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ESTIMATING THE RESIDUAL DEMAND CURVE FACING A SINGLE FIRM*

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This paper presents an econometric technique for estimating the single firm residual demand curve that does not require the estimation of demand cross-elasticities. The technique is particularly suited for the estimation of firm market power in product differentiated industries, where cross-elasticities are notoriously difficult to measure. One estimated parameter is directly related to a firm's markup of price over marginal cost when product differentiation is extensive, when an industry consists of a dominant firm and a price-taking fringe, when a Consistent Conjectures Equilibrium is the correct oligopoly solution concept, when firms are Stackelberg leaders relative to their environment, or when firms are perfect competitors. The estimates can indicate power over price in other circumstances. An instrumental variables technique is employed, using firm-individuated factor prices to identify firm-specific residual demand. Yet even when instruments are unavailable, the technique produces elasticity estimates biased in the conservative direction of disproving market power. This methodology is applied to estimate the market power of three firms in an industry characterized by product differentiation: brewing. Over our 1962–82 sample period, Pabst and Coors had similar national market shares and each had high shares in several states. Yet Pabst was virtually a price-taker while Coors possessed substantial market power. Anheuser-Busch had market power in the early part of the sample, but little after 1975 when Miller Brewing changed the competitive nature of the industry.

1. Introduction

In industries with differentiated products, the extent of market power is hard to measure quantitatively. Any empirical method for measuring market power must take into account the theoretical insight that firms could interact in a variety of ways, each leading to different industry performance.[1] With

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[1]See Landes and Posner (1981) and Ordover, Sykes and Willig (1982) for recent theoretical treatments. Econometric studies quantifying the impact of firm conduct on market power include Rosse (1970), Iwata (1974), Gollop and Roberts (1979), Appelbaum (1979, 1982), Sumner (1981), and Bresnahan (1980, 1981b).

product differentiation, an additional problem for measuring market power arises: substitutability in demand. A firm producing a unique product may have substantial market power, as when no other firm produces a close substitute. But when another firm produces a nearly identical product, the first firm's 'monopoly' may be inconsequential. In an industry with many products, market power inferences therefore seem to require estimates of a great number of own- and cross-elasticities of demand, a project that is often stymied by data limitations. Several authors have attacked this problem by employing observable indicators of substitution closeness, like 'quality' or 'location',[2] to reduce the number of parameters that must be estimated. However, the data required for that approach cannot be observed in many industries.

In this paper we develop a new econometric approach to the problem of market power estimation, based on specification and estimation of the residual demand function facing a single firm. By residual demand function we mean the relationship between one firm's price and quantity, taking into account the supply response of all other firms. The residual demand curve of a firm in a perfectly competitive industry is flat, that of a monopolist is the same as the industry demand curve, and that of a firm in a product-differentiated industry lies between these extremes. The point of estimating a single firm residual demand curve rather than a structural demand system involving all firms in an industry is to economize on data. Even when the available data would not allow estimation of all of the elasticities with any precision, it is still possible to estimate the degree of market power through the appropriate summary statistic, the elasticity of the residual demand curve.[3] This approach should be particularly fruitful when the degree of product differentiation is uncertain or when the boundaries of the relevant market are unclear. In these same circumstances, accounting profits will be a poor indicator of market power; product differentiated firms may be earning socially valuable rents on superior product design, not monopoly profits.

The model presented in section 2 below specifies a general demand and supply system for all products; the 'supply curves' need not be those of perfect competitors, nor need the different products be perfect substitutes. Solving out the prices and quantities of all other firms' products the residual demand function for the firm of interest. By this procedure, any model of the demand and supply for all firms in an industry implies an equation for each firm's residual demand, and thus a demand elasticity for that firm. Under perfect competition with homogeneous products, one firm's contraction of output will be offset exactly by another's expansion, so that the residual

[2]See Bresnahan (1987), Cowling and Cubbin (1979) and Joskow (1983) for three such approaches to the automobile industry.

[3]See Lerner (1934) for this definition of market power. Landes and Posner (1981) provide a recent treatment.

demand curve is infinitely elastic. In the more general model, either product differentiation or oligopoly behavior[4] can lead to a residual demand curve with a negative slope. While the slope of the residual demand curve is a sensible definition of market power under product differentiation, the relationship between the residual demand elasticity and the firm's markup of price over marginal cost is unclear in some oligopoly theories; this issue is taken up in section 3.

Section 4 specifies and estimates the slopes of the residual demand curves for three U.S. brewing firms, Anheuser-Busch, Coors, and Pabst. The brewing industry has substantial product differentiation, but no satisfactory estimates of structural demand elasticities and cross-elasticities exist to support traditional methods of assessing market power.[5] Antitrust enforcers and some economists who study the industry have suspected that brewers have substantial market power, but no study has yet claimed to quantify the degree of that market power.[6] However, several recent proposed mergers in the industry have been prevented on antitrust grounds.

This paper provides a methodology to detect single-firm power by econometric means. In a competitive world, movements in market price will be completely explained by the supply curve of other firms. If Firm 1, a competitor, should autonomously decide to change its output, Q_1, that will have no effect on price. Thus all changes in Q_1 which originate within Firm 1 will have no predictive power for price; its residual demand curve is flat. We show below how this observation leads to an econometric test for whether a firm has market power and just give the intuition here. The econometric method predicts Firm 1's price P_1 on the basis of Q_1 and of variables that shift other firm's costs. If, empirically, the variables shifting other firms' costs, rather than the firm's own quantity, explain prices, we conclude that the firm has no market power. In this analysis, Q_1 is treated as endogenous, and instrumented for with variables that shift Firm 1's costs alone. In an application, these instruments will be an important part of the procedure. In our brewing application, the natural experiment is created by regional variations in wage rates and by firm capacity, as brewing plant alterations are infrequent and plant capacity is a lumpy investment.

We find that for the period 1962–82, Anheuser-Busch had some market power, Coors had substantial market power, and Pabst faced a flat residual demand curve. These estimates sharply distinguish the market power held by

[4]See Ordover, Sykes and Willig (1982) and section 3.

[5]Elzinga (1982) presents a detailed review of brewing industry history. The demand for beer has been discussed by Greer (1971, 1981), Hogarty and Elzinga (1972), and Kelton and Kelton (1982). Product differentiation issues are discussed in Greer (1981).

[6]Brewing industry market power is evaluated in Elzinga (1982), Horowitz and Horowitz (1965), and Greer (1981). These studies dispute the importance of market power in the industry. Ornstein (1981) describes several beer industry anti-merger enforcement actions brought by the Justice Department during our sample period.

Pabst and Coors even though the two firms had similar nationwide market shares. These empirical findings and other institutional details are used to form a unified picture of the brewing industry in the discussion below.

2. Derivation of residual demand

In this section, the notion 'residual demand curve facing a particular firm' is derived. This notion is familiar in the case of a dominant firm with a price-taking fringe. We first show how the same notion can be derived in an arbitrary context. Throughout this derivation demand curves are arbitrary, so that product differentiation may or may not be present. Similarly, the supply of substitutes can vary, as the conduct of other firms may vary from perfect competitors with flat marginal cost curves to part of a cartel with the firm of interest.

The (inverse) demand function for Firm 1, the firm of interest, is

$$P_1 = P^1(Q_1, \boldsymbol{Q}, Y; \alpha^1). \tag{1}$$

Here P_1 and Q_1 are price and quantity for Firm 1's (single)[7] product, $\boldsymbol{Q}$ is a vector of quantities for other firms' products, Y are exogenous variables entering the demand system, and α^1 are parameters. Q_i is a typical element of $\boldsymbol{Q}$. $\boldsymbol{Q}$ includes all possible substitutes for the product including production by firms in different 'industries'. No a priori market delineation has been performed. In the special case where all firms' products are identical, eq. (1) would be written

$$P_1 = P^1\left(Q_1 + \sum_i Q_i, Y; \alpha^1\right) \tag{1'}$$

In this case, the parameters α^1 are the own-price demand elasticity, the income elasticity, etc., for the 'market' as a whole. If, as in (1'), there is no product differentiation, both market definition analyses and econometric estimation of α^1 are straightforward. In the more general (and usual) case, (1), both of these can form formidable undertakings. Then α^1 includes cross-price as well as own-price demand elasticities.

[7]The methods described in this article can also be used to estimate the market power of an aggregate of firms. Estimating the market power of a group of firms is of particular interest because a hypothetical cartel price increase of five percent forms part of the algorithm for an antitrust market under the U.S. Department of Justice Merger Guidelines (1984, section 2.0). In this way, our methods have been applied to a market definition problem by Scheffman and Spiller (1987). The present paper is extended to estimate the gains from merger in product differentiated industries in Baker and Bresnahan (1985).

The model also includes (inverse) demand equations for Q, the vector of quantities of all other relevant products.

$$P_i = P^i(\boldsymbol{Q}, Q_1, Y; \alpha^i) \quad \text{for all} \quad i \neq 1. \tag{2}$$

Eq. (2) continues the notational convention of treating Q_1 asymmetrically. The parameters α^i include many also found in α^i the parameters of the demand curve for Firm 1. For example, if (1′) holds, then the α^i are constrained so that Q and Q_1 enter $P^i(\cdot)$ only through their sum. The vector of prices P_i, for $i \neq 1$, is denoted P.

The third element of the model is the supply behavior of all the firms $i \neq 1$. Their supply relations are written in the form 'marginal cost equals perceived marginal revenue' (PMR)

$$MC^i(Q_i, \boldsymbol{W}, W^i; \beta^i) = PMR^i(\boldsymbol{Q}, Q_1, Y; \alpha^i, \theta^i) \quad \text{for all} \quad i \neq 1, \tag{3}$$

where $PMR^i(\cdot)$ is $P^i(\cdot) + Q_i \cdot \sum_j ((\partial P^i/\partial Q_j)(\partial Q_j/\partial Q_i))$.

Marginal cost depends on quantity and on a vector of industry-wide factor prices, W. It further depends on firm-specific factor prices, W^i, none of which are in the industry-wide vector W. Firm i may face different prices for some inputs because of its location, or W^i may be reinterpreted as the shadow rental value of some untraded asset of firm i. Costs also depend on parameters β^i. On the marginal revenue side, PMR's first four determinants are the variables in the structural demand curves (2). Following Bresnahan (1981a) and Ordover et al. (1982), we also let PMR depend on conduct variables denoted θ^i; the vector θ^i indexes the oligopoly solution concept for all firms and thus determines the 'conjectures' $\partial Q_j/\partial Q_i$.

Just as the investigator does not know the cross-price elasticity of demand, so too are the conduct parameters θ^i unknown. The approach taken by the sources cited in footnotes 1 and 2 is to, at this stage, specify functional forms for (1), (2), and (3), and to complete the model by adding another equation like those in (3) for Firm 1. Then the parameters α^i, β^i, and θ^i are estimated econometrically on industry data. Our approach will be to first manipulate the model so that we only estimate a single equation – Firm 1's residual demand curve. This approach will not separately estimate any of the individual cost, demand, or behavioral parameters β^i, α^i and θ^i. Instead, we estimate only their joint impact on market power through the slope of the residual demand curve.

The first step in deriving the single-firm residual demand function is to solve the eqs. (2) and (3) simultaneously for the vectors $\boldsymbol{Q}$ and P. The notation β^I is the union of all cost parameters β^i, and α^I represents all demand parameters α^i, for all $i \neq 1$. W^I is the union of the W^i, and θ^I the union of the θ^i, for all $i \neq 1$. This emphasizes that W^I and θ^I are the

firm-specific costs and conduct variables for all the firms *except* the one under study. In this notation, the solution to (2) and (3) for $\boldsymbol{Q}$ is

$$\boldsymbol{Q} = E^I(Q_1, Y, \boldsymbol{W}, W^I; \alpha^I, \beta^I, \theta^I), \tag{4}$$

where $E^I(\cdot)$ means that this is the equilibrium quantity in all of the markets $i \neq 1$. $E^I(\cdot)$ is a vector of functions of the form $Q_i = E^i(\cdot)$. Each element of E^I is a partial-reduced form; the only endogenous variable on the right is Q_1. The elasticity of Q_i with respect to Q_1 in this partial-reduced form is denoted ε_{i1}

$$\varepsilon_{i1} = \frac{\partial \ln E^i}{\partial \ln Q_1}.$$

The residual demand curve facing Firm 1 is derived by substituting E^I into (1)

$$P_1 = P^1(Q_1, E^I(Q_1, Y, \boldsymbol{W}, W^I; \alpha^I, \beta^I, \theta^I), Y; \alpha^1). \tag{5}$$

Substituting out the redundancies, and employing the notation α for the union of α^I with α^1 we have

$$P_1 = R(Q_1, Y, \boldsymbol{W}, W^I; \alpha, \beta^I, \theta^I), \tag{6}$$

where the notation $R(\cdot)$ means (inverse) residual demand. The observable arguments of the residual demand curve are threefold: own quantity, structural demand variables, and other firms' cost variables. The parameters of the residual demand curve are functions of the underlying structural parameters α and β^I, and the behavioral parameters θ^I. A residual demand curve has the costs of all other firms included, so that factor prices paid by those firms are properly incorporated in $R(\cdot)$. Except in the case of perfect competition, however, the costs of other firms do not completely determine P_1, so that $R(\cdot)$ varies with Q_1.

Differentiating (5) in the logarithm shows that its elasticity with respect to Q_1 depends on all of the elasticities of $P_1(\cdot)$, the (inverse) demand function in eq. (1), as well as on the elasticities of other firms' reactions, ε_{i1}

$$\eta_1^R \equiv \frac{\partial \ln R}{\partial \ln Q_1} = \eta_{11} + \sum_{i \neq 1} \eta_{1i} \varepsilon_{1i}. \tag{7}$$

In eq. (7), η_1^R is the parameter we will estimate, and η_{1j} is $\partial \ln P^1(\cdot)/\partial \ln Q_j$.[8] The underlying parameters α, β^I, and θ^I cannot in general be recovered by estimating (6). Only the degree of market power, given by η_1^R, can be estimated, not its source. Because the (inverse) residual demand curve for Firm 1, eq. (6), contains only one quantity (Q_1), $1/\eta_1^R$ is the elasticity of residual demand and η_1^R is the (inverse) elasticity or flexibility of residual demand.

The model is closed by specifying the supply relation for Firm 1.

$$P_1 - MC^1(Q_1, \boldsymbol{W}, W^1; \beta^1) = M^1(\boldsymbol{Q}, Q_1, Y; \alpha^1, \theta^1), \tag{8}$$

where $M^1(\cdot) = MR^1(\cdot) - P_1$. Eq. (8) can be thought of as a transformation of the familiar equilibrium condition equating marginal revenue with marginal cost. To write the model entirely in (P_1, Q_1) space, we substitute out the Q on the right of (8). Again, we use E^I and suppress redundancies

$$P_1 - MC^1(Q_1, \boldsymbol{W}, W^1; \beta^1) = MK^1(Q_1, Y, \boldsymbol{W}, W^I; \alpha, \beta^I, \theta), \tag{9}$$

where $MK(\cdot)$ is the residual markup, and θ is the union of θ^I and θ^1. The intersection of supply relation (9) and residual demand curve (6) determines P_1 and Q_1.

In oligopoly theory, specifying the model this way would be a peculiar but correct way to determine equilibrium values. Our purpose in doing so is to demonstrate that the residual demand curve (6) is econometrically identified, because we estimate (6) at the level of the firm. Eq. (6) can be econometrically estimated when a firm-specific cost variable W^1 exists because W^1 is the exogenous variable in eq. (9) excluded from eq. (6).

3. The residual demand elasticity and the markup

Unless the firm is a price taker, its residual demand curve will not be flat. Thus a nonzero η_1^R implies $P_1 > MC_1$. It is important to clarify, however, that there is not always an exact relationship between η_1^R and the markup.

First, consider a firm which is a Stackelberg leader relative to its environment. For such a firm

$$-\eta_1^R = \frac{P_1 - MC_1}{P_1}, \tag{10}$$

and it *is* proper to infer the markup from the residual demand curve. The point is more general than the simple Stackelberg model. For example, in the

[8]Thus η_{ij} is a demand 'flexibility'. See Frisch (1959).

case of a dominant firm with a fringe of smaller producers, Firm 1 is in fact a leader relative to its whole environment. It knows that the fringe's supply curve affects the elasticity of demand it faces, and acts accordingly. Thus, the markup it chooses will be directly related to the residual demand curve it faces.

More generally, firms in a Consistent Conjectures Equilibrium (Bresnahan 1981a) will have markups given by (10). For such firms, there is no distinction between the residual demand curve and the demand curve the firm acts as if it is facing. Such a firm will chose its output to equate

$$\frac{P_1 - MC_1}{P_1} = -\left(\eta_{11} + \sum_{i \neq 1} \eta_{1i}\hat{\varepsilon}_{i1}\right), \tag{11}$$

where $\hat{\varepsilon}_{i1}$ are Firm 1's 'conjectural variations' in elasticity form. In a Consistent Conjectures Equilibrium $\hat{\varepsilon}_{i1} = \varepsilon_{i1}$ for all i, so the right-hand side of eq. (11) equals $-\eta_1^R$ in eq. (7). Thus, a direct relationship between the residual demand elasticity and markup, eq. (10), holds for this case.

Product differentiation provides another cirumstance in which $-\eta_1^R$, is likely to be near the markup. When the bulk of a firm's market power arises because its products are distinct from others', then the distinction between actual and conjectured marginal revenue is less important. Questions of oligopoly strategic variables are known to disappear as the products become very poor substitutes.[9] There will not be an exact relationship between $-\eta_1^R$ and the markup except in the limit in which strategic variables do not affect the equilibrium, but a large $-\eta_1^R$ will generally indicate substantial market power for firms selling differentiated products.

A final noncooperative example in which our method will reveal the markup of price over marginal cost is perfect competition in an unconcentrated industry. Then our method correctly estimates the flat residual demand curve.

4. Empirical estimates of demand elasticities facing three brewing industry firms

In this section we estimate on yearly data the slopes of the residual demand curves facing three brewing firms: Anheuser-Busch, Pabst, and Coors. These three firms played different market roles over our 1962–1982 sample period. Both Anheuser-Busch (A-B) and Pabst benefited from the late 1950s demand shift from 'popular' to 'premium' beers such as their Budweiser and Pabst Blue Ribbon brands. A-B was the largest brewer over the entire sample period; its market share rose from under ten percent to over 30

[9]See Sonnenschein (1968) for a demonstration.

percent of nationwide unit sales, overwhelmingly through internal growth. Pabst's national market share, on the other hand, remained in the 7.5 percent to 11.5 percent range throughout the last decade. Its regional market share was substantially higher in the upper midwest,[10] but there is considerable dispute about how much market power this implied.[11]

The third firm, Coors, was slightly smaller than Pabst on a nationwide basis, but had the largest market share in each of ten western states; over the last decade Coors averaged a 40 percent market share in the mountain states and nearly 30 percent in the Pacific states.[12] Many industry observers believe that Coors' products (or their images) are distinct in product space, as well. Coors chose a different balance between scale economies and transportation costs than other brewers by using only a single brewery, the largest in the industry, in Golden, Colorado. By contrast, A-B had ten plants, many much smaller. Throughout our sample period the size of the largest plants in the industry increased steadily, and small firms exited in large numbers, suggesting the exploitation of scale economies.[13]

We estimate eq. (6) in double log form for each of three firms j so that the coefficients are elasticities. Let $\langle,\rangle$ denote the inner product operation, let δ_j and γ_j be vectors of parameters, and let lowercase stand for the natural logs of variables. Recall that the vector of W's represents cost side variables and the vector of Y's represents demand side variables. We then estimate eq. (6″) for each firm:

$$\rho_j = \eta_j^R q_j + <\delta_j, (w, w^I)> + <\gamma_j, y> + \varepsilon_{dj}. \tag{6″}$$

Eq. (6″) will be different for each of the three firms, since the parameters vary across firms.

We specify the industry-wide cost variables w to include prices and industry average plant size.[14] The effects of factor prices other than capital are summarized by short-run average variable cost, calculated by dividing all non-capital costs by quantity. If short-run marginal cost is rising, short run average variable cost will be endogenous in our system of demand and supply equations. We therefore instrument for it using exogenous factor prices: the brewing industry wage rate, an agricultural materials price index,

[10] *Beer Marketer's Insights* reports that Pabst maintained a one-quarter share of dollar sales in the East North Central states (Illinois, Indiana, Michigan, Ohio, and Wisconsin) through the 1970s. Market share figures exclude imports, which were below three percent throughout the upper Midwest.

[11] The Justice Department has often attempted to prevent Pabst from merging. In contrast, Elzinga (1982, p. 226–228) argues that Pabst has little regional market power in the upper midwest.

[12] These market share statistics, based on dollar sales, are reported in *Beer Marketer's Insights*.

[13] Brewing industry scale economies are carefully investigated in Scherer (1975).

[14] All data series are defined in the appendix.

a packaging materials price index, and a price index for advertising services brought by brewers. Industry-wide capital costs enter through a cost of capital measure. Individual cost variables for other firms in the industry, w^I, are summarized as industry excess capacity (nameplate capacity minus production) excluding the firm at hand.

Demand side variables include real per capita national income, advertising expenditure, time, and several demographic measures. The reported estimates omit advertising and the demographic measures as they failed to attain significance or affect the coefficient of any other variable.[15]

Miller's nationwide marketing introduction of light beer in 1975 changed the nature of product differentiation in the brewing industry, and may also have altered the nature of the strategic interaction among firms.[16] We deal with this innovation by including a dummy variable for the period from 1975 onward, both by itself and interacted with each firm's quantity. The expected effect of this new product is unclear. A-B, the largest firm, introduced its own light beer shortly after Miller. The impact of a rival's successful innovation on A-B is clearly negative, although it could take the form of a shift of the residual demand curve toward the origin rather than as a flattening of the demand curve. In theory, the market power of A-B could remain unchanged despite the negative shock to firm demand. The structural interpretation of the light beer dummy variable in each firm's demand equation is also unclear. It could represent a change in the structural demand curve because consumers had more choices, or a change in the conditions of competition because of added product differentiation, or simply stand for the increase in advertising and marketing efforts after 1975.

We use two different definitions of firm price: beer revenue divided by gallons sold[17] and the price of the firm's flagship brand (Budweiser, Coors,

[15]Tests of these exclusion restrictions described in Baker and Bresnahan (1984) show little effect of advertising or demographics on demand for three firms studied. In the unrestricted specification, advertising is treated as endogenous. We are not surprised by the small effect, since a mid-1970s bulge in brewer advertising is collinear with the marketing introduction of light beer, which we treat with a dummy variable in our estimated equations. Advertising remains in our specification as an (endogenous) cost.

[16]Miller acquired the rights to Meister Brau Lite beer in 1972, which had been unsuccessfully marketed as a diet beer for women by a small Chicago brewery. Miller's innovation was in the nationwide marketing of light beer. Light beers, now made by many firms, are lower in alcohol and calories than premium beers. In estimating demand curves from time series data, we implicitly assume that no unobserved changes in product quality or reputation occur. The one exception to this is the obvious change in the relative attractiveness of different brands after the invention of light beer, which we treat by introducing a dummy variable in the residual demand curve of each firm. At the same time, Miller 'repositioned' the Miller High Life brand closer to A-B's Budweiser brand and heavily advertised it. Industry advertising/sales ratios increased dramatically during the mid-1970s. As a result of the collinearity between advertising and the dummy, we are uncertain of its interpretation.

[17]Data on each firm's beer revenue were obtained with the help of Professor George Foster of the Stanford Graduate School of Business. We are unable to construct this price series for Miller or Schlitz, so we do not study them.

Table 1
Correlations among prices.[a]

	$P_{A\,B}$	P_{Coors}[b]	P_{Pabst}	P_{Bud}	$P_{Coors\ Br}$[c]	P_{BlueR}
$P_{A\text{-}B}$	1.0	0.82	0.93	0.96	0.84	0.91
P_{Coors}[b]		1.0	0.65	0.80	0.94	0.58
P_{Pabst}			1.0	0.95	0.65	0.99
P_{Bud}				1.0	0.86	0.93
$P_{Coors\ Br}$[c]					1.0	0.60
P_{BlueR}						1.0

[a]Log of real prices.
[b]Coors, the firm.
[c]Coors, the brand.

or Pabst Blue Ribbon) in northern California.[18] The use of average revenue as a measure of firm-wide price may make the brewing industry appear more competitive than it truly is because of a bias introduced by the changing brand composition of total sales. This bias is empirically not important; use of the flagship brand price and quantity in place of average revenue does not alter the elasticity estimates reported below. This is not surprising: table 1 shows that the flagship brand produces correlation coefficients of 0.96, 0.94, and 0.99 with average revenue for the three brewers, much higher correlations than shown between the prices of different brewers. Because of this high correlation, the results of this section are little different from the flagship-brand results [reported in Baker and Bresnahan (1984).]

Own quantity is endogenous in (6) because of the presence of a simultaneous relation (9) connecting price and quantity.[19] We instrument for it with different exogenous variables for each firm. All of the instruments we employ can be viewed as proxies for firm-individuated factor prices, W^1, which are the natural instruments for identifying residual demand. For each firm we use its capacity as one instrument for quantity. The nature of brewing industry investment suggests that capacity is exogenous in the short run, since capacity is altered infrequently and in large increments. Although A-B has between one-quarter and one-third of nationwide sales in our sample, it typically adds capacity in increments of 20 percent of its annual production. Capacity is typically added in anticipation of growth, so that each firm has long periods of capacity constraint followed by long periods of substantial excess capacity. As a result, firm short-run marginal cost varies according to location in the investment cycle: marginal cost is lowest immediately following capacity expansion and highest immediately before the next plant

[18]Source: *Beverage Industry News of Northern California*, various issues. When we use a single product price, we also use that product's quantity as the output measure in our regressions.
[19]As an econometric matter, however, it is not important on our data to treat own Q as endogenous.

Table 2
Glossary.

Price and quantity	
qj	Log per capita barrels of beer sold by firm *j*
pj	Log real average revenue of firm *j*
qaltj	Log per capita barrels of beer sold for firm *j*'s flagship product
paltj	Log real price of firm *j*'s flagship product in northern California
Cost variables	
sravc	Log real short-run average variable cost for industry
APS	Average industry plant size
pk	Log real user cost of capital for industry
EKTIj	Per capita excess capacity in the rest of industry
Demand variables	
pcdi	Log per capita real disposable income
POP<45	Percentage of over-18 population under 45 years old
FBEER	Percentage of women reporting they drink beer
Instruments	
Kj	Per capita capacity of firm *j*
APSj	Average plant size for firm *j* (A-B and Pabst only)
cw	Log real manufacturing wage rate in Colorado (Coors only)
pl	Log real brewing industry wage rate
pm	Log real brewing industry materials price index
pa	Log real brewing industry advertising price index
Other variables	
LITE	Dummy variable for 1975 and later
MC	Industry marginal cost [see eq. (12)]
TIME	Years
LITExqa−b	Interaction between LITE and A-B quantity

comes on line. Under this investment process, both excess capacity and capacity will be correlated with firm marginal cost. Excess capacity is an unattractive instrument for quantity, however, as it is endogenous even in the short run.

We also employ a second instrument for quantity. For Anheuser-Busch and Pabst, both multiplant firms, we use average capacity of all firm plants because this variable is related to the exploitation of plant-level scale economies over time, and thus to cost. For Coors, which has a single brewery in Colorado, we use the level of manufacturing wages in that state as a second instrument. Since the nationwide brewing industry wage is included as an industry-wide cost variable, the independent movement of Colorado wages shifts costs for Coors alone.

A glossary of variable names used in our regression appears in table 2. As

table 2 indicates, we deflated monetary values and put quantity variables in per capita terms to conserve degrees of freedom. The appendix reports the origins of the data.

We estimate eq. (6″) jointly for Coors, Pabst, and A-B by three-stage least squares.[20] The joint estimation takes advantage of information available from the correlation of errors in the three equations, and allows us to conserve degrees of freedom by imposing the cross-equation restriction in eq. (12)

$$\delta_{1j}sravc+\delta_{2j}APS+\delta_{3j}pk+\delta_{4j}EKTI$$

$$=\delta_j(sravc+\beta_{APS}APS+\beta_{KAP}pk+\beta_{EKTI}EKTI)\equiv\delta_j(MC). \tag{12}$$

The restriction in (12) has the interpretation of assuming that all of the firms in the industry other than Firm 1 use different inputs in the same proportions.[21]

Results for our preferred specification appear in table 3. This specification was reached by deleting all demand variables with coefficients estimated to be smaller than their standard errors in absolute value. As a result, no demographic variables appear. The Lite beer dummy variable, alone and interacted with output, appears only for A-B. Time is not dropped from the equations for Pabst and Coors only.[22] We have not deleted cost-side variables, even if they are statistically insignificant.[23] The estimates in table 3 incorporate the restriction of eq. (12).

The coefficient on log quantity directly estimates η_1^R. As the industry has been characterized by substantial product differentiation throughout our sample period, these estimates are interpreted under the assumption that they correspond to estimates of firm markup of price over marginal cost. Thus, Coors had very substantial market power over our sample period; its inverse demand elasticity of -0.74 corresponds to a 74 percent markup over marginal cost. This coefficient is estimated with a very small standard error. At the other extreme Pabst faced an insignificantly downward-sloping

[20] Similar results were obtained for each firm's elasticity using single equation estimation employing two-stage least squares with little noticeable efficiency loss.

[21] Tests of this restriction do not reject it, although they have little power because δ_j is imprecisely estimated when (12) is not imposed. Demand elasticity results are robust to the imposition of this restriction.

[22] Time most likely serves as a proxy for demographic variables omitted from these equations.

[23] Industry-wide cost variables enter both the residual demand curve and the supply relation (9). Omitting them would tend to make the structural supply and demand equations more (positively) correlated, which would tend to bias point estimates of the residual demand elasticity in the direction of finding market power. Omitting industry-wide demand shift variables is less troublesome, because this specification error would tend to bias the results in the conservative direction of not finding market power. These issues are considered more fully in Baker and Bresnahan (1984).

Table 3
Results.

Variable	Coefficient estimate	Standard error
A-B equation ($pa-b$)		
Constant	2.113	0.505
$qa-b$	−0.312	0.064
PCDI	0.040	0.157
MC	0.278	0.019
LITE	0.591	0.068
LITExqa−b	0.282	0.040
Pabst equation (*ppb*)		
Constant	3.979	0.362
qpb	−0.058	0.031
PCDI	−0.041	0.132
MC	0.107	0.089
TIME	−0.017	0.004
Coors equation (*pcs*)		
Constant	−1.638	0.805
qcs	−0.745	0.054
PCDI	0.440	0.306
MC	0.266	0.226
TIME	0.032	0.010
Common parameters		
APS	−0.194	0.291
PK	0.042	0.115
EKTI	−0.033	0.022
Summary statistics		
Equation	Durbin-Watson	Sample size
$pa-b$	2.13	21
pab	1.95	21
pcs	1.70	21

demand curve. This firm had very little market power, only raising price six percent above marginal cost by our point estimate, with a 95 percent confidence interval varying between one percent and 11 percent. Industry leader Anheuser-Busch had considerable market power (with an estimated markup of 31 percent) before the introduction of Lite beer by a rival. This point estimate is reduced to just three percent when Lite beer was introduced.

The general pattern of these inferences is robust to the log-log functional form. In results not shown, we used a linear functional form and calculated the elasticities at the sample means. This had no qualitative impact on the pattern of market power, and the two sets of elasticities, linear and log-log,

are not statistically significantly different (under the conservative assumption of independence). As a quantititative matter, the linear model suggested somewhat less market power for A-B in the early period and for Coors overall, though still substantial market power for these firms. We prefer the log-log estimates because the linear specification involves substantial serial correlation in the errors.

The interpretation of these estimates as revealing the firms' markups in an exact, quantitative way may be too strong. Nonetheless, the results clearly show that Coors is a very valuable monopoly, that A-B once was a valuable monopoly, and that A-B post-1975 and Pabst are less valuable monopolies. These results are consistent with the price premium received by Coors through much of the sample period.

These estimates lead to several inferences about the nature of competition in the brewing industry over our sample period. First, product differentiation is important. Coors' and A-B's downward-sloping demand curve probably originate in products distinct in image and geography. Second, regional market share is a poor indicator of market power since Pabst has so little market power.[24] Third, the increased concentration and product differentiation in the industry since 1975 appears to reflect competition, not anti-competitive acts. A-B's residual demand curve reflects a significant loss of market power following the introduction of Lite beer, even though the new product apparently raised the demand for all beer. Fourth, it is unlikely that brewers price in a tacitly collusive way. If they did, we would expect to observe that each firm's residual demand curve has significant slope, and that prices are highly correlated across firms. Pabst belies both conditions. It has negligible market power and its price is not highly correlated with other brewers.[25]

In general, the coefficients other than the residual demand elasticity have no clear interpretation since other coefficients may reflect both direct effects on the firm's demand and indirect effects through the adjustments of other firms. For example, the positive coefficient on PCDI in the Coors equation does not imply positive income elasticity for that brand; instead, it implies that the net effect of an income increase, including the effects through other brands' demands, is to shift sales to Coors. [See eq. (5).] Nonetheless, it is probably not misleading to label Coors as a normal good in (residual) demand, and Pabst as inferior. That is, the coefficients probably mean that Coors is more income elastic than other brands, Pabst less. In this interpretation, our results are consistent with the view of Keithan (1978)

[24]Therefore our estimate lends support to Elzinga's argument that Pabst's market share in the upper midwest overstated that brewer's market power.

[25]However, we cannot reject the unlikely possibility that all firms except Pabst collude to raise price to the level charged by Pabst, the high-cost producer.

that shifts in demand toward a brand or group of brands (like premium or light brands) are what create market power in this industry.

If no firm-individuated factor prices are observed, the residual demand curve (6) will not be identified, and no instruments will be available to estimate its elasticity consistently. Eq. (6) can be estimated, for example by ordinary least squares, but the resulting parameter estimates will be subject to simultaneous equations bias.[26] In that event, the likely bias is in the direction of disproving the presence of market power. Hence, estimating the residual (inverse) demand curve without correcting for the endogeneity of own-quantity will provide a conservative estimate of the residual demand elasticity.

5. Conclusion

The beer industry, characterized by product differentiation, provided a suitable situation to test our technique for estimating firm market power. Our technique, applied to three of the firms in the industry, allows us to describe both the main features of industry structure and the behavior of individual firms. The results appear quite robust to changes in specification. We are able to differentiate the market power of the three firms with a great deal of confidence despite the fact that all have high market shares, both nationally and regionally. Coors had substantial market power over our sample period, A-B lost most of its market power in the middle of the period, and Pabst is a price-taker. Individual firm market power appears to arise because products are distinct in demand, not because of cooperative behavior by firms. Otherwise, Pabst would surely have market power.

Appendix

This appendix describes the source for the variables employed in our study. Variable names are listed in table 2 of the text.

Price and quantity

Nationwide production figures are available from trade publications and firm revenue from beer production is reported in the annual reports of publicly traded brewers. Per capita adjustments were made using the U.S. population over age 18. Prices were transformed into real terms by dividing by the GNP deflator. Flagship brand prices are reported in issues of the *Beverage Industry News of Northern California.*

[26]This bias is shown in our data, but is small. When we treat quantity as exogenous, the residual demand elasticities are estimated as Coors −0.738, Pabst −0.053, and A-B −0.312.

Factor prices (cost variables)

Time series on four factors of production were assumed to apply industry-wide: labor, materials, variable capital, and advertising. The price of labor is the average hourly wage of brewing production workers collected by the Bureau of Labor Statistics, reprinted annually in *Brewers Almanac*. The price of variable capital is the user-cost measure developed by Fraumeni and Jorgensen (1982) for food and beverage industries, and updated by us through the end of the sample period.

Two variants of the materials price series were used. The first uses data on the prices and quantities of a list of specific inputs: malt, corn, rice, hops, cans, bottles, and power. The second divides cost of materials for brewers, as reported in *Brewers Almanac*, by quantity of beer manufactured in barrels. The quantitites consumed of all specific inputs are found in *Brewers Almanac*, except power. *MBA Bluebook* reports expenditures on power. The price series for the specific inputs are from *Producer Prices and Prices Indexes*. In real terms, the two materials price series are correlated at 0.99. The advertising price series is computed as an index of media prices; brewing industry weights are from *Leading National Advertisers*.

Demand variables

Population and income variables are taken from Census and other Commerce Department Sources.

Instruments

Brewer capacity, by plant, is reported in *Beer Marketer's Insights*. This is the basis of both K and APS. The Colorado manufacturing wage rate series is from the *Statistical Abstract of the United States*.

Other variables

Advertising variables, used to compute table 5, include each firm's expenditures on advertising, as reported in *Brewers Almanac*. These variables are normalized either by sales, or by the industry price of advertising as described above and a population index.

References

Appelbaum, E., 1979, Testing price-taking behavior, Journal of Econometrics, July, 313–331.
Appelbaum, E., 1982, The estimation of the degree of oligopoly power, Journal of Econometrics 19, 287–299.

Baker, J. and T. Bresnahan, 1984, Estimating the elasticity of demand facing a single firm: Evidence on three brewing firms, Research paper no. 54 (Stanford Workshop on Factor Markets, Department of Economics, Stanford University, Stanford, CA).
Baker, J. and T. Bresnahan, 1985, The gains from merger or collusion in product-differentiated industries, Journal of Industrial Economics 33, 427–444.
Bresnahan, T., 1981a, Duopoly models with consistent conjectures, American Economic Review 71, 934–945.
Bresnahan, T., 1981b, Departures from marginal-cost pricing in the American automobile industry: Estimates for 1977–78, Journal of Econometrics 11, 201–227.
Bresnahan, T., 1987, Competition and collusion in the American automobile industry, The 1955 price war, Journal of Industrial Economics, June, 457–482.
Cowling, K. and J. Cubbin, 1981, Hedonic price indexes for cars in the U.K., Economic Journal, Sept.
Elzinga, Kenneth G., 1982, The beer industry, in: Walter Adams, ed., The structure of American industry, 6th ed. (Macmillan, New York).
Fraumeni, B. and D. Jorgenson, 1980, The role of capital in U.S. economic growth, 1948–1976, in: G. von Furstenberg, ed., Capital, efficiency, and growth (Ballinger, Cambridge).
Frisch, R., 1959, A complete scheme for computing all direct and cross demand elasticities in a model with many sectors, Econometrica 27, 177–196.
Gollop and Roberts, 1979, Firm interdependence in oligopolistic markets, Journal of Econometrics, July, 313–331.
Greer, Douglas F., 1971, Product differentiation and concentration in the brewing industry, Journal of Industrial Economics 19, July, 201–219.
Greer, Douglas F., 1981, The causes of concentration in the brewing industry, Quarterly Review of Economics and Business, Winter, 87–106.
Hogarty, Thomas F. and K.G. Elzinga, 1972, The demand for beer, Review of Economics and Statistics 54, May, 195–198.
Horowitz, Ira and A. Horowitz, 1965, Firms in a declining market: The brewing case, Journal of Industrial Economics, March, 129–153.
Iwata, G., 1974, Measurement of conjectural variations in oligopoly, Econometrica, Sept., 947.
Joskow, A., 1983, A welfare analysis of industry product variety, Mimeo. (Yale University, New Haven, CT).
Keithan, C., 1978, Staff report on the brewing industry (Staff Report on the Brewing Industry, Federal Trade Commission, Washington, DC).
Kelton, Christina M.L. and W.D. Kelton, 1982, Advertising and intra-industry brand shift in the U.S. brewing industry, Journal of Industrial Economics 30, March, 293–303.
Landes, W. and R. Posner, 1981, Market power in antitrust cases, Harvard Law Review 94, 937–996.
Lerner, A., 1934, The concept of monopoly and the measurement of monopoly power, Review of Economic Studies 1, 157–175.
Ordover, J., A. Sykes and R. Willig, 1982, Herfindahl concentration, rivalry, and mergers, Harvard Law Review 95, 1857–1874.
Ornstein, S., 1981, Antitrust policy and market forces as determinants of industry structure: Case histories in beer and distilled spirits, The Antitrust Bulletin, Summer, 281–313.
Rosse, J., 1970, Estimating cost function parameters without using cost data: Illustrated methodology, Econometrica, March, 150.
Scheffman, D. and P. Spiller, 1987, Geographic market definition under the DOJ guidelines, Journal of Law and Economics 30, April, 123–147.
Scherer, F. et al., 1975, The economics of multi-plant operation (Harvard University Press, Cambridge, MA).
Sonnenschein, H., 1968, The dual of duopoly is complementary monopoly, Journal of Political Economy 76, March/April, 316–318.
Sumner, D., 1981, Measurement of monopoly behavior: An application to the cigarette industry, Journal of Political Economy 89, Oct., 1010–1019.
U.S. Department of Justice, 1984, Merger guidelines (Washington, DC).