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INTERNAL NON-PRICE COMPETITION, PRICING, AND INCENTIVE SYSTEMS IN THE COOPERATIVE SERVICE FIRM: THE CASE OF U.S. MEDICAL GROUP PRACTICE

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ABSTRACT

The model developed in this paper is a model of internal non-price competition among members of a cooperative firm. Members take price and income distribution method as given, but perceive a positive relationship between their own production of quality and the flow of consumers to them, when constrained by demand. At an internal Nash equilibrium, each member may be producing "too much" quality, yet will not reduce production for fear of losing customers. In this paper, the focus is on the price and income distribution method, which serve as an incentive mechanism for coordinating behavior. An unusual feature of this model is the switching behavior generated as members of the firm move form the unconstrained to the constrained regime. This feature is incorporated for empirical testing by specifying the model to be estimated as a spline function. The empirical testing is possible due to the existence of a unique data set for American medical group practice.

The estimation results of this study confirm the hypotheses of switching behavior and a positive relationship between price and the strength of the link between reward and productivity. This provides strong evidence to support the contention that internal non-price competition is present in cooperative service firms, and that it increases as members' rewards are linked more closely with their own productivity.

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I. Introduction

Recent work on the theory of the firm has emphasized the importance of internal organization of the firm and the accompanying structure of incentives (e.g., Williamson, 1975; Alchian and Demsetz, 1972; Marschak and Radner, 1972). In order to highlight and isolate the nature of internal organization and incentives, this paper studies the cooperative firm. In the cooperative firm all members are claimants to the residual, and thus the incentive effects of alternative forms of organization are highlighted.

Past studies of the cooperative firm have emphasized the negative incentive effects of equal sharing of group net income (e.g., Sen, 1966; Meade, 1974; Carson, 1977). The less that rewards are linked to performance, the less efficient will be the collective outcome. It is not necessary, however, that this result always obtain. In the case where non-price competition exists between members of the firm, it has been shown that stronger links between reward and individual action can lead to outcomes which are non-optimal from the point of view of the group (Gaynor; 1983, 1984). This paper develops a model of firm behavior in the face of internal non-price competition and tests it for the case of U.S. medical group practice. The results paint a quite different picture of the behavior of the cooperative firm and U.S. medical group practices than the literature in either area has presented in the past.

The literature on cooperatives and on medical groups has mainly focused on the production and cost inefficiencies present in these groups due to lack of proper incentives in the member reimbursement system. The early papers on co-ops, such as Ward (1958), Domar (1966), and Sen (1966), recognized the problem of shirking in such a context. Sen (1966) had formulated a model of the effect of income distribution on labor supply in an agricultural cooperative and recognized the problem of shirking present in such a context. The later literature on co-ops is in the same vein, thus non-price competition within the firm never appears. The empirical part of this literature is restricted almost entirely to the Yugoslav labor-managed firms or to other firms which are labor, but not producer/seller, cooperatives and thus never needs deal with the issue of non-price competition.

There are a few papers which deal with pricing or income distribution behavior in seller cooperatives located in market economies. These cooperatives are typically service firms, such as medical or legal groups, formed because of indivisibilities in inputs or stochastic or lumpy demand. Sloan (1974) postulates a theoretical model of a profit-maximizing physician who sets price independent of the group. The only collective aspect of this model is in cost. Scheffler (1975) constructs an empirical model and estimates it on data obtained from a survey of medical groups in North Carolina. The salient finding is that groups with a non-salaried system of remuneration set lower prices. Presumably this is because non-salaried groups have a closer link between income and productivity, which leads to greater efficiency, and, thus, lower prices. This is not necessarily the case, however, due to the lack of precision with which the link between income and productivity is measured, lack of control of market-level determinants of price, and the small sample size of 61 physicians. Leibowitz and Tollison (1980) conducted a study of legal group practices in which they attempted to determine whether team production of legal services is efficient relative to solo production. Their results are consistent with efficiency in team production, but they have no measure of income distribution method, only cost, size, and general organizational measures.

II. The Model

The model developed in this paper is a model of internal non-price competition among members of a cooperative firm. Members take price and income distribution method as given, but perceive a positive relationship between their own production of quality and the flow of consumers to them, when constrained by demand. At an internal Nash equilibrium, each member may be producing "too much" quality, yet will not reduce production for fear of losing customers. The literature on non-price competition under regulation running from White (1972), to Vanderweide and Zalkind (1981), contains models which are similar, yet differ because they examine the behavior of firms in an industry, not individual members within a firm. In this paper, the focus is on the price and income distribution method which serve as an incentive mechanism for coordinating behavior.

A. Members

Individual members of the firm maximize a utility function assumed to be linear in income and strongly separable in the members' actions, which are production levels of quantity and quality. The utility function is

$$u_i = y_i - V_i(q_i, z_i, T) \qquad i = 1, \ldots, n \tag{1}$$

where i is the index for the n members of the firm, u is utility, y is income, q is quantity, z is quality, and V_i is the function transforming i's actions into a real, nonmonetary, cost. $V_i(q_i, z_i, T)$ is the member's "cost function," measured in terms of disutility. T is a factor assumed to have a positive effect on cost. The utility function is assumed to be strictly concave, differentiable, increasing, and to take on value zero when all its arguments are zero.

Firm members derive income only from their activities with the firm, and that income is equal to a share of the revenue they generate plus a share from a firm level revenue-sharing pool.[1] Therefore, member i's income is expressed as

$$y_i = \alpha P q_i + \frac{1}{n}(1 - \alpha) \sum_{i=1}^{n} P q_i, \qquad 0 \leq \alpha \leq 1 \tag{2}$$

where α is the proportion of i's revenue "kept" by i and P is the price charged by the firm for q_i, a unit of its output. The member views P as invariant with respect to its actions.[2] The first term in (2) is the member's share of its "own" revenue, the second term is the share from the revenue-sharing pool.

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[1]It is assumed that the only inputs to production are supplied by co-op members, and therefore there is no pecuniary cost of production. This is not a critical assumption, since all results follow through without it, but it does simplify the exposition considerably. For the case of services, this is reasonably realistic anyway.

[2]One can describe this as pure price-taking behavior, or else think of a process in which all members set a price collectively, after which it is regarded as a fixed by all. The latter process may be more realistic, but operationally amounts to the same thing.

Each member perceives a demand function by which they are inexactly constrained,[3] so

$$q_i \leq f(P, z_i, \hat{z}_j, n), \tag{3}$$

where $\hat{z}_j$ is the vector of quality levels produced by all other n - 1 members of the firm $j \neq i$. Economic considerations suggest that demand for a member's output decrease if firm price is increased, that a member's demand increase as his product quality increases, decrease with others' quality, and decrease as additional members enter the firm. These considerations imply

$$f_1 < 0,\ f_2 > 0,\ f_3 < 0,\ f_4 < 0,$$

where a subscript k indicates the first partial derivative with respect to the kth argument. f is called the member's "perceived" demand function because, due to the assumptions of price-taking and Cournot-Nash behavior, the member sees P, $\hat{z}_j$, and n as fixed. When the other variables are allowed to change as z_i changes, f gives true, or actual, demand.[4] Since price is fixed for the member when the demand constraint is binding, his

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[3]This implies no inventories. In the case of a service firm inventories are impossible. Shortages are possible since members could always manage to see fewer customers than are scheduled for them in any given time period.

[4]Ignoring market level interactions.

only choice variable is quality, which also determines quantity through (3).

Further, each member is constrained to produce a certain minimum level of quality either by group requirements, peer pressure, or the legal system, so $z_i \geq z_{min}$.

Given the model outlined above, a member's objective is to choose quantity, q_i, and quality, z_i, to maximize the Kuhn-Tucker objective function

$$K_i = \alpha P q_i + \frac{1}{n}(1 - \alpha) \sum_{i=1}^{n} P q_i - V_i(q_i, z_i T)$$

$$- \lambda(q_i - F(P, z_i, \hat{z}_j, n)) - \mu(z_i - z_{min}). \tag{4}$$

Each member maximizes K_i under the assumption that all other members' decisions $(\hat{q}_j, \hat{z}_j)$ are invariant with respect to changes in q_i and z_i and taking P and n as fixed. The first order conditions are[5]

$$[\alpha + \frac{1}{n}(1 - \alpha)]P - V_{i1} - \lambda = 0, \tag{5}$$

$$\lambda f_2 - V_{i2} - \mu = 0, \tag{6}$$

$$q_i - f(P, z_i, \hat{z}_j, n) \leq 0, \lambda \geq 0, \lambda[q_i - f(P, z_i, \hat{z}_j, n)] = 0, \tag{7}$$

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[5]These are necessary and sufficient Kuhn-Tucker conditions for a global maximum, since the objective function is strictly concave and the constraint convex.

$$z_i - z_{min} \geq 0, \ \mu \geq 0, \ \mu[z_i - z_{min}] = 0. \tag{8}$$

The demand constraint multiplier, λ, is interpreted as the effect of a change in quantity demanded on income,

$$\lambda = [\alpha + \frac{1}{n}(1 - \alpha)]P.$$

When the demand constraint is binding, λ is positive, and thus the first order condition in equation (5) drops out. When the demand constraint is binding, the member does not choose quantity explicitly, but rather, implicitly, through the choice of quality, z_i.

When the member is not bound by the demand constraint, $\lambda = 0$, and thus (5) corresponds to the standard interpretation of producing where marginal revenue equals marginal cost. The choice of quality is then bound by the minimum, z_{min}, since producing more quality to shift the demand constraint has no payoff for the member. Equation (6) reduces to

$$-V_{i2} - \mu = 0,$$

where μ is the effect on i's income of an increase in the minimum quality level. In this case quantity is the choice variable, not quality, since the quality constraint is binding.[6]

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[6] While it is possible that both the demand and quality constraints are binding simultaneously, this case is of little interest, since then the member has no choice.

Evaluated across all members of the firm, equations (5) through (8) define an equilibrium for the members of the firm.[7] The solution to this system defines a member's equilibrium production of quantity and quality as functions of group price, income distribution method, and group size,

$$q_i^* = \begin{cases} g_i(P, \alpha, n, T) & \text{if } \lambda > 0 \\ \\ f(P, z_i^*, \hat{z}_j^*, n, T) & \text{if } \lambda = 0, \end{cases} \tag{9}$$

$$z_i^* = \begin{cases} z_{min} & \text{if } \lambda > 0 \\ \\ h_i(P, \alpha, n, T) & \text{if } \lambda = 0. \end{cases} \tag{10}$$

Implicit differentiation of the system (5) through (8) yields comparative static derivatives which reveal the character of g_i and h_i under the two separate regimes where the demand constraint is binding or free. Table 1 displays these results, which are developed in detail in the Appendix.

When the demand constraint is free, quantity is the choice variable. Increases in price or increases in the retention of private earnings lead to an increased supply of quantity, since both increase the marginal revenue realized from quality production. An increase in group size will reduce the supply because more members take shares of i's revenue. The results are the same when the demand constraint is binding, except that, in

[7]Given the mathematical assumptions made, the first-order conditions are necessary and sufficient for an optimum, so the solution to (5) - (8) exists, is unique, and is differentiable over any one regime.

Table 1

Characteristics of Member's Production

from Comparative Static Analysis

Regime	Endogenous Variables	Exogenous Variables			
		P	α	n	T
$\lambda = 0$	q_i^*	+	+	-	-
$\lambda > 0$	z_i^*	+,-,0**	+	-	-

**Conditions under which $\frac{\partial z_i^*}{\partial P}$ assumes each sign are outlined in the appendix.

general, an increase in price could have any effect on production of quality.[8]

B. The Firm

The firm controls P and α, the price and incentive scheme variables, and sets them in order to maximize group welfare,

$$W = \sum_{i=1}^{n} u_i = PQ - \sum_{i=1}^{n} V_i(q_i, z_i). \tag{11}$$

This is assumed to be an unweighted sum of individual members' utilities. In effect, W amounts to "non-monetary" profit, or a standard profit measure net of non-monetary costs.[9]

The members' supply functions are constraints on the group's choices with the form,

$$Z = H(P,\alpha,n,\ T) = \sum_{i=1}^{n} z_i^* = \sum_{i=1}^{n} h_i(P,\alpha,n,\ T), \text{ when } \lambda > 0 \tag{12}$$

$$Q = G(P,\alpha,n,\ T) = \sum_{i=1}^{n} q_i^* = \sum_{i=1}^{n} g_i(P,\alpha,n), \text{ when } \lambda = 0. \tag{13}$$

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8 If we assume that the demand function is of form $q = z^{\alpha}P^{-\alpha}g(n)$ as in VanderWeide and Zalkind (1981), then $\frac{\partial z_i^*}{\partial P}$ is positive.

9 In an economy where markets for all claims exist, non-monetary costs would find monetary expression as opportunity costs, and there would be no difference between W and standard profits.

The firm faces a demand function for quantity of its output which depends in the standard way on its price, its quality, other firms' prices, other firms' qualities, and the number of firms in the market. The demand function is

$$Q = F(P,Z,\hat{P},\hat{Z},m,X), \tag{14}$$

where $\hat{P}$ and $\hat{Z}$ are vectors of prices and qualities, respectively, of other firms in the market, m is the number of firms, and X is an exogenous factor which is assumed to have a positive effect on demand. We assume Cournot-Nash behavior by all firms, so $\hat{P}$, $\hat{Z}$ and m are taken as fixed by any firm with respect to its actions. F has the characteristics that increases in own price decrease demand, F is increasing and concave, other prices are positively related to demand, and other firms' quality affects demand negatively, as does entry,

$$F_1 < 0,\ F_2 > 0,\ F_{22} < 0,\ F_3 > 0,\ F_4 < 0,\ F_5 < 0,\ F_6 > 0.$$

All other firms in the market face the same demand function, so demand is symmetric.[10]

When members are not bound by the demand constraint the group's problem is

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[10] If each firm has the same distribution of member disutility types (V_i's), then they have identical "cost" functions, and the resulting Nash equilibrium will be symmetric.

$$\max_{P,\alpha} \quad PQ - \sum_{i=1}^{n} V_i(q_i,z_i) + \lambda(Q - F(P,Z,\hat{P},\hat{Z},m,X) + \mu(Q - \sum_{i=1}^{n} g_i(P,\alpha,n)). \quad (15)$$

The first order conditions are

$$\frac{\partial W}{\partial P} \quad Q - \lambda F_1 - \mu \sum_{i=1}^{n} g_{i1} = 0, \quad (16)$$

and

$$\frac{\partial W}{\partial P} \quad -\mu \sum_{i=1}^{n} g_{i2} = 0. \quad (17)$$

λ, the demand constraint multiplier, is interpreted as the effect of a change in quantity demanded on group welfare. The member supply constraint multiplier, μ, gives the effect of a change in quantity supplied on group welfare. In equation (16), $Q - \lambda F_1$ corresponds to marginal (welfare) revenue, and $\mu \sum_{i=1}^{n} g_{i1}$ corresponds to marginal (welfare) cost. In equation (17), $\mu \sum_{i=1}^{n} g_{i2}$ is the marginal effect on group welfare of changing α. In effect, this means that the firm sets price so that profits are maximized, and then sets α so that members will be induced to produce the quantity demanded at the profit maximizing price.

When the constraint is binding, the member's problem is

$$\max_{P,\alpha} \quad PF(P,H(P,\alpha,n),\hat{P},\hat{Z},m,X) - \sum_{i=1}^{n} V_i(f(P,h_i(P,\alpha,n, T),\hat{z}_j n),h_i(P,\alpha,n, T)). \quad (18)$$

The first-order conditions for the firm's choice of price and sharing system which maximize (11) subject to (12) and (14) are

$$\frac{\partial W}{\partial P} = Q + PF_1 + PF_2H_1 - \sum_{i=1}^{n} [V_1f_1 + V_1f_2h_{i1} + V_2h_{i1}] = 0, \tag{19}$$

and

$$\frac{\partial W}{\partial \alpha} = PF_2H_2 - \sum_{i=1}^{n} [V_1f_2h_{i2} + V_2h_{i2}] = 0. \tag{20}$$

This is a unique, global optimum, given all the assumptions on the relevant functions which make the firm's welfare function strictly concave in P and α, twice differentiable, and take the value zero when either P and α equal zero. Evaluated at all firms' P and α, this is a Nash equilibrium, and if costs as well as demand are symmetric, then the equilibrium is symmetric as well (Schmalensee, 1977; VanderWeide and Zalkind, 1981).

As before, the firm sets price to maximize profit, and α to induce members to produce the optimal amount of quality. The difference here is that there are feedback effects from the members' supply function of quality through demand, due to the fact that members are constrained and thus produce quality above the minimum. Thus, in (19), marginal revenue ($Q + PF_1 + PF_2H_1$) includes the effect on revenue of a change in quality supply caused by a change in price changing demand (PF_2H_1). The summation terms in (19) represent marginal cost and include the effects of increased quality production on costs ($\sum [V_1f_2h_{i1} + V_2h_{i1}]$). Equation (20) includes only terms which reflect feedbacks from members' quality supply function. The first term in (20) gives the marginal revenue effect of additional quality production induced by an increase in the sharing rate. The summation terms are the marginal cost of the additional quality production induced by an increase in the group's sharing rate.

III. Specification of the Empirical Model

The previous sections outlined a model of price and income distribution determination for a co-operative firm where members engage in non-price competition. The purpose of this section is to outline a method for generating and testing the predictions of the model via econometric estimation. The type of function to be estimated, and its form, will also be examined. In addition, the types of variables to be used in estimation will be examined.

In order to generate some testable hypotheses, let us first define the "efficient price locus." The efficient price locus gives an optimal price for the group for any given combination of group size, exogenous demand and cost shifters, and group sharing rate. It is defined by the first order conditions for price setting laid out in the last section,

$$Q + (P - \sum_{i=1}^{n} V_{i1})(F_1 - \sum_{i=1}^{n} g_{i1}) = 0, \qquad (16)$$

when the constraint is free, and

$$Q + PF_1 + PF_2H_1 - \sum_{i=1}^{n} [V_{i1}f_1 + V_{i1}f_2h_{i1} + V_{i2}h_{i1}] = 0, \qquad (19)$$

when it is binding. Equations (16) and (19) define two different efficient price functions,

$$P^* = P^1(\alpha,n,X,T), \tag{21}$$

and

$$P^* = P^2(\alpha,n,X,T), \tag{22}$$

respectively. The comparative static properties of P^1 and P^2 are derived in the Appendix, Part C and displayed in Table 2. In the unconstrained regime where P^1 is the efficient price function, α and P move in opposite directions, since an increase in α leads members to produce more and thus decrease the optimal price. When members are constrained, an increase in α induces them to produce more quality, thus increasing the optimal price.

Whether firm members are constrained or not depends on the value of α, since higher levels of α induce higher levels of production, thus moving members toward the constraint as α increases. When α is at its minimum ($\alpha = 0$), members will be unconstrained by demand. To see this, compare the member's first-order condition determining his utility maximizing output (5) with the condition which determines the level of output for the member which would maximize group welfare (23):

$$[\alpha + \frac{1}{n}(1 - \alpha)]P - V_{i1} = 0, \tag{5}$$

$$P + Q\frac{\partial P}{\partial q} - V_{i1} = 0. \tag{23}$$

Table 2

Comparative Static Effects on Efficient Prices

Independent Variables	Efficient Prices	
	p^1	p^2
α	−	+
n	+	−
X	+	+
T	+	−

When $\alpha = 0$, the member may produce less than the quantity dictated by (23), if the second term in (23) is less than $(\frac{1 - n}{n})P$. In other words, the member will produce too little unless the demand curve is very steep. As α increases, members increase production and move towards the demand constraint. When $\alpha = 1$, (5) is $P - V_{i1} = 0$, and the member will want to produce "too much." Therefore, at some $\alpha < 1$, members hit the demand constraint. Before that, $\frac{\partial P}{\partial \alpha} < 0$, and after that, $\frac{\partial P}{\partial \alpha} > 0$.

The behavior being described can effectively be summarized mathematically by using a spline function. A spline function is a function with distinct pieces which are themselves continuous functions (see Poirier; 1976 for a thorough exposition on this topic) In the case where there are only two pieces (as predicted by the theory), and those pieces are linear, the relationship to be estimated is

$$P_i = \beta_1 + \beta_2\alpha_i + \beta_3(\alpha_i - \bar{\alpha}^*)D_i + \beta_4 n_i + \beta_5 X_i + \beta_6 T_i + \varepsilon_i, \tag{24}$$

where

$$D_i = \begin{cases} 1 \text{ if } \alpha_i > \bar{\alpha}^* \\ 0 \text{ otherwise} \end{cases}$$

Or course, α, the sharing rate, while being treated as an independent variable in this exposition, is not exogenous. It is set by the group and will vary when the truly exogenous variables themselves vary. α is set so that the first-order conditions for a welfare maximum of the group are met. These are equations (17) and (20) from section II. The directions of the effects of changes in the exogenous variables on the optimal sharing rate are derived in section B of the Appendix. Table 3 presents the results. When group size (n) increases, the group optimally increases α if members are not bound by the demand constraint in order to counteract the increased disincentive effects on supply. If the demand constraint is binding, however, an increase in group size does some of the work of keeping members from oversupplying quality, and thus the sharing rate must be reduced.

When X increases, demand increases. Whether the members are bound or not by the demand constraint, the group must induce greater production to meet the increased demand, and thus, must increase α.

Increases in T cause costs to rise. When the demand constraint is slack, optimal price rises and optimal quantity falls. Therefore, the firm must cut α to counteract the positive effect of the price increase on member supply. Of course, oversupply is not physically possible in the case of a service, but it is certainly better to have incentives for optimal behavior rather than not. When physicians face a binding demand constraint, the optimal action for the firm is to increase the sharing rate. This is because at the old α and the new, higher price, members will cut back too much in response to the shift in costs, since price increases by less than marginal cost, and α is less than one. Thus, at the old α and new price members are not getting the right signals, and α must be increased.

All of this discussion indicates that the most appropriate method of estimation to test these hypotheses is by two-stage least squares. The

Table 3

Signs of Comparative Static Derivatives of α

Status of Demand Constraint	$\frac{\partial\alpha}{\partial n}$	$\frac{\partial\alpha}{\partial X}$	$\frac{\partial\alpha}{\partial T}$
Free	+	+	-
Binding	-	+	+

efficient price locus is the function to be estimated, and one of its independent variables, the sharing rate, is clearly endogenous.

V. Data

The data utilized for this study were assembled by Mathematica Policy Research, Inc., under contract to the National Center for Health Services Research, Department of Health and Human Services, U.S. Government. The bulk of the data set is composed of surveys conducted by Mathematica, although some secondary data sources have been merged in. During the period March to June of 1978, Mathematica conducted a nationwide survey of medical group practices. The final sample included 957 groups and 6353 physicians practicing in those groups. The sample was stratified by: group size, type of group (multispecialty or single specialty), physician specialty, and prepaid vs. fee-for-service. Large group practices were oversampled in an effort to supply a reasonable number of observations, and a census was taken of pre-paid groups, for the same purpose. Further, only five medical practice specialties were sampled: general practice, internal medicine, pediatrics, general surgery, and obstetrics/gynecology. Approximately 60 percent of all office-based physicians practice in these specialties.

Since surveys tend to produce low response rates, Mathematica conducted analysis for nonresponse bias on their data. Examining each of the survey instruments and using statistical techniques (e.g., the Heckman Technique) Mathematica concluded that nonresponse bias was not a problem to be faced in the utilization of the data set for purposes of statistical analysis.

This data set also includes data measuring characteristics of the area in which the group practiced and data on the hospital with which the group is affiliated. The data on area characteristics were obtained from many sources, including the American Medical Association, the County and City Data Book, and various other sources. For a full listing of all these data sources see Boldin, Carcagno, Held, Jamieson, and Wooldridge (1979). The hospital data were obtained from the American Hospital Association Guide tape for 1978.

This data set is currently the most complete and comprehensive of its kind in the U.S., and as such is appropriate for the empirical analysis conducted in this paper.

V. Estimation

In this section we first translate the theoretical variables into variables from the data set, then present some summary statistics, and finally the estimation results. The unit of output is a first-time office visit to a physician. The acronyms and definitions of the variables used in estimation are reported in Table 4.

Since the true full price (P) for an office visit includes not just money price but also measures of time cost, measures of waiting time (OFFWAIT and APPTWAIT) are included along with the money price (PRICE). Waiting time is not exogenous, so OFFWAIT and APPTWAIT must be treated as endogenous variables.

Some standard exogenous demand shifters (X) such as measures of income (PCAPINC and LOWINC) and cost of living (RENT) are included, along with some others specific to the medical care sector or data set. MDPOP and

Table 4

Variable Acronyms and Definitions

Acronym	Definition
Full Price Variables:	
PRICE	Usual, customary and reasonable (UCR fee for an office visit
APPTWAIT	Days wait for an appointment
OFFWAIT	Minutes spent waiting in the office to see the physician
Exogenous Demand Variables:	
PCAPINC	Per Capita Income for the area
LOWINC	Percent of group's patients with incomes below $10,000
MDPOP	Physician-population ratio in the area
MDENS	Physician Density in the areaInformation Variables:
EDUCATE	Median years of education of persons over 25 in area
FEMHEAD	Percent of area families with a female head
PCTMOVED	Percent of families in area who moved within last 5 years
Area Attractiveness Variables:	
PUBTRANS	Percent of total labor force using public transit to work

Table 4 (continued)

Acronym	Definition
Area Attractiveness Variables: (continued)	
PCTURBAN	Percent of population urban
ARPRICE	Average price for an office visit
GOVSPEND	Per capita local government expenditures
PCTPROF	Percent of labor force professionals
Group Characteristics:	
PRODSCAL	Scale relating productivity to reimbursement
DUMDIFF5	Dummy Variable. Equals difference between PRODSCAL and 5 if PRODSCAL is greater than 5
GRPSIZE	Number of FTE physicians in the group
DUMGRP	Equals difference between GRPSIZE and the mean value of GRPSIZE when PRODSCAL is greater than 5
MANAGER	Whether the group has a manager or not
PROGDLN	Whether the group has productivity guidelines
IM	Group specialty is internal medicine
GP	Group specialty is general practice

Table 4 (continued)

Acronym	Definition
Group Characteristics: (continued)	
OB	Group specialty is obstetrics/ gynecology
GS	Group specialty is general surgery
Exogenous Cost Variables:	
WAGERN	Wage of a registered nurse
DUMWAGE	Equals the difference between WAGERN and its mean when PRODSCAL equals 5, if PRODSCAL exceeds 5

MDENS are variables aimed at controlling for the observed positive correlation between fees and physicians per capita, and the Pauly-Satterthwaite (1980) increasing monopoly model, respectively. The increasing monopoly model proposes that increasing physician density makes information gathering more difficult for consumers. This leads to less elastic demand and a higher price. In addition, anything which makes information gathering more difficult is expected to lead to a higher price. MDPOP should then have a negative or negligible effect.

Also associated with the increasing monopoly model are variables which serve as proxies for consumers' ease in gathering information. FEMHEAD and PCTMOVED are hypothesized to make information gathering more difficult and EDUCATE to make it easier.

Since the number of physicians in an area is in reality endogenous, variables representing attractiveness characteristics of the area should have an effect on MDPOP and MDENS. These are: PUBTRANS, PCTURBAN, ARPRICE, GOVSPEND, and PCTPROF.

PRODSCAL (α) and DUMDIFF5 are the measures of α and $(\alpha_i - \alpha^*)D_i$ from equation (24). GRPSIZE is expected to have a positive effect on price. DUMGRP picks up the break in the effect of GRPSIZE on PRODSCAL. MANAGER and PRODGDLN should help explain the group's choice of PRODSCAL, which is endogenous. The specialty dummy variables IM, GP, OB and GS are intended to pick up the variation in price across medical specialties. WAGERN is an exogenous variable expected to increase group costs, and thus, price. DUMWAGE picks up the expected break in the effect of WAGERN on PRODSCAL.

Table 5 presents the means and standard deviations of all the variables. The results from the first-stage of the two-stage estimation process are contained in Table 6. PRODSCAL, DUMDIFF5, OFFWAIT, APPTWAIT, MDPOP and MDENS are endogenous, independent variables. The results for DUMDIFF5 are not presented for the purpose of brevity, since they are qualitatively identical to those of PRODSCAL.

In general, the first-stage results are consistent with theory and intuition. The variable PRODSCAL varies positively with the presence of a business manager, and negatively with the presence of productivity guidelines set by the group. A manager does not face the incentive to free ride that a group member does, and thus may be expected to try to relate physician income more closely to productivity. Productivity guidelines are an alternative to income distribution incentive schemes, and thus their presence may be expected to lower PRODSCAL. GRPSIZE has a negative effect on PRODSCAL throughout its entire range. DUMGRP has no statistically significant effect, indicating the absence of the hypothesized break in the effect of GRPSIZE on PRODSCAL. This may indicate that even at low levels of PRODSCAL, increases in group size have an extremely strong effect. Interestingly enough, GRPSIZE has a negative effect on PRODSCAL, which is the opposite of the theoretical prediction. This may be due to higher costs (e.g., monitoring costs) of implementing a productivity based system in a large group. Variables which would make demand less elastic or shift it out, such as FEMHEAD, PCTMOVED, ARPRICE, and PCAPINC, all have a positive effect on PRODSCAL. The effect of wage (WAGERN, DUMWAGE) is negative when physicians are "unconstrained" by demand (PRODSCAL $\leq$ 5), since an increase in the wage would increase the firm's profit-maximizing price, and decrease the quantity demanded, but increase the quantity

Table 5

Means and Standard Deviations

Variable	Mean	Standard Deviation
PRICE	13.92	3.77
PRODSCAL	6.01	3.32
MDPOP	1.57	0.50
MDENS	1.27	1.70
DUMDIFF5	2.02	2.05
APPTWAIT	7.88	12.62
OFFWAIT	18.66	13.17
GRPSIZE	25.94	15.49
MANAGER	0.90	0.30
PRODGDLN	0.18	0.39
IM	0.09	0.28
GP	0.15	0.36
OB	0.04	0.20
GS	0.04	0.20
PCAPINC	4849.98	1137.54
PCTURBAN	73.99	23.21
PUBTRANS	6.47	6.98
EDUCATE	11.89	0.82
FEMHEAD	10.27	3.29
PCTMOVED	50.61	11.97
ARPRICE	11.42	2.18
WAGERN	4.94	0.92

Table 5 (continued)

Variable	Mean	Standard Deviation
DEMANDGS	1.98	0.56
GOVSPEND	259.16	89.09
PCTPROF	25.60	12.47
RES	0.87	0.20
YRSRES	3.22	0.72
BOARD	0.70	0.27
SUBSPEC	0.28	0.26
IMPREGY	2.18	0.46
IMPREGHR	2.17	0.45
IMPROTEC	3.07	0.55
IMPRODY	1.95	0.49
MDFEM	0.05	0.21
YRSGRP	11.64	7.27
FOREIGN	0.06	0.23
YRGRAD	18.86	8.23
YRGRAD2	478.87	349.08

Table 6

First Stage Estimation Results

Independent Variables	Dependent Variables: PRODSCAL	MDPOP	MDENS	APPTWAIT	OFFWAIT
Intercept	6.83 (14.30)	0.18 (1.68)	-2.49 (-6.88)	-5.04 (-1.47)	39.65 (10.80)
GRPSIZE	-0.01 (-6.03)	7.74×10^{-4} (1.56)	-3.95×10^{-3} (-2.38)	0.02 (1.35)	-0.02 (-1.10)
DUMGRP	8.38×10^{-4} (0.31)	1.91×10^{-3} (3.06)	-2.09×10^{-3} (-1.00)	7.32×10^{-3} (0.37)	0.02 (0.78)
MANAGER	0.57 (7.67)	0.03 (1.59)	0.03 (0.47)	0.91 (1.71)	-0.58 (-1.02)
PRODGDLN	-0.43 (-7.50)	0.04 (3.10)	-0.05 (-1.05)	-0.50 (-1.23)	-1.30 (-2.97)
IM	0.30 (3.76)	-0.06 (-3.04)	0.16 (2.69)	3.14 (5.51)	-2.32 (-3.80)
GP	-0.25 (-4.00)	-0.22 (-15.48)	0.20 (4.10)	-3.90 (-8.54)	-0.08 (-0.17)
OB	-0.89 (-8.12)	-0.03 (-1.35)	0.01 (0.16)	12.42 (15.73)	4.48 (5.30)
GS	-0.79 (-6.96)	0.07 (2.57)	0.10 (1.19)	-0.39 (-0.48)	-1.76 (-2.02)
PCAPINC	6.14×10^{-5} (2.19)	5.45×10^{-6} (8.57)	1.12×10^{-4} (5.25)	-9.89×10^{-4} (-4.92)	1.31×10^{-4} (-0.61)
PCTURBAN	-1.83×10^{-3} (-1.16)	-9.52×10^{-4} (-2.66)	0.02 (12.34)	-0.04 (-3.59)	-0.03 (-2.68)
PUBTRANS	-4.47×10^{-3} (-1.02)	0.02 (14.88)	0.08 (22.79)	-0.04 (-1.09)	0.10 (3.00)
EDUCATE	-0.02 (-0.50)	2.54×10^{-3} (0.27)	-0.09 (-2.84)	1.51 (4.98)	-1.67 (-5.14)
FEMHEAD	0.03 (3.50)	0.02 (9.87)	-0.02 (-2.98)	0.09 (1.29)	-0.15 (-2.06)

Table 6 (continued)

Independent Variables	Dependent Variables				
	PRODSCAL	MDPOP	MDENS	APPTWAIT	OFFWAIT
PCTMOVED	5.52×10^{-3} (2.25)	1.77×10^{-3} (-3.18)	-7.02×10^{-3} (-3.77)	-0.06 (-3.59)	0.11 (5.96)
ARPRICE	0.04 (3.52)	0.03 (9.18)	0.17 (17.68)	0.30 (3.42)	0.16 (1.69)
WAGERN	-0.90 (-33.04)	0.02 (2.66)	0.09 (4.46)	0.15 (0.79)	-0.19 (-0.91)
DUMWAGE	1.11 (68.04)	-4.67×10^{-3} (-1.26)	-1.00×10^{-3} (-0.08)	-0.13 (-1.14)	0.16 (1.29)
GOVSPEND	-1.18×10^{-3} (-3.95)	9.84×10^{-3} (14.47)	1.33×10^{-4} (0.58)	-9.52×10^{-3} (-4.43)	-8.71×10^{-3} (-3.78)
PCTPROF	-0.01 (-5.14)	9.55×10^{-3} (19.12)	0.04 (22.65)	-0.06 (-3.76)	-6.34×10^{-3} (-0.38)

physicians desire to supply. To control this, α would be optimally set lower. When physicians are constrained, an increase in the wage would increase costs and thus induce a smaller supply, thus α must be increased to achieve the optimal quality level.

A priori, the qualitative effects of independent variables on MDPOP and MDENS are expected to be the same, but that is not the case. The variables expected to be most relevant are characteristics of the area: PCAPINC, PCTURBAN, PUBTRANS, ARPRICE, GOVSPEND, and PCTPROF. Per capita income in the area has a positive effect on both the physician-population ratio and physician density, although the effect is one order of magnitude larger for MDPOP. The percent of the population which is urban has no significant effect on MDPOP and a positive effect on MDENS. It is reasonable to suppose that the degree of urbanization of the population is more closely related to physician density than to the physician-population ratio since a largely urban population will likely be more dense and this will have a relatively high physician density. The percent of the population commuting via public transit has no significant effect on MDPOP, but a positive effect on MDENS. This is also likely due to population density. The prevailing UCR price in the area for an office visit has a positive effect on both MDPOP and MDENS, since ARPRICE functions as one signal of potential profitability. The level of local government expenditures, a measure of the area's attractiveness, increases MDPOP, but has no effect on MDENS. PCTPROF has a positive effect on both variables.

Just as in the case of MDPOP and MDENS, the effects of independent variables on APPTWAIT, number of days wait for an appointment, and OFFWAIT, number of minutes spent waiting in the office, were expected to be the same. GRPSIZE had no significant effect on either measure of waiting time. The presence of a manager lowered APPTWAIT and productivity guidelines lowered OFFWAIT. Per capita income had a negative effect on APPTWAIT, and no significant effect on OFFWAIT. PCTURBAN decreased both waiting times, and PUBTRANS raised OFFWAIT. EDUCATE had a positive effect on APPTWAIT and a negative effect on OFFWAIT. This may reflect APPTWAIT as associated more closely with quality than time cost. ARPRICE has a positive effect on both waiting time variables, which is the opposite of what was expected. If high quality is associated with both high price and high waiting times, this result is rationalized.

Table 7 contains the major empirical results of this study. The second-stage results give estimates of the price spline function, with endogenous dependent variables converted into instruments through the first stage of the estimation procedure. The system is identified by the order condition. The number of included endogenous variables minus one equals 8 and the number of excluded predetermined variables equals 11.

The results presented are for a spline function with a knot at PRODSCAL equal to 5. Goldfeld and Quandt (1972, 1973) and Poirier (1976) discuss the problem of estimating models with unknown points of structural change. Such models are commonly referred to in the literature as "switching regression" models. The method proposed for a straightforward estimation is to estimate the model for all possible spline knot values, or points of structural change, and choose the model for which the sum of squared errors is minimized. The model was estimated for all possible switching values of PRODSCAL, which are the integer values in the closed

Table 7

Second Stage Estimation Results[a]

Dependent Variable: Price

Independent Variables	
Intercept	17.03 (2.97)
DUMDIFF5	5.57 (2.92)
PRODSCAL	-2.19 (-1.99)
IM	0.78 (-0.92)
GP	0.93 (1.67)
OB	-0.83 (-0.53)
GS	-0.23 (-0.29)
GRPSIZE	0.02 (1.67)
DUMGRP	0.02 (0.95)
APPTWAIT	0.35 (3.44)
OFFWAIT	-0.26 (-2.52)
WAGERN	0.52 (1.71)
DUMWAGE	-0.80 (-2.23)
MDPOP	5.88 (4.68)

Table 7 (continued)

Independent Variables	
MDENS	0.76 (2.47)
PCAPINC	-1.47×10^{-4} (-0.78)
EDUCATE	-0.97 (-2.96)
FEMHEAD	-0.18 (-2.27)
PCTMOVED	0.08 (3.63)

Number of Observations: 361

Degrees of Freedom: 342

[a]Asymptotic t-statistics are reported in parentheses below estimated coefficients.

interval between one and ten. The sum of squared errors is minimized for the model where the switch occurs at PRODSCAL equals 5.

The results of the estimation are largely consistent with the theoretical predictions. The most important result is that a switch in the effect of PRODSCAL on PRICE does occur, and that initially the effect is negative, and later, positive. For values of PRODSCAL in the interval [1,5], the constant equals 17.03 and the effect of PRODSCAL on PRICE ($\frac{\partial P}{\partial \alpha}$) is equal to -2.19. This indicates that over this range, when PRODSCAL (α) is increased, price falls, which is consistent with the theoretical predictions of the model for the regime where physicians are unconstrained by demand. In this regime, price falls by \$2.19 for every increase by 1 of PRODSCAL. When PRODSCAL ε [6,10], the results are consistent with the regime in which group members are constrained by demand and compete internally. The value of the (mythical) constant term is -10.82 and the coefficient on PRODSCAL equals 3.38. This result is consistent with the hypothesis that group member physicians are constrained, and in competing over quality, drive price up by \$3.38 for every unit increase in PRODSCAL.

The medical specialty dummies control for differences in price across major medical specialties. They indicate that there is no statistically significant difference between the UCR prices for office visits of internists or obstetricians or surgeons and pediatricians. General practitioners have higher prices than pediatricians.

The size of the group, GRPSIZE, has a positive and significant effect on price, which is consistent with the prediction that the disincentive effects of increased group size lead to inefficiency and, therefore, a higher price. DUMGRP turns up statistically insignificant, rejecting the hypothesis of a structural break in the relationship between group size and price. It seems that, even at higher levels of PRODSCAL, the disincentive effects of increased group size are present.

The waiting time variables both are significant, but have opposite signs. The number of days spent waiting for an appointment has a positive effect on price. It was hypothesized that APPTWAIT was a component of the time price of a visit and thus would have a negative effect on PRICE. That effect should be present, but is overpowered by a positive effect. It was previously hypothesized that APPTWAIT is strongly linked with quality, and if that is so, such a link would produce the result observed in the estimation results.

OFFWAIT, on the other hand, has the expected negative effect on price. This is consistent with a hypothesis that office waiting time is a component of full price, and, if linked with quality, linked in a weak fashion.

The effect of registered nurses' wages on price is positive, as expected. DUMWAGE is negative and significant, indicating a structural break. Thus, for PRODSCAL ε [1,5], the coefficient on WAGERN equals 0.52, meaning that a \$1 increase in wages increases price by 52¢. When PRODSCAL ε [6,10], the coefficient on WAGERN equals -0.28. A \$1 increase in nurses' wages causes doctors to cut back on production of quality, causing price to fall by 28¢.

The physician-population ratio has a positive, significant, and large effect upon price, even after controlling for endogeneity via first stage estimation. This fact, associated with the negative and significant coefficient on FEMHEAD, does not provide much support for the increasing monopoly model of Pauly and Satterthwaite (1980). That model would have the coefficient on MDPOP negative, and positive on MDENS, FEMHEAD, and PCTMOVED. MDENS and PCTMOVED are positively related to price, but FEMHEAD turns up negative, and MDPOP is positive. These results tend to reject the increasing monopoly theory, but neither support nor reject a model of induced demand.

The coefficient on the variable EDUCATE is negative, indicating that higher levels of education may make consumers more efficient at gathering information.

Lastly, per capita income has no statistically significant effect on price. This may occur because per capita income for the area is too far removed to have a significant effect on a group's demand curve. The ideal measure would be per capita income of the group's patients, but that is not available.

VI. Summary

Co-operative firms operating in the market for professional services defy some of the commonly held notions about cooperative type firms. The model proposed in this paper generates these differences through the mechanism of non-price competition. An unusual feature of this model is the switching behavior generated as members of the firm move from the unconstrained to the constrained regime. This feature is incorporated for empirical testing by specifying the model to be estimated as a spline function. The empirical testing is possible due to the existence of a unique data set for American medical group practice.

The estimation results of this study confirm the hypotheses of switching behavior and a postive relationship between price and the strength of the link between reward and productivity. This provides strong evidence to support the contention that internal non-price competition is present in cooperative service firms, and that it increases as members' rewards are linked more closely with their own productivity.

These results raise a new set of questions about the nature of this non-price competition, the design of optimal incentive systems in the face of such behavior, and the effects on equilibrium in markets where this phenomenon is present. Future research can focus on generating hypotheses about these questions, and testing them in the various service sectors of the economy where co-operative firms are present.

References

Alchian, A. and H. Demsetz (1972), "Production, Information Costs, and Economic Organization," American Economic Review, 62: 777-795, December.

Domar, E. (1966), "The Soviet Collective Farm as a Producer Cooperative," American Economic Review, 56: 734-757.

Gaynor, M. (1983), "The Effect of Income Distribution on Equilibrium Price in Medical Group Practice," unpublished doctoral dissertation, Northwestern University.

Gaynor, M. (1984), "Internal Non-Price Competition, Equilibrium, and Optimal Sharing in the Cooperative Firm," Working Paper, Department of Economics, The University of Texas at Arlington.

Goldfeld, S. and R. Quandt, Nonlinear Methods in Econometrics, North-Holland Publishing Company, Amsterdam, 1972.

__________ (1973), "The Estimation of Structural Shifts by Switching Regressions," Annals of Economic and Social Measurement, 2: 475-485.

Held, P. and U. Reinhardt (1979), "Analysis of Economic Performance in Medical Group Practice," Project Report 79-05, Mathematics Policy Research, Princeton, NJ, July.

Leibowitz, A. and R. Tollison (1980), "Free Riding, Shirking, and Team Production in Legal Partnerships," Economic Inquiry, 18: 380-394, July.

Marschak, J. and R. Radner (1972), Economic Theory of Teams, Yale University Press, New Haven.

Pauly, M. and M. Satterthwaite (1981), "The Pricing of Primary Care Physicians' Services: A Test of the Role of Consumer Information," Bell Journal of Economics, 12: 488-506, Autumn.

Poirier, D. (1976), The Econometrics of Structural Change, North-Holland Publishing Company, Amsterdam.

Sen, A. (1966), "Labor Allocation in a Cooperative Enterprise," Review of Economic Studies, October: 361-371.

Scheffler, R. (1975), "The Pricing Behavior of Medical Groups," Milbank Memorial Fund Quarterly: Health and Society, Spring.

Sloan, F. (1974), "Effect of Incentives on Physician Performance," in J. Rafferty, ed., Health Manpower and Productivity, Lexington Books, Lexington, MA.

VanderWeide, J. and J. Zalkind (1981), "Deregulation and Oligopolistic Price-Quality Rivalry," American Economic Review, 71: 144-154, March.

Ward, B. (1958), "The Firm in Illyria: Market Syndicalism," American Economic Review, 48: 566-689, September.

White, L. (1972), "Quality Variation When Prices are Regulated," Bell Journal of Economics, 3: 425-435, Autumn.

Williamson, O. (1975), Markets and Hierarchies, Free Press, New York.

Appendix

A. Comparative Statics for the Member

When the demand constraint for the member is free, $\lambda = 0$, and the first order condition for the member is

$$[\alpha + \frac{1}{n}(1 - \alpha)]P - V_{i1} = 0, \tag{A1}$$

since q_i is the only free variable.

To determine the effects of infinitesimal changes in P, α, or n on q_i^* totally differentiate (A1) and solve for the appropriate partial derivative. The total differential of (A1) is

$$-V_{i11}dq_i + [\alpha + \frac{1}{n}(1 - \alpha)]dP + (1 - \frac{1}{n})pd\alpha - \frac{(1 - \alpha)}{n^2}pdn = 0. \tag{A2}$$

Thus,

$$\frac{\partial q_i^*}{\partial P} = \frac{\partial g_i(P,\alpha,n)}{\partial P} = \frac{[\alpha + \frac{1}{n}(1 - \alpha)]}{V_{i11}} > 0, \tag{A3}$$

since V_i is increasing and convex in q_i,

$$\frac{\partial q_i^*}{\partial \alpha} = \frac{(1 - \frac{1}{n})P}{V_{i11}} > 0, \tag{A4}$$

and

$$\frac{\partial q_i^*}{\partial n} = \frac{-[(1 - \alpha)/n^2]P}{V_{i11}} < 0. \tag{A5}$$

When the member's demand constraint is binding, $\lambda > 0$, and z_i is the only free variable, thus the first order condition is

$$([\alpha + \frac{1}{n}(1 - \alpha)]P - V_{i1})f_2 - V_{i2} = 0, \tag{A6}$$

where $[\alpha + \frac{1}{n}(1 - \alpha)]P - V_{i1}$ corresponds to λ in equation (6).

The total differential of (A6) is

$$\begin{aligned} &([\alpha + \frac{1}{n}(1 - \alpha)]Pf_{22} - V_{i12} - V_{i22})dz_i + ([\alpha + \frac{1}{n}(1 - \alpha)]f_2 \\ &+ [\alpha + \frac{1}{n}(1 - \alpha)]Pf_{21} - V_{i11}f_1 - V_{i21}f_1)dP + (1 - \frac{1}{n})Pf_2 d\alpha \\ &- \frac{(1 - \alpha)}{n^2} Pf_2 dn = 0 \end{aligned} \tag{A7}$$

Thus,

$$\frac{\partial z_i^*}{\partial P} = \frac{\partial h_i(P,\alpha,n)}{\partial P} =$$

$$\frac{-\{[\alpha + \frac{1}{n}(1 - \alpha)]f_2 + ([\alpha + \frac{1}{n}(1 - \alpha)]P - V_{i1}f_{21}) - V_{i11}f_1f_2 - V_{i21}f_1\}}{[\alpha + \frac{1}{n}(1 - \alpha)]Pf_{22} - V_{i12} - V_{i22}}. \tag{A8}$$

The denominator of (A8) must be negative by the second-order conditions for a maximum. Thus the sign of (A8) will be the same as the sign of the expression within brackets in the numerator of (A8). Whether this is positive depends on the signs of f_{21} and V_{i21}, and the magnitude to the second and last terms relative to the first and third terms. If f_{21}, the effect of an increase in price on the marginal effect of quality on demand is positive, and if V_{i21}, the effect of an increase in quantity on marginal disutility "cost" of quality, is positive, then

$$\frac{\partial z_i^*}{\partial P} > 0.$$

It will also be positive if either one of the aforementioned cross-partials is negative, but the positive terms outweigh its effect. The most plausible situation is one where V_{i21} is positive, since producing more quantity will plausibly make providing an extra unit of quality more costly, and f_{21} is non-positive, since the effect of increasing quality on demand will likely fall off with price or be unaffected. In this case,

$$\frac{\partial z_i^*}{\partial P} \gtrless 0 \text{ as } [\alpha + \frac{1}{n}(1 - \alpha)]f_2 - V_{i11}f_1f_2 - V_{i21}f_1 \gtrless$$

$$([\alpha + \frac{1}{n}(1 - \alpha)] - V_{i1}]Pf_{21}.$$

$$\frac{\partial z_i^*}{\partial \alpha} = \frac{-(1 - \frac{1}{n})Pf_2}{S} > 0, \qquad \text{(A9)}$$

where S is the denominator of (A8).

$$\frac{\partial z_i^*}{\partial n} = \frac{[(1-\alpha)/n^2]Pf_2}{S} < 0. \qquad \text{(A10)}$$

B. Comparative Statics for the Firm

Case 1: Demand Constraint Not Binding

The first-order conditions are

$$Q + (P - \sum_{i=1}^{n} V_{i1})(F_1 - G_1) = 0, \qquad (16)$$

$$(P - \sum_{i=1}^{n} V_{i1})(G_2) = 0. \qquad (17)$$

Totally differentiating w.r.t. P,α,n,X,T,

$$(F_1 + PF_{11} - G_1 - PG_{11})dP - (P - \sum V_{i1})G_{12}d_\alpha - PG_{13}dn$$

$$+ (PF_{15} - PG_{14})dX + [(F_1 - G_1)(- \sum V_{i13}) + G_{15} \sum V_{i1}]dT = 0, \qquad \text{(B1)}$$

and

$$(G_2 + PG_{21})dP + (P - \sum V_{i1})G_{22}d\alpha + (P - \sum V_{i1})G_{23}dn$$

$$+ (P - \sum V_{i1})G_{24}dX + ((P - \sum V_{i1})G_{25} - \sum V_{i13}G_2)dT = 0. \qquad \text{(B2)}$$

In matrix form,

$$\begin{bmatrix} L_{PP} & L_{P\alpha} \\ L_{\alpha P} & L_{\alpha\alpha} \end{bmatrix} \begin{bmatrix} dP \\ d\alpha \end{bmatrix} = \begin{bmatrix} -L_{Pn}dn - L_{PX}dX - L_{PT}dT \\ -L_{\alpha n}dn - L_{\alpha X}dX - L_{\alpha T}dT \end{bmatrix} \tag{B3}$$

To find $\frac{\partial P^*}{\partial n}$ and $\frac{\partial \alpha^*}{\partial n}$, use Cramer's Rule. So

$$\frac{\partial P^*}{\partial n} = \frac{-L_{Pn}L_{\alpha\alpha} + L_{\alpha n}L_{P\alpha}}{L_{PP}L_{\alpha\alpha} - L_{\alpha P}L_{P\alpha}} < 0 \tag{B4}$$

$$L_{Pn} = - PG_{13} + -P \sum \frac{\partial^2 g_i(P,\alpha,n)}{\partial P \partial n} = - P \sum \frac{\frac{-(1-\alpha)}{n^2}}{V_{i11}} > 0$$

$$L_{\alpha\alpha} = (P - \sum V_{i1})G_{22} = (P - \sum V_{i1})\ 0 = 0$$

$$L_{\alpha n} = (P - \sum V_{i1})G_{23} = (P - \sum V_{i1}) \frac{P/n^2}{V_{i11}} > 0$$

$$P_{P\alpha} = - (P - \sum V_{i1})G_{12} = - (P - \sum V_{i1}) \frac{(1 - \frac{1}{n})}{V_{i11}} < 0$$

So $\frac{\partial P^*}{\partial n} < 0$ because the second-order condition makes the denominator of (B4) positive.

$$\frac{\partial P^*}{\partial X} = \frac{L_{\alpha X}P_{P\alpha}}{H} = 0, \tag{B5}$$

since members aren't constrained by demand,

$$L_{\alpha X} = (P - \sum V_{i1})G_{24} = 0.$$

$$\frac{\partial P^*}{\partial T} = \frac{L_{\alpha T} + L_{P\alpha}}{H} > 0 \tag{B6}$$

$L_{\alpha T} = (P - \sum V_{i1})G_{25} - \sum V_{i13}G_Z < 0$, since $G_{25} = \dfrac{\partial^2 G(P,\alpha,n,X,T)}{\partial P \partial T}$

$= \dfrac{-[\alpha + \frac{1}{n}(1-\alpha)]}{V_{i11T}} \leq 0$, and $V_{i13} > 0$, $G_2 > 0$. So $\dfrac{\partial P^*}{\partial T}$ is positive,

since $L_{\alpha T}$ and $L_{P\alpha}$ are both negative and H is positive.

$$\frac{\partial \alpha^*}{\partial n} = \frac{-L_{PP}L_{\alpha n} + L_{\alpha P}L_{Pn}}{H} > 0 \tag{B7}$$

$L_{PP} < 0$, by the second order condition $l_{\alpha n} = (P - \sum V_{i1})G_{23} > 0$

$$G_{23} = \frac{\partial G(P,\alpha,n)}{\partial \alpha \partial n} = \frac{P/n^2}{V_{i11}} > 0$$

$$L_{\alpha P} = G_2 + PG_{21} > 0$$

$$L_{Pn} = - PG_{13} > 0$$

$$\frac{\partial \alpha^*}{\partial X} = \frac{-L_{PP}L_{\alpha X} + L_{\alpha P}L_{PX}}{H} > 0 \tag{B8}$$

$$L_{\alpha X} = (P - \sum V_{i1})G_{24} = 0$$

$$L_{PX} = PF_{16} - PG_{14}$$

$$F_{16} = \frac{\partial^2 F(.)}{\partial O \partial X} > 0 \qquad G_{14} = \frac{\partial^2 G(.)}{\partial P \partial X} = 0$$

$$\frac{\partial \alpha^*}{\partial T} = \frac{- L_{PP}L_{\alpha T} + L_{\alpha P}L_{PT}}{H} > 0 \tag{B9}$$

$$L_{PT} = (F_1 - G_1)(- \sum V_{i13}) + G_{15} \sum V_{i1} > 0$$

$$\frac{\partial P^*}{\partial \alpha} = \frac{(P - \sum V_{i1})G_{12}}{S} < 0 \tag{B10}$$

When the demand constraint is binding, the first-order conditions are

$$Q + PF_1 + PF_2H_1 - \sum_{i=1}^{n} [V_i f_1 + V_1 f_2 h_{i1} + V_2 h_{i1}] = 0 \tag{19}$$

$$PF_2H_2 - \sum_{i=1}^{n} [V_1 f_2 h_{i2} + V_2 h_{i2}] = 0 \tag{20}$$

The total differentials of (19) and (20) are

$$\{2F_1 + PF_{11} + F_2H_1 + PF_{21}H_1 + PF_2H_{11} + PF_{22}H_1^2 - \sum_{i=1}^{n} [V_{i1}f_{11} + V_{i11}f_1^2$$

$$+ V_{i12}f_1h_{i1} + V_{i1}f_{21}h_{i1} + V_{i1}f_{22}h_{i1}^2 + V_{i1}f_2h_{i11} + V_{i11}f_1f_2h_{i1}$$

$$+ V_{i12}f_2h_{i1}^2 + V_{i2}h_{i11} + V_{i22}h_{i1}^2 + V_{i21}f_1h_{i1}]\}dP + \{F_2H_2 + PF_{12}H_2$$

$$+ PF_2H_{12} + PF_{22}H_1H_2 - \sum_{i=1}^{n} [V_{i1}f_{12}h_{i2} + V_{i12}f_1h_{i2} + V_{i1}f_2h_{i11}$$

$$+ V_{i1}f_{22}h_{i1}^{2} + V_{i11}f_2h_{i1}h_{i2} + V_{i2}h_{i12} + V_{i22}h_{i1}h_{i2}$$

$$+ V_{i21}h_{i1}f_2h_{i2}]\}dX + F_2H_3 + PF_{12}H_3 + PF_2H_{13} + PF_{22}H_2H_3$$

$$- \sum_{i=1}^{n} [V_{i1}f_{12}h_{i3} + V_{i12}f_1h_{i3} + V_{i1}f_2h_{i13} + V_{i1}f_{22}h_{i1}h_{i3}$$

$$+ V_{i12}f_2h_{i1}h_{i3} + V_{i1}h_{i13} + V_{i21}h_{i1}f_2h_{i3}]\}dn + \{F_X + PF_{2X}H_1$$

$$+ PF_2H_{1X} - \sum_{i=1}^{n} [V_{i1}f_{1X} + V_{i11}f_1f_X + V_{i1}f_{2X}h_{i1} + V_{i1}f_2h_{i1X}$$

$$+ V_{i11}f_2f_Xh_{i1} + V_{i12}f_2h_{i1}h_{iX} + V_{i2}h_{i1X} + V_{i22}h_{i1}h_{iX}$$

$$+ V_{i21}H_{i1}f_X)\}dX + \{PF_{12}H_T + PF_2H_{1T} + PF_{22}H_1H_T$$

$$- \sum_{i=1}^{n} [V_{i1}f_{12}h_{iT} + V_{i12}f_1h_{iT} + V_{i1}f_2h_{i1T} + V_{i1}f_{22}h_{i1}h_{iT}$$

$$+ V_{i12}f_2h_{i1}h_{i1} + V_2h_{i1T} + V_{i22}h_{i1}h_{iT}]\}dT = 0, \qquad \text{(B11)}$$

and

$$\{F_2H_2 + PF_{21}H_2 + PF_{22}H_1H_2 + PF_2H_{21} - \sum_{i=1}^{n} [V_{11}f_1f_2h_{i2}$$

$$+ V_{12}f_2h_{i1}h_{i2} + V_1f_{21}h_{i1} + V_1f_{22}h_{i1}h_{i2} + V_1f_2 + h_{i21}$$

$$+ V_{22}h_{i1}h_{i2} + v_{21}f_1h_{i2} + V_2h_{i21}]\}dP + \{PF_{22}H_2^2 + PF_2H_{22}$$

$$= \sum_{i=1}^{n} [V_1f_2h_{i22} + V_{11}f_2^2h_{i2}^2 + V_{12}f_2h_{i2}^2 + V_1f_{22}h_{i2}^2 + V_2h_{i22}$$

$$+ V_{22}h_{i2}^2]\}d\alpha + \{PF_{2X}H_2 + PF_2H_{2X} - \sum_{i=1}^{n} [V_1f_{2X} + V_1f_2h_{i2X}$$

$$+ V_2h_{i2X}]\}dX + \{PF_2H_{23} - \sum_{i=1}^{n} [V_1f_2h_{i23} + V_2h_{i23}]\}dn + \{PF_2H_{2T}$$

$$- \sum_{i=1}^{n} [V_{1T}f_2h_{i2} + V_1f_2h_{i2T} + V_{2T}H_{i2} + V_2h_{i2T}]\}dT = 0 \qquad \text{(B12)}$$

For simplicity in notation, refer to the elements of (B11) and (B12) as

$$M_{PP}dP + M_{P\alpha}d\alpha + M_{PX}dX + M_{Pn}dn + M_{PT}dT = 0 \qquad \text{(B11)}$$

and

$$M_{\alpha P}dP + M_{\alpha\alpha}d\alpha + M_{\alpha X}dX + M_{\alpha n}dn + M_{\alpha T}dT = 0. \qquad \text{(B12)}$$

Use Cramer's rule to solve for the comparative static derivatives. Form the matrix form equation

$$\begin{bmatrix} M_{PP} & M_{P\alpha} \\ M_{\alpha P} & M_{\alpha\alpha} \end{bmatrix} \begin{bmatrix} dP \\ d\alpha \end{bmatrix} = \begin{bmatrix} - M_{PX}dX - M_{Pn}dn - M_{PT}dT \\ - M_{\alpha X}dX - M_{\nu}dn - M_{\alpha T}dT \end{bmatrix}$$

$$\frac{\partial P^*}{\partial X} = \frac{- M_{PX}M_{\alpha\alpha} + M_{\alpha X}M_{P\alpha}}{M} > 0,$$

$$\text{where } M = \begin{vmatrix} M_{PP} & M_{P\alpha} \\ M_{\alpha P} & M_{\alpha\alpha} \end{vmatrix} > 0.$$

$$M_{PX} > 0 \qquad M_{\alpha\alpha} < 0,$$

$$M_{\alpha X} = 0 \qquad M_{P\alpha} > 0$$

$$\frac{\partial P^*}{\partial n} = \frac{- M_{Pn}M_{\alpha\alpha} + M_{\alpha n}M_{P\alpha}}{M} < 0$$

$$M_{Pn} < 0, \qquad M_{\alpha n} < 0$$

$$\frac{\partial P^*}{\partial T} = \frac{- M_{PT}M_{\alpha\alpha} + M_{\alpha T}M_{P\alpha}}{M} > 0$$

$$M_{PT} > 0 \qquad M_{\alpha T} = 0$$

$$\frac{\partial \sigma^*}{\partial X} = \frac{- M_{PP}M_{\alpha X} + M_{\alpha P}M_{PX}}{M} > 0.$$

$$M_{PP} < 0, \qquad M_{\alpha X} = 0$$

$$M_{\alpha P} > 0 \qquad M_{PX} > 0$$

$$\frac{\partial \alpha^*}{\partial n} = \frac{- M_{PP}M_{\alpha n} + M_{\alpha P}M_{Pn}}{M} < 0$$

$$M_{\alpha n} < 0 \qquad M_{Pn} < 0$$

$$\frac{\partial \alpha^*}{\partial T} = \frac{- M_{PP}M_{\alpha T} + M_{\alpha P}M_{PT}}{M} > 0$$

$$\frac{\partial P^*}{\partial \alpha} = \frac{- M_{P\alpha}}{M_{PP}} > 0$$

C. Comparative Static Properties of Efficient Price Loci

$$Q + (P - \sum V_{i1})(F_1 - \sum g_{i1}) = 0 \tag{16}$$

defines

$$P^* = P^1(\alpha,n,X,T). \tag{21}$$

The total differential of (16) is

$$[F_1 = \sum g_{i1} + (P - \sum V_{i1})(F_{11} - \sum g_{i11})]dP - (P - \sum V_{i1})(\sum g_{i12})d\alpha$$

$$- (P - \sum V_{i1})(\sum g_{i13})dn + (P - \sum V_{i1})(F_{1X} - \sum g_{i1X})dX$$

$$- [(\sum V_{i1T})(F_1 - \sum g_{i1}) + (P - \sum V_{i1})(\sum g_{i1T})]dT$$

$$= L_{PP}dP + L_{P\alpha}dX + L_{Pn}dn + L_{PX}dX + L_{PT}dT = 0. \qquad \text{(C1)}$$

By assumption, L_{PP} will be negative.

$$\frac{\partial P^1}{\partial \alpha} = \frac{-L_{P\alpha}}{L_{PP}} = \frac{(P - \sum V_{i1})(\sum g_{i12})}{L_{PP}} < 0.$$

$$\frac{\partial P^1}{\partial n} = \frac{-L_{Pn}}{L_{PP}} = \frac{(P - \sum V_{i1})(\sum g_{i13})}{L_{PP}} > 0$$

$$\frac{\partial P^1}{\partial X} = \frac{-L_{PX}}{L_{PP}} = \frac{(P - \sum V_{i1})(F_{2X} - \sum g_{i1X})}{L_{PP}} > 0.$$

$$\frac{\partial P^1}{\partial T} = \frac{-L_{PT}}{L_{PP}} = \frac{(\sum V_{i1T})(F_1 - \sum g_{i1}) + (P - \sum V_{i1})(\sum g_{i2T})}{L_{PP}} > 0.$$

$$Q + PF_1 + PF_2H_1 + \sum_{i=1}^{n} [V_{i1}t_1 + V_{i1}f_2h_{i1} + V_{i2}h_{i1}] = 0 \qquad (19)$$

defines

$$P^* = P^2(\alpha,n,X,T). \qquad (22)$$

The total differential of (19) is

$$\{2F_1 + PF_{11} + F_2H_1 + PF_2H_{11} + PF_{21}H_1 + PF_{22}H_1^2 + \sum_{i=1}^{n}[V_{i1}F_{i1}$$

$$+ V_{i11}f_1^2 + V_{i12}F_1h_{i1} + V_{i1}f_{12}h_{i1} + V_{i1}f_2h_{i11} + V_{i2}f_{21}h_{i1}$$

$$+ V_{i11}f_1f_2h_{i1} + V_{i2}h_{i11} + V_{i21}f_1h_{i1}]\}dP + \{F_2H_2 + PF_{12}H_2$$

$$+ PF_2H_{12} + PF_{22}H_1H_2 + \sum_{i=1}^{n}[V_{i1}f_{12}h_{i2} + V_{i12}f_1h_{i2} + V_{i1}f_2h_{i12}$$

$$+ V_{i1}f_{22}h_{i1}h_{i2} + V_{i2}h_{i12} + V_{i22}h_{i1}h_{i2}]\}d\alpha + \{F_2H_3 + PF_{12}H_3$$

$$+ PF_2H_{13} + PF_{22}H_1H_3 + \sum_{i=1}^{n}[V_{i1}f_{12}h_{i3} + V_{i1}f_2h_{i13}$$

$$+ V_{i2}h_{i13}]\}dn + \{F_X + PF_{12}H_X + PF_2H_X + \sum_{i=1}^{n}[V_{i1}f_{12}h_{iX}$$

$$+ V_{i1}f_2h_{i1X} + V_{i2}h_{i1X}]\}dX + \{F_2H_T + PF_{12}H_T + PF_2H_T + \sum_{i=1}^{n}[V_{i1}f_{12}h_{0T}$$

$$+ V_{i1}f_2h_{i1T} + V_{i2}h_{i1T}]\}dT = M_{PP}dP + M_{P\alpha}d\alpha + M_{Pn}dn$$

$$+ M_{PX}d_X + M_{PT}dT = 0. \tag{C2}$$

M_{PP} is negative, by assumptions made on the objective function and constraints.

$$\frac{\partial P^2}{\partial \alpha} = \frac{-M_{P\alpha}}{M_{PP}} > 0,$$

definitely if F_{12} and F_{22} are non-negative, maybe if not, since an increase in α causes members to produce more quality and up the optimal price.

$$\frac{\partial P^2}{\partial n} = \frac{-M_{Pn}}{M_{PP}} < 0,$$

since an increase in group size causes members to produce less quality and thus decrease the optimal price.

$$\frac{\partial P^2}{\partial X} = \frac{-M_{PX}}{M_{PP}} > 0.$$

$$\frac{\partial P^2}{\partial T} = \frac{-M_{PT}}{M_{PP}} < 0.$$