frac{n_j}{2}; \\ v_j(\frac{3}{2} - \frac{d_{ij}}{n_j}) + v_{j+1}(\frac{d_{ij}}{n_j} + \frac{1}{2}) & \text{if } d_{ij} \geq \frac{n_j}{2}. \end{cases}$$

In unreported estimates, we used a cubic rather than a linear spline. The results are robust to the interpolation technique.

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ishments to simplify exposition, but their results do not depend on infinite punishments. If punishments are infinite, all future periods are relevant and the near term periods are relatively more important than later periods through discounting. If punishments are of finite duration, the relative importance of near-term periods will be greater. In the absence of any information about how long the punishment period might be in this market, we include only next period values and estimate the magnitude of a Rotemberg-Saloner effect by the response of current margins to the expected change in demand and terminal price between this period and next. If the punishment is longer than one period, we will be measuring the relevant variable with error, and our estimate of the magnitude of the effect will be biased downward. The procedures used to generate the expected change in terminal price ($EXP\ TERMCHG$) and in demand ($EXP\ VOLCHG$) are discussed at the end of this section.

To test for a Rotemberg-Saloner effect in expected demand, current demand must be held constant. For this reason, some measure of current demand must be in the regression. Although our primary interest is in the effect of expected demand, we anticipate that margins also might be responsive to current demand for a number of reasons. Changes in the quantity demanded might be accompanied by changes in the composition of demand, *e.g.*, the August peak in volume probably includes a higher proportion of consumption due to leisure travel than does the January trough. If leisure travelers are more likely to purchase gasoline in areas where they are unfamiliar with the prices and locations of nearby stations, they will have higher search costs. As a result, demand elasticity at the station level will increase, leading to higher prices in high demand periods. Current demand might also affect margins through peak-load pricing (Png and Reitman, 1992). If higher seasonal demand is correlated with higher demand at peak

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times, peak-load pricing also can lead to a positive correlation between current demand and margins. We have no way to distinguish between these hypotheses or others that might suggest a positive effect of current demand on margin.

To control for current demand, we need some measure of volume that reflects primarily demand at the retail market level. *VOLUME* is not a particularly good measure of the relevant demand. The cross-sectional variation in state volumes is quite large because states have very different populations: over 99% of the variance in *VOLUME* is accounted for by differences between state means. States with higher means also have more variation around the mean in absolute magnitude. If the effect of current volume is estimated using absolute deviations from state means in a standard fixed effects formulation, the estimates will be heavily influenced by differences in state populations. To get a better indicator of market-level demand, we focus on proportional changes in state-level demand. For example, a 20% change in California daily volume we assume represents the same proportional demand shift in the observed California markets as does a 20% change in Vermont demand represent in observed Vermont markets. Accordingly, the empirical model uses volume data for each state divided by the state mean volume over the sample period. This normalized state volume (*NVOLUME*) has a mean of one for each state.

Current terminal prices also may affect margins if the passthrough rate for terminal price changes is different from one. Furthermore, if the response to terminal price changes is not immediate, margins will be affected by terminal price changes even if the eventual passthrough rate is one. Prior empirical research has shown that retail prices in gasoline markets are heavily influenced by lagged responses to past shocks to terminal

prices.[15] The response may involve lags longer than a month and may be asymmetric with respect to terminal price increases or decreases. In addition to the lagged response to terminal price changes, retail price changes also display persistence: today's price change is a function of past price changes. One common effect of persistence is some form of autocorrelation in the error structure of price equations. More generally, prices are a function of lagged prices.

A standard approach to estimation in the presence of lagged responses is to model price as a vector autoregression process in which the current change in price is a function of past shocks and an error correction term that takes into account the underlying structural relationship. In our context, this means modeling the change in retail price as a function of contemporaneous and lagged changes in terminal prices, lagged changes in retail prices and an error correction term involving the one period lags of retail and terminal prices:[16]

$$
\begin{aligned}
RETAIL_{it} - RETAIL_{it-1} = {} & \beta_1 \Delta TERM_{it}^+ + \beta_2 \Delta TERM_{it-1}^+ \\
& + \beta_3 \Delta TERM_{it-2}^+ + \beta_4 \Delta TERM_{it}^- + \beta_5 \Delta TERM_{it-1}^- \\
& + \beta_6 \Delta TERM_{it-2}^- + \beta_7 \Delta RETAIL_{it-1}^+ + \beta_8 \Delta RETAIL_{it-2}^+ \\
& + \beta_9 \Delta RETAIL_{it-1}^- + \beta_{10} \Delta RETAIL_{it-2}^- \\
& + \beta_{11} RETAIL_{it-1} + \beta_{12} TERM_{it-1} + \epsilon_{it},
\end{aligned}
\tag{1}
$$

where ΔX_{it} denotes $X_{it} - X_{it-1}$, and the $+$ superscript denotes an increase and $-$ a decrease. The contemporaneous and lagged changes capture the transmission of shocks, while the error correction term captures the tendency to revert gradually to the long-term equilibrium relationship between

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[15] See, for example, Karrenbrock (1991), Bacon (1991), Borenstein, Cameron and Gilbert (1993), and General Accounting Office (1993).

[16] In this and the following estimation equations, we suppress the constant term which is absorbed by fixed effects, as described below.

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retail and terminal prices.[17] Including an error correction term reduces the volatility of estimated price changes. The number of one period lags has been chosen to allow for longer than expected lags in response. In the spirit of imposing only a minimal structure on the data, both retail and terminal price changes have been decomposed to allow an asymmetric response to price increases and decreases.[18]

Because we are interested in retail margins, we rearrange terms in this equation, adding $RETAIL_{it-1}$ and subtracting $TERM_{it}$ from both sides to get current retail margin on the lefthand side:[19]

$$
\begin{aligned}
MARGIN_{it} = {} & (\beta_1 - 1)\Delta TERM^+_{it} + \beta_2 \Delta TERM^+_{it-1} + \beta_3 \Delta TERM^+_{it-2} \\
& + (\beta_4 - 1)\Delta TERM^-_{it} + \beta_5 \Delta TERM^-_{it-1} + \beta_6 \Delta TERM^-_{it-2} \\
& + \beta_7 \Delta RETAIL^+_{it-1} + \beta_8 \Delta RETAIL^+_{it-2} \\
& + \beta_9 \Delta RETAIL^-_{it-1} + \beta_{10} \Delta RETAIL^-_{it-2} \\
& + (\beta_{11} + 1)RETAIL_{it-1} + (\beta_{12} - 1)TERM_{it-1} + \epsilon_{it},
\end{aligned} \tag{2}
$$

This equation characterizes the autoregressive structure of prices. Augmenting it to take into account the effect of current demand and of expected demand and terminal price produces the basic estimating equation:

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[17] Take the equilibrium relationship between retail and terminal prices to be $RETAIL = \gamma_0 + \gamma_1 TERM$. The extent to which prices deviate from equilibrium in period $t - 1$ would be $RETAIL_{t-1} - \gamma_0 - \gamma_1 TERM_{t-1}$. If the next period margin adjusts toward the equilibrium by some factor ρ $(0 > \rho > -1)$, the error correction effect for period t would be $\rho(RETAIL_{t-1} - \gamma_0 - \gamma_1 TERM_{t-1})$, which can be rewritten as $\rho RETAIL_{t-1} - \rho\gamma_0 - \rho\gamma_1 TERM_{t-1}$. The first term requires including $RETAIL_{t-1}$, the second term is subsumed in the fixed effects, and the third term requires including $TERM_{t-1}$.

[18] Including more lags than may be required or allowing for asymmetries unnecessarily will not bias the estimate of other coefficients.

[19] Subtracting $TERM_{it}$ from the right-hand side of (1) requires subtracting one from the coefficients on $\Delta TERM^+_{it}$ and $\Delta TERM^-_{it}$, each of which contains a positive $TERM_{it}$. Because each also contains a negative $TERM_{it-1}$ that has been removed, subtracting one from the coefficient on $TERM_{it-1}$ reintroduces these terms. The equivalence is not exact because the coefficients are allowed to be asymmetric in the adjustment (Δ) terms, but not in the error correction term ($TERM_{it-1}$).

$$MARGIN_{it} = \alpha_1 NVOLUME_{it}$$
$$+ \alpha_2 EXP\ VOLCHG_{it} + \alpha_3 EXP\ TERMCHG_{it}$$
$$+ \beta_1 \Delta TERM^+_{it} + \beta_2 \Delta TERM^+_{it-1} + \beta_3 \Delta TERM^+_{it-2}$$
$$+ \beta_4 \Delta TERM^-_{it} + \beta_5 \Delta TERM^-_{it-1} + \beta_6 \Delta TERM^-_{it-2} \qquad (3)$$
$$+ \beta_7 \Delta RETAIL^+_{it-1} + \beta_8 \Delta RETAIL^+_{it-2}$$
$$+ \beta_9 \Delta RETAIL^-_{it-1} + \beta_{10} \Delta RETAIL^-_{it-2}$$
$$+ \beta_{11} RETAIL_{it-1} + \beta_{12} TERM_{it-1} + \epsilon_{it},$$

where the coefficient adjustments to get from (1) to (2) are now implicit.

Econometric Issues

Two econometric issues arise in estimating Equation (3). First, the residuals are correlated across cities for a point in time and over time for a given city. This problem is addressed by estimating (3) with fixed city and time effects. Time effects are incorporated as 72 monthly effects. In all reported regressions, both the city and the time effects are jointly significant.

The second complication is endogeneity. The estimating equation regresses retail margin on terms in volume and terminal and retail prices. Volume is directly a function of the retail price and, therefore, a function of retail margin. As a result, OLS estimates of the margin equation would be biased, though prior studies have shown that gasoline demand is quite inelastic in the short run so the bias would probably be small. A standard approach to producing consistent estimates is to instrument for volume. Unfortunately, there are no valid identifying instruments of the usual type available.

To motivate the problem and our approach to resolving it, consider the following equation system:

$$M = \alpha Q + X'\gamma + e \qquad (4)$$

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$$\ln Q = Z\beta + \eta \ln P + v \qquad (5)$$

where M is the price-cost margin, Q is volume, X is a vector of exogenous variables included in (4), P is the retail price, and Z is a vector of variables some of which are exogenous and excluded from (4). Equation (4) is a simplified representation of the equation we wish to estimate, and equation (5) is the isoelastic industry demand function. The error terms v and e are uncorrelated with each other. The exogenous variables in Z that are not in X are valid instruments that identify (4). If data were available on these variables, we could proceed in the usual fashion.

In the absence of observing the identifying instruments in Z, suppose we knew η, the industry demand elasticity. We could then construct a variable Q' such that

$$\ln Q' = \ln Q + \ln k - \eta \ln P = Z\beta + \ln k + v, \qquad (6)$$

where k is some constant. Q' is Q purged of any direct price effect. We could then proceed with 2SLS estimation using Q' as an instrument if we knew η and if no variable in Z were a function of P. Since neither of these assumptions holds strictly, we discuss them further before proceeding.

It is possible that some variable in Z is a function of P, implying that Q' would be correlated with e. In our case, this means that price would have both a direct and an indirect effect on volume. An increase in the retail price of gasoline, for example, might directly reduce the quantity demanded (the usual movement along the demand curve that the adjustment in (6) removes). It also might increase the price of other goods (through an increase in transportation costs for example), thereby reducing the *relative* price increase in gasoline and increasing gasoline demand. It seems likely that indirect effects of this sort will be small over the short run relative to the direct effect.

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These indirect effects can be removed by partitioning Z into two parts: Z_1, which we assume is a linear function of $\ln P$, and Z_2, which is not a function of P. Equation (5) can be rewritten:

$$\ln Q = Z_1\beta_1 + Z_2\beta_2 + \eta \ln P + v = (\theta_0 + \theta_1 \ln P)\beta_1 + Z_2\beta_2 + \eta \ln P + v \quad (5')$$

Then there is a valid instrument Q'' such that:

$$\ln Q'' = \ln Q + k - (\eta + \theta_1\beta_1)\ln P = \theta_0\beta_1 + Z_2\beta_2 + k + v. \quad (6')$$

Let $\tilde{\eta} \equiv \eta + \theta_1\beta_1$. Q'' can be written:

$$\ln Q'' = \ln Q + k - \tilde{\eta}\ln P. \quad (7)$$

When the indirect effects are small, $\tilde{\eta}$ is close to η and $Q'' \approx Q'$.

Since Q'' is a valid instrument, the only remaining problem is that we do not observe $\tilde{\eta}$. However, the industry demand elasticity has been measured in many previous studies.[20] For the most part, these studies take the position, either explicitly or implicitly, that the indirect effects are sufficiently small that ignoring them will have no substantive effect on the parameter estimates. As a result, the reported industry demand elasticities might best be interpreted as estimates of $\tilde{\eta}$. Under this interpretation, we have a very good idea of the range of reasonable values for $\tilde{\eta}$. By repeating 2SLS estimation for values of $\tilde{\eta}$ spanning the reasonable range, we can test the estimates for robustness to mismeasurement of the price elasticity. If the coefficient estimates for the margin equation change only slightly with variations in $\tilde{\eta}$, we can be fairly confident that our estimates are robust to this possible specification error. Because there is some question about whether the existing studies estimate $\tilde{\eta}$ rather than η, we use a range of

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[20] See Dahl and Sterner.

parameter values somewhat larger than the one that spans the reported estimates.

To implement the elasticity correction implied by equation (7), we multiply the interpolated daily volume $(VOLUME)$ for each city by $kP^{-\hat{\eta}}$, where $k \equiv \bar{P}^{\hat{\eta}}/\bar{Q}$, and $\hat{\eta}$ is the assumed elasticity parameter. $\bar{P}$ is the average retail price for the city over the sample period, and $\bar{Q}$ is the average value of Q'' for the city over the sample period. Normalizing by $\bar{P}$ minimizes any distortion from misspecifying the functional form of the demand curve. If the demand function is not isoelastic, the approximate elasticity correction will be better for smaller changes in P. Normalizing by $\bar{P}$ means we are taking the price deviations from the mean, thereby reducing the size of the changes to which the correction is applied. Normalizing by $\bar{Q}$ is analogous to the normalization that produced $NVOLUME$. The resulting series, $TNVOLUME$, is used as the identifying instrument in 2SLS estimation of (3) with $NVOLUME$ taken to be endogenous. Because the untransformed series $(NVOLUME)$ would be exogenous if $\tilde{\eta} = 0$, we refer to the transformation that creates $TNVOLUME$ as the elasticity correction.

Descriptive statistics for $TNVOLUME$ for values of $\hat{\eta}$ ranging from -0.1 to -0.3 are reported in Table 1. Because demand is relatively inelastic, applying the elasticity correction has only a small effect on the distribution of $NVOLUME$. If the retail price is, say, 20 percent above the city mean at time t, the elasticity correction with $\hat{\eta} = -0.3$ would yield a $TNVOLUME_t$ that is 5.6% percent greater than $NVOLUME_t$. With $\hat{\eta} = -0.1$, $TNVOLUME_t$ would be about 1.8% percent greater than $NVOLUME_t$. A survey of gasoline demand studies by Dahl and Sterner reports that estimates of the demand elasticity range from -0.1 to -0.3.

When estimates are based on quarterly or monthly data, the period more relevant to our analysis, the estimates range from -0.1 to -0.2. The range of $\hat{\eta}$ used in Table 1 and in later regressions is, then, slightly larger than the reported range for $\tilde{\eta}$.

The other variable that raises an endogeneity issue for (3) is contemporaneous terminal price, which is in the $\Delta TERM_{it}$ terms and is used in the forecast of future terminal price.[21] If the market for gasoline at the terminal is competitive, then the terminal price will not be a direct function of the retail margin. In fact, supplier behavior at city terminals is quite competitive. There are ten or more refiners operating at most major terminals, including branded suppliers (e.g., Chevron or Shell, who have a branded presence at the consumer level) and unbranded suppliers. Unbranded refiners sell to jobbers who supply minor brand (e.g., Merit which has chains of stations in several East Coast cities) and unbranded stations. Branded suppliers sell through their directly supplied network and to jobbers. Some of the gasoline sold by branded refiners to jobbers is sold through unbranded stations. For these sales, the jobbers view gasoline as a commodity and all refiners are in direct competition.[22] Thus, *marginal* sales at the terminal for both branded and unbranded refiners are made to buyers who consider all sellers' products as virtually perfect substitutes.

Because pricing is competitive at the terminal, the terminal price is not directly a function of the retail margin. Terminal prices might still be endogenous, however, if the marginal cost of supplying gasoline to the

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[21] Because there is no serial correlation in the residuals of (3), lagged dependent variables do not present an endogeneity problem.

[22] The extent to which branded refiners participate in the wholesale market for unbranded gas may vary across refiners and, for a given refiner, across terminals. In general, however, the marginal sale for suppliers is to the unbranded market.

terminal varies with output. In this case, changes in quantity demanded will change the terminal price and, because quantity is a function of the retail margin, terminal prices will also be a function of the retail margin. Any bias this introduces is likely to be small, however, because the total "feedback" effect is the product of the price elasticity of quantity demanded and the quantity elasticity of the marginal cost of supply. Demand is quite inelastic and the marginal cost curve for supplying a specific city is probably fairly flat because gasoline supplies can easily be shifted among cities or regions of the country (Henly, Potter and Town).

While we expect that the estimated coefficients will be largely unaffected by bias from this source, a Hausman tests rejects exogeneity of contemporaneous terminal price and expected, future terminal price change. We therefore instrument for these variables. To construct an instrument for contemporaneous terminal price, we regress $TERM$ on $NVOLUME$ and use the residuals, which are orthogonal to $NVOLUME$ by construction. We also use this orthogonalized terminal price series to forecast future terminal price, as explained below, and use the resulting variable as an instrument. In practice, instrumenting for these variables does not change our results in a statistically or economically significant way.

Predicting Expected Cost and Volume

Equation (3) includes variables capturing the expected terminal price change and expected volume change to test for a Rotemberg-Saloner effect. To measure expected change in demand we construct the variable EXP $VOLCHG$, which is the difference between expected next period volume and actual current volume. We assume that station operators and suppliers form their expectations of next period volume based on current and past values of demand observed in their markets. Demand changes are caused

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largely by seasonal shifts in consumption patterns and by variations in retail prices. Seasonal demand patterns vary across geographic locations in both pattern and amplitude. Although the average state sees its peak demand in August and lowest demand in January, August demand is below the state mean in Florida and January demand is above the state mean in Colorado and Hawaii. The state with the greatest average annual variation (Wyoming) has a peak-to-trough difference equal to 51% of mean volume for that state; the state with the smallest variation (Arizona) has a peak-to-trough difference equal to 7% of its mean. To allow the data to reflect these variations, we predict volume on a state-by-state basis. Accordingly, the predicting equation for state i is:

$$NVOLUME_{it} = a_0 + a_1 NVOLUME_{it-1} + a_2 NVOLUME_{it-2}$$
$$+ \sum_{j=2}^{12} \delta_j MONTH_j + a_3 TIME_t + a_4 TIME_t^2 + a_5 TIME_t^3 \quad (8)$$
$$+ \epsilon_{it},$$

where $MONTH_j$ are monthly dummy variables.[23] For nearly all states, the R^2 of these predicting equations is between 0.80 and 0.95. The one period lead of the fitted values from this regression is expected period $t+1$ volume in state i at time t. $EXP\ VOLCHG$ is the difference between the one period lead and current volume: $EXP\ VOLCHG_{it} = \widehat{NVOLUME}_{it+1} -$

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[23] Our procedure uses future values of volume to estimate the coefficients in the predicting equation. This is, in principle, incorrect because it uses information the decisionmakers do not have. If, however, the coefficients do not change over time, we would get similar results using only data available to them. To check for robustness to the predicting procedure, we also predicted values using a rolling regression with volume data for 1982-1991. Neither the predicted values nor the coefficients in the final regressions were substantively affected. We use the approach represented in equation (8), because we do not have data on prices for the pre-sample period and therefore cannot use the rolling regression approach for prices or for volume once we adjust for volume endogeneity.

Station operators and suppliers form their expectations of next pe-
riod terminal prices based on observing the price of crude oil and the time
structure of terminal prices in their market. Terminal prices display some
independence across markets (Spiller and Huang, 1986). One source of the
differences can be traced to the geographic pattern in production and distri-
bution of oil products (Slade, 1986b). Geographic markets are also affected
differently by seasonal production changes associated with the demand for
heating oil. Because heating oil and gasoline are essentially complements
in production, there is excess production of gasoline during some winter
months in cold-weather states. In these states, terminal prices for gasoline
tend to decline relative to other locations in the winter.

To accommodate these and other location-specific patterns, we predict
terminal prices on a city-by-city basis. At each city, we treat terminal prices
as a vector autoregression with an error correction term. In a straightfor-
ward variation on Equation (1), the predicting equation for city i is:

$$
\begin{aligned}
\Delta TERM_{it} = {} & b_0 + b_1 \Delta TERM^+_{it-1} \\
& + b_2 \Delta TERM^+_{it-2} + b_3 \Delta TERM^-_{it-1} + b_4 \Delta TERM^-_{it-2} \\
& + b_5 \Delta CRUDE^+_{it-1} + b_6 \Delta CRUDE^+_{it-2} + b_7 \Delta CRUDE^-_{it-1} \\
& + b_8 \Delta CRUDE^-_{it-2} + b_9 TERM_{it-1} + b_{10} CRUDE_{it-1} \\
& + \sum_{j=2}^{12} \delta_j MONTH_j + \epsilon_{it},
\end{aligned}
\tag{9}
$$

where we have added monthly time effects because terminal prices appear

---

[24] For 2SLS estimation, instruments for $EXP\ VOLCHG$ are generated by using
the fitted values from equation (8) estimated with $TNVOLUME$ rather than
$NVOLUME$.

to have a seasonal pattern in some cities, and $CRUDE$ is the crude oil price. The crude oil price used is the gulf coast spot price for West Texas Intermediate crude as reported by *Dow Jones International Petroleum Report* and published in the *Wall Street Journal*.[25] Contemporaneous change in CRUDE ($\Delta CRUDE_{it}$) is not included in (9), because the purpose of this estimation is to generate the best available forecast of change in $TERM$ from the previous period when such information would not be available. The R^2 of these regressions varies across cities within the 0.30 to 0.60 range. Price forecasts are less accurate than volume forecasts because volume follows a seasonal pattern while terminal prices are determined in large part by crude oil prices which approximately follow a random walk. The one period lead of the fitted values from these regressions is the expected change in the terminal price: $EXP\ TERMCHG_{it} = \widehat{\Delta TERM}_{it+1}$. We also create an instrument for $EXP\ TERMCHG$ by estimating (9) using the constructed terminal price series that is orthogonal to quantity as described above.

V. Results

The two-stage least squares estimates from equation (3) are reported in Table 2 for a range of elasticity values. For all values of $\hat{\eta}$, the coefficient on expected change in volume is positive, as the Rotemberg-Saloner hypothesis would predict, and significantly different from zero at the 1% significance level. Increasing the value of $\hat{\eta}$ appears to have little effect on the $EXP\ VOLCHG$ coefficient. For the $\hat{\eta} = -0.1$ results, which probably most closely approximate results using the true $\bar{\eta}$, the estimates imply that increasing $EXP\ VOLCHG$ by one standard deviation (about a 5% increase

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[25] Borenstein, Cameron and Gilbert report that using futures prices rather than spot prices or using spot prices for other commonly traded crude oils does not affect the estimated relationship between terminal and crude oil prices.

in the one-month change) adds about 0.19 cents to the retail margin. The elasticity of margins with respect to expected next-period volume is about 0.37 at mean margin and volume. The estimated effect is somewhat larger at a demand elasticity as high as -0.3.

The estimated effect of an expected change in terminal price is also consistent with a Rotemberg-Saloner effect and is statistically significant at the 1% level for all values of $\hat{\eta}$. Again for $\hat{\eta} = -0.1$, increasing *EXP TERMCHG* by one standard deviation (about 4 cents) reduces the margin by about 0.26 cents. The elasticity of margin with respect to the expected, next-period terminal price is approximately -0.37. The sign of this coefficient is inconsistent with an inventory effect from anticipated input price changes.

The effects of expected changes in volume and terminal price are small in absolute magnitude. But if the overall effect of collusion on margins also is small, the relative effect of expected changes could be substantial. Unfortunately, the data do not allow us to estimate the overall effect of collusion on margins. The average observed margin of 10.6 cents is simply retail minus terminal gasoline price. Other input costs that are variable in the short run, such as the cost of delivering gasoline from the terminal to the station, are still in the calculated margin. Thus, the margin attributable to collusion must average less than 10.6 cents, but we are not able to isolate the collusive effect.

The estimated change in margin over the seasonal volume cycle is a composite of the responses to the change in current volume and the expected change in next-period volume. The coefficient on *NVOLUME* estimates the effect of changes in current volume, holding constant the expected change in volume. At $\hat{\eta} = -0.1$, increasing volume 10% above its

Table 2: Estimation of Equation (3)

Dependent Variable: $MARGIN$

Assumed Elasticity	$\hat{\eta} = 0.0$	$\hat{\eta} = -0.1$	$\hat{\eta} = -0.2$	$\hat{\eta} = -0.3$
$NVOLUME_t$	3.397 (0.754)	5.563 (0.758)	7.926 (0.768)	10.455 (0.785)
$EXP\ VOLCHG_t$	4.081 (1.324)	3.860 (1.335)	4.362 (1.365)	5.492 (1.409)
$EXP\ TERMCHG_t$	-0.057 (0.018)	-0.062 (0.017)	-0.066 (0.018)	-0.068 (0.018)
$\Delta TERM_t^+$	-0.303 (0.021)	-0.305 (0.021)	-0.306 (0.021)	-0.304 (0.021)
$\Delta TERM_{t-1}^+$	0.153 (0.023)	0.148 (0.023)	0.143 (0.023)	0.138 (0.023)
$\Delta TERM_{t-2}^+$	0.065 (0.021)	0.063 (0.021)	0.062 (0.021)	0.061 (0.022)
$\Delta TERM_t^-$	-0.589 (0.019)	-0.584 (0.019)	-0.578 (0.019)	-0.572 (0.018)
$\Delta TERM_{t-1}^-$	0.175 (0.023)	0.169 (0.023)	0.163 (0.023)	0.155 (0.023)
$\Delta TERM_{t-2}^-$	0.078 (0.020)	0.074 (0.020)	0.069 (0.020)	0.065 (0.020)
$\Delta RETAIL_{t-1}^+$	-0.017 (0.022)	-0.018 (0.023)	-0.020 (0.023)	-0.022 (0.023)
$\Delta RETAIL_{t-2}^+$	-0.066 (0.022)	-0.069 (0.022)	-0.072 (0.022)	-0.076 (0.022)
$\Delta RETAIL_{t-1}^-$	-0.029 (0.022)	-0.027 (0.022)	-0.026 (0.023)	-0.025 (0.023)
$\Delta RETAIL_{t-2}^-$	0.039 (0.020)	0.039 (0.020)	0.039 (0.020)	0.039 (0.020)
$RETAIL_{t-1}$	0.623 (0.015)	0.619 (0.015)	0.615 (0.015)	0.612 (0.015)
$TERM_{t-1}$	-0.668 (0.020)	-0.660 (0.020)	-0.650 (0.020)	-0.639 (0.020)
Observations	3838	3838	3838	3838

Fixed time and city effects not reported. Asymptotic standard errors in parentheses.

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mean is estimated to increase the current margin by 0.56 cents. Holding constant the expected change, however, implies that the increase in current demand is matched by an increase in expected, next-period demand. If next-period demand is not expected to increase, the effect of a demand increase this period will be reduced. The effect of a 10% increase in volume, holding constant expected, next-period demand is estimated to be 0.17 cents for $\hat{\eta} = -0.1$. [26]

What this means for the influence of seasonal volume fluctuations on retail margins can be demonstrated by examining behavior around the seasonal peak. In July, volume averages 8.3% above the sample mean, implying the average July margin would be 0.46 cents above the mean, *if* expected August demand were also 8.3% above the sample mean, so that *EXP VOLCHG* would equal zero. But August demand is, on average, 8.8% above the mean. The expected change in volume between July and August, then, averages 0.5% of the mean, implying an additional increment to the average July margin of 0.02 cents, for a total margin of 0.48 cents above the mean. In contrast, the expected decline in demand from August to September reduces the August margin. August volume averages 8.8% above the mean implying a margin 0.49 cents above the mean, but the expected change from August to September of -4.6% reduces the August margin by 0.18 cents. The net effect is August margins that average only 0.31 cents above the annual average.

The remaining estimates of the effects of lagged changes and levels of terminal and retail prices are consistent with previous research. The

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[26] *EXP VOLCHG$_{it}$* is expected, next-period volume minus actual volume in period t, so the estimated effect of a change in this period volume holding constant expected, next-period volume is the coefficient on *NVOLUME* minus the coefficient on *EXP VOLCHG*.

impulse response function implied by these estimates exhibits asymmetric adjustment to terminal price changes: increases are passed through more quickly than decreases. This is consistent with the response found by Karrenbrock; the size of the asymmetry and the general patterns of response are very close to those found by Borenstein, Cameron, and Gilbert using national average data. The estimates also imply that terminal price changes are passed through about 90% in the long run, but the estimated passthrough rate is not statistically distinguishable from a 100% rate.[27]

Although there is no obvious alternative economic explanation of the response of current margins to anticipated demand and cost conditions that is consistent with the data, it is possible that the effect is a statistical artifact. If current variables are measured with error and there is additional information about the true value of current variables in measured next-period variables, our results could be misleading. Because the price and volume data are not well-matched, this is of particular concern with respect to the effect of future, expected volume on margins. If current volume is measured with noise and there is some additional information about current volume in the change in volume between the current period and the next, the coefficient on *EXP VOLCHG* might reflect the actual impact of current volume. Since current volume is estimated to affect margins positively, the estimated effect of future volume would also then be positive, mimicking a Rotemberg-Saloner effect.

To investigate this explanation, we consider the effect of future, *unexpected* changes in demand. Under the Rotemberg-Saloner hypothesis, unexpected shocks cannot affect current margins because they cannot be

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[27] See Borenstein, Cameron and Gilbert for a description of the method used to construct the impulse response function and to calculate the passthrough rate.

anticipated. But, if the result is an effect of measurement error, unexpected changes would also affect current margins.

To distinguish a Rotemberg-Saloner effect from measurement error, we estimate:

$$
\begin{aligned}
MARGIN_{it} =\ & \alpha_1 EXP\ VOL_{it} + \alpha_2 UNX\ VOL_{it} \\
& + \alpha_3 EXP\ VOLCHG_{it+1} + \alpha_4 UNX\ VOLCHG_{it+1} \\
& + \alpha_5 EXP\ TERMCHG_{it} + \alpha_6 UNX\ TERMCHG_{it} \\
& + \beta_1 \Delta TERM_{it}^+ + \beta_2 \Delta TERM_{it-1}^+ + \beta_3 \Delta TERM_{it-2}^+ \\
& + \beta_4 \Delta TERM_{it}^- + \beta_5 \Delta TERM_{it-1}^- + \beta_6 \Delta TERM_{it-2}^- \\
& + \beta_7 \Delta RETAIL_{it-1}^+ + \beta_8 \Delta RETAIL_{it-2}^+ \\
& + \beta_9 \Delta RETAIL_{it-1}^- + \beta_{10} \Delta RETAIL_{it-2}^- \\
& + \beta_{11} RETAIL_{it-1} + \beta_{12} TERM_{it-1} + \epsilon_{it},
\end{aligned} \tag{3'}
$$

where "UNX" stands for unexpected. In this regression, expected volume change is defined as before: the one-period lead of the fitted values of equation (8) minus current volume. $UNX\ VOLCHG$ is actual next period volume minus expected next period volume.[28] As reported in Table 3, the coefficient on unexpected change is not significantly positive for any value of $\hat{\eta}$. Further, the coefficients on expected and unexpected change are significantly different from each other for all values of $\hat{\eta} > 0$.

The very different effects of unexpected and expected volume change suggest that the mismeasurement hypothesis is unlikely. There is still some chance that our result is a statistical artifact of mismeasurement, however. Suppose that, for some reason, margins do not respond even to contemporaneous volume changes that could not have been predicted. Then the failure of margins to respond to future unanticipated shocks could not be interpreted as inconsistent with the mismeasurement hypothesis.

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[28] $UNX\ VOLCHG = NVOLUME_{it+1} - NVOLUME_{it} - (\widehat{NVOLUME}_{it+1} - NVOLUME_{it})$, the total change minus expected change.

Table 3: Estimation of Equation (3')

Dependent Variable: *MARGIN*

Assumed Elasticity	$\hat{\eta} = 0.0$	$\hat{\eta} = -0.1$	$\hat{\eta} = -0.2$	$\hat{\eta} = -0.3$
$EXP\ NVOLUME_t$	4.116 (0.824)	5.150 (0.830)	6.273 (0.846)	7.478 (0.871)
$UNX\ NVOLUME_t$	0.926 (1.388)	7.003 (1.402)	13.347 (1.447)	19.751 (1.518)
$EXP\ VOLCHG_t$	3.720 (1.334)	4.064 (1.347)	4.930 (1.382)	6.129 (1.436)
$UNX\ VOLCHG_t$	1.178 (1.292)	0.146 (1.309)	-1.478 (1.355)	-3.532 (1.425)
$EXP\ TERMCHG_t$	-0.059 (0.018)	-0.059 (0.018)	-0.057 (0.018)	-0.054 (0.018)
$UNX\ TERMCHG_t$	0.013 (0.016)	0.011 (0.016)	0.009 (0.016)	0.006 (0.016)
$\Delta TERM_t^+$	-0.305 (0.021)	-0.299 (0.021)	-0.292 (0.021)	-0.283 (0.021)
$\Delta TERM_{t-1}^+$	0.153 (0.023)	0.149 (0.023)	0.146 (0.023)	0.142 (0.024)
$\Delta TERM_{t-2}^+$	0.065 (0.021)	0.063 (0.021)	0.061 (0.022)	0.060 (0.022)
$\Delta TERM_t^-$	-0.590 (0.019)	-0.578 (0.019)	-0.565 (0.019)	-0.552 (0.020)
$\Delta TERM_{t-1}^-$	0.175 (0.023)	0.171 (0.023)	0.167 (0.023)	0.162 (0.023)
$\Delta TERM_{t-2}^-$	0.078 (0.020)	0.075 (0.020)	0.071 (0.020)	0.067 (0.021)
$\Delta RETAIL_{t-1}^+$	-0.017 (0.022)	-0.018 (0.023)	-0.019 (0.023)	-0.020 (0.023)
$\Delta RETAIL_{t-2}^+$	-0.068 (0.022)	-0.069 (0.022)	-0.070 (0.022)	-0.071 (0.022)
$\Delta RETAIL_{t-1}^-$	-0.030 (0.022)	-0.028 (0.022)	-0.027 (0.023)	-0.026 (0.023)
$\Delta RETAIL_{t-2}^-$	0.040 (0.020)	0.039 (0.020)	0.039 (0.020)	0.039 (0.021)
$RETAIL_{t-1}$	0.623 (0.015)	0.620 (0.015)	0.618 (0.015)	0.615 (0.015)
$TERM_{t-1}$	-0.666 (0.020)	-0.657 (0.020)	-0.647 (0.021)	-0.636 (0.021)
Observations	3838	3838	3838	3838

Fixed time and city effects not reported. Asymptotic standard errors in parentheses.

We therefore break out current volume into the portion that would have been anticipated in the previous period ($EXP\ VOL_{it} = \widehat{NVOLUME}_{it}$ from equation (8)) and that part that would have been unanticipated ($UNX\ VOL_{it} = NVOLUME_{it} - \widehat{NVOLUME}_{it}$). In contrast to the estimates for the effects of unexpected, *future* changes, the coefficients on unexpected, *current* volume are significantly positive for all values of $\hat{\eta} > 0$.

For completeness, the regressions also distinguish between expected and unexpected changes in terminal price ($EXP\ TERMCHG$ and $UNX\ TERMCHG$, respectively). The coefficient on unexpected terminal change is effectively zero and is significantly different from the coefficient on expected terminal change in all of the regressions. This too is consistent with a Rotemberg-Saloner effect, but inconsistent with the mismeasurement hypothesis.

VI. Conclusion

Using a panel of data on retail gasoline margins in 59 cities over 6 years, we have found evidence consistent with the Rotemberg-Saloner theory of coordinated pricing as extended by Haltiwanger and Harrington. Anticipated changes in demand and input prices affect current retail margins significantly and in the direction implied by these theories. The two most plausible alternative explanations for our results, inventory effects or noisy measurement, are not supported in these data.

The results are somewhat surprising because the structure of the retail gasoline industry is not the tight oligopoly setting supposed by the formal models or investigated in prior empirical studies of collusion. A simple structural analysis might lead one to expect that prices above the one-shot Nash equilibrium levels would not be possible. If this is true, however, the

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dynamic pattern we observe in retail prices has yet to be explained. This pattern is particularly striking because both expected cost and expected volume have the effects predicted by models of collusive pricing. Further, the conclusion that firms are colluding does not necessarily mean that they are able to set prices at, or even close to, the monopoly level. Indeed, given the inelastic industry demand for gasoline, it is quite clear that the actual margins fall far short of the monopoly level.

If the possibility of collusion, however imperfect, is admitted then the dynamic pricing story seems quite reasonable in this market. If there is some tacitly collusive price in effect, it is not surprising that retailers would recognize that the cost of punishment changes with cost and demand conditions. If a retailer deviates by cutting price, nearby sellers are likely to cut price in response, even if there is no clearly understood policy with respect to the length or severity of the punishment. Once retaliation begins, the return to tacitly collusive prices would take time and be costly to all sellers. Recognizing this, a seller might very well be less willing to deviate from the tacit agreement if collusive profits are expected to be high in the succeeding periods than if they are expected to be low.

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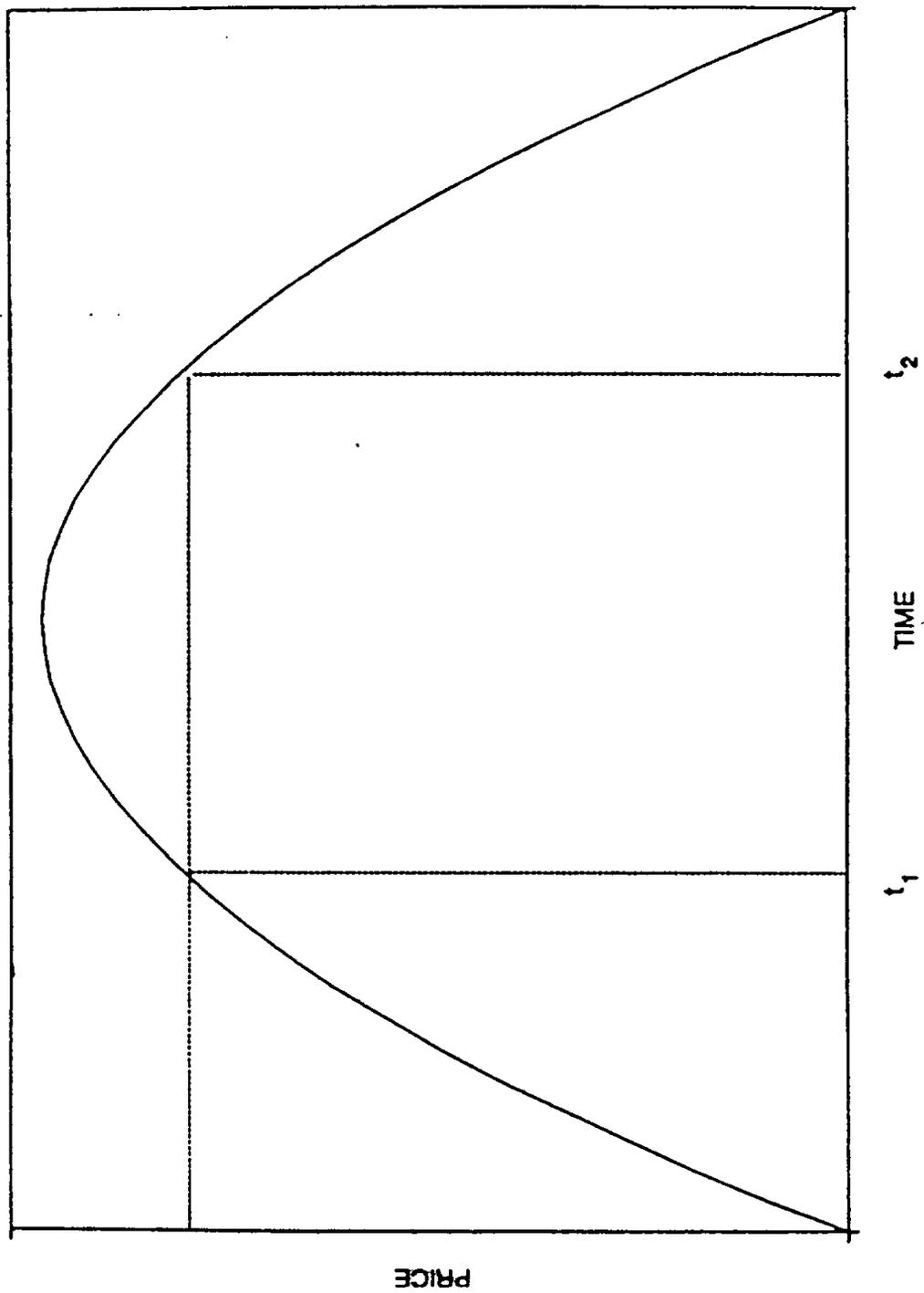FIGURE 1: MONOPOLY PRICE OVER THE CYCLE
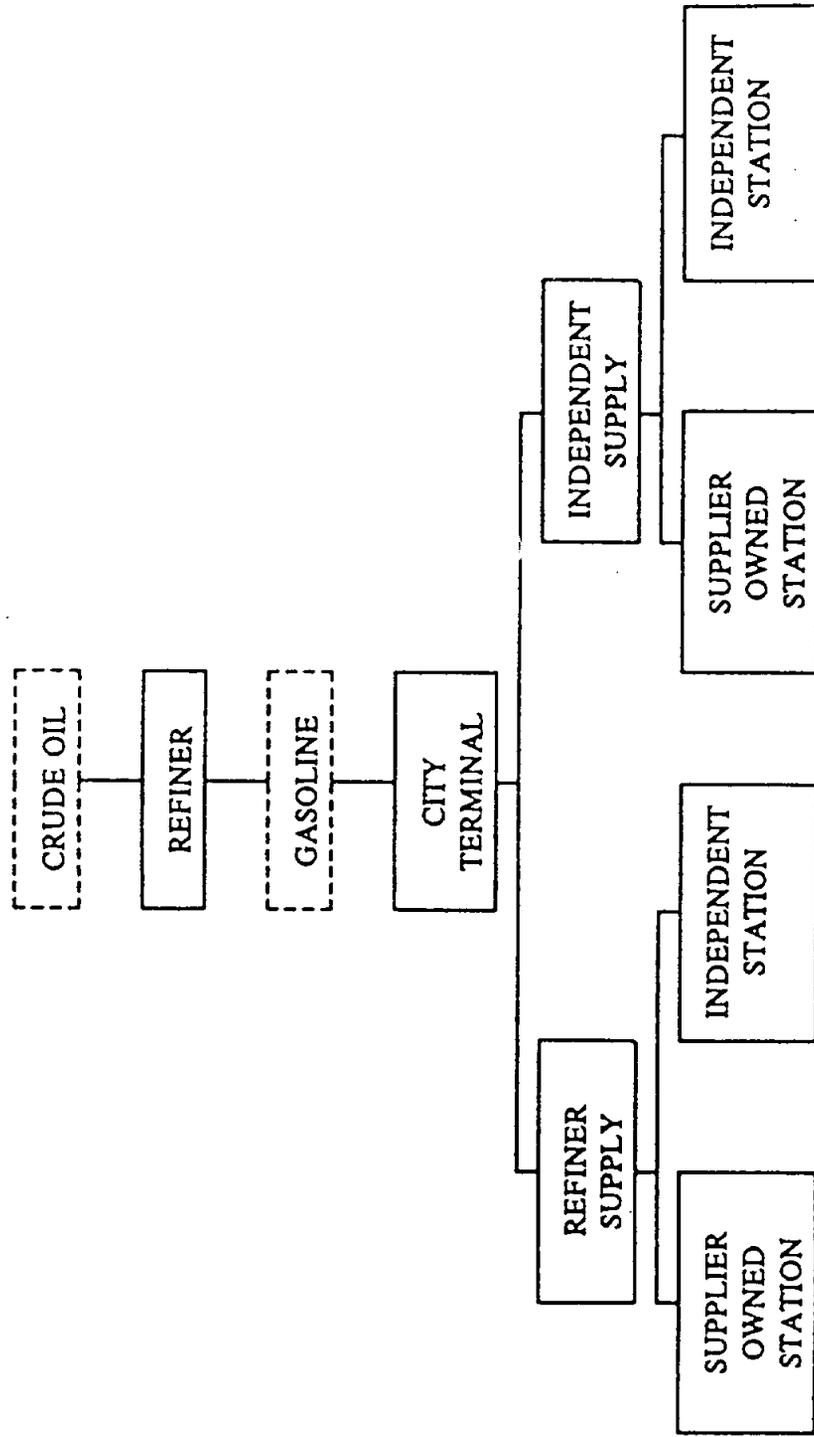
FIGURE 2: GASOLINE DISTRIBUTION

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│STATION ││STATION││STATION ││STATION│
└───────┘└───────┘└───────┘└───────┘
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FIGURE 3: PRICES (1986-1991)
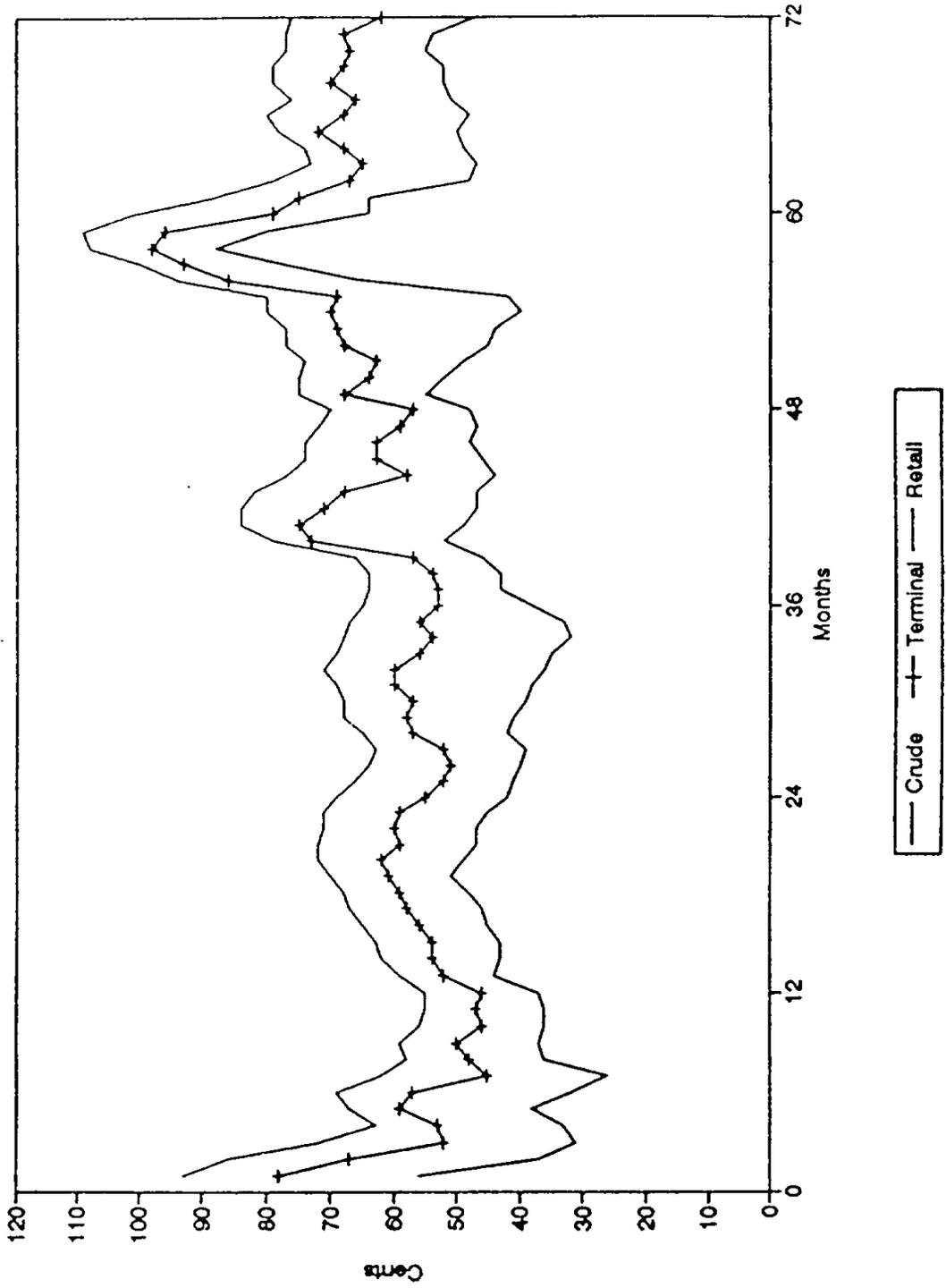(Average City Prices)

Cents

Months

— Crude —+— Terminal —— Retail

FIGURE 4: DAILY VOLUME (1986-1991)
(Average State Volume)