An Estimable Model of Supermarket Behavior: Prices, Distribution Services and Some Effects of Competition*

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Abstract

In this paper we present and estimate a simple model of supermarket behavior that has several attractive properties: It permits the incorporation of the (distribution) services provided by a supermarket as an output of supermarkets and a determinant of demand for supermarket products; it generates, as a special case, one of its main competitors in the supermarket literature -- the so called full price model of services; and, it can be estimated with a unique data set originally constructed by the Economic Research Service of USDA. The main results of the analysis are three. First, the aggregate demand for a supermarket=s products depends critically on distribution services: at the substantive level, a 1 % increase in these services increase quantity demanded by 0.4%; at the methodological level, the restrictions on the parameter values implied by the model are critical in the evaluation of functional forms for demand. Second, supermarkets exhibit constant marginal costs with respect to the quantity of output or turnover and substantially declining marginal costs with respect to (distribution) services, which implies substantial multiproduct economies of scale. Third, in response to an exogenous increase in competition those supermarkets that have adopted newer formats such as superstores and that employ newer technology such as optical scanners choose prices and (distribution) services in ways that increase consumer welfare, whereas those that do not have these characteristics choose prices and services in ways that lower consumer welfare.

JEL Classification: L81, L1, L4.

Key Words: Supermarkets, prices, distribution services, demand; economies of scale.

I. Introduction.

Supermarkets are an important component of modern economies. For instance, according to the U.S. Statistical Abstract (1998), in 1996 the retail trade accounted for 9.37% of U.S. GDP and supermarket sales accounted for 12.3 % of sales in the retail trade. At the same time the supermarket category has undergone major structural changes in the 1980's, for example according to the U.S. Statistical Abstract (1991) the share of sales of conventional supermarkets went from 73.1% in 1980 to 42% in 1989. Newer formats gained the ground lost by conventional supermarkets. These formats provide either broader and/or deeper assortments (for example superstores, combination food and drug and hypermarkets), or in the case of warehouses lower prices in exchange for less assurance of product delivery in the desired form (large packages rather than small ones). By 1996, the share of conventional supermarkets had fallen to 22.2%, U.S. Statistical Abstract (1998).

In the trade literature the importance of the services provided by supermarkets is frequently mentioned. For instance in a 1987 survey of customers reported by The Progressive Grocer, prices were only one of 16 items considered important by half of the sample in selecting a food store. The others were services of various kinds such as availability of a produce department, unit pricing, convenient location, cleanliness, short waits at checkout counters, etc. Similar results appear in other years, see for example the April issue in 1993. By and large this aspect of supermarkets has been either ignored or tangentially acknowledged in the mainstream economics literature, including the industrial organization literature.

The major aim of this paper is to capture the importance of these services as an economic variable that determines supermarket behavior both theoretically and empirically. We will do so by treating them explicitly as an output of supermarkets and as a determinant of consumers= demand for supermarket products. In Section II, we present a simple theoretical model that adapts the one in Betancourt and Gautschi (1993) for empirical implementation with the data available to us. We show how this model generates as special cases the standard textbook monopoly model, a model of retail pricing proposed by Bliss (1988), and the perfectly competitive model referred to as the full price model of services. The latter was put forth by Ehrlich and Fisher (1982) to analyze the demand for advertising and has been applied to supermarkets by Oi (1992) and to retailing in general by Divankar and Ratchford (1995). Our simple model can be viewed as a slight generalization of the Bertrand model that implies supermarkets behave as imperfect competitors.

What makes this project feasible is a unique data set put together by the Economic Research Service of USDA, see Kaufman and Handy(1989). Supermarkets often provide over a 100,000 products and it is not easy to obtain an average price charged by a supermarket; they also offer a variety of services and it is not easy to obtain information on them. By combining price surveys with a store survey, this data set allows the construction for each supermarket of an index of prices and an index of services. The latter correspond to the ones identified as distribution services in the retailing literature from which the model is derived. Since this data was also combined with social and economic information at the zip code level, it becomes possible to estimate an aggregate demand function for each supermarket that incorporates price and distribution services as endogenous variables and that must satisfy certain theoretical restrictions implied by the model. The results of this estimation are reported in Section III. They show that distribution services are an important determinant of the demand for supermarket products and that not all functional forms for the demand functions satisfy the restrictions implied by the theory.

From the simple model one can extract the first-order conditions that determine the choice of prices and distribution services by a supermarket. By imposing functional forms on cost functions and on the limited characterization of competition in the model, it becomes possible to estimate these first-order conditions given the aggregate demand for the supermarket products. These functional forms and their implications for estimation are discussed in Section IV. Of particular interest is allowing for the possibilities of increasing returns to scale, since this issue is controversial in the literature. Some authors argue in favor of their existence, Oi(1992) and Ofer (1973); other authors argue in favor of constant returns to scale, Ingene (1984) and Cotterill(1991). We find that both groups are right. That is we find constant returns to scale with respect to turnover or the standard output measure but increasing returns to scale with respect to distribution services or the output measure we are emphasizing here.

The last section of the paper presents the results, discusses various econometric issues and reports a simulation: namely, the effect of a change in the exogenously given level of competition for each observation (supermarket) using the estimated parameter values. The simulation results are interesting for two reasons. First, they confirm the main criticisms of the traditional linear regressions of prices against measures of market power in grocery retailing made by Anderson (1990). He argues that a change in competition may not have the same effect on prices in all markets and we find that prices sometime increase and sometimes decrease; he also argues that it is necessary to control for differences in quality (what we call distribution services) and we find that these services also sometimes increase and sometimes decrease. Second, we find that our sample splits along interesting characteristics in their response to a change in competition. For instance supermarkets where consumer welfare increases have a higher proportion of superstores and use of optical scanners than those where welfare decreases, which suggests the structural changes we have observed in the 1980's have been beneficial to consumers.

II. The Model and Its Main Special Cases.

The essence of the model is that retailers choose prices and distribution services simultaneously given the demand function for supermarket products and the level of competition in the market. Formally, we write the constrained maximand for a supermarket as

$$L = pQ - C(v, Q, D) - wQ + \mu N[\bar{E} - E(p, \bar{p}, D, z^{0})]$$

where p is a store's average retail price; Q is the level of output, which is determined by the aggregate demand faced by the store. N is the number of transactions. We will assume that all repeated purchases are the same and that all consumers of any one supermarket are identical; hence, Q= qN, where q is the demand function per transaction of the representative consumer, and N will be normalized at unity. C is a neoclassical cost function describing the costs of supermarket activities as a function of input prices (v) and the two outputs of this retailing activity, explicit products and services (Q) and the implicit levels of distribution services (D). w is the average price of the explicit products and services purchased from suppliers. E is the expenditure function of the representative consumer, which depends on the store's average retail price (p), the distribution services of the supermarket (D), other prices (p') faced by the consumer and the optimal level of the consumption activities, z^0.[1] E' is the lowest cost to this 'representative consumer' of attaining her maximum level of utility at an alternative establishment. μ is a Lagrange multiplier.

Since this constrained maximand is unfamiliar to many economists, it is instructive to discuss what it captures explicitly. The first three terms are the standard definition of profits for a retail establishment, in which it is useful to separate sales (pQ) and two dimensions of costs: those due to the distribution activities of the retailer (C(v, Q, D)) and those due to the production activities of wholesalers or suppliers (wQ). The fourth term represents a constraint that captures the effects of competition on supermarket behavior in the following sense. If there is a lowering of the competitive standard that a store faces, for example by a 1 $ increase in the lowest cost per transaction to a 'representative consumer' of attaining her maximum level of utility at an alternative establishment, the Lagrange multiplier, μ, measures the marginal contribution to profits of such an experiment. μ ranges between zero and unity.[2] This constraint captures Bliss (1988) concept of retail competition as offering the consumer better value for her money than at the next best alternative store in terms of an expenditure function that allows for the existence of distribution services and makes explicit the assumption of identical transactions across consumers and repeat purchases.[3]

Optimal choices of prices and services by a supermarket must satisfy

Price: $(p - C_Q - w)(\partial Q/\partial p) + Q(1-\mu) = 0$ (1)

Distribution Services: $(p - C_Q - w)(\partial Q/\partial D) + \mu r - C_D = 0$ (2)

Constraint: $E^{=} - E(p, p^{=}, D, z^{0}) = 0$ (3).

It is insightful to proceed by considering several special cases that this model generates, which can be seen through these conditions. Suppose we assume first that $\mu = 0$. The constraint becomes irrelevant and we have a generalization of the standard monopoly case in the literature. (1) and

(2) simply imply that the retailer chooses prices and distribution services such that marginal revenues equal marginal costs in both cases.

Suppose we assume instead that $\mu = 1$. Condition (1) implies $p = C_Q + w$, or the average retail price equals the marginal cost of retailing an additional unit of output plus the cost of purchasing this unit from suppliers; condition (2) implies that $r = C_D$, or the shadow price of an additional unit of distribution services to the representative consumer equals the marginal cost of providing this additional unit to the consumer. Thus, we have a generalization of standard competitive behavior in a model that incorporates distribution services as a variable. Notice that in this model the conjectural variation is zero. That is the supermarket takes its rivals prices and distribution services as given.[4] Hence, this model has all the advantages and disadvantages of the Bertrand model as discussed, for example, in Tirole (1988, Ch. 5). In particular, the slightest departure from competitive behavior results in the supermarket losing all of its sales to the representative consumer. This helps interpret the more general model. Namely, when $0 < \mu < 1$, the supermarket loses a fraction of its sales to the representative consumer when it fails to meet the competitive standard represented by the constraint.

By making an additional assumption in this special case when $\mu = 1$, it is possible to generate the full price model of services. Ehrlich and Fisher (1982) argued that perfect competition implies that the full price paid by the consumer must be the same at every store. Retailers can compete by offering whatever combination of services and prices they want as long as they meet this constraint. The full price in our model is the sum of the retail price and the shadow price of distribution services, p + r. The implication of Ehrlich and Fisher=s argument is that this sum is equal to a constant, let us say K, which must be the same for every store. From equation (1) and (2) when $\mu = 1$, this also implies that $p + r = K = C_Q + w + C_D$. The second equality brings out a little known feature of the full price model. Namely if there are decreasing marginal costs with respect to distribution services (information in Ehrlich and Fisher=s case), for example, the model breaks down. That is, given K, increases in p and decreases in r imply that C_Q decreases (if marginal costs are increasing with respect to output or turnover, Q) and C_D decreases (if marginal costs are decreasing with respect to distribution services, D) and the second equality can not be met.

III. Specification and Estimation of the Aggregate Demand Function for a Supermarket.

Implementing the previous model empirically requires estimation of the aggregate demand function for a supermarket. In this section we specify and estimate this aggregate demand function, taking into account the restrictions implied by the previous model. Equation (4) below specifies the aggregate demand function for a supermarket,

$$Q = g(p, D, Y, X)u_3 . \qquad (4).$$

Q is the level of demand, which is measured as the annual level of sales of the store deflated by the store=s average price. u_3 is a disturbance term, which is assumed to be lognormally distributed so that $\ln u_3$ is normally distributed with $E(\ln u_3) = 0$. We follow the applied literature by specifying g in ACobb-Douglas@ form so that it generates elasticities as parameters and a 'double log' type of demand function[5], i.e.,

$$\ln Q = \alpha + \delta_1 \ln p + \delta_2 \ln D + \delta_3 \ln Y + \delta_4 \ln X + \ln u_3. \quad (5)$$

One modification of (5) is useful in an empirical setting because it allows us to take advantage of one of the strengths of our data, which permit the representative consumer faced by a supermarket to differ across supermarkets. Namely, the elasticities affecting the endogenous variables, p and D, need not be assumed constant. Instead, they will be allowed to vary with characteristics of the households in the zip code area in which a supermarket is located, that is

$$\delta_1 = \delta_{10} + \delta_{11} X_1 < -1 \quad (6)$$

$$0 \leq \delta_2 = \delta_{20} + \delta_{21} X_2 < 1. \quad (7)$$

Economic theory leads us to expect a negative price response and a positive distribution services response. Thus, we would expect $\delta_{10} < 0$ and $\delta_{20} > 0$. The signs of δ_{11} and δ_{21}, however, would be determined by whether we expect the household characteristic to increase or decrease the sensitivity of demand to retail prices or distribution services, respectively. In the empirical analysis we will assume X_1 to be the percentage of households without cars in the zip code area where a supermarket is located; hence, we would expect it to decrease the absolute value of the price elasticity of demand, so that we would expect $\delta_{11} > 0$ because the lesser the access to a car of the representative consumer the less price elastic is demand. This allows us to investigate empirically one of the mechanisms by which supermarkets may charge different prices to poor households. We will assume X_2 to be the socioeconomic status of the zip code area where the supermarket is located.[6] The inequalities in (6) and (7) have to be satisfied or second-order conditions in the model of Section 2 would be violated. This provides a test of the empirical judgements made, including the selection of X_1 and X_2. Y was measured as the median income in the zip code area where the supermarket was located and δ_3 is, of course, expected to be positive.

X was specified as a vector of three exogenous variables: a dummy variable indicating whether or not the store was in a shopping center (X_{41}),[7] the population of the zip code area where the store was located (X_{42}) and the selling area of the supermarket measured in squared feet of store space devoted to selling (X_{43}). Selling area captures the consequences of an estimate of the level of demand made by those who designed the supermarket and unobserved by the researcher and it should be positively related to the level of demand. Population should be positively related to the level of demand facing the supermarket if everything else in the zip code area were equal. Finally, the dummy controls for one of the things that may not be equal: namely, the pattern of store traffic may be different when a store is located in a shopping center so that it may have a higher or lower level of demand given population and selling area.

The Economic Research Service (ERS) of USDA has developed a unique data base which is the basis for our analysis. It consists of three price surveys (waves 1,2,3) taken six weeks apart in 1982; a separate survey of store characteristics undertaken over the same period; demographic and socioeconomic information for zip code areas purchased by ERS from Claritas Corporation; and SMSA data. We gathered data on the number of food stores in each SMSA. A detailed description of the data is provided in an Appendix available upon request.

The data is essentially cross-section data with the unusual feature that for one variable there are three observations or drawings. That is, each of the three price surveys generated a store price index, p. Not all the stores were the same in each price survey, so we worked with a sample of 430 observations that were included in each wave and checked our results against the wider samples. The annual sales of each store and the price index were used to generate Q for each wave. The store characteristics survey generated the data to construct an index of distribution services for each store, D, based on the response to twenty questions about whether or not the store provided a particular service. In addition, for the estimation of demand the variables X_{41} and X_{43} were taken from the store survey while X_1, X_2, Y, and X_{42} were taken from the Claritas data set. Descriptive statistics on these variables as well as on those introduced in the next section are presented in Table 1.

>>>>>Table 1 GOES HERE>>>>>>

Table 2 presents the results of estimating (5) with the modifications implied by (6) and (7) for each of the three waves. The equation to be estimated is linear in the parameters but nonlinear in the endogenous variables (p and D); hence, it was estimated by nonlinear two stage least squares.[8] The results are not very sensitive to the price survey used in the analysis. In all three cases, inequalities (6) and (7) are satisfied without violations at any data point. The coefficients of price, distribution services, the interaction between price and percentage of households without a car, median income and selling area have the expected sign and are statistically significant at well beyond the 1% level in all three price surveys. The coefficients of population and the shopping center dummy are not statistically significant at the 2.5% and at the 5% level, respectively, in any of the three waves. Finally, the interaction between distribution services and socioeconomic status is statistically significant at the 5% level in waves 1 and 2 and at the 10% level in wave 3.

>>>>>Table 2 GOES HERE>>>>

Our results show that it is feasible empirically to incorporate distribution services into the estimation of demand functions for supermaket products in a theoretically consistent fashion. Substantively, a 1% increase in store price decreases quantity demanded by about 2.0 to 2.2 % on average and a 1% increase in store distribution services increases quantity demanded by about 0.38 to 0.42% on average. In addition, we find that one of the mechanisms through which the poor face higher prices is that their price elasticity of demand is smaller (in absolute value) when they reside in households without a car. Not surprisingly, establishments built to sell more do so, but not proportionately (the hypothesis that the coefficient is unity is rejected at the 1% level); on the other hand, households with a higher level of median income buy proportionally more at the supermarket. Higher socioeconomic status in an area reduces the magnitude of the increase in demand from increasing distribution services, perhaps because households in these areas take for granted a high level of distribution services.

In the course of our analysis we performed a number of experiments, some of which are worth reporting. We set the interaction terms to zero ($\delta_{11} = \delta_{21} = 0$). The estimated price elasticity was negative and statistically significant at the 5% level, but less than unity in absolute value which violates second-order conditions. We also estimated our specification with SMSA dummies added. The price elasticity estimate was negative but the null hypothesis that it was greater than or equal to minus unity could not be rejected at any reasonable level of significance. We estimated the specification with (not shown) and without an intercept (Table 2). The intercept estimate is quite large and statistically insignificant ($t < 1$), and the null hypothesis that the coefficient of distribution services is greater than or equal to unity can not be rejected at any reasonable level of significance for two of the waves and at the 1% level for all three waves. All three alternatives were discarded because of their inconsistency with the theoretical restrictions emanating from the simple model of Section II.

IV. Specification of the First- Order Conditions.

Because the model presented in Section II is a perfect information one, we introduce error terms in equations (1) and (2), u_1 and u_2 respectively, by assuming that the source of the errors is in the application of the decision rules for optimization by each agent (supermarket), not in their perceptions of the objective function. These considerations lead to the following set of equations for estimation.[9]

Price: $(p - C_Q - w)(\partial Q/\partial p) + Q(1-\mu) = u_1$ (8)

Distribution Services: $(p - C_Q - w)(\partial Q/\partial D) + \mu r - C_D = u_2$ (9).

We will assume $E(u_i) = 0$, and $E(u_1 u_2) \neq 0$. That is, the errors in the two equations capturing the decisions of a supermarket with respect to prices and distribution services are likely to be correlated and will be allowed to be in the estimation.[10]

In order to estimate (8) and (9), we need to specify the marginal costs with respect to Q and D and the (exogenous) level of competition faced by a supermarket (μ). Since Q depends on the endogenous variables, p and D, it will be treated as an endogenous variable in the estimation of (8) and (9). While equations (8) and (9) have the same form for every supermarket, their values vary across supermarkets because aggregate demand, the slopes of the demand functions, marginal costs and the level of competition can vary across supermarkets. The disturbance terms will be assumed to be independent and identically distributed across supermarkets.

In order to proceed, we need to specify functional forms for the marginal cost functions for explicit products, C_Q, and distribution services, C_D. Our choice was guided by several considerations. First, the strength of our data is in the measurement of the two aggregate outputs of supermarkets, Q and D. Second, whether marginal costs are increasing or decreasing in these outputs is an important consideration in the full price model, as shown in Section II, but the logic extends to the more general model. Finally, as noted in the introduction, the issue of whether or not there are returns to scale in retailing, including supermarkets, has attracted considerable attention in the literature. Of the multiproduct cost functions suggested in the standard reference in the industrial organization literature for multiproduct cost functions, Baumol, Panzar and Willig (1982, Ch. 15), the one that seemed most suitable in light of these considerations is a slight generalization of the quadratic cost function attributed to Braunstein by Baumol and Braunstein (1977).

It generates the following marginal cost functions,

$$C_Q = (\exp(\theta S))[\alpha_1 + \alpha_{11} \beta Q^{(\beta - 1)} + \alpha_{12} D][v_1^{\pi(1)} v_2^{\pi(2)}] \quad (10)$$

$$C_D = (\exp(\theta S))[\alpha_2 + \alpha_{22} \lambda D^{(\lambda - 1)} + \alpha_{12} Q][v_1^{\pi(1)} v_2^{\pi(2)}] \quad (11)$$

where v_1 is occupancy cost, constructed on the basis of SMSA data, and v_2 is labor compensation, which was measured in terms of an index of within SMSA=s variations for each store.[11] S is a vector of shift variables that lead to differences in the levels of costs, for example store type (S_1 is a dummy for superstores and S_2 is a dummy for traditional supermarkets with warehouses as the residual category) or the existence of a scanner at the store (S_3). θ is a vector of corresponding coefficients. These four variables were taken from the store survey.

This specification generalizes the standard quadratic form. That is, if $\beta = 2 = \lambda$, it collapses to the quadratic. It allows for richer behavior in terms of multiproduct returns to scale and the shape of marginal costs than permitted by the standard quadratic.[12] For instance, with these functions marginal costs can increase at either an increasing or a decreasing rate with distribution services or output as λ or β is greater or less than one, respectively. Moreover the standard definition of multiproduct returns to scale as the proportionate increase in costs as a result of a proportionate increase in outputs, RTS, yields in this case

$$RTS = 1 + [(\beta - 1)\alpha_{11} Q + (\lambda - 1)\alpha_{22} D]/C. \quad (12)$$

Thus, we can easily identify whether returns to scale, if any, are being generated by a decreasing marginal cost function with respect to distribution services or with respect to output.

Finally, a data limitation imposes the need to estimate a component of cost, namely the wholesale price. The latter was assumed to be a function of whether or not the supermarket belonged to a chain as follows : $w = \sigma_0 + \sigma_1 S_4$, where S_4 takes on the value of unity if the store reported belonging to a chain in the store survey and zero otherwise. σ_0 is expected to be positive and σ_1 is expected to be negative, i.e., one of the benefits of belonging to a chain is to secure products at advantageous prices. One way of checking the reasonableness of this procedure is to check whether or not the estimated margin, p- C_Q - w, for any observation is negative, which would violate second-order conditions. Fortunately, our data and estimation procedures allow us to perform this check.

Just as indicated in Section II, the Lagrange multiplier (μ) captures the level of competition faced by a supermarket as the fraction of sales to the representative consumer diverted to other stores from a failure to meet the competitive standard. Hence, one would expect it to vary across the market areas[13] where the supermarkets are located as characteristics of these market areas differ. Thus, while the value of μ faced by any supermarket is assumed constant, the value this constant takes on is allowed to differ across supermarkets. In addition, the value that μ can take on for any supermarket must lie between zero and unity. These considerations were incorporated into the empirical analysis by specifying the following logistic functional form

$$\mu = e^{\gamma M} /(1 + e^{\gamma M}), \qquad (13)$$

where M is a vector of variables describing the characteristics of the market area.[14]

One characteristic of a market area is market growth, which will be measured as the rate of growth of food store sales over the previous five years (M_3). We would expect that a market area with high market growth, given the same number of stores for example, would have a lower value of μ than one with low market growth. That is the fraction of sales to the representative consumer of any one supermarket diverted to other stores as a result of failing to meet the competitive standard would be less in the market area with high growth, which implies $\gamma_3 < 0$ since $\partial\mu / \partial M_j = \gamma_j \mu(1 - \mu)$.

Two other variables were used in the vector M. The number of food stores per 1000 persons in the SMSA where the supermarket is located, M_2. One would expect that the higher this number, given market growth for example, the higher the fraction of sales to the representative consumer of anyone supermarket in the area that can be diverted to other stores as a result of a failure to meet the competitive standard, i.e., $\gamma_2 > 0$. Finally, the last variable included in this vector was the market share of the firm that owns the store in the SMSA where the store is located, M_1.[15] Statistically, this variable is appealing because, in contrast to the previous two, it varies across supermarkets within an SMSA as well as across SMSA=s. Its economic interpretation, however, is complex. A high market share by a firm in an SMSA can be an indicator of ability to differentiate its offerings and, thus, lowers competition ($\gamma_1 < 0$); on the other hand, it can also be an indicator of dominance by a firm with a competitive fringe, which increases competition ($\gamma_1 > 0$). While our model says nothing about how the level of competition in a market area is determined, Ansari, Economides and Ghosh (1994) develop a model in which either outcome can arise in equilibrium depending on the nature of consumer preferences over attributes. When preferences are nonuniform, the second outcome is more likely to arise.

Imposing all these functional forms on (8) and (9), we have

$$[p-\{\exp(\theta S)[\alpha_1 + \alpha_{11}\ \beta Q^{(\beta -1)} + \alpha_{12} D][v_1^{\pi(1)} v_2^{\pi(2)}]\} - (\sigma_0 + \sigma_1 S_4)]\ [\delta_1\ (Q/p)\ ] + Q\ (1/(1 + e^{\gamma M})) = u_1 \quad (8)'$$

$$[p-\{\exp(\theta S)[\alpha_1 + \alpha_{11}\ \beta Q^{(\beta -1)} + \alpha_{12} D][v_1^{\pi(1)} v_2^{\pi(2)}]\} - (\sigma_0 + \sigma_1 S_4)]\ [\delta_2\ (Q/D)\ ] + (e^{\gamma M}/(1 + e^{\gamma M}))(r_0 + r_1 t) - \{\exp(\theta S)[\alpha_2 + \alpha_{22}\ \lambda D^{(\lambda -1)} + \alpha_{12} Q][v_1^{\pi(1)} v_2^{\pi(2)}]\} = u_2 \quad (9)',$$

where the only new term is $(r_0 + r_1 t)$. That is, we have replaced the shadow price of distribution services, r, by a linear function of the opportunity cost of time, t , which was measured by the between SMSA variation in the index of labor compensation.[16]

V. Results.

Estimation by nonlinear two stage or three stage least squares requires specifying an instrument matrix. We included every variable treated as exogenous in the model as an instrument, which gave rise to 16 variables in the instrument matrix, and is similar to what would be done in the linear case. In the nonlinear case, however, the use of squares of the original variables and interaction terms improves the efficiency of the estimates, by making the nonlinear approximations more accurate, although if carried to an extreme, adding as many variables as one has observations for example, it can lead to inconsistent estimates.[17] We selected six variables that vary both within and across SMSA=s and introduced their squares as instruments.[18] In addition, we introduced a variable not used earlier and its square as instruments: the percentage of families with two or more earners in the zip code area where each supermarket was located. Finally, we added interaction terms between selling area and the other six variables mentioned in this paragraph and between the percentage of households with more than two earners and the remaining five variables. To conclude we used the same 35 instruments, when the squares and interaction terms are included, in the estimation of the demand equation and the first-order conditions.[19]

In Table 3 we present the results of estimating (8)= and (9)= by nonlinear three stage least squares for each of the waves. Our most statistically robust results are for the parameter estimates associated with the two output variables in the cost function. The substantive implications of these parameter estimates also represent the most important results of our estimation. The estimates of λ and β suggest that economies of scale with respect to distribution services and not with respect to output are the main source of increasing returns to scale for supermarkets. The null hypothesis that marginal costs with respect to output (Q) are constant can not be rejected at the 1% level of significance in any of the three waves, although the point estimate indicates slightly declining marginal costs. On the other hand the null hypothesis that marginal costs are constant with respect to distribution services (D) is rejected at the 1% level of significance and above for all three waves in favor of the alternative that marginal costs are declining. These results are also consistent with the literature cited in the introduction.[20] Finally, a higher level of turnover (Q) increases the marginal costs of providing a given level of distribution services (D) and viceversa.

>>>>>>Table 3 GOES HERE>>>>>>>>

Our estimates of the shadow price of distribution services are statistically significant at the 1% level and above for every wave. If for simplicity we evaluate the estimates at t=0, they imply that the value over a year to all the consumers of a supermarket of a one unit increase in the distribution services index varies between $22,100 and 27,800 across the waves.[21] To put this number in perspective note that this represents between 0.32% and 0.33% of average supermarket sales in the sample, which were close to 7 million in 1982$. The construction of our index of distribution services implies that a one unit increase in the index at the sample mean corresponds to an 11% increase in any of the 20 components making up the index, i.e., the average value from adding the 20 services , which is 11.2357, divided by the average value of the index, which is 101.40. Adding a whole service category implies increasing the distribution services index by 9, which implies a value to consumers between 2.88% and 2.97 % of sales.[22]

With respect to the competition variables, market share and market growth are statistically significant at the 1% level or above in all three waves but the number of stores per 1000 persons is not statistically significant at this level. The coefficient of market growth suggests that the ability to retain patronage by supermarkets is substantially greater in areas where demand is increasing very rapidly. The coefficient of market share, on the other hand, suggests that an increase in the market share of a firm in a market area lowers its ability to retain patronage, perhaps due to increased competition from the fringe. This effect, however, is much smaller in magnitude than the effect of market growth.

Of the shift parameters in the cost function, the presence of scanners generates the most stable results. It is statistically significant at the 1% level in all three waves and their presence implies a lowering of costs between 2 and 3 %. The differences in costs between traditional stores and warehouses are not statistically significant at any reasonable level, but the differences in costs between warehouses and superstores are at the 2.5 % level in waves 2 and 3. They imply that superstores experience between 5 and 6 % higher levels of costs than warehouses. Of the input parameters, the coefficient of occupancy cost is positive and statistically significant at the 2.5% level but the coefficient of labor costs while positive is not statistically significant at any reasonable level.

Finally, our attempt to compensate for the lack of data on the cost of goods sold was successful in the following sense. The estimated value of σ_0 is positive and statistically significant at the 2.5% level in waves 1 and 2 and belonging to a chain systematically lowers the costs of acquiring goods in all three waves. Perhaps more importantly, the bottom of the table shows that using these estimates there are no violations of second-order conditions at any data points in waves 2 and 3 and only 1 violation in wave 1. The estimated value of the price cost margin index at the sample mean varies between 23 and 26 index units across the waves. Expressed relative to the store price index, $(p - C_Q -w)/p$, it also implies a margin between 23% and 26% of sales.[23]

We performed two experiments that tested alternative specifications of competition in the model. Namely, we reestimated the model assuming first that $\mu = 0$ and subsequently that $\mu = 1$, i.e., the extreme cases of monopoly and perfectly competitive behavior. In neither case were we able to obtain convergence, which suggests that imposing these assumptions leads to a misspecified model. In contrast to these specification tests, we also performed other specification tests that did not substantially affect any of the results reported in Tables 2 and 3.[24]

We also considered an econometric issue especially relevant to our context. Moulton (1990) argues that cross-section estimates of the effects of aggregate variables , for example our SMSA variables, on micro units, the stores in our sample, will be biased if there is spatial correlation. We took the estimated residuals from (8)′ and (9)′ and calculated for each SMSA the test statistic developed by Anselin and Kelejian (1997) for the case of endogenous regressors with no spatially lagged dependent variables. This statistic (TS) is defined as

$TS = \{[v' W v]/ s^2]/ tr (WW + W'W')$, where v is a an Nx1 vector of residuals from an equation for an SMSA with N observations; s^2 is the sample variance of the residuals from an equation within an SMSA; W is the spatial weighting matrix, which in our case takes the form of an NxN matrix with zeros in the diagonal and ones= in the offdiagonal elements. TS has a χ^2 distribution with one degree of freedom. The null hypothesis of zero spatial correlation could not be rejected at the 1 % level for any of the 28 SMSA=s in either of the two equations.

Finally, we used the estimated model to explore the effects of an increase in competition, either through a 1 % increase in the price elasticity of demand (in absolute value terms) or a 1% increase in μ. We solved the model for p and D for each observation using the values of our parameter estimates. We augmented the coefficient values as indicated above and solved the model again for p and D for each observation. This allowed us to calculate the change in price and the change in distribution services. We were also able to evaluate these changes in terms of monetary units. That is, $r\Delta D - \Delta pQ$ (= V) is a money metric utility measure of the change in consumer welfare. This is especially valuable when changes in p an D occur in the same direction, because assessing welfare implications requires an evaluation in terms of monetary units which is provided by V.

Two conclusions emerged from this experiment. First, different supermarkets respond in different ways to these changes. Some change prices and distribution services in the same direction, indeed they can both increase or decrease; some in opposite directions. Second, the four characteristics (statistically significant at the 5% level) differentiating the sample of supermarkets where consumer welfare increased (V>0) from those where it decreased (V<0) were a larger turnover (Q), a larger market share in the SMSA for the firm owning the supermarket, a higher proportion of superstores and a higher presence of scanners. Hence, these results suggest that recent trends toward the adoption of superstore formats and optical scanners are welfare improving for supermarket costumers when there is an increase in either intratype competition or general competition for the consumer=s dollar.

Notes

* Earlier versions of this paper were presented at the AEA Meetings in Washington, DC, and at the third conference on Retailing and Services in the Gold Coast, Australia. Seminar presentations were given at U. of Miami, U. of Maryland, U. of Vienna and the Social Science Research Center in Berlin (WZB). We would like to thank without incriminating the following individuals: James MacDonald, Walter Oi, I. Prucha, H. Kelejian, A. Sen, R. Kranton, L. Locay and N. Wallace. Part of the research for this paper was undertaken while Betancourt was an IRIS Fellow.

1. E is a restricted expenditure or cost function in that D plays the role of a fixed input in this function. It has the well known implication (Shephard=s Lemma) that $\partial E/\partial p = q(p, D, p=, z^0)$. This is the Hicksian demand function which upon substitution of the demand for the commodities, $z^0 = g(p, p=, D,Y)$, generates the Marshallian demand function. See Deaton and Muellbauer (1980, Chs. 2 and 10) for the general procedure or Betancourt and Gautschi (1992) for its application to retail demand. In particular the last reference shows that, if we assume that other prices faced by the representative consumer (p=) are constant, the Marshallian demand can be written as q(p, D, Y) and it will be decreasing in price (p), and increasing in distribution services (D) and the consumer=s full income (Y). Finally, just as any restricted cost or expenditure function, it has the property that $\partial E/\partial D < 0$. And, this property can be used to define the shadow price of distribution services, $r = - \partial E/\partial D$, or how much the

consumer would be willing to pay for an additional unit of distribution services if it were available in the market at an explicit price.

2. If in the above example μ equals zero, we have the case of a monopolist and there are no gains from meeting the competitive standard. If μ equals unity the supermarket gains all the business of the representative consumer. For values between zero and unity the supermarket gains a fraction of the business of the representative consumer. If μ exceeds unity second-order conditions are violated. Thus the maximum value of μ is unity.

3. Incidentally μ captures intratype competition from other supermarkets. General competition for the consumer=s dollar is captured in the price elasticity of demand. Unless otherwise stated competition will refer to the former and not the latter.

4. Tirole (1988, p.244) notes that this is the only consistent conjecture in a static model.

5. For applications of variants of this function to the demand for supermarket products see Bode (1990).

6. There is a certain amount of judgement in what variables one selects as X_1 and X_2. The first variable suggested itself pretty easily in light of arguments that the poor pay more at supermarkets, MacDonald and Nelson (1991). There is no prior literature to guide the choice of the second one, or to provide expectations about

its sign; hence, we chose an indicator of well- being with independent variation that was not going to be used elsewhere in the analysis.

7. The latter should be viewed as introduced in exponential form in (4), e.g., as $e^{\delta x}$.

8. The list of instruments is the same as used in Section 5 and it will be discussed there.

9. In the equations below the constraint in (3) is not present. Since the source of the errors is in the application of the decision rules not in the objective function, the constraint is assumed to hold with certainty. Note that it is not directly observable or estimable by the econometrician.

10. The slopes of the demand function in (8) and (9) can be expressed in terms of elasticities as $(\partial Q/\partial p) = \delta_1 (Q/p)$ and $(\partial Q/\partial D) = \delta_2 (Q/D)$, where δ_1 and δ_2 correspond to the price elasticity of demand and the distribution services elasticity of demand estimated in the previous section, respectively.

11. See the data appendix for additional details.

12. We also considered a different functional form for the cost function, namely the one employed by Pulley and Braunstein (1984). This function is the standard quadratic with interaction terms between input prices and outputs added to allow for heterotheticity. The results deteriorated and we abandoned experimentation with alternative functional forms.

13. In our empirical work the market area was defined as the SMSA in which the supermarket was located.

14. The variables in the vector M can be thought of as capturing variations in E=, the minimum expenditure at alternative establishments, across supermarkets in different market areas.

15. We also considered the SMSA=s four firm concentration ratio and four firm Herfindhal index. Since these variables, just like the previous two, take on the same values for each supermarket in an SMSA, they only vary over the 28 different SMSA=s and this limited variation resulted in severe multicollinearity problems.

16. Setting r_1 to zero made no difference to the substantive results reported in Section V.

17. See Kelejian and Oates (1981, Ch. 8) for an elementary but insightful discussion of this issue and Amemiya(1985) for an advanced treatment.

18. Namely the index of labor compensation, the selling area of the supermarket and four variables available for the zip code area where each supermarket was located: the percentage of households without cars, socioeconomic status, median income and population.

19. We checked the sensitivity of our results to the choice of instruments. For instance, we dropped the interaction terms between the percentage of households with more than two earners and the six other

variables and reestimated the demand equation and the first-order conditions with the reduced set of 29 instruments. No substantive statement made about the coefficient estimates in Section III or in this section would be altered by using these results instead of those based on the 35 instruments.

20. For instance, Ofer (1973) measured output as value added and argued that, under certain assumptions, it is a perfect measure of the (distribution) services provided by a store, D; he found evidence of increasing returns to scale. On the other hand, Ingene (1984) measured output as sales per establishment and argued that, under certain assumptions, it was a perfect measure of turnover or explicit output, Q; he found evidence of constant returns to scale.

21. Sales were measured in hundred of 1982$. Thus, we multiplied the estimate by 100.

22. Parenthetically, Messinger and Narasinham (1997) have estimated the average value of one-stop shopping at supermarkets to be between 2.24% and 2.37 % of sales.

23. The average retail margin for food stores in 1982, according to the Census of Retail Trade, was about 22%. Our numbers, however, are estimates of the price-cost margin and our cost variables do not account for any equipment costs.

24. For instance, we changed the values of α_1 and α_2 from 1 to .5 and

1.5 and reestimated the model for all three waves with these new values. Also, we added the excluded observations from each wave and reestimated the demand function and the first-order conditions.

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TABLE 1: DESCRIPTIVE STATISTICS

VARIABLE	MEAN	STD. ERROR	MINIMUM	MAXIMUM
Price wave 1	99.24	5.71	66.36	118.85
Price wave 2	99.66	5.42	73.72	120.92

Price wave 3	99.82	5.83	68.76	135.27
Output[1] wave 1	704. 47	528.42	52.86	3836.48
Output[1] wave 2	702.64	534.47	51.62	3811.87
Output[1] wave 3	699.98	528.74	51.66	3772.14
dist. services[2]	101.40	24.75	8.90	160.20
% wo cars	12.29	13.48	0.	90.
Socec. stat. idx.	54.20	11.23	30.	99.
Median Income	19082.65	6013.86	5901.	51175.
Sh. center dum.	0.6186	0.4863	0.	1.
Population	31586.72	17034.07	189.	93751.
Selling area	18397.20	11234.71	3000.	68381.
Occ. Cost	100.95	23.62	63.70	167.37
Lab. cost[3]	98.90	23.94	13.54	163.50
Superstore du.	0.1674	0.3738	0.	1.
Traditional du.	0.7883	0.4089	0.	1.
Scanner du.	0.2465	0.4315	0.	1.
Chain dummy	.6140	.4874	0.	1.
Market sh.	0.0801	0.0848	0.0001	0.4661

# sts.(per 000's)	0.9792	0.2094	0.6483	1.7838
Market growth	0.0082	0.0425	-0.0900	0.1060
opp. cost[4]	-0.280	21.28	-37.50	54.66

[1] We constructed the output indexes by taking annual store sales in hundreds of $1982 and dividing by the store price index.

[2] We constructed the distribution services index. Its main difference from the services index constructed by ERS is the elimination of one of the twenty services categories (scanners, which is an input not an output) and the addition of another available elsewhere in the original data (extended hours, which is an output); see the Data Appendix for details.

[3] Within SMSA labor cost.

[4] Between SMSA labor cost

TABLE 2: NONLINEAR TWO STAGE LEAST SQUARES - [DEMAND EQUATIONS]						
PARAMETER	WAVE 1		WAVE 2		WAVE 3	
	ESTIMATE	STD ERROR[1]	ESTIMATE	STD ERROR[1]	ESTIMATE	STD ERROR[1]
δ_{10} price	-2.1336*	.4496	-2.2276*	.4525	-2.0194*	.4229
δ_{11} price * hh wo cars	.0039*	.0006	.0040*	.0006	.0038*	.0006

δ_{20} services	.5016*	.1677	.5221*	.1586	.4639*	.1567
δ_{21} serv.* socec. sta.	-.0017*	.0008	-.0019*	.0009	-.0015**	.0008
δ_{41} shopping center	-.0433	.0508	-.0450	.0505	-.0403	.0508
δ_{3} median income	.9336*	.1829	.9708*	.1733	.8842*	.1705
δ_{42} population	.0535**	.0316	.0553**	.0315	.0568**	.0316
δ_{43} selling area	.8592*	.0504	.8583*	.0483	.8703*	.0481
R^2	.515		.536		.525	
δ_{1} MEAN	-2.0856		-2.1785		-1.9727	

MINIMUM	-2.1335		-2.2276		-2.0194	
MAXIMUM	-1.7825		-1.8676		-1.6774	
δ_2 MEAN	.4094		.4192		.3827	
MINIMUM	.3332		.3340		.3154	
MAXIMUM	.4505		.4651		.4189	

[1] White robust standard errors. * \|t\|>1.96. ** \|t\|>1.645.

TABLE 3: NONLINEAR THREE STAGE LEAST SQUARES -FIRST-ORDER CONDITIONS[1]							
	Parameter	Wave 1		Wave 2		Wave 3	
		Estimate	Std Error[2]	Estimate	Std Error[2]	Estimate	Std Error[2]
SHIFT PARAMETERS IN COST FUNCTION	θ_1 super	-.0385	.0496	.0100	.0364	.0240	.0287
	θ_2 trad.	.0162	.0465	.0459	.0357	.0584*	.0188
	θ_3 scan.	-.0263**	.0152	-0.212*	.0107	-.0178**	.0099
INPUT PARAMETERS	π_1 occu.	.0720*	.0315	.0606*	.0239	.0524*	.0227
	π_2 lab.	.0271	.0206	.0209	.0188	.0220	.1860
	α_{11}	21.16*	8.380	36.76*	13.93	35.81*	14.08
	β turno.	.9701*	.0373	.9577*	.0274	.9834*	.0190

	α_{22}	1633.90	1021.33	1217.76**	722.17	1087.49*	538.372
	γ serv.	.4567*	.1359	.5393*	.1393	.5819*	.1251
	α_{12}	.0692*	.0153	.0684*	.0133	.0686*	.0131
WHOLESALE PRICE PARAMETERS	σ_0	35.34*	10.70	25.15**	15.05	17.92	15.72
	σ_1 chain	-1.6044*	.6732	-1.0385*	.5293	-1.5991*	.6010
COMPETITION PARAMETERS	γ_1 sh.	.5140*	.2111	.4716*	.2272	.4182**	.2450
	γ_2 # st.	-.1154**	.0674	.0141	.0896	.0876	.0790
	γ_3 m.gr.	-1.6642*	.5888	-1.7869*	.6429	-1.6101*	.6170
SHADOW PRICE PARAMETERS	r_0	220.51*	62.95	250.98*	76.40	278.16*	84.27
	r_1 time	.1873**	.0994	.1996*	.0988	.1817**	.0981
$p - C_Q - w$	Mean	25.98		23.03		25.04	
	Minimum	-9.73		4.74		5.65	
	Maximum	52.75		51.24		60.22	
	Obs.<0	1		0		0	

[1] These estimates were obtained given values of unity for α_1 and α_2 and using the estimates of δ_1 and δ_2 for each wave presented in Table 2.

[2] White robust standard errors. * $|t| > 1.96$. ** $|t| > 1.645$.