The Impact of Upstream Mergers on Retail Gasoline Markets

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Abstract

In recent years, a number of mergers have occurred in the petroleum industry involving upstream firms that are imperfectly integrated into retail markets. In order to empirically evaluate the competitive effects of such mergers, this paper proposes a structural model of supply and demand that reflects divisions between upstream producers and downstream retailers. Neither downstream costs including wholesale prices nor upstream costs are observed. A standard differentiated products oligopoly model of retail competition provides an expression for downstream costs including wholesale prices as the difference between observed prices and downstream mark-ups. The downstream model is combined with a model of upstream competition that relates wholesale prices and upstream costs to upstream mark-ups. The supply model is estimated along with a demand model reflecting downstream product differentiation using data from the Hawaiian islands in the early 1990s.
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Beginning with the merger of Shell, Star Enterprise and Texaco in 1997, the last five years have seen a wave of merger and acquisition activity in the American petroleum industry. These mergers, listed on table 1, have combined the exploration, production, distribution and marketing operations of various major petroleum firms. While antitrust authorities have closely scrutinized many of

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these mergers, none have been blocked although conditions have occasionally accompanied approval.

Economists have developed a battery of procedures to analyze the competitive effects of mergers. Recently, a number of studies have used structural models to address the effects of mergers on market outcomes in the presence of product differentiation (Baker and Bresnahan 1985, Nevo 2000, Dube 2000, Pinkse and Slade 2001). Such studies combine an assumption about the pricing behavior of firms with a demand model that provides information about market power that a merged firm might possess. Estimation of the model allows simulation of the new equilibrium that would arise following a hypothetical merger as well as the computation of welfare effects.[1]

However, this approach is best suited to an industry in which the firms of interest are vertically integrated into the final goods market or the downstream sector is perfectly competitive. As in many other settings, such conditions may not be tenable in the petroleum industry. Instead, various relationships exist between upstream producers and downstream sellers, and significant downstream differentiation may be present. In such cases, analysis that focuses on either the upstream or downstream sector in isolation may not accurately characterize the effects of the merger. Complete analysis of an upstream merger must account for the direct effect on downstream competition through the combination of marketing activities that are vertically integrated as well as the more indirect effect arising from the wholesale prices that upstream producers charge affiliated downstream dealers.

In this paper, I present and estimate a structural model in which some divisions exist between upstream producers and downstream firms to analyze

[1] An alternative approach involves reduced form analysis of the impact of a merger on prices or quantities as in Hastings (2001). Beyond endogeneity concerns, such analysis does not provide much guidance for mergers that have been proposed, but not consummated. Moreover, reduced form analysis does not allow detailed welfare calculations.

the potential effects of an upstream merger on retail gasoline prices and other market outcomes. On the demand side of the model, the analysis reflects the possibility of significant differentiation in the downstream sector arising from, for example, the locations of firms. This differentiation bestows some market power on retailers and, due to the exclusive contracts in the industry, on their suppliers. Downstream firms set retail prices given the costs charged by their upstream suppliers. Given contractual relationships, the upstream firms in turn choose their wholesale prices recognizing the effect on the downstream equilibrium and, hence, on upstream profits.

A crucial econometric issue concerns upstream and downstream costs. Neither downstream marginal costs including wholesale prices nor upstream costs are observed.[2] As in previous research, a model of downstream competition yields expressions for retail costs as the difference between observed prices and estimated downstream mark-ups.[3] Wholesale prices comprise one component of these downstream costs. A model of competition between suppliers provides a relationship between these wholesale prices and upstream mark-ups and costs. I then combine the upstream and downstream pricing equations by replacing the wholesale price component in the downstream sector with the implied wholesale prices from the upstream sector. This combined pricing equation allows the inference of total marginal costs as the difference between observed prices and mark-ups from both sectors. In general, it is only possible to estimate the sum of upstream and downstream costs. However, in many applications such as merger analysis, this sum may suffice for simulation of counterfactuals. Moreover, in the current setting, features of the industry arguably allow a decomposition of costs into upstream and downstream components.

[2] Throughout, I use the term "wholesale price" to refer to any costs that the upstream firm imposes on its downstream affiliates.

[3] See Bresnahan (1989) and the references cited therein. Notable recent examples include Berry, Levinsohn and Pakes (1995) and Nevo (2001). In effect, this approach involves estimation of marginal revenue accounting for strategic interaction between firms.

Intuitively, this approach infers marginal cost through an extension of standard techniques in empirical industrial organization. Previous studies combine demand estimates with an assumption about oligopoly pricing behavior to compute mark-ups. Observed prices net of mark-ups then yield estimates of marginal cost for a single part of the distribution chain. In this paper, the standard approach allows estimation of downstream costs including wholesale prices. I then extend this logic to the upstream sector in order to provide an expression for unobserved wholesale prices as a function of upstream costs and mark-ups. The two sectors together yield combined pricing equations that reflect downstream and upstream market power and costs.[4]

The relationships between upstream and downstream firms is an important issue in any vertical structure. For instance, upstream firms may use nonlinear pricing such as quantity discounts or franchise fees to alleviate problems arising from double marginalization. Moreover, brand affiliations are not immutable, nor is the extent of vertical integration. In this study, I abstract from these issues and focus on inferring overall market power and its implications for mergers given particular assumptions about the vertical relationship.

I estimate the model using data from the early 1990s for two islands in Hawaii. While the Hawaiian islands may not constitute a large or representative component of the petroleum market, these data are useful for two reasons. First, the closed nature of the markets provides a convenient laboratory in which to examine possible forms of differentiation among gasoline retailers. Second, antitrust authorities have imposed divestiture requirements that explicitly involve Hawaii. For example, Texaco withdrew from the Hawaiian market in order to obtain approval for its merger with Shell. The analysis in this paper per-

[4]This insight was developed independently in the research of Villas-Boas (2001). Villas-Boas (2001) is concerned with the important question of distinguishing between different price structures in a vertical relationship when the intermediate transactions are unobserved. In this paper, I take a particular form of vertical pricing and attempt to draw inferences about upstream and downstream market power given that framework.

mits evaluation of whether these concerns were warranted. In addition, other hypothetical mergers can be examined.

The paper is organized as follows. The first section presents a model of supply and demand for the retail gasoline industry. The second section describes the data and discusses the petroleum industry in Hawaii. The third section presents the estimation strategy. The fourth section presents and discusses the estimation results while the fifth section uses the estimates to analyze the effects of a variety of upstream mergers. The final section concludes.

I. A Model of Supply and Demand for the Petroleum Industry

The data contain observations on each automotive gasoline product $j = 1, ..., J_{tm}$ for time periods $t = 1, ..., T_m$ in a series of independent markets $m = 1, ..., M$. A product is a particular gasoline grade, $g \in \{RU, MU, PU\}$, and service level, $s \in \{SS, FS\}$, sold at a certain station where RU, MU and PU denote regular, medium and premium unleaded while SS and FS denote self- and full-service levels.[5] Thus, an alternative is a combination of a grade, service level and station so that SS-RU at one station is a distinct product as are SS-MU at the same station and SS-RU at a different station. Gasoline products are sold at stations $f = 1, ..., F_{tm}$ that are associated with and may be directly owned by upstream parent firms $r = 1, ..., R_{tm}$. For each observation, the data include the variables $(q_{jtm}, p_{jtm}, x_{jtm}, L_{jtm})$ where q is the volume sold in gallons, p is the price in dollars per gallon, x is a vector of product and station characteristics including grade, service level and brand, and L is the location of the product in decimal degrees (latitude-longitude). In addition, the data

[5] In reality, three service levels exist in the Hawaiian islands: self-service (SS), full-service (FS) and mini-service (MS). The latter involves an attendant pumping the gasoline without providing any additional services generally associated with full-service. I treat SS and MS as the same product type.

provide limited information about the relationship between the retailers and the upstream supplier.[6]

The goal of this section is to derive a system of demand and supply equations. The supply relations are the pricing equations of multiproduct downstream retailers and upstream producers. The demand side relies on an extension of recent research by Berry (1994), Berry, Levinsohn and Pakes (1995), and Bresnahan, Stern and Trajtenberg (1997). A notable feature of the demand model is the treatment of geographic differentiation among gasoline stations. Despite the large theoretical literature on spatial differentiation beginning with Hotelling (1929), studies such as Feenstra and Levinsohn (1995), Goettler and Shachar (forthcoming), Manuszak (2000), Davis (2000), Thomadsen (2000) and Pinkse, Slade and Brett (forthcoming) have only recently attempted to quantify the importance of this type of differentiation for own- and cross-price substitution effects. Moreover, while almost all products are geographically differentiated to some extent, spatial differentiation is undoubtedly more important in some industries than others. Indeed, such differentiation is possibly more important in the retail gasoline industry than in almost any other.[7] The product itself is fairly homogeneous, and location is arguably the only factor distinguishing one seller from another.

A. Demand for Retail Gasoline Products

I assume that each consumer makes a discrete choice among possible sources of gasoline and has preferences over product characteristics including price, product location and product type where a product's grade and service level

[6] For simplicity of notation and exposition, the market and time subscripts are hereafter suppressed.

[7] Most empirical work on the retail gasoline industry either takes a reduced form approach to analyze prices (Marvel 1976, Borenstein 1991, Shepard 1991, Manuszak 2001, Hastings 2001) or imposes strong restrictions on substitution patterns to obtain tractable demand specifications (Slade 1987, Slade 1992).

define the product type. Application of a discrete choice framework in this setting requires a number of stringent assumptions. Gasoline consumption choices involve two simultaneous decisions.[8] The first is the discrete choice between stations. I assume this discrete choice is strong enough that consumers do not choose interior bundles involving multiple sources of gasoline at a given time. The second decision concerns the amount of gasoline to buy. Since the available data reflect only the aggregate outcome of discrete and continuous decisions of many different consumers, I implicitly assume that all consumers purchase the same amount of gasoline regardless of price and make those purchases at the same frequency. Thus, the model implies that any responses to price changes will involve discrete shifts in purchases from one alternative to another. In other words, there is no possibility that a consumer will simply decrease consumption from a given source if its price rises. Moreover, no heterogeneity in the size of these discrete purchases could arise due to consumer characteristics or preferences.

Formally, consumer i has conditional indirect utility for product j given by

$$V_{ij} = x_j'\beta + \alpha p_j + \xi_j + \lambda d(l_i, L_j) + u_{ij}. \tag{1}$$

In this expression, $x_j'\beta$ is the mean utility from observable characteristics of product j in the population of consumers while ξ_j represents the mean valuation of characteristics of product j that all agents in the market observe, but that the econometrician does not observe. Similarly, αp_j is the mean disutility associated with the price of product j. The term $d(l_i, L_j)$ is the distance from consumer i's location, l_i, to the product's location, L_j, according to some metric, while λ is the disutility of distance. The final term, u_{ij}, represents unobserved idiosyncratic variation in the preferences of consumer i for product j with some distribution in the population of consumers.

[8] Hanemann (1984) provides a general treatment of models involving both discrete and continuous choices.

In addition, consumers have the option of not purchasing any of the available products and instead could use, for example, some other mode of transportation. Given the strict discrete choice assumption, a uniform increase in the prices of all alternatives not change the quantities purchased without the presence of this additional alternative. Denoting this alternative as product $j = 0$, I assume that the mean utility of this option is normalized to zero and that $d(l_i, L_0) = 0$ for all i so that

$$V_{i0} = u_{i0} \tag{2}$$

is the indirect utility of this alternative. Due to the assumption that consumers do not vary the size of their purchases following a price change, the elasticity of aggregate demand for gasoline arises only through this option.

Consumers choose whichever product yields the highest indirect utility. That is, consumer i purchases product j if and only if

$$V_{ij} = \max_{k=0,\ldots,J} V_{ik}. \tag{3}$$

Assuming that the unobservable, u_{ij}, is independent of the consumer's location and that ties occur with zero probability in the population of consumers, the utility maximization condition implies a set of consumer unobservables that induces a consumer located at l to purchase product j. Denoting the mean utility across consumers by $\delta_j = x_j'\beta + \alpha p_j + \xi_j$, this set is defined as

$$\Lambda_j(l) = \{u : \delta_j + \lambda d(l, L_j) + u_{ij} \geq \delta_k + \lambda d(l, L_k) + u_{ik} \ \forall k\} \tag{4}$$

which implicitly depends on prices, product locations and other product characteristics as well as parameters to be estimated. Letting $f(u; \phi, x)$ denote the joint pdf of u that depends on some set of unknown parameters ϕ and may also depend on characteristics of the products x, the local choice probability with respect to product j is

$$P_j(l) = \int_{\Lambda_j(l)} f(u; \phi, x) du. \tag{5}$$

The market share of product j as a fraction of total potential sales is then determined by integrating over the distribution of consumer locations to yield

$$S_j(p, x, \xi, L; \theta_1) = \int_{\bar{l}} P_j(l) g(l) dl \tag{6}$$

where $g(l)$ is the pdf describing the distribution of consumer locations in the market with support $\bar{l}$, $\theta_1 = (\alpha, \beta, \lambda, \phi)$ are the unknown demand parameters, and $L = (L_1, ..., L_J)'$ with x, p and ξ defined similarly. Letting $\bar{Q}$ denote the potential amount sold in the market, the demand function for product j is given by

$$\begin{aligned} q_j &= \bar{Q} \cdot S_j(p, x, \xi, L; \theta_1) \\ &= q_j(p, x, \xi, L; \theta_1). \end{aligned} \tag{7}$$

The assumption of no systematic heterogeneity in the size of individual purchases implies that the market size, $\bar{Q}$, is a function of the number of consumers in the market and the assumed size of purchases.

The unknown demand parameters are (α, β, λ) as well as any parameters ϕ associated with the distribution of unobserved heterogeneity. I employ a model proposed by Bresnahan, Stern and Trajtenberg (1997) to specify the distribution of unobserved heterogeneity while I use various external data sources to empirically approximate the distribution of consumer locations. Briefly, the distributional assumptions on unobserved heterogeneity yield two parameters, ϕ_g and ϕ_s, which characterize correlation in preferences along grade and service level dimensions. For example, when ϕ_g equals one, differentiation along the grade dimension becomes unimportant. Conversely, there is no substitution across products with different grades when ϕ_g approaches zero. Appendix A discusses these distributional assumptions in more detail.

B. The Pricing Problems of Upstream and Downstream Gasoline Suppliers

I assume that pricing in a market occurs in the following manner. First, upstream companies simultaneously choose wholesale prices for their retailers that are not vertically integrated. In the second stage, stations simultaneously choose retail prices to maximize profits given the wholesale prices and other costs. In this stage, upstream firms directly choose prices for vertically integrated stations given the upstream costs, while affiliated stations act independently of the upstream firm and each other. Hence, there are two stages of competition with each involving noncooperative Bertrand conduct. Analysis of this structure begins with the downstream market and works backwards to the implied upstream equilibrium. For simplicity, I focus on the case where no retailers are operated by the upstream firms.[9] The extension to allow for some vertical integration is discussed below. Moreover, I assume that it is sufficiently costly to change affiliation that the set of retailers associated with each upstream firm is exogenous when this pricing game occurs.

Beginning with the retail problem, downstream firm f selects prices for some goods in the market in order to maximize

$$\Pi_f^D = \sum_{j:f(j)=f} p_j q_j \left(p, x, \xi, L; \theta_1\right) - C_j^D \left[q_j \left(p, x, \xi, L; \theta_1\right)\right] - FC_f^D \tag{8}$$

where $f\left(j\right)$ denotes the firm that sells product j, $C_j^D\left(q\right)$ is the cost of producing q units of good j, and FC_f^D are fixed costs of firm f.[10] Since downstream costs primarily reflect the wholesale price of gasoline in the retail gasoline industry, I assume that downstream costs are constant and can be decomposed as

$$C_j^D = W_j + c_j^D \tag{9}$$

where W_j is the wholesale price of product j and c_j^D reflects product-specific costs that are not determined by an upstream firm.

[9] As noted later, vertical integration is almost non-existent in the data used in this study.

[10] Gasoline is a heavily taxed commodity. In Hawaii, there are state, federal and island-specific quantity taxes as well as a 4% ad valorem state tax. In other words, the pricing equations should reflect that producer prices are $\widetilde{p}_j = \frac{p_j - \tau_2}{1+\tau_1}$ where τ_2 and τ_1 are respectively the quantity and ad valorem taxes. To simplify the exposition, these taxes are ignored. However, in the empirical implementation, the pricing equations reflect these taxes.

Assuming the existence of a pure strategy Nash equilibrium in prices, retail prices must satisfy the first order conditions

$$q_j\left(p,x,\xi,L;\theta_1\right)+\sum_{m:f(m)=f(j)}\left[p_m-W_m-c_m^D\right]\frac{\partial q_m(p,x,\xi,L;\theta_1)}{\partial p_j}=0 \qquad (10)$$

for $j=1,...,J$. In matrix notation, the first order conditions can be rewritten as

$$q\left(p,x,\xi,L;\theta_1\right)+\Delta_1\left(p,x,\xi,L;\theta_1\right)\left(p-W-c^D\right)=0 \qquad (11)$$

where p, c^D, W and $q\left(p,x,\xi,L;\theta_1\right)$ are $J\times 1$ vectors of prices, costs, wholesale prices, and quantities, and $\Delta_1\left(p,x,\xi,L;\theta_1\right)$ is a $J\times J$ matrix with (j,m)th element $D_{jm}^D\cdot\frac{\partial q_m(p,x,\xi,L;\theta_1)}{\partial p_j}$ where D_{jm}^D is a binary variable equal to one if $f(j)=f(m)$. Rearranging these equations yields a system of pricing equations characterizing the decisions of the price-setting downstream firms

$$\left(p-W-c^D\right)=-\Delta_1\left(p,x,\xi,L;\theta_1\right)^{-1}q\left(p,x,\xi,L;\theta_1\right). \qquad (12)$$

This expression relates observed retail prices to wholesale prices, downstream costs and a mark-up reflecting market power due to downstream product differentiation.

Turning to competition in the upstream sector, downstream competition implies equilibrium prices $p_j^*=\rho_j\left(W,x,c^D,L,\xi;\theta_1\right)$ that depend on all wholesale prices W and downstream costs as well as all observed and unobserved demand variables. Thus, the upstream firm that sells product j faces derived demand $\widetilde{q}_j\left(W,x,c^D,L,\xi;\theta_1\right)=q_j\left[\rho\left(W,x,c^D,L,\xi;\theta_1\right),x,\xi,L;\theta_1\right]$ where $\rho\left(W,x,c^D,L,\xi;\theta_1\right)$ is the vector of downstream equilibrium price functions. Upstream suppliers simultaneously choose wholesale prices for each product that its affiliates sell in order to maximize

$$\Pi_r^U=\sum_{j:r(j)=r}\left(W_j-c_j^U\right)\widetilde{q}_j\left(W,x,c^D,L,\xi;\theta\right)-FC_r^U \qquad (13)$$

where $r(j)$ denotes the upstream supplier of product j, and c_j^U is the constant marginal cost of product j for upstream firm r.

When setting the wholesale price, suppliers account for the impact of cost changes on the downstream equilibrium. Suppressing the dependence of derived demand on all variables except W and assuming the existence of a pure strategy Nash equilibrium, the wholesale price W_j must satisfy

$$\widetilde{q}_j(W) + \sum_{k:r(k)=r(j)} \left(W_k - c_k^U\right) \frac{\partial \widetilde{q}_k(W)}{\partial W_j} = 0 \tag{14}$$

where

$$\frac{\partial \widetilde{q}_k(W)}{\partial W_j} = \sum_{m=1}^{J} \frac{\partial q_k(p)}{\partial p_m} \frac{\partial \rho_m(W)}{\partial W_j}. \tag{15}$$

The downstream equilibrium price responses in this latter expression, namely $\frac{\partial \rho_m(W)}{\partial W_j}$, can be derived from the pricing equations (12) via the Implicit Function Theorem.[11] As in the case of the downstream sector, combining all first order conditions and rearranging terms yields the vector of pricing equations

$$\left(W - c^U\right) = -\Delta_2(W)^{-1} \widetilde{q}(W) \tag{16}$$

where $\Delta_2(W)$ is a $J \times J$ matrix with (j,k)th element $D_{jk}^U \frac{\partial \widetilde{q}_k(W)}{\partial W_j}$ where $D_{jk}^U = 1$ if $r(j) = r(k)$ and zero otherwise. This expression relates (unobserved) wholesale prices and upstream costs to upstream mark-ups.

The crucial components of the supply model are the downstream and upstream pricing equations, (12) and (16). The downstream pricing equations are similar to those used in other empirical studies of oligopolistic industries. The crucial difference is the interpretation of part of marginal cost as the wholesale price. The upstream model then provides a characterization of the wholesale prices. These two sets of pricing equations can be combined to yield

$$p = c^D + c^U - {\Delta_1}^{-1} q - {\Delta_2}^{-1} q. \tag{17}$$

[11] In general, these price responses are complicated functions of first and second derivatives of demand. In the empirical implementation, these derivatives are computed numerically.

These combined pricing equations relate observed retail prices to costs and mark-ups from both the upstream and downstream sectors. Assuming that the total cost of product j can be expressed as a function of observable cost characteristics w_j, unknown parameters γ and an unobserved cost component ω_j so that

$$c_j^D + c_j^U = w_j'\gamma + \omega_j, \tag{18}$$

the combined pricing equations can be written

$$p = w\gamma - \Delta_1{}^{-1}q - \Delta_2{}^{-1}q + \omega. \tag{19}$$

Given this econometric specification, the pricing equations (19) can be jointly estimated along with the demand model.[12]

In general, it is not possible to separately estimate upstream and downstream costs. Similarly, one generally cannot obtain actual estimates of wholesale prices. However, the restrictions of the model imply that estimation of wholesale prices is not necessary. The only necessary information is the way in which the wholesale prices are related to upstream costs and mark-ups as well as the relationship between observed retail prices and wholesale prices. This information allows the wholesale price in the downstream pricing equation to be replaced by the upstream margins and costs. Moreover, in many applications, the only costs of interest are the combined upstream and downstream costs. For instance, in merger analysis, one can examine the impact of combining upstream operations of two firms given the total costs faced by suppliers and retailers. Since a major justification for mergers is cost savings, one could alternatively simulate the effect of a merger given hypothetical cost changes from the initial combined cost level.

[12] An alternative two-stage approach would involve estimation of the demand parameters followed computation of marginal costs as in Nevo (2001). Such an approach does not rely on a model of pricing behavior in order to obtain demand estimates, but will yield less precise estimates when the supply model is correctly specified.

However, in some settings, industry characteristics may permit a reasonable decomposition of costs as well as direct estimation of wholesale prices. In the case of the petroleum industry, wholesale prices are generally grade specific. In other words, upstream pricing primarily affects downstream costs through a grade-specific wholesale price, and downstream costs for a given grade mainly reflect wholesale prices. Moreover, upstream firms typically charge uniform prices for a given grade to all firms in a market.[13] Given this relationship between wholesale prices and product type as well as the common wholesale price across downstream firms, one could envision estimating wholesale prices as brand-product type fixed effects using the downstream model. These wholesale price estimates along with the upstream pricing equations would yield estimates of upstream costs for a given product type. Estimation of the combined pricing equations merges these two steps. However, this feature of the industry suggests the interpretation of product type or brand-product type fixed effects in the combined pricing equations as upstream costs. Wholesale prices could then be viewed as the fixed effects plus the upstream mark-up.

The model could be easily extended to a situation in which upstream firms are partially integrated into the downstream market.[14] In particular, one could amend the downstream model to reflect joint profit maximization for products at a set of stations that are vertically integrated. In most gasoline markets, such a framework would be needed since petroleum companies often directly own and

[13] Due to this feature of the industry, I assume in the estimation that upstream firms choose a common wholesale price for all affiliated products of a given grade. That is, upstream firm r maximizes $\Pi_r^U = \sum_g \left[\left(W_{g,r} - c_{g,r}^U \right) \sum_{j:r(j)=r,g(j)=g} \widetilde{q}_j \left(W \right) \right]$ where $W_{g,r}$ and $c_{g,r}^U$ are the wholesale price and upstream costs for grade g and upstream firm r. However, in principle, the model could allow wholesale prices to vary across downstream firms. One interesting application of the model would be to examine the predicted gains from such differential wholesale pricing.

[14] A related concern is the possibility that multiple downstream stations are owned and operated by a single retailer. The current model would tend to overstate downstream costs in the presence of joint ownership. Unfortunately, the available data contain no information about such relationships. However, individual retailers generally do not operate multiple stations with different brands, and stations of the same brand rarely locate near one another.

operate some stations.[15] Interestingly, in such a setting, the cost estimates for vertically integrated stations would yield a direct estimate of the upstream marginal cost. Moreover, a specification test for the upstream model could involve a comparison of the costs for vertically integrated stations and the upstream costs estimated through non-integrated stations. Alternatively, the existence of both types of downstream firms could directly address the importance of double marginalization at non-integrated stations. However, in the current data, only one company, BHP Gas Express, directly runs stations, and all of that company's stations are vertically operated. Hence, the empirical analysis is amended to reflect joint downstream ownership of Gas Express stations. The lack of vertical integration in the data simplifies application of the model, but does not diminish its generality.

II. The Data and the Petroleum Industry of the Hawaiian Islands

The data that I use are a panel of detailed product-level observations for two Hawaiian islands, namely Maui and Kauai, over the period 1990 to 1995. The preponderance of the data was gathered by Whitney Leigh Corporation, a market analysis firm specializing in the retail gasoline industry.[16] Whitney Leigh produces two types of reports on the retail gasoline industry for a variety of markets: annual censuses and detailed periodic data called Gas Track Reports. The former involves an enumeration of every gasoline station in a market and includes various station characteristics. The latter is a monthly report that

[15] Branded gasoline retailers that are not directly run by a parent company can be either lessee-dealer or open-dealer stations. The former involves a retailer who rents the station's physical assets from the upstream company and makes all marketing decisions for the station. In the latter case, the retailer independently owns the station, but has a contract to purchase gasoline from a certain upstream firm. See Shepard (1993) or American Petroleum Institute (1992) for more details.

[16] I would like to thank MacDonald Beavers and Whitney Leigh Corporation for making these data available. I would also like to thank Rob Porter, John Panzar and Ron Braeutigam for assisting in the purchase of the data.

contains detailed sales and price information for a sample of stations.

The Hawaiian islands are unique markets. Their small size and, as discussed below, unusual structure are unlikely to yield general conclusions about the petroleum industry. However, these data provide an attractive application of the model for a number of reasons. First, the closed nature of the markets has attractive implications for empirical analysis since many market definition issues are irrelevant. Second, as noted earlier, a number of mergers have involved firms that are active in Hawaii, and divestiture requirements have explicitly addressed competition in the Hawaiian market. Finally, the small number of stations allows Whitney Leigh to compile Gas Track Reports that essentially include every active station.

A combination of information from the annual censuses and Gas Track Reports comprises the bulk of the main dataset. The resulting unbalanced panel dataset contains 4,910 product observations sold at 1,350 stations across the two markets.[17] These observations correspond to products sold over 24 non-successive monthly intervals for Maui and 22 for Kauai beginning in late 1990 and ending in mid 1995.[18] Table 2 lists the variables in the data. For each product observation, the data include a number of product-level variables such as grade and service level as well as a number of station-level characteristics common to all products sold at a given station. These latter variables include brand, number of fueling positions and pumps, weekly operating hours, and whether a station has a convenience store or automotive service. A crucial station-level characteristic is location. I used a handheld differential global positioning system (GPS) to obtain extremely accurate latitude and longitude readings for each station on the islands.

The data also contain volumes and prices for each product. The price data

[17]These observations correspond to 31 stations on Kauai and 36 stations on Maui. Entry and exit implies that all of these stations are not active at all dates.

[18]Note that these data precede the wave of upstream mergers and the associated divestitures.

reflect the price posted at the end of the time period, while the volume data generally were obtained through a comparison of meter readings at the beginning and end of a time period. Obviously, this observation frequency is not ideal since a great deal of intratemporal price and sales variation may not be recorded. However, as I discuss below, relative prices are fairly stable over the course of the sample suggesting that relative prices within the time periods may not have varied much from those recorded at the end of a time period. Thus, the observation frequency may not be terribly problematic, although such price patterns may cause other difficulties.

As table 3 documents, Shell, Texaco, Chevron and Unocal sell the bulk of the gasoline on the two islands in the study. Kauai is especially dominated by Chevron and Shell. BHP Gas Express and various independent operators are also active, but generally comprise a small part of total sales. Chevron and BHP refine the vast majority of gasoline in Hawaii at facilities on Oahu.[19] In general, the crude oil that these refiners use is Alaska North Slope Crude supplemented with imports from Australia and southeast Asia. Chevron and BHP operate main terminals on Oahu from which they supply gasoline to the other petroleum companies for storage at their own terminal facilities.[20] The companies then ship some gasoline via inter-island barge to terminal facilities on the neighbor islands. As noted earlier, vertical integration is effectively non-existent in these two markets. Hence, retailers either purchase gasoline at a terminal paying what is known as the rack price or pay the dealer tankwagon

[19] The existence of only two refiners raises the possibility that the model should also reflect the pricing problem of the refiners. In this analysis, I abstract from this problem since it is difficult to gauge the threat of shipment of gasoline into the market or entry into refining. However, I can empirically test whether costs differ systematically by brand. Certain cost patterns may reflect an effect arising from whether or not a company is a refiner in the market.

[20] Often, this transaction between the refiners and the other petroleum companies occurs under an "exchange agreement" in which a company that refines gasoline in Hawaii provides some to one that does not in exchange for gasoline in another market refined by the second petroleum company less the estimated cost of transportation.

(DTW) price for gasoline delivered from a terminal to the station.

Table 4 provides some descriptive statistics for the stations in the data by station configuration where a configuration relates to the combination of service levels that a station sells. These figures suggest that Hawaii has a somewhat unusual industry structure. In particular, the prevalence of full-service is striking. Over 55% of the stations on Maui and Kauai offer full-service while almost half of all stations on Kauai sell only full-service gasoline. Stations which offer FS also tend to be somewhat different from those selling only SS. The latter are more likely to have a convenience store, are less likely to offer automotive service, and tend to operate longer hours. These features of the Hawaiian gasoline industry contrast sharply with industry characteristics on most of the mainland. In other parts of the country since the late 1970s, the retail gasoline industry has generally moved away from traditional stations offering full-service and automotive care to the point that the self-service share of total volume exceeded 90% in 30 mainland states by 1990 (American Petroleum Institute 1992). In most markets, petroleum companies have emphasized self-service stations with newer equipment and alternative ancillary services such as convenience stores.

A superficial glance at the unconditional distribution of prices indicates a great deal of price variation. However, much of this variation can attributed to time and product type effects. As table 5 suggests, grade and service level account for much of the cross-sectional variation in prices, particularly for self-service products. Substantially more price variation exists for full-service prices with notable differences across markets. The cross-sectional distributions described in table 5 remain roughly constant over time so that the conditional price distributions for each date are essentially shifted versions of one another. In simple hedonic regressions, product type, market and date effects explain approximately 78% of the observed variation in prices. Moreover, price variation exhibits a large station-specific effect as inclusion of station dummies in hedonic price regressions increases the R^2 to 0.94. These station-specific effects are suggestive of another feature of the data, namely the lack of relative price variation over time. An examination of the correlation between relative prices in either levels or logs at adjacent dates indicates that they remain roughly constant over time.

Volumes, on the other hand, are significantly more variable even after conditioning on product type. While RU products are generally the highest volume for any service level followed by PU and MU products, and SS products are generally higher volume for any grade, there are generally high volume products of each product type. This variation in quantities is evident from the fact that the date and product type variables that explained a great deal of the variation in prices account for only 40% of the variation in quantities. However, volumes also exhibit a large station-specific component as inclusion of station effects in hedonic regressions for quantities raises the R^2 to 0.7.

The lack of price and quantity variation over time is generally reflective of the stable market structures on the islands. While some entry and exit occurs as seen in table 3, these episodes primarily reflect long-run trends in market evolution such as the entry of Gas Express on Maui and the withdrawal of Chevron from Maui and Unocal from Kauai. This lack of intertemporal variation in market structures and outcomes suggests that much of the estimation will be driven by cross-sectional or cross-market variation. However, as the earlier discussion suggests, cross-sectional variation in prices is also limited. Given the relative dearth of variation in many variables within a market or over time, the pricing equations, along with the restrictions on the cost specification, play an important role in estimating the demand parameters.[21] In effect, the pricing equations provide a means for explaining the variation, or lack thereof, in prices.

[21] In fact, various studies such as Feenstra and Levinsohn (1995) and Thomadsen (2000) rely exclusively on the pricing equation to obtain estimates of the demand parameters.

One potential source of significant variation is the location of firms. The relatively static market structures over time suggests that most of this variation will occur within or across markets. The distribution of pairwise distances between stations on Maui depicted in figure 1 suggests that large variation in locations may exist. However, as figure 2 shows, stations tend to locate in clusters with most stations facing at least one, and often up to three, competitors in close proximity. The spikes in the pairwise distribution of figure 1 primarily reflect the distances between station clusters. Clustering is also an important phenomenon on Kauai, although clusters tend to be smaller.

These clustering effects appear to have a significant effect on pricing patterns. Examination of a spatial autocovariance function for prices typically shows that products of the same type which are near one another tend to have highly correlated prices. However, a problem arises since prices across clusters are also very similar. In other words, stations within clusters set similar prices, and pricing behavior across clusters is similar. An analysis of the spatial autocovariance shows that prices are highly correlated exactly at distances between station clusters.

Fundamentally, these data patterns reflect the endogeneity of the location decision. Firms wish to locate where demand is high. On the other hand, insufficient differentiation could induce cutthroat competition. The actual patterns of firm locations suggest that the first concern tends to dominate the second. Despite the fact that stations could differentiate themselves through their location choices, such locations would have an insufficient mass of consumers to support a station. Such location patterns may complicate demand estimation even without endogeneity concerns. The lack of distance variation within and across station clusters combined with the relative dearth of firms in intermediate areas implies that the data may not contain the variation that would be ideal for uncovering spatial substitution patterns.

III. Econometric Specification and Instruments

This section addresses estimation of the model presented in section I. To reiterate, the equations to be estimated relate to demand and the pricing functions of downstream firms. The unknown demand and cost parameters are $\{\beta, \alpha, \lambda, \phi_g, \phi_s\}$ and γ. The econometric goal is estimation of the unknown parameters using observations of product characteristics, cost characteristics, prices and quantities, or equivalently market shares, for the J alternatives in the market along with information on the distribution of locations in the population of consumers.

As Berry (1994) notes, the inclusion of the structural error terms, ξ_j and ω_j, introduces an econometric problem analogous to the simultaneity bias arising in the study of homogeneous goods. Prices will be correlated with the unobserved factors influencing demand since price-setting firms will recognize the valuations of unobserved characteristics and will choose their prices accordingly. Since both price and ξ enter the demand equation, failure to account for this potential correlation would lead to inconsistent estimates.[22] Similarly, the imputed upstream and downstream mark-ups depend on quantities and derivatives of the market share equations, both of which are endogenous. Thus, the mark-up terms will be correlated with ω necessitating the use of instruments for the pricing equation.

Following Berry (1994), I employ GMM estimation (Hansen 1982) under the assumption that there exists some set of instruments that are correlated with prices and quantities, but uncorrelated with the demand and cost unobservables. In particular, I assume that there is some set of exogenous instruments such that

$$E\left[z_{1j}\xi_j\right] = E\left[z_{2j}\omega_j\right] = 0 \tag{20}$$

where z_{1j} are instruments for the demand side of the model and z_{2j} are instru-

[22] Generally, this correlation will tend to bias the price estimates and, hence, elasticities towards zero.

ments for the pricing equation of product j. Letting $\xi_j(\theta)$ and $\omega_j(\theta)$ denote the cost and demand unobservables implied by a value of $\theta = \{\beta, \alpha, \lambda, \phi_g, \phi_s, \gamma\}$, the GMM estimator is defined as

$$\hat{\theta} = \arg\min_{\theta} \varepsilon(\theta)' ZAZ' \varepsilon(\theta) \tag{21}$$

where Z is the appropriately constructed matrix of instruments, A is positive definite weighting matrix, and $\varepsilon(\theta) = \left[\xi(\theta)' \ \ \omega(\theta)'\right]'$ with $\xi(\theta)' = [\xi_1(\theta), ..., \xi_J(\theta)]$ and $\omega(\theta)' = [\omega_1(\theta), ..., \omega_J(\theta)]$. The demand terms $\xi(\theta)$ are obtained through the inversion suggested in Berry (1994) using a variant of the contraction mapping in Berry, Levinsohn and Pakes (1995). In the estimation, I employ the weighting matrix $A = (Z'Z)^{-1}$ that yields consistent, albeit inefficient estimates of the parameters. However, I obtain consistent estimates of the standard errors by using the estimates along with the weighting matrix of Conley (1999). The latter provides a non-parametric estimate of the asymptotic covariance matrix of the moment conditions in the presence of both temporal and spatial autocorrelation.

Consistent estimation of the parameters requires the existence of instruments, z_{1j} and z_{2j}, which are exogenous in the sense that they are correlated with prices and quantities, but are uncorrelated with the demand and cost unobservables. Standard instruments for demand include cost shifters which are excluded from the demand equations. However, the available cost shifters such as tax rates are market-wide variables and, hence, do not explain any cross-sectional variation in prices. These variables explain fluctuations in aggregate price patterns, but provide no information about variation in prices within a market. A related problem is that the tax variables will be perfectly collinear with the market and date dummies that are included in the specification as discussed later.

The lack of product specific cost variables is a common problem for demand estimation in the presence of product differentiation. One solution is to employ instruments related to the competitive environment that firms face as suggested by Berry (1994). As the product space becomes more crowded, a firm's pricing behavior will be affected. Hence, variables characterizing the product space environment will be correlated with prices that maximize profits, but will be uncorrelated with the unobservables under the assumption that product characteristics are fixed in the short-run.

In all specifications, I employ these types of instruments. For the demand-side instruments, I include own-product characteristics excluding price, namely x_j. In addition, I employ instruments related to competing products in the market. These variables include the number of all other stations, the number of all stations selling the same product type as product j, and the number of stations with the same brand as product j. The use of instruments related to product types exploits segmentation of the industry as in Bresnahan, Stern and Trajtenberg (1997). Moreover, I relate these counts to the proximity of products by further breaking down the instruments according to various distance criteria. Since substitution effects, and hence prices, will depend on the location of alternatives if spatial differentiation is important to consumers, information about the proximity of alternative products provides an intuitive and attractive improvement over simpler instrument sets. In particular, for a given group of instruments, I include counts of the number of relevant stations within $\frac{1}{2}$ mile, 1 mile, 5 miles and 15 miles where, as before, the relevant metric is the driving distance between locations. For example, the instruments for product j contain counts of all stations within $\frac{1}{2}$ mile, 1 mile, 5 miles and 15 miles of product j. I use similar instruments to construct z_{2j}. Specifically, I include the cost characteristics w_j. In addition, the instruments contain the counts of the three competing station types, namely all stations, those selling the same product type as j, and those having the same brand as j, within the four distance criteria noted earlier. Thus, both z_{1j} and z_{2j} contain 12 instruments related to the four proximity criteria for the three types of competing stations. In addition, z_{1j} includes x_j while z_{2j} includes w_j.

A potential problem exists since there is little intertemporal variation in the instruments despite some entry and exit over the sample period. This absence of intertemporal variation raises some questions about the ability of the instruments to account for variation in outcomes over time. The problem is that relative prices may change over time, but the underlying market conditions as described by the instruments may not also change. In other words, the largely time-invariant instruments will not be able to explain relative variation in prices over the course of the panel. However, as discussed earlier, there is little intertemporal variation in prices. Hence, the estimates primarily identify cross-price elasticities off the cross-sectional and cross-market dimensions of the data.

An alternative strategy involves using prices for analogous products in one market to instrument for prices in another market. As Hausman, Leonard and Zona (1994) argue, products in different markets may face common cost factors. Hence, prices in one market will be correlated with prices in another market through the cost effect.[23] In some specifications, I supplement the competitive environment instruments by using prices on Oahu as instruments for prices on Maui and Kauai at a given date. In particular, the instruments for some product j at time t include the average price for the same type of product on Oahu (net of taxes) and the average price on Oahu for products that are the same type and brand. Ideally, these instruments will provide information about variation in relative prices across product types and, more importantly, brand. Moreover, to the extent that there is intertemporal variation in prices across

[23] These instruments will be invalid if there are common demand shocks across markets. However, I include time effects in the demand variables which allays this concern to some extent.

product types, these instruments will provide information about any shocks, such as changes in the cost of labor for full-service, that specifically impact a particular type of product. The result is two additional instruments that I use in some specifications.

Finally, I consider instruments based on station configuration. The station configuration variables are dummy variables defined in the following way. First, there is a dummy variable reflecting whether a station offers the same grade of gasoline at a different service level. The second configuration variable reflects whether a station offers medium unleaded at the same service level as a product. In other words, these variables address the mix of grades and service levels that a station offers as an alternative to a given product. In effect, these variables are competitive environment instruments related to a firm's portfolio of goods. The result is two additional instruments that I consider in some specifications. However, these instruments may be invalid if there are systematic unobserved station-level variables that are correlated with station configuration and also impact demand. For instance, stations that only sell full-service gasoline tend to be older than multiproduct stations.[24] If a station's age impacts its attractiveness to consumers, then the station configuration variables will be correlated with the unobserved age component of demand.

IV. Estimation Results

Tables 6 and 9 present the demand and cost parameter estimates resulting from joint estimation of the demand model and the combined pricing equations. The columns in these tables correspond to the three sets of instruments described earlier. Specifically, the estimates in column 1 employ only the competitive

[24] On the other hand, stations that sell only self-service tend to be newer than multiproduct stations.

environment instruments while columns 2 and 3 respectively add prices on Oahu and station configuration instruments. This section begins with a discussion of the demand estimates and their implications before turning to the estimated cost parameters.

The demand parameters reflect the following variables. First, the variables x_j include a number of station-level variables, namely number of fueling positions, weekly hours, branded status, and whether a station offers automotive service or a convenience store. All of these variables are defined in table 2 except for Branded which is a binary variable equal to one if the product is sold at an affiliate of one of the six branded companies. In addition, x_j includes the product-level binary variables MU, PU, FS and MS that reflect grade and service level.[25] Finally, I include a set of 46 date-market fixed effects. These variables are intended to crudely control for aggregate demand shocks that affect all products in a market at a given date. There is also a demand parameter α reflecting price sensitivity as well as parameters ϕ_s and ϕ_g that characterize correlation in the idiosyncratic preference shocks along the service level and grade dimensions.

To begin with, the estimates do not differ substantively across the three sets of instruments. Rather than investigating the performance of the different instrument sets in more detail, I focus on one set of estimates noting that the implications of the others are very similar. Since the estimates from column 3 imply slightly more market power for firms, I focus on these estimates in the interpretation and later merger simulations to obtain welfare calculations that are less favorable to consumers.

Many of the coefficients in table 6 have the expected sign. For example, the coefficient on Branded is positive and relatively large suggesting that consumers

[25] Thus, although I do not segment the products along the mini-service dimension, I include a mini-service effect in the mean utilities.

value branded status when purchasing gasoline. Similarly, the coefficients on PU, FS and MS are positive reflecting the vertical differentiation that one would expect in the industry.

However, not all of the coefficients have the expected sign. I attribute the negative, albeit insignificant, coefficient on fueling positions to the poor nature of the variable. If one wished to examine the impact of fueling capacity on product demand due to, for instance, the desire of consumers to avoid queues, a more appropriate variable would in fact be product-specific fueling positions instead of the station-level variable Fuelpos. Since stations that have a large number of fueling positions are generally those that sell multiple service levels and since FS products generally have smaller volumes, the effect of the station-level variable Fuelpos is distorted. Similarly, the negative coefficients on Cstore and Service may reflect other characteristics of stations rather than indicating a negative valuation of those services. Stations offering automotive service, for example, are generally older and may be less attractive as a result. The most troubling coefficient estimate is the negative value for the coefficient on MU. One would expect consumers to value medium unleaded more than *RU* taking into account differences in prices. However, the estimates imply that this is not the case. The extremely small volumes of MU, particularly compared to *RU* products, lead the model to conclude that the average consumer does not place a premium on MU gasoline.[26]

The price coefficient implies fairly elastic product-level demand as seen in table 7. Since both ϕ_g and ϕ_s are relatively close to zero implying high correlation in preferences across grades and service levels, most substitution occurs between products which are of the same type. In effect, the estimates of ϕ_g and ϕ_s are roughly consistent with the notion that there is a "type" of consumer

[26] One interesting point is that if octane levels are the sole difference between grades of gasoline, then one could generally obtain the same octane in *MU* at a lower price through a convex combination of *RU* and *PU* given standard price differences.

for each grade/service level combination who is not inclined to switch to a less preferred product type. Moreover, the negative distance coefficient implies that substitution depends on the proximity of alternatives. Figure 3 plots cross-price elasticities against the distance between alternatives on Maui in the last time period. Since the estimates imply low substitution across different product types, this figure considers only *SS-RU* products. This figure displays a clear negative relationship between substitution effects and distance, although some large elasticities occur at relatively far distances.[27] These results suggest that the proximity of products does have an important impact on substitution patterns. However, as the large own-price elasticities suggest, this spatial differentiation does not provide many of the stations with significant local market power.

In contrast to the highly elastic station-level demand, the estimates imply significantly less elastic aggregate demand. The estimates suggest that a 1% increase in all prices leads to a decrease in aggregate sales of approximately 1.2%. This aggregate demand elasticity is somewhat higher than those reported in other studies using aggregate data which typically find inelastic aggregate demand (Dahl and Sterner 1991). This discrepancy could arise due to the strict discrete choice assumption used in this study. However, the overall implications of the demand estimates, namely highly elastic station-level demand and substantially less elastic aggregate demand, are intuitively appealing.

As would be expected given the elastic product-level demand, downstream market power is limited. The first panel of table 8 presents the average downstream mark-ups by brand for each grade and service level combination for the last time period on Maui. In general, the estimates imply downstream mark-ups of approximately 8-11¢ per gallon. The implied upstream mark-ups are somewhat larger, ranging from approximately 10-12¢ per gallon.[28] The latter results

[27] These outliers are likely an artifact of the extreme value assumption for the distribution of unobserved heterogeneity which tends to imply high substitution towards "popular" products.

[28] As noted earlier, I assume that each upstream firm charges the same price for a given

suggest that upstream market power is not severe, largely due to the dispersed downstream outlets of each brand which prevents any single upstream firm from exploiting the relative inelasticity of aggregate demand. Overall, these results imply total mark-ups of around 20¢ per gallon or approximately 10% of the gross price or 16% of the price net of taxes for *SS-RU* products.

Table 9 presents the cost parameters that are estimated simultaneously with the demand coefficients. One issue in specifying the variables w is the extent of cost heterogeneity that the model allows. I include a set of time dummies to reflect common costs that affect all products at a given date. Moreover, I include dummy variables for grade and service level so that the incremental cost of different product types is the same across all markets and brands. However, I allow heterogeneity in costs through the inclusion of brand-market effects. Thus, I allow for differing base costs across brands and markets, but this difference does not change across time or product types. Table 9 presents the estimated brand-market effects along with the product type effects.[29] Figure 4 displays the estimated costs for Chevron *SS-RU* products on Maui including the common time effects.[30] As discussed earlier, the strict relationship between wholesale prices and grade in the industry implies an interpretation of these costs as upstream costs. Wholesale prices could then be viewed as these costs plus the upstream mark-ups.

The most striking feature of table 9 is the difference in the cost estimates across markets. While the estimated costs differ across brands within a market, these differences are generally statistically insignificant. However, the differences across markets are large and statistically significant implying that costs

grade to each downstream retailer. The second panel of table 8 reflects the mark-up of each brand for each grade given this uniform upstream pricing.

[29] As noted earlier, the estimates in the third specification imply slightly more market power for firms. The estimated costs are correspondingly lowest in column 3 of table 9.

[30] The total costs for different products and brands can be constructed in an analogous fashion.

on Kauai are substantially lower than on Maui. Cost differences across markets seem implausible to the extent that table 9 suggests. These differences likely arise for a number of reasons. First, table 3 documents that Kauai is a much more concentrated market at the aggregate level. According to the model of upstream competition, this fact yields higher upstream mark-ups on Kauai relative to Maui, although higher upstream mark-ups account for a very small portion of the implied cost difference. Second, prices on Kauai are typically lower than prices on Maui particularly for FS products as table 5 indicates.[31] The combination of slightly higher upstream mark-ups, lower general prices on Kauai and especially lower FS prices on Kauai imply lower overall costs. These possibilities suggest either a misspecification of the upstream model, an underestimated elasticity of aggregate or disaggregate demand on Kauai relative to Maui (or vice versa), or a misclassification of some FS products on Kauai. In light of these potential problems, I focus on merger simulations related to Maui rather than Kauai.

V. Merger Simulations

In this section, I analyze a number of hypothetical upstream mergers using the cost and demand estimates from the previous section. Competition in the downstream sector is unaffected by the merger except through the wholesale prices emerging from the new upstream equilibrium.[32] Due to the relationship between upstream mark-ups and wholesale prices, any change in upstream mark-ups can be interpreted as a change in wholesale prices. The issues of interest concern the effect of the merger on prices, quantities, upstream and downstream mark-ups, consumer and producer surplus, and total welfare.

[31] Taxes on Kauai are 1¢ higher per gallon throughout the sample.

[32] In markets where vertical integration exists, merger simulation would also need to account for the coordination of downstream pricing activity following a merger.

These simulations involve a number of assumptions. First, I assume that the market structure does not change following a merger. In particular, no entry occurs at the upstream or downstream levels in response to a merger. Moreover, no retailers change their brand affiliation. Second, I assume that the cost structure does not change following the merger. Thus, the merger only involves coordination of upstream pricing for the merged firms given their idiosyncratic costs. Alternatively, I could assume that the merged firm faces the lower of the pre-merger costs. To the extent that cost savings are associated with a merger, the reported calculations would serve as an upper bound on price changes and welfare effects.

I consider five primary mergers: Shell-Texaco, Chevron-Texaco, Chevron-Shell, and Chevron-Shell-Texaco. As noted earlier, Texaco withdrew from the Hawaiian petroleum market in order to obtain approval for its merger with Shell. Thus, the first simulation addresses the validity of these concerns in a subset of the Hawaiian islands. Given the later merger of these companies with Chevron, the next two simulations examine the impact of these subsequent mergers under different possible divestitures by Shell and Texaco. The final simulation reflects the predicted outcome of the various mergers when no divestiture requirements were placed on Shell or Texaco. As an additional albeit unrealistic experiment, I consider the implications of an upstream merger to monopoly.

Table 10 presents the market responses to the various mergers. The primary effect of the mergers arises through the higher upstream mark-ups and, hence, higher wholesale price charged by the merged firms. In other words, the coordination of upstream pricing implies sufficient market power to permit the merged firms to increase their wholesale prices without losing too many consumers. Other upstream firms, on the other hand, respond very little to the higher prices of the merged firms. Regardless of brand affiliation, downstream firms do not adjust their mark-ups very much in response to the higher costs faced by the subset of retailers associated with the merger. These latter results reinforce the interpretation of the parameter estimates as implying fairly competitive behavior at the retail level.[33] The net effect of these changes in pricing behavior implies overall increases in retail prices at stations affiliated with the merged companies approximately equal to the increase in the wholesale price. Prices at other stations do not change very much.

Turning to the aggregate welfare effects of the mergers, table 11 presents the implications of the merger simulations for consumer and producer welfare. Naturally, the higher retail prices imply that consumer welfare falls. However, the highly elastic product-level demand implies relatively low welfare losses to consumers due to the price increases. Given the approximately 112,000 registered vehicles on Maui at this date, the simulations suggest that the average consumer would require roughly 23¢ to 46¢ compensation per month to offset the negative effects of the merger.[34] Only in the fourth case where Chevron, Texaco and Shell merge (or the monopoly case) leading to large predicted increases in prices do the consumer welfare losses become substantial. Nonetheless, the model implies that consumers are sufficiently willing to substitute among alternatives that the effects of the merger on consumer welfare are never terribly severe.

Predicted profits naturally rise following the merger. However, these effects are asymmetric across types of firms. While both the merged and other upstream firms experience significant profit increases, downstream stations affiliated with the merger experience non-trivial decreases in profits. To a large extent, these downstream profit decreases are offset by increases in the profits of stations not associated with the merger. Moreover, the net effect on overall upstream and downstream profits is significantly positive.

[33] However, the finding of nearly competitive behavior at the retail level does not diminish the usefulness of the two sector model since the exact nature of substitution among downstream firms has possible implications for the effect of different upstream combinations.

[34] However, such a direct statement is somewhat inappropriate due to uneven effects across consumers.

The overall effect of most of the mergers is fairly small. Intuitively, while product-level demand is highly elastic, aggregate demand is relatively inelastic. Thus, the model predicts that much of the lost consumer welfare due to the purchase of less desirable alternatives involves a transfer to firms, but few of the consumers cease purchasing altogether. Interestingly, the point estimates of welfare losses are not monotonic in the combined pre-merger market shares of the merging companies. This latter result indicates the importance of accurately characterizing the implications of downstream competition for upstream market power.

The exact evaluation of these results is debatable and largely depends on the criteria that one wishes to use to evaluate the effect of a merger. On the one hand, the model predicts that aggregate market power will increase following a merger leading to higher prices and decreases in consumer and total welfare. Such a prediction may suggest that antitrust authorities should prevent such mergers. However, these predicted decreases in consumer welfare appear to be relatively small. Moreover, increases in profits largely offset the declines in consumer welfare implying small decreases in overall welfare. In the event that cost savings are realized following the merger, the predicted decreases in both consumer and overall welfare may disappear.

Of course, these results are applicable to a very small portion of the national market that would be affected by such mergers. Thus, any general conclusions about the overall effects of these types of mergers in the petroleum industry are limited.[35] Nonetheless, the results suggest that the nature of aggregate and disaggregate demand for gasoline products may imply relatively modest decreases in overall welfare due to most mergers. Moreover, the general techniques pre-

[35] The lack of post-merger observations in the data implies another weakness of the current analysis, namely the inability to compare the predicted impact of prices and quantities with actual observed changes following a merger. Such analysis could provide a useful form of validation for this type of structural analysis.

sented in this study allow examination of alternative merger scenarios in the petroleum industry and other industries.

VI. Conclusion

This paper proposes techniques for examining mergers in settings where firms are not perfectly integrated into the final goods market. In particular, the model allows evaluation of the effect of upstream mergers through the inference of both downstream and upstream mark-ups by combining a model of downstream competition with a model of upstream competition. To the extent that downstream firms are differentiated or situated in a certain way in the product space, upstream market power and the effect of an upstream merger will depend on appropriate measurement of downstream market power. The current model allows such considerations by modelling both upstream and downstream pricing behavior.

More generally, the techniques presented in this paper expand the scenarios that can be examined in empirical work of oligopolistic industries. Although costs are unobserved at both the downstream and upstream levels, the restrictions of a combined model of upstream and downstream competition allows computation of both upstream and downstream mark-ups thereby permitting the calculation of the discrepancy between observed prices and total marginal costs. Thus, one can infer upstream and overall market power even without observing actual intermediate transactions. Since market power may exist at multiple levels of an industry and final prices reflect the behavior of agents at multiple levels of a distribution chain, such techniques may often be required to accurately characterize the extent to which final outcomes in an industry diverge from perfectly competitive outcomes.

However, the reliance on the structural model of upstream and downstream competition naturally implies a number of potentially unreasonable restrictions. The current model places strong restrictions on the terms of exchange between upstream and downstream firms. These assumptions may be violated if upstream firms use nonlinear pricing strategies such as quantity discounts or fixed franchise fees. Due to the unobservable nature of these intermediate transactions, the ability to distinguish between different vertical relationships may be limited.[36] Nonetheless, situations in which vertical relationships differ in known ways as when some retailers are vertically integrated may provide variation that permits identification of alternative relationships. The combination of this type of information along with other information about the terms of vertical relationships may allow more complete analysis of overall market power in an industry.[37]

The current study also imposes strong assumptions on the competitive conduct of both upstream and downstream firms. As in other settings, these assumptions may be invalid when firms engage in tacitly collusive behavior. Such assumptions may be particularly problematic in industries such as the petroleum industry where a small number of upstream firms supply much of the downstream market. While previous research has examined the possibility of collusive behavior in single sectors of an industry, the prospect of distinguishing between different modes of conduct at the upstream as well as downstream level is an important avenue of for future research.

Appendix

The demand model developed in Section I requires specification of two dis-

[36] As noted earlier, the work of Villas-Boas (2001) provides an important initial step in this direction based on non-nested GMM tests.

[37] However, an obvious problem is the potential endogeneity of the vertical relationship. Shepard (1993) provides an analysis of these decisions for the petroleum industry.

tributions. The first relates to unobserved heterogeneity reflected in u_{ij} while the second concerns the distribution of consumer locations. I will address each of these distributions in turn.

One possibility would be to assume that u_{ij} is distributed *iid* across consumers and products with, for example, a Type I extreme value distribution. In general, such an assumption imposes untenable restrictions on consumer behavior as all substitution effects depend only on mean utilities, and thus aggregate market shares, rather than on specific characteristics of alternatives. However, if the disutility of distance is sufficiently large, the consumer-specific location term implies that consumers have preferences which are correlated across products located near her. Thus, the standard problems with an *iid* assumption would not arise.

Despite the attractive tractability of an *iid* assumption, consumers may have correlated preferences across product characteristics other than location. In particular, consumers may have an affinity for a particular grade of gasoline and service level. Since grade and service level are discrete characteristics, a nesting approach, such as a nested logit model, may be appropriate. However, a complication arises from the overlapping nature of the grade and service level nests. For example, a SS-RU product shares the SS nest with other products which are SS-RU, but also those which are SS-MU and SS-PU. Similarly, it shares the RU nest with some products which are FS. An *a priori* ordering of the nests restricts substitution between products that differ in one dimension, but coincide in the other.

To account for this problem, I employ Bresnahan, Stern and Trajtenberg's (1997) adaptation of McFadden's (1978) GEV model. Letting $g(j) \in \{RU, MU, PU\}$ denote the grade and $s(j) \in \{SS, FS\}$ denote the service level of product j, the resulting local choice probability for product j in the setting of demand for retail gasoline products is given by

$$P_j(l_i) = \frac{a_g \exp\left(\frac{\delta_j+\lambda d_{ij}}{\phi_g}\right)\left[\sum\limits_{k\in g(j)} \exp\left(\frac{\delta_k+\lambda d_{ik}}{\phi_g}\right)\right]^{\phi_g-1} + a_s \exp\left(\frac{\delta_j+\lambda d_{ij}}{\phi_s}\right)\left[\sum\limits_{k\in s(j)} \exp\left(\frac{\delta_k+\lambda d_{ik}}{\phi_s}\right)\right]^{\phi_s-1}}{G_i} \tag{A1}$$

where $\phi_g \in [0,1]$ and $\phi_s \in [0,1]$ are unknown parameters, $a_g = \frac{(1-\phi_g)}{(2-\phi_g-\phi_s)}$, $a_s = \frac{(1-\phi_s)}{(2-\phi_g-\phi_s)}$, $d_{ik} = d(l_i, L_k)$ and

$$\begin{aligned} G_i = a_g &\left\{\left[\sum_{k\in RU} \exp\left(\frac{\delta_k+\lambda d_{ik}}{\phi_g}\right)\right]^{\phi_g} + \left[\sum_{k\in MU} \exp\left(\frac{\delta_k+\lambda d_{ik}}{\phi_g}\right)\right]^{\phi_g} + \left[\sum_{k\in PU} \exp\left(\frac{\delta_k+\lambda d_{ik}}{\phi_g}\right)\right]^{\phi_g}\right\} \\ &+ a_s\left\{\left[\sum_{k\in SS} \exp\left(\frac{\delta_k+\lambda d_{ik}}{\phi_s}\right)\right]^{\phi_s} + \left[\sum_{k\in FS} \exp\left(\frac{\delta_k+\lambda d_{ik}}{\phi_s}\right)\right]^{\phi_s}\right\} + e^{(\delta_0+\lambda d_0)}. \end{aligned} \tag{A2}$$

with alternative 0 as the only member of a unique set of goods. Thus, there are two distributional parameters to estimate, ϕ_g and ϕ_s.

The numerator of $P_j(l_i)$ contains two components, one related to the grade of product j and another related to service level. Goods that coincide with product j along the grade or service level dimensions will have a systematic effect on the choice probabilities in a way which becomes stronger as the goods share more characteristics. The strength of this correlation depends on the values of the parameters ϕ_g and ϕ_s. As either ϕ goes to one, the strength of the correlation associated with the relevant product characteristic diminishes. For example, if $\phi_s = 1$, the model is a nested logit by grade only. Moreover, $\phi_g = \phi_s = 1$ yields a standard multinomial logit model. As either ϕ goes to zero, the correlation in preferences for products sharing the associated characteristic becomes stronger. In the limit, differentiation is absolute with no substitution across products that differ in the relevant dimension.

The demand model also requires information on the locations of consumers as well as specification of a metric describing the distance from consumer locations to products. The precise locations relevant for consumers depend on dynamic issues and consumer travel behavior with the potential of yielding an extremely complex and unstable distribution of locations. I make the simplifying assumption that the relevant location is the consumer's residence. Since it is automobile owners who are deciding where to purchase gasoline, one potential source of information about consumer locations is census data on vehicle holdings of residents. From a conceptual point of view, this assumption may not be a particularly bad first approximation. If consumers return to their homes at some point, then it may be reasonable to assume that they use this location as a main point of reference when considering where to purchase gasoline taking into account their current gasoline holdings and future travel patterns. Moreover, consumers likely spend a fair amount of time travelling in close proximity to their residences.

Given this assumption, I select the driving distance between the consumer's residence and the locations of products along a reasonable route as the metric $d(l_i, L_j)$. While the choice of a route is slightly arbitrary, certain main roads appear to be logical routes between two points while other routes can be ruled out as unreasonable. Although this metric is not ideal, it avoids problems associated with other metrics such as the great circle distance, or "distance as the crow flies," that could distort the actual travelling distance between locations. This distortion would be particularly severe in Hawaii since roads tend to circle the islands rather than crossing the interior.

Employing census data on the distribution of vehicles by residence requires additional assumptions due to aggregation found in the census. While the census provides detailed information to the level of census block groups, it contains no information of the distribution of consumers within the block groups. I make the simplifying assumption that all consumers in a census block are located at roughly the center of the block where the central point is generally determined according to the Census Bureau's interior latitude and longitude points. In many cases, census blocks are small enough that this assumption is not particularly troubling. In most cases where blocks are relatively large, it is fairly easy to identify regions which should be the primary site of residence.[38]

The use of census data ignores the importance of one major group of consumers who are ubiquitous in Hawaii, namely tourists. To account for these consumers, I compiled a fairly complete list of accommodations found in Hawaii and use these sites as the relevant locations for tourists. I assume that each room of a hotel is occupied and that a single vehicle is associated with each room. Of course, these assumptions are likely to be violated since all lodging properties will rarely be fully occupied nor will each tourist necessarily rent a single (or any) car. The hope is that these two effects will roughly negate each other so that the bias introduced to the distribution of tourist locations is negligible. In addition, a major focal point for tourists is the airport where rental car companies are located. Consequently, I assume that tourist consumers equal to the number of lodging tourists are also located at the major airport on any given island.

To summarize, I assume that there is a set of consumer locations l_i for $i = 1, ..., I$. For permanent inhabitants of Hawaii, these locations are the residences of automobile owners about whom information is available from census block group data. For tourists, locations are either the major airport on the island or the locations of accommodations.[39] One convenient implication of these assumptions is that the distribution of consumer locations is discrete. Thus, the aggregate market share function for product j is

$$S_j(\delta, L, \lambda, \phi) = \sum_{i=1}^{I} \varphi_i P_j(l_i) \tag{A3}$$

[38] Most of the large census blocks in Hawaii cover areas which are primarily jungles, mountains or volcanoes. Both commonsense and the absence of roads would suggest that consumers do not in fact inhabit large portions of these blocks.

[39] I do not distinguished between permanent residents and tourists except in terms of their locations. An interesting extension could examine whether the composition of the consumer population impacts product-level demand and market outcomes due to, for example, differences in price sensitivity across consumer groups.

where $\varphi_i = \Pr(l = l_i)$ is the empirical probability that a consumer's location is l_i.[40] This simplification avoids difficulties that could arise if one were to use a parametric specification for $g(l)$ particularly in light of the irregular support of consumer locations.

Linking the predictions of the model to the observed outcomes requires specification of the total amount that could be sold in the market, namely $\bar{Q}$ from equation (7). This potential quantity is important since it determines the share of the outside alternative and, thus, has implications for the elasticity of aggregate demand. Due to this strict discrete choice formulation that I use, I follow Nevo (2001) and choose to parameterize $\bar{Q}$ as proportional to the number of vehicles registered in a market at a given date. While the factor of proportionality could be estimated as in Berry, Carnall and Spiller (1996), I assume that each vehicle could make five 10 gallon fill-ups over the course of a time period so that $\bar{Q}$ equals 50×the number of registered vehicles for a market-date combination. Admittedly, this assumption is a bit ad hoc. However, given the restrictive nature of the outside alternative, this assumption should not introduce any more systematic bias than already exists. In any case, the results do not appear sensitive to choice of the factor of proportionality.

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Table 1: Major Recent Mergers in the Petroleum Industry

Companies	Year
Conoco - Phillips Petroleum	2001
Conoco - Gulf Canada Resources	2001
Valero Energy - Ultramar Diamond Shamrock	2001
Phillips Petroleum - Tosco	2001
Chevron - Texaco	2000
BP Amoco - ARCO	1999
Exxon - Mobil	1998
Shell - Star Enterprise - Texaco	1997

Source: U.S. Department of Energy

Table 2: Product-level Variable Definitions

Variable Name	Description
Market	island (Kauai, Maui)
Date	time period (1-24)
Price	$/gallon
Volume	gallons
MU	= 1 if product is medium unleaded
PU	= 1 if product is premium unleaded
FS	= 1 if product is full-service
MS	= 1 if product is mini-service
Service	= 1 if station offers automotive service
Cstore	= 1 if station has convenience store
Brand	Chevron, Gas Express, Shell, Texaco, Unocal, unbranded
Fuelpos	number of fueling positions at station
Pumps	total number of fueling pumps at station
Hours	weekly operating hours of station
Location	latitude and longitude (decimal degrees) of station

Table 3: Number of Stations and Aggregate Market Shares by Brand, Market and Selected Dates

		Maui		Kauai	
Date	**Brand**	**Stations**	**Mkt Share**	**Stations**	**Mkt Share**
10/90	**Chevron**	13	32.4%	9	53.0%
	Gas Express	-	-	-	-
	Shell	8	30.8%	8	35.1%
	Texaco	4	10.4%	-	-
	Unocal	6	19.0%	8	11.9%
	Unbranded	3	7.5%	-	-
8/92	**Chevron**	11	33.3%	9	45.0%
	Gas Express	1	2.7%	-	-
	Shell	7	31.2%	8	39.7%
	Texaco	5	11.1%	-	-
	Unocal	7	18.8%	6	14.1%
	Unbranded	3	2.9%	1	1.1%
7/95	**Chevron**	7	23.7%	8	48.9%
	Gas Express	4	16.3%	-	-
	Shell	6	26.2%	7	40.2%
	Texaco	5	16.4%	-	-
	Unocal	8	15.6%	4	8.3%
	Unbranded	3	1.9%	2	2.6%

Source: Whitney Leigh Corporation

Table 4: Station Characteristics by Configuration, All Dates & Markets

Variable		Station Configuration					
		SS only	MS only	FS only	SS & FS	MS & FS	All
Automotive service (%)		14.2	57.4	74.7	77.8	93.1	56.4
Convenience store (%)		72.5	22.3	7.4	35.2	5.6	35.9
Branded (%)		82.3	91.2	99.6	100.0	99.6	93.0
Fueling positions	mean	5.8	2.8	1.9	7.2	5.9	5.0
	std dev	3.0	1.1	0.3	2.5	2.0	2.9
Total pumps	mean	17.0	6.5	4.1	21.3	14.8	13.8
	std dev	9.7	3.3	1.1	8.1	5.7	9.5
Weekly hours	mean	146.1	85.6	76.5	147.6	117.6	121.6
	std dev	26.9	18.0	16.9	24.9	29.1	38.2
Total volume	mean	86437	42648	30019	101603	91164	74644
	std dev	67119	30886	20210	39776	74042	60481
	max	248858	122291	96503	201317	353162	353162
	median	78693	29846	25368	99811	79944	61619
	min	3618	7099	4024	23191	15201	3618
Maui		344	88	5	217	163	817
Kauai		107	60	252	44	70	533
Total		451	148	257	261	233	1350

Note: Station configuration relates to the service levels sold at a station.

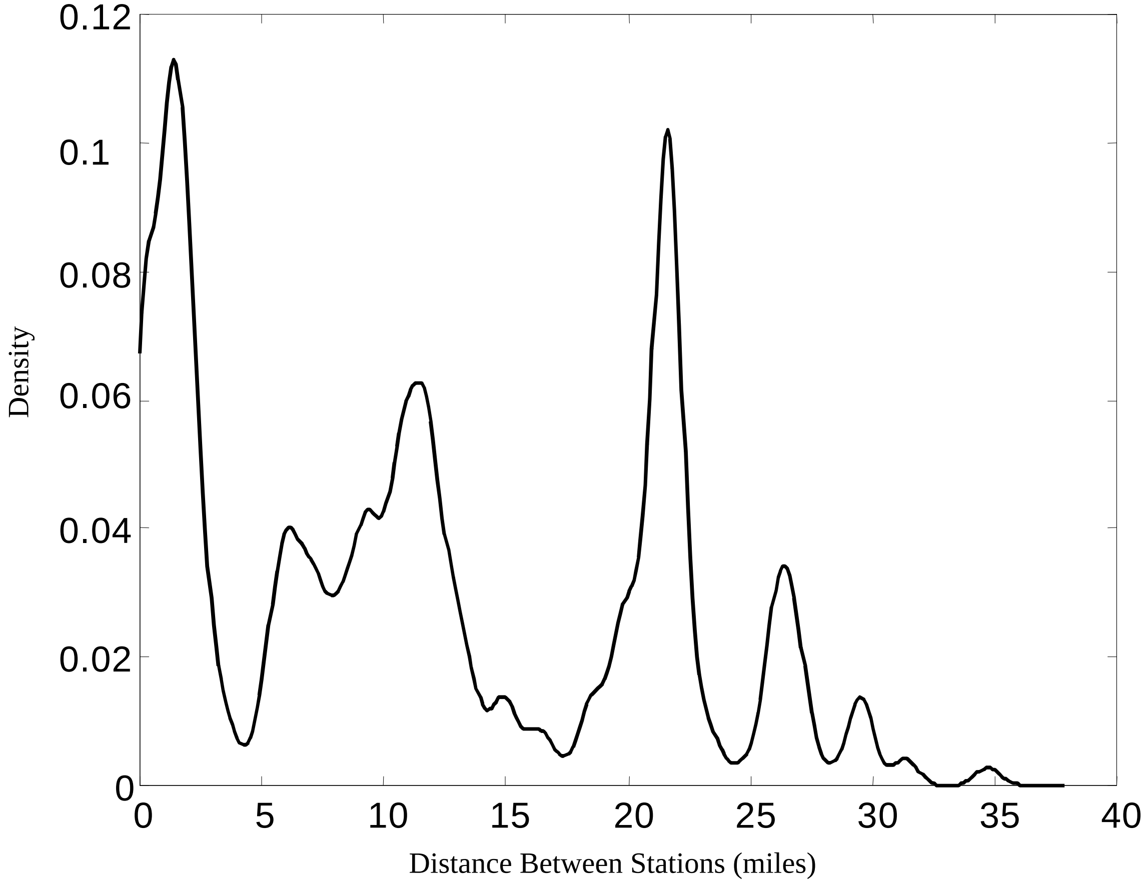
Source: Whitney Leigh Corporation.

Table 5: Price and Volume Statistics by Product Type and Market, 8/92

		Market			
		Maui		Kauai	
Product Type		Price	Volume	Price	Volume
SS/MS-RU	mean	1.616	42631	1.563	57902
	std dev	0.079	37433	0.073	34987
	max	1.926	168000	1.699	143466
	median	1.589	33835	1.539	56823
	min	1.567	4002	1.489	14311
	n	34		12	
SS/MS-MU	mean	1.699	13776	1.666	14924
	std dev	0.066	13494	0.049	11137
	max	2.002	65305	1.759	34190
	median	1.688	9464	1.669	11669
	min	1.659	755	1.609	3129
	n	25		7	
SS/MS-PU	mean	1.811	17108	1.732	22787
	std dev	0.072	17179	0.048	18240
	max	2.078	76647	1.809	71202
	median	1.789	12309	1.724	17307
	min	1.719	504	1.659	3982
	n	33		12	
FS-RU	mean	2.028	11366	1.721	17505
	std dev	0.093	8168	0.139	11348
	max	2.169	29168	1.934	52956
	median	2.039	7385	1.702	15490
	min	1.839	2200	1.502	5867
	n	18		18	
FS-MU	mean	2.105	3049	1.822	2321
	std dev	0.066	3984	0.172	1732
	max	2.206	17020	1.984	5980
	median	2.109	2256	1.939	2097
	min	1.959	500	1.593	815
	n	15		7	
FS-PU	mean	2.163	8056	1.840	11382
	std dev	0.073	7077	0.134	7248
	max	2.279	30284	2.039	27470
	median	2.162	5436	1.816	9646
	min	1.999	2013	1.673	3080
	n	18		17	

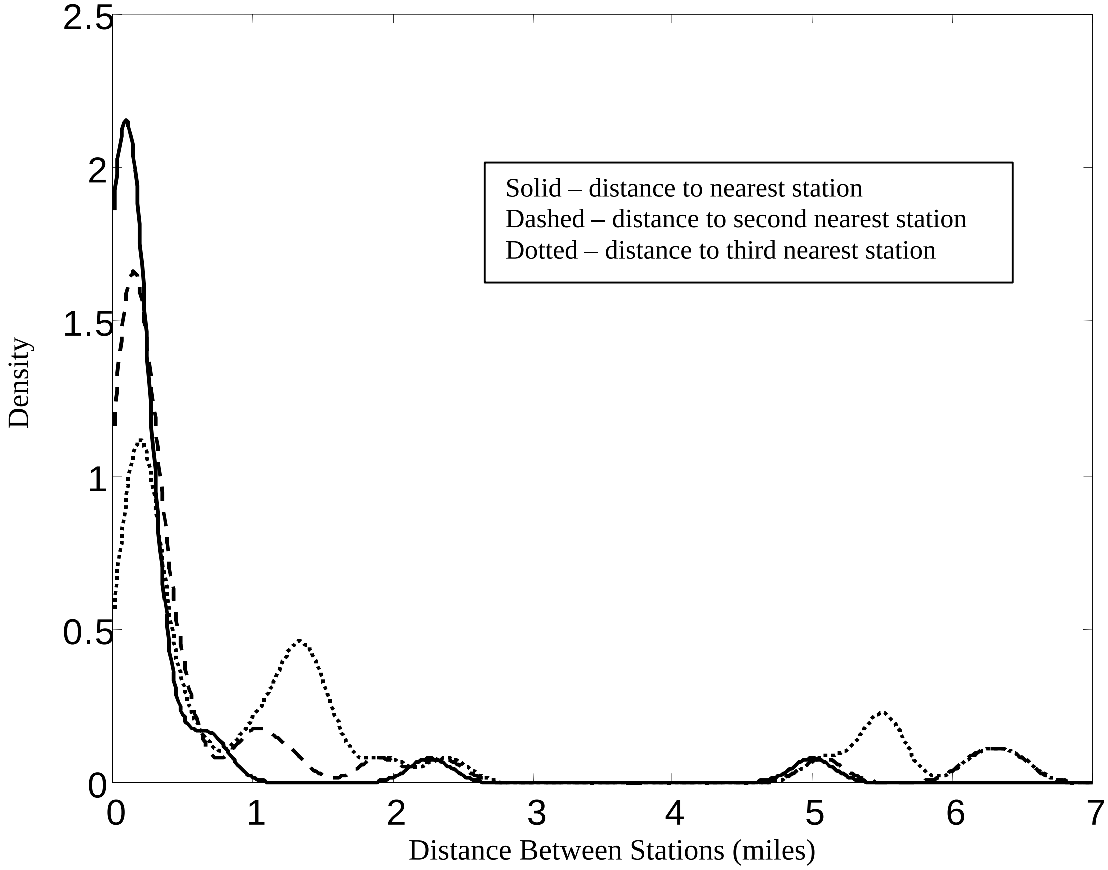
Source: Whitney Leigh Corporation

Figure 1: Nonparametric Density of Pairwise Distance Between Stations, Maui 12/92



Note: Gaussian kernel, bandwidth=0.5, N=561.

Figure 2: Nonparametric Densities of Distance to Competing Stations by Distance Criteria, Maui 12/92



Note: Gaussian kernel, bandwidth=0.15, N=34.

Table 6: Demand Parameter Estimates

Variable	Specification (1)	(2)	(3)
Fuelpos	-0.003	-0.005	-0.001
	(0.004)	(0.003)	(0.003)
Branded	0.114	0.088	0.138
	(0.039)	(0.037)	(0.041)
Hours	0.0017	0.0016	0.0017
	(0.0002)	(0.0002)	(0.0002)
Cstore	-0.018	-0.019	-0.017
	(0.016)	(0.014)	(0.014)
Service	-0.059	-0.062	-0.052
	(0.015)	(0.014)	(0.013)
MU	-0.523	-0.504	-0.553
	(0.039)	(0.041)	(0.038)
PU	0.0704	0.092	0.039
	(0.009)	(0.017)	(0.008)
FS	0.225	0.244	0.175
	(0.016)	(0.036)	(0.014)
MS	0.059	0.059	0.044
	(0.016)	(0.014)	(0.015)
l	-0.0214	-0.0173	-0.0242
	(0.0023)	(0.0008)	(0.003)
$f_{\mathbf{g}}$	0.1084	0.0905	0.1362
	(0.0104)	(0.0046)	(0.0014)
$f_{\mathbf{s}}$	0.1756	0.1419	0.1868
	(0.0007)	(0.0015)	(0.0006)
a	-2.013	-1.9714	-1.918
	(0.0204)	(0.0948)	(0.03)

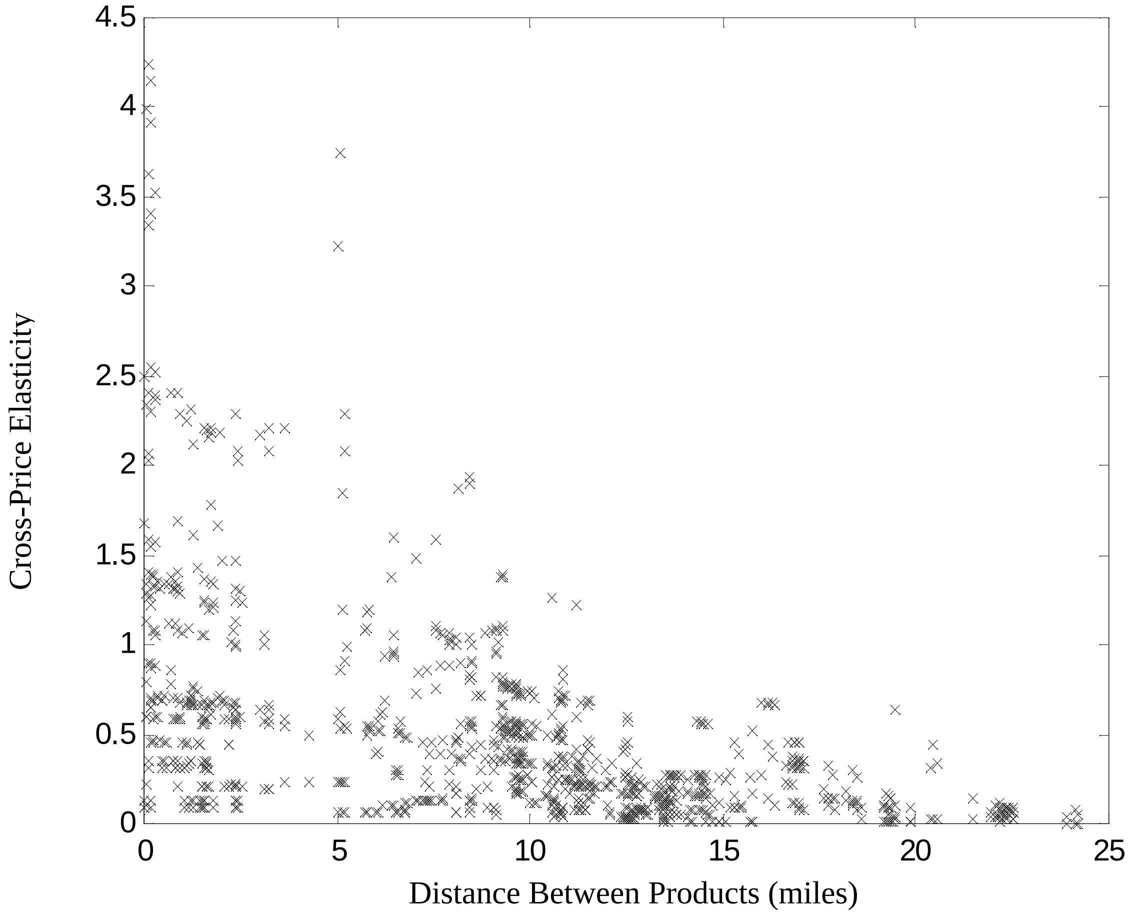
Note: Asymptotic standard errors corrected for spatial and temporal autocorrelation (Conley 1999) in parentheses. Date-market effects not reported. Columns differ by instruments employed.

Table 7: Average Estimated Own-Price Elasticities by Product Type and Market, All Dates

	Market	
Product type	**Maui**	**Kauai**
SS/RU	-18.34	-16.89
	(1.36)	(1.49)
SS/MU	-22.05	-20.01
	(1.92)	(2.2)
SS/PU	-23.08	-20.64
	(1.84)	(1.94)
FS/RU	-19.69	-17.79
	(1.61)	(1.64)
FS/MU	-23.29	-23.67
	(1.2)	(3.66)
FS/PU	-22.1	-21.15
	(0.95)	(1.63)

Note: Entry provides average estimated percentage change in quantity given 1% change in price. Number in parentheses is standard deviation of estimated own-price elasticities. Elasticities based on demand estimates from column 3 of table 6.

Figure 3: SS-RU Cross-Price Elasticities and Distances Between Products, Maui 7/95



Note: Each marker represents the percentage change in the volume of SS-RU product *j* given a 1% change in the price of SS-RU product *k* plotted against the distance between the products. $N = 33$ implying 1,056 cross-price elasticities.

Table 8: Estimated Downstream and Upstream Mark-ups by Brand and Product Type, Maui 7/95

A. Downstream mark-ups

		Chevron	Gas Express	Shell	Texaco	Unocal
SS/RU	**(1)**	0.0862	0.1004	0.0846	0.0895	0.084
	(2)	5.06%	6.03%	5.04%	5.42%	5%
SS/MU	**(1)**	0.0764	0.0885	0.0746	0.0805	0.0736
	(2)	4.25%	4.98%	4.2%	4.55%	4.16%
SS/PU	**(1)**	0.0775	0.085	0.0755	0.0812	0.0742
	(2)	4.09%	4.61%	4.02%	4.35%	3.95%
FS/RU	**(1)**	0.1039	-	0.1118	0.0977	0.1062
	(2)	4.91%	-	5.42%	4.63%	5.21%
FS/MU	**(1)**	0.0988	-	0.1016	0.0947	0.1011
	(2)	4.52%	-	4.75%	4.41%	4.89%
FS/PU	**(1)**	0.1022	-	0.1084	0.0971	0.1041
	(2)	4.56%	-	4.9%	4.45%	4.77%

Note: (1) provides average mark-up per gallon in dollars. (2) provides average percentage of retail price attributable to mark-up (i.e. mark-up/p). No Gas Express stations offer FS.

B. Upstream Mark-ups

		Chevron	Gas Express	Shell	Texaco	Unocal
RU	**(1)**	0.1132	-	0.1237	0.1161	0.1035
	(2)	6.64%	-	7.37%	7.03%	6.16%
MU	**(1)**	0.1099	-	0.1131	0.1107	0.0936
	(2)	6.11%	-	6.36%	6.27%	5.29%
PU	**(1)**	0.1105	-	0.115	0.1083	0.0965
	(2)	5.84%	-	6.12%	5.8%	5.14%

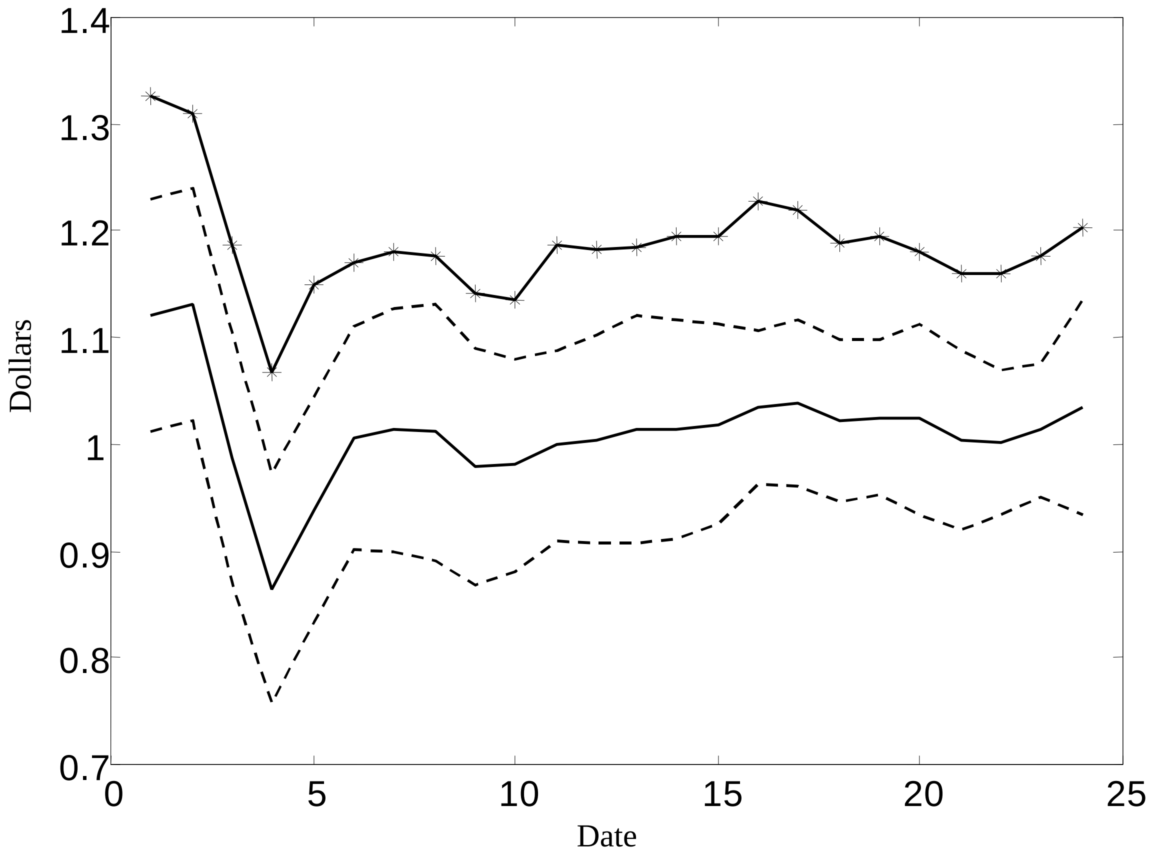
Note: (1) provides mark-up per gallon in dollars. (2) provides average percentage of SS retail prices attributable to the upstream mark-up (i.e. mark-up/p). Gas Express stations are vertically integrated and have no upstream mark-up.

Table 9: Cost Parameter Estimates

Variable		Specification (1)	(2)	(3)
Kauai	**Chevron**	0.871	0.904	0.824
		(0.059)	(0.045)	(0.048)
	Shell	0.863	0.894	0.819
		(0.04)	(0.031)	(0.034)
	Unocal	0.839	0.863	0.806
		(0.049)	(0.031)	(0.022)
	Unbranded	1.021	1.046	0.992
		(0.825)	(0.519)	(0.093)
Maui	**Chevron**	1.071	1.098	1.035
		(0.029)	(0.023)	(0.052)
	Gas Express	1.089	1.102	1.075
		(0.028)	(0.032)	(0.018)
	Shell	1.048	1.076	1.011
		(0.059)	(0.027)	(0.066)
	Texaco	1.035	1.063	1.0
		(0.187)	(0.089)	(0.031)
	Unocal	1.075	1.1004	1.042
		(0.03)	(0.023)	(0.025)
	Unbranded	1.09	1.114	1.063
		(0.036)	(0.063)	(0.075)
MU		0.096	0.092	0.089
		(0.051)	(0.044)	(0.053)
PU		0.176	0.174	0.173
		(0.017)	(0.016)	(0.014)
FS		0.28	0.284	0.285
		(0.018)	(0.019)	(0.0195)
MS		0.023	0.023	0.024
		(0.0067)	(0.0069)	(0.0064)

Note: Asymptotic standard errors corrected for spatial and temporal autocorrelation (Conley 1999) in parentheses. Date effects not reported.

Figure 4: Estimated SS-RU Costs for Chevron on Maui



Note: Solid line is estimated total costs of SS-RU for Chevron at each date. Dashed lines are asymptotic 95% confidence interval. Starred line is average SS-RU price (net of taxes) for Chevron at each date.

Table 10: Effects of Various Upstream Mergers on Market Outcomes, Maui 7/95

		(1)	(2)	(3)	(4)	(5)
Merging upstream firms		Chevron Texaco	Shell Texaco	Chevron Shell	Chevron Shell Texaco	All firms
Number of affiliated downstream firms	**M**	12	11	13	18	33
	NM	21	22	20	15	0
Dp_U	**M**	4,941	4,188	10,282	35,570	722,111
	NM	4,755	3,953	6,233	25,116	-
Dp_D	**M**	-1,288	-1,263	-1,773	-2,466	-4,111
	NM	667	555	1,099	2,767	-
D**p**	**M**	0.023	0.019	0.034	0.066	0.607
	NM	0.003	0.003	0.006	0.012	-
D**q**	**M**	-13,778	-13,205	-19,516	-26,944	-45,566
	NM	6,517	5,493	10,313	24,887	-
D**mark-up**$_U$	**M**	0.023	0.2	0.034	0.065	0.59
	NM	0.003	0.002	0.004	0.01	-
D**mark-up**$_D$	**M**	-0.001	0	0	-0.002	-0.001
	NM	0	0	0.002	0.004	-

Note: Each entry presents the average change in the relevant variable for the relevant group of firms. M refers to firms associated with the merger and NM refers to firms not associated with the merger. Example: Δq row M refers to the average change in volume (all products) for downstream stations affiliated with the merging upstream firms. Mark-up changes in dollar terms. Change in upstream profits for merging firms computed as combined post-merger profits less combined pre-merger profits.

Table 11: Welfare Effects of Various Upstream Mergers, Maui 7/95

	(1)	(2)	(3)	(4)	(5)
Merging upstream firms	Chevron Texaco	Shell Texaco	Chevron Shell	Chevron Shell Texaco	All firms
Pre-merger combined market share	40.1%	42.6%	49.8%	66.3%	100%
CV	31,041	26,729	52,223	120,524	1,320,527
Dp	17,747	14,362	27,919	57,808	586,451
$Dp_{\mathbf{U}}$	19,206	16,047	28,982	60,688	722,111
$Dp_{\mathbf{D}}$	-1,459	-1,685	-1,063	-2,880	-135,660
D**W**	-13,294	-12,367	-24,304	-62,716	-734,076

Note: CV is compensating variation. All welfare effects in dollars.