Fragmented Duopoly: A Conceptual and Empirical Investigation

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Abstract. Where wireline distribution networks compete, each network typically will have some customers over which it competes and others for which it is the sole provider. This paper conceptually and empirically assesses the effects of such competition on market prices, demand, and service quality for cable television service. The results suggest that the effectiveness of competition in lowering prices is contingent on the degree of system overlap. In particular, in equilibrium an increase in overlap substantially reduces prices. The conceptual model of fragmented duopoly developed in the paper may be useful in analyzing emerging competition in other network distribution industries.

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I. Introduction

In recent years, a number of economists have focused their attention on the economics of networks, particularly the competitive consequences of network externalities and compatibility (e.g., Katz and Shapiro 1985; Farrell and Saloner 1992; Economides 1989). Another interesting feature of some networks, particularly the physical networks required for local distribution of telecommunications services, multichannel video services, and electric power, is that consumers must physically connect to the network in order to purchase the services sold over it. Where physical, wireline interconnection by consumers is required, only those homes near the physical network can interconnect. Thus, the potential subscriber base of the wireline distribution network operator is geographically limited to an area frequently described as "homes passed."[1] A consequence of this feature of wireline networks is that even where competition between networks occurs, it is quite possible that the rival networks will not share identical geographic markets.

The *Telecommunications Act of 1996* is expected to bring increased levels of competition in telecommunications, video, and broadcast media markets.[2] Since the political feasibility of any perpetuation of price regulation will likely require

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[1] Geographic limitations of distribution networks are far less important for wireless networks. However, wireless networks do not always cover areas ubiquitously and some require line-of-sight transmission and reception. Geographic coverage areas vary sometimes considerably among mobile telephony carriers, and these differences may be important to consumers.

[2] Telecommunications Act of 1996, Pub. LA. No. 104-104, 110 Stat. 56 (1996).

arguments about the degree of competition, economists increasingly will be required to quantify the degree of competition in these markets. As in telecommunications, video, and broadcast markets, competition in the electric utilities industry is the subject of extensive public policy debate and economic inquiry. While competition in the electric utilities industry generally is expected at the generation rather than at the distribution stage, duopolistic competition in electricity distribution has been observed and analyzed in numerous markets (Nelson and Primeaux 1988).

Where competition exists in telecommunications, multichannel video, and electric utilities, economists typically have analyzed competition with somewhat standard models, comparing market structure and performance to the equilibria of Cournot or Bertrand competition, perfect competition, and dominant firm/price-leadership models.[3] While such models may be useful in some instances, competition among wireline distribution networks, where a firm's market is bounded by the geographic area "homes passed," does not readily conform to the implicit assumption that all consumers may freely choose which supplier to patronize. Since ubiquity of physical networks is unlikely to occur in a competitive environment, competition among local carriers of telecommunications and video services will occur over some, but not all, customers. The purpose of this paper is to contemplate such competition within the framework of the theory of *fragmented duopoly* and provide an empirical test of the static equilibrium concepts of the model using competition in local cable television markets as an experiment.[4]

In this paper, a simple model of fragmented duopoly, similar to that of Basu and Bell (1991) but directly applicable to cable television service competition is specified and described. Theoretical analysis implies that the stable Nash equilibrium price charged by a duopolist increases with the "size" of the captive, or monopoly, segment. A simultaneous equations model of pricing, sales, and quality is specified and estimated, and the empirical results suggest that the degree of system overlap is critically important to the determination of price, sales and quality. An increase of 10 percentage points in the extent of provider monopoly causes monthly prices to rise by about $1.63, a significant increase of about 8.8 percent at average prices. Service quality rises slightly and, in equilibrium, the level of penetration ultimately declines as multiple firms share

[3] Whether or not competition is explicitly couched in terms of these models, empirical tests based on "market structure" dummy variables rest on these assumptions.

[4] The data used in the empirical analysis precedes the implementation of cable regulation subsequent to the passage of the *1992 Cable Act*.

the market. The "equilibrium" interaction between prices, quality and sales are examined in detail.

The paper proceeds as follows. Section II presents a theoretical model of duopolistic competition, with specific reference to competition in cable television markets, which captures the comparative static effects of varying degrees of cable system overlap. In Section III, the empirical model is specified; the results are presented in Section IV. Concluding comments are found in Section V.

II. A Model of Fragmented Duopoly

In standard duopoly models it generally is an implicit assumption that customers may choose to patronize either of the market's two firms. Depending on the focus of the theoretical model, patronage is a function of price, quality, location, and/or other determining factors. Given that cable systems (and physical networks generally) face strict short-term constraints on the set of potential customers, determined by the geographic area over which the cable system's wires pass (homes passed), rival cable systems usually compete only over a subset of a market's potential customers. Thus, in most markets where competition between cable systems exists, the rival cable operators are neither monopolists nor duopolists but something in between.

The following example from Basu and Bell (1991) illustrates the nature of fragmented markets:

> ... suppose that there are three villages, A, B and C, in a row. Moneylender 1 lives in village A; and moneylender 2 lives in C. If we suppose the inhabitants of A would go only to their 'resident' moneylender and likewise for C, and that those of B would go to whoever charges less, then we have a case of fragmented duopoly (p. 146-7).

The similarity between this example and cable television markets is apparent. For example, in Montgomery, Alabama, two rival cable systems compete over about 30 percent of the entire cable market and each system serves areas unwired by its rival.[5] Contrariwise, in Greenville, Tennessee, almost every household within the local cable market has the option to patronize either of two cable operators.

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[5] The system overlap was observed in 1992, when the data was collected. Econometric analysis of competition in the cable television industry after 1992 is made difficult by the regulation of cable rates subsequent to the *1992 Cable Act* and the Act's lingering effects (Cable Television Consumer Protection and Competition Act of 1992, 47 U.S.C. §§ 521-573).

The application of the model of fragmented duopoly to the cable television industry is straightforward, and the analysis proceeds with a simple model focusing on the pricing decisions of rival firms with different degrees of system overlap.[6] The formal, theoretical analysis is based on two underlying assumptions. First, for purposes of pricing, the degree of system overlap is treated as "strategically" exogenous. This assumption does not mean, however, that such overlap is not itself the result of interesting strategic behavior. Rather, the assumption is made that these decisions are made prior to ordinary product market competition (Kreps and Scheinkman 1983). As will be seen below, the empirical modeling will not assume that the existence or extent of system overlap are "econometrically" exogenous.

Second, the analysis focuses solely on cases in which the firms cannot price discriminate between customers in competitive and noncompetitive segments. There are several reasons why this restriction is, in fact, nearly universal. First, instituting the billing protocols needed for discrimination is difficult, as it would require a house-by-house inventory of customers and competitor's facilities. Second, charging different prices for identical service in contiguous locales is quite likely to lead to very unfavorable public comment (Mayes 1991; Walsh 1993). Finally, many jurisdictions have flatly prohibited price discrimination (Smiley 1986, ft. 18). In collecting the data, all systems where price discrimination was known to occur were excluded from the final sample

To begin, let the demand for a cable subscription from firm i be given, for a specified area of population N, by the expression $Nx_i(p_i,p_j)$ where p_i is the price of cable service from i, p_j is the rival's price for a similar service, and x_i is interpreted as the probability that a household buys service from i. This approach is consistent with that adopted by other studies where demand is specified as a penetration rate (the percent of homes passed that subscribe to service).[7] By assumption, $\partial x_i/\partial p_i < 0$, $\partial x_i/\partial p_j \geq 0$, and $\lim_{p_j \to \infty} x_i(p_i, p_j)$ is a finite, positive value, less than or equal to unity, that may be suggestively written as $x_i(p_i, \infty)$. In other words, demand slopes downward, the rivals' services are substitutes, and demand is positive and limited to the unit interval (as is required by the use of a penetration rate).

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6 Basu and Bell (1991) present a model of duopoly introducing the theory of *fragmented duopoly* in the context of informal credit markets. The conceptual model developed in this paper is markedly different than that of Basu and Bell (1991) though the general conclusions are similar.

7 Penetration rates are a common specification of quantity demanded for cable service and are often used as a measure of cable quantity in empirical studies. For example, see Webb (1983), Mayo and Otsuka (1991), and Beil, et al (1993).

In the model of fragmented duopoly, firm i sells service in two markets, the first of which is monopolized and contains n_i customers, and the second of which has a duopoly structure and contains n_c customers. Importantly, the *same price* must be set in both market areas. Customers are assumed to be demographically identical between markets, so only their numbers and the market structure varies. Profits to firm i are

$$\Pi_i = n_i x_i(p_i, \infty) \cdot (p_i - c_i) + n_c x_i(p_i, p_j) \cdot (p_i - c_i) - FC_i, \tag{1}$$

where c_i is firm i's unit costs and FC_i is fixed cost. This formulation assumes constant incremental costs. This assumption is for convenience only and is not imposed in the econometric analyses.

Dividing both sides of (1) by the constant $n = n_i + n_c$ yields (1′)

$$\Pi_i / n = \lambda_i x_i(p_i, \infty) \cdot (p_i - c_i) + (1 - \lambda_i) x_i(p_i, p_j) \cdot (p_i - c_i) - FC_i / n \tag{1′}$$

where λ_i is the proportion of potential customers served by i under monopoly conditions. Since homes-passed is regarded here as exogenous, attention is restricted to (1′).[8] A similar representation exists for firm j, although in general $\lambda_i \neq \lambda_j$.

Interest focuses on the relationship between equilibrium prices (p_i^*, p_j^*) and the λ's. The intuition is that the presence of a competitive segment, and the inability to price discriminate between market segments (for regulatory and legal reasons), will reduce prices to levels below unrestricted monopoly levels, and that the "larger" the competitive segment (proxied by $1 - \lambda$), the lower the price of service. Clearly, if $\lambda_i = \lambda_j = 1$, the monopoly outcome prevails, while if $\lambda_i = \lambda_j = 0$, the non-cooperative, Bertrand outcome with differentiated products is observed.

The price game proceeds as follows. Firms i and j simultaneously and non-cooperatively select their prices p_i and p_j, respectively, and these prices (p_i^*, p_j^*) are an equilibrium only if they satisfy the conditions

$$\lambda_i x_i(p_i, \infty)\left[1 + \varepsilon_i^m L_i\right] + (1 - \lambda_i) x_i(p_i, p_j)\left[1 + \varepsilon_i^c L_i\right] = 0 \tag{2a}$$

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[8] Basu and Bell (1991) and Smiley (1986) provide a conceptual framework of both pricing and overlap decisions. In the empirical analysis, the overlap variables are treated as endogenous.

$$\lambda_j x_j(p_j,\infty)\left[1+\varepsilon_j^m L_j\right]+(1-\lambda_j)x_j(p_j,p_i)\left[1+\varepsilon_j^c L_j\right]=0 \qquad \text{(2b)}$$

where ε_i^m is the elasticity of demand for firm *i* in its monopoly market (where $p_j = \infty$), $L_i = (p_i - c_i)/p_i$ is the Lerner index, and ε_i^c is the elasticity of demand for *i*'s subscriptions in the "competitive" segment, and similarly for firm *j*.

The equations in (2) specify the simultaneous first-order necessary conditions for (p_i^*, p_j^*) to be a Nash equilibrium. Several facts are apparent. First, equation (2) expresses the necessary condition as requiring that a weighted sum of terms of the form $x(1 + \varepsilon L)$ equal zero. This condition requires that one of the terms be non-positive, the other non-negative. Second, it cannot be true that these terms are simultaneously zero for the same price p_i^* because they cannot in general be equal to the same value, zero or otherwise.

When λ is close to 1, equation (2) can be satisfied only if $x(1 + \varepsilon^m L) \cong 0$, which corresponds to the monopoly price in the captive market. Symmetrically, when λ is close to 0, it is the case that $x(1 + \varepsilon^c L) \cong 0$, the non-cooperative duopoly outcome. Further, inspection of (2) implies that, when the term $(1 + \varepsilon^m L)$ lies strictly between 0 and 1, then the terms $(1 + \varepsilon^c L)$ must be negative, else equation (2) cannot be satisfied. This result is intuitive: the existence of a competitive segment, when price discrimination is impossible, imposes pricing discipline "indirectly" on the monopoly segments in the sense that prices are *below* those that would prevail with totally separate monopolies (for which $(1 + \varepsilon^m L = 0)$ must hold).[9] Note, however, if $\lambda_i = \lambda_j = 0$, then marginal cost pricing is not obtained, but rather non-cooperative pricing such that $L_i > 0$, $L_j > 0$ in equilibrium. With undifferentiated products, the existence and nature of equilibrium with $\lambda_i = \lambda_j = 0$ depends on the sizes of the unit costs c_i and c_j. This case is not the focus here.

Stability of the equilibrium (p_i^*, p_j^*) requires both that the goods are strategic complements (i.e., reaction functions in price space are upward sloping), and that the slope of firm *j*'s reaction function be steeper than *i*'s in the sense that

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[9] This idea formed the basis for a proposed merger condition in the failed merger of the two direct broadcast satellite companies (Echostar and Directv). The merging parties offered to charge a nationwide uniform price so that competition in some segments of the market would constrain prices in rural markets where competition would be eliminated by the merger (McConnell 2002).

$$\left.\frac{\partial p_i}{\partial p_j}\right|_{\frac{\partial \Pi_i}{\partial p_i}=0} < \left.\frac{\partial p_i}{\partial p_j}\right|_{\frac{\partial \Pi_j}{\partial p_j}=0}$$

where $\partial p_i/\partial p_j$ is the slope of the relevant reaction (best reply) function (Bulow, et al, 1985). The first condition requires that the cross terms $\partial \Pi_i^2/\partial p_i \partial p_j$ be positive, while the second condition requires that the matrix of second derivatives, **H**, where

$$\mathrm{H} = \begin{bmatrix} \frac{\partial^2 \Pi_i}{\partial p_i^2} & \frac{\partial^2 \Pi_i}{\partial p_i \partial p_j} \\ \frac{\partial^2 \Pi_j}{\partial p_j \partial p_i} & \frac{\partial^2 \Pi_j}{\partial p_j^2} \end{bmatrix}, \tag{3}$$

have a positive determinant. Second order conditions require that $\partial^2\Pi_i/\partial p_i^2 < 0$ and $\partial^2\Pi_j/\partial p_j^2 < 0$. The effect of a change in competitive overlap on prices is now determined.

Intuitively, an increase in the size of the captured segment (λ) of one firm would be expected to increase the equilibrium price of that firm, which is shown now to be the case. The sign of $dp_i^*/d\lambda_i$ can be obtained by totally differentiating the first-order conditions of firm *i* and *j* which can be written in matrix form as:

$$\begin{bmatrix} \frac{\partial^2 \Pi_i}{\partial p_i^2} & \frac{\partial^2 \Pi_i}{\partial p_i \partial p_j} \\ \frac{\partial^2 \Pi_i}{\partial p_j \partial p_i} & \frac{\partial^2 \Pi_j}{\partial p_j^2} \end{bmatrix} \begin{bmatrix} dp_i \\ dp_j \end{bmatrix} = -\begin{bmatrix} \frac{\partial^2 \Pi_i}{\partial \lambda_i} & 0 \\ 0 & \frac{\partial^2 \Pi_j}{\partial \lambda_j} \end{bmatrix} \begin{bmatrix} d\lambda_i \\ d\lambda_j \end{bmatrix}. \tag{4}$$

Solving for the derivatives of interest, the relationship between price and the size of the captured segment of firm *i* is

$$\frac{dp_i}{d\lambda_i} = \frac{-\partial^2 \Pi_i / \partial p_i \partial \lambda_i \cdot \partial^2 \Pi_j / \partial p_j^2}{|\mathrm{H}|} \tag{5}$$

where $|\mathrm{H}|$ is the determinant of **H**. Stability requires that $|\mathrm{H}| > 0$. Because the term $\partial^2\Pi_i/\partial p_i^2$ must be negative for a maximum, the crucial issue is the sign of the term $\partial^2\Pi_i/\partial p_i \partial \lambda_i$. This term is just

$$x_i(p_i,\infty)\left[1+\varepsilon_i^m L_i\right]+x_i(p_i,p_j)\left[1+\varepsilon_i^c L_i\right]. \quad (6)$$

Since $x_i(p_i,\infty) > x_i(p_i,p_j)$ for finite p_j, it remains only to argue that $(1 + \varepsilon_i^m L_i) > (1 + \varepsilon_i^c L_i)$. Since price ($p_i$) is the same in both market segments, it is the case that $0 > e_i^m > e_i^c$, i.e., demand is more elastic in the competitive segment because of the presence of a competing vendor. Thus, it must be the case that $\partial^2\Pi_i/\partial p_i\partial\lambda_i > 0$ and $dp_i^*/d\lambda_i > 0$ in equilibrium.

It is also clear that, by a nearly identical analysis, the additional testable restriction that $dp_i^*/d\lambda_j > 0$ is obtained: an increase in the firm *j*'s monopoly segment results in an increase in the equilibrium price charged by firm *i*. This relationship arises because, as strategic complements, the increase in the price p_j arising from an increase in *j*'s monopoly position will induce firm *i* to raise price.

The practical size of this effect is an empirical issue, and following section contains an empirical test of the model's predictions. Specifically, an empirical model is specified that estimates the relationship between cable television prices and the size of the cable operators monopoly segment (i.e., $dp_i/d\lambda_i$). As predicted by the model, a positive relationship is expected.

III. Empirical Analysis

A number of economic studies on the cable industry, both empirical and anecdotal, have analyzed the effects of competition in the provision of cable television services. All of these studies have shown that prices are lower in competitive cable markets, or overbuilds, in some cases exhibiting differentials of over 25 percent (Hazlett 1986, 1990; Merline 1990, Levin and Meisel 1991; Beil, et al. 1993, and Emmons and Prager 1997). The prior studies that have taken explicit account of competition in cable markets uniformly employ a dichotomous variable to account for the presence of two rival cable operators. The theoretical view presented earlier, however, highlights the result that the mere presence of multiple providers need not significantly affect price; the key factors are the percent of market captured by each provider as compared to the percent contested. [10]

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[10] Historically, overbuilding in cable television markets has been scarce. In 1992, there were a total of 11,083 cable systems - around 100 of which were competitive. See *Television and Cable Factbook* (1993) and *Cable TV Franchising* (1992). Today, overbuilding is more common. See, e.g., *Annual Assessment of the Status of Competition in the Market for the Delivery of Video Programming, Eighth Annual Report,* CS Dkt. No. 01-129, 17 F.C.C.R. (2002).

To measure these effects, each cable system's homes passed are divided into captured and contested segments as described in the preceding section. As the discussion above makes clear, the equilibrium prices charged by firm *i* will presumably depend on both the proportion of *i*'s market area that is "monopolized" by *i* (λ_i), and perhaps the proportion of rival firm *j*'s market that is monopolized for *j* (λ_j). Firm *i*'s equilibrium price may depend on λ_j because, the greater is the monopolized segment enjoyed by firm *j*, the less is firm *j*'s incentive to lower price to capture more business on the contested segment. Thus, if firm *j* does only a small portion of its business in competition with firm *i*, the analysis suggests that *j* will not offer intense competition to *i*, a circumstance firm *i* might exploit to establish higher prices.

1. Specification

While some recent empirical studies of cable television pricing have adopted two-equation systems in which price and "subscription" (the percentage of home-passed that subscribe to cable service) are jointly determined, such an approach can overlook the potentially important role of non-price competition in these markets. In particular, the quality of services, ordinarily taken to be equal to the number of satellite and/or other channels offered, may represent an important element of competitive rivalry that can affect prices and demand. In order to both accommodate this complication, and evaluate the effects of overlap on service quality, a three-equation system is estimated in which price, demand, and service quality are jointly determined.

More formally, each sample firm is envisioned as simultaneously selecting price and service quality. Given these, consumers respond by subscribing to the offered services in some numbers, reflecting an underlying structural demand relationship between subscription, price and quality. Thus, the chosen framework is such that price, quality, and subscription ("quantity") are simultaneously determined magnitudes. Further, it is assumed that several exogenous factors, such as those affecting service costs, have a direct structural relationship with a given endogenous variable (e.g., price), and affect the other endogenous variables only through their effects on the given variable. This framework is explicitly presented below.

Price equations in the literature generally specify monthly subscription fees as a function of cost variables, including channels offered, system size, density, fiber deployment, and other factors. In studies that evaluate the effect of competition on cable prices, price is a function of variables measuring the presence of competition in the relevant market. These competition studies uniformly measured the presence of competition with dummy variables indicating the presence of *any* amount of cable system overlap. In addition, a measure of demand (the penetration rate typically) is often included in the price equation, and price and sales are jointly determined.

Demand, measured by either the quantity of subscribers or the penetration rate, is ordinarily taken to depend on price, in addition to demographic variables such as per-capita income, alternative entertainment opportunities, and the quality of offered services. In addition, the presence of a rival is clearly relevant since the presence of a practical substitute for the firm's services almost surely reduces the demand of that firm, other things equal, though the demand for cable services across the *entire* market may increase (Beil, et al 1993).

Service quality is measured generally as the total number of satellite channels (Rubinovitz 1993, Ford and Jackson 1998, Beard, et al 2001).[11] The selection of service quality (in this sense) is regarded as a choice made simultaneously with price. In particular, quality is assumed to depend on prices, subscription ("quantity demanded"), the degrees of overlap, market size, and other market characteristics.

The general format of the empirical model is:

$$P_i = F(PR_i, C_i, X_1, \lambda_i, \lambda_j) \quad (7a)$$

$$PR_i = G(P_i, C_i, X_2, \lambda_i) \quad (7b)$$

$$C_i = H(P_i, PR_i, X_3, \lambda_i, \lambda_j) \quad (7c)$$

where P_i is the natural log of the tier-weighted price of cable service (per month); PR_i is the logistic transformation of the penetration rate for firm i; C_i is the natural log of the total number of satellite channels offered by firm i; X_1, X_2, and X_3 are vectors of various exogenous variables; and λ_i and λ_j are the overlap variables defined in the previous section.[12] Of particular interest is the impact of λ_i and λ_j on price P_i and service quality C_i. Note that this formulation is completely simultaneous, and is thus consistent with the view that price, sales,

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11 We do not include local originating channels in the quality measure, as such channels are often obligatory, and many probably offer little benefit to consumers.

12 The logistic transformation of the penetration is defined as log $[W/(1 - W)]$, where W is the penetration rate defined as the ratio of subscriptions to homes-passed. See Webb (1983), Appendix 4A.

and quality are simultaneously determined in equilibrium. Also note that the specification implies that PR_i depends directly on λ_i and not λ_j, since PR_i is defined as the penetration of firm *i* in areas in which *i* operates. Thus, λ_j is assumed to affect this value only through its effects, if any, on prices and quality.

The degrees of overlap, λ_i and λ_j, also may reflect earlier strategic choices by firms and thus may be properly regarded as endogenous. Although plausible, it is not the purpose of this paper to evaluate the process that determines overbuilds.[13] However, in order to obtain unbiased and consistent estimates of the parameters of interest, this potential endogeneity is accommodated in the estimation procedure.

The recognition of the (potential) endogeneity of overlap brings with it an important issue in identification of the resulting structural model. If prices, sales, and qualities depend on λ_i and λ_j which are, themselves, "endogenous," the estimation methodology must, in effect, consistently estimate three equations of a five equation system. Of particular concern is the rank condition for estimability of the partial system. Although identification conditions always refer to true parameter values and are not testable in the conventional sense, Wooldridge (2002) gives a very useful conceptual description of this problem. In effect, rank conditions with an endogenous regressor are equivalent to the claim that there exists an instrument (or instruments) that are both (i) uncorrelated with the target equation's disturbance, and (ii) have a non-zero coefficient (coefficients) in the "unknown" structural equation that generates the endogenous regressors. Curiously, this latter condition is, in an approximate sense, testable, as will be explained below.

The following three-equation model is estimated:

$$P_i = \alpha_0 + \alpha_1 PR_i + \alpha_2 C_i + \alpha_3 FIBER + \alpha_4 DENSE + \alpha_5 HPASS + \alpha_6 FFEE + \alpha_7 \lambda_i + \alpha_8 \lambda_j \tag{8a}$$

$$PR_i = \beta_0 + \beta_1 P_i + \beta_2 C_i + \beta_3 POP + \beta_4 INCOME + \beta_5 INCOME^2 + \beta_6 AIRCHAN + \beta_7 MEDAGE + +\beta_8 AGE + \beta_9 AGE^2 + \beta_{10} DNE + \beta_{11} DMW + \beta_{12} DSTH + \beta_{13} \lambda_i \tag{8b}$$

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13 Some empirical evidence on the determinants of overbuilding is provided by Beil, et al (1993) and Hazlett and Ford (2001).

$$C_i = \kappa_0 + \kappa_1 P_i + \kappa_2 PR_i + \kappa_3 POP + \kappa_4 INCOME + \kappa_5 INCOME^2 + \kappa_6 MSO + \kappa_7 CAP + \kappa_8 \lambda_i + \kappa_9 \lambda_j \quad (8c)$$

where the variables are defined, and descriptive statistics are provided, in Table 1.

The specification of the empirical model follows previous work in this area, including Mayo and Otsuka (1991), Rubinovits (1992), Ford and Jackson (1997), Beard et al., (2001), among others. Price (*P*) is assumed to be affected by exogenous variables that affect costs of service. Thus, we include a measure of fiber deployment (*FIBER*), potential customer density (*DENSE*), the size of the system in question measured by homes passed (*HPASS*), and the imposition of a service provider franchise fee (*FFEE*). The number of homes passed seeks to capture distribution plant scale economies, and density is expected to affect the average cost of services. *FFEE* reflects financial arrangements made by the provider with the relevant political jurisdiction. Fiber exhibits different costs characteristics and service capacities than coaxial cables. Included also are penetration (*PR*), "quality" as measured by the (log of the) number of satellite channels offered (*C*), and λ_1 and λ_2. Theory implies that λ_1 and λ_2 should increase prices.

The specification of the penetration equation also follows past practices. The log of the logistic transformation of penetration, which represents the demand relationship, depends on service price and quality (*P* and *C*), the monopoly enjoyed by the provider (λ_1), and exogenous variables that seek to account for market demographics and alternative entertainment opportunities. Market "size" (*POP*) and local over-the-air broadcast channels represent alternatives for buyers. Demographic factors hypothesized to affect demand include income (*INCOME*), the median age of market residents (*MEDAGE*), and regional dummy variables for the Northeast, Midwest, and South (*DNE*, *DMW*, and *DSTH;* the western state category is excluded). System age (*AGE*) is included to allow for the diffusion through time of customer acceptance of cable services.

The equation for service quality (*C*) assumes that the (log of the) number of satellite channels offered, a widely-accepted measure of cable service quality, depends on price, penetration, λ_1, λ_2, and a set of exogenous factors that affect consumer valuation of channels, and costs of offering them. Since those households with higher incomes are presumably more likely to be willing to pay for more channels, income and its square are included as regressors (to allow for more complex, non-linear relationships between income and demand). Costs depend on possible scale effects arising from multiple system operation (*MSO*), market size (*POP*) and the network's capacity to transmit channels (*CAP*).

The equations for price (*P*) and quality (*C*) include the overlap variables λ_i and λ_j, which measure the relative percentages of the firm-specific "markets" which are monopolized by *i* and *j*, respectively. The theoretical analysis indicates that λ_i and λ_j should positively affect prices in equilibrium. These variables also may affect quality to the extent that quality is a strategic choice.

The model described above satisfies the order conditions for identification. Compliance with the rank condition is a more complex issue since structural equations for λ_1 and λ_2 are not specified. However, the nature of the rank requirement is easily described. The system can be written as

$$Y\Gamma + X\beta + E = 0 \tag{9}$$

where Y = [P, PR, C, λ_1, λ_2] and X contains all the predetermined variables in the system, including the constant. Our price equation (8a) is then given as

$$Y\Gamma_1 + X\beta_1 + E_1 = 0 \tag{10}$$

where Γ_1 and β_1 are the first column of Γ and β, respectively. Define

$$\Delta = \begin{bmatrix} \Gamma \\ \beta \end{bmatrix} \text{ and } i^{\text{th}} \text{ column } \Delta_i = \begin{bmatrix} \Gamma_i \\ \beta_i \end{bmatrix}. \tag{11}$$

For equation (8a), say, X's excluded are denoted X_1^*, and these restrictions are written $R_1\Delta = 0$. R_1 consists of 12 rows consisting of 1's and 0's which select parameters attached to variables in X_1^* and set them equal to 0. The rank condition for equation 1 is then rank $(R_1\Delta) = 4$, i.e., there must be 4 linearly independent rows in the 12×4 matrix $R_1\Delta$.

It is clear that this requirement (which applies to equation 8a) is satisfied if the "unobserved" structural equations for λ_1 and λ_2 depend upon at least 4 of the variables in X_1^* that are excluded from equation (8a). Similar arguments apply to the equations (8b) and (8c). (In terms of instrumental variables or GMM estimation, an "identical" condition required to identify equation 8a is that $E(X_1^*, Y_1')$ has rank 4.)

Rank identification of the model, then, reduces to the assumption that enough coefficients attached to specifically excluded, predetermined variables in unspecified structural equations for λ_1 (and λ_2 in 2 cases) not be zero. Interestingly, the plausibility of this assumption may to some extent be "tested" by estimating reduced form equations for λ_1 and λ_2 and performing t- and F-tests for the significance of various sets of X variables corresponding, equation by equation, to predetermined excluded variables. If significance is observed in these tests, then that result *supports* the assumptions underlying rank identification. (One should say "supports" only, because identification arises from relationships among the true values of parameters, which are never observed.) The results of these tests are reported below.

2. DATA

The empirical model estimated in this study uses firm-specific data gathered from the *Cable & Television Factbook* (1993). This particular source contains firm-specific data for virtually every cable system in the United States, including price, quantity, channel, tiering, and physical plant statistics. Only systems with data falling between the dates of June 1991 to June 1992 are included. These dates precede the passing of the *Cable Act of 1992* and, thus, the price data is not directly affected by the price regulation of cable systems that resulted from the *Act*. Firms selected for the overbuild sample include those listed in the *Cable TV Overbuild Census* published in the April 1992 edition of *Cable TV Franchising*. Some overbuilds that were not listed in the census are included as well. *Demographics USA: Survey of Buying Power* (1992) provides all demographic data, including the additional instrumental variables discussed above. Overlap data was gathered via the authors' own survey of competitive cable system operators via facsimile and telephone interviews.[14] Thus, the model given in (8) can be estimated despite the unavailability of overlap details in published sources. The data set used in the subsequent analysis consists of 274 firms, 230 monopoly systems and 44 systems in multiple provider jurisdictions.

IV. Results

The model given in Equations (8) is estimated by the generalized method of moments ("GMM") technique using SAS. The GMM technique is based on the assumption that the errors in any equation, ε, are uncorrelated with some set of variables that need not include "endogenous" variables (such as P_i, PR_i, C_i, λ_i, or λ_j), and may include other variables that do not appear as regressors in any of

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[14] The respondents provided three figures: the number of homes passed by their own system (N_i), the number of homes passed by the rival system (N_j), and the number of homes passed by both systems ($N_i \cap N_j = n$). Of about fifty markets in the competitive sample, twenty-seven are represented in the final sample.

the equations. Hansen (1982) provides a technical exposition. Orthogonality conditions used here are limited to those generated using the exogenous variables included in the model.

Results from the estimation of the model described above are summarized in Table 2. The results may be evaluated and interpreted in two distinct ways. First, as a structural model, the coefficients obtained in the individual equations estimated provide information on the underlying relationships of interest. Thus, the structural equations are examined in some detail. Second, the ordinary interpretation of a simultaneous equations model of the sort estimated here is as a statistical approximation to firm optimality conditions, and it is especially useful to solve the entire system for the variables *P*, *PR*, and *C*, and evaluate the resulting equilibrium (or *mutatis mutandis*) responses to changes in competitive conditions (Ford and Jackson, 1998). An evaluation of these equilibrium changes is also provided.

First, however, the results of F-tests for the joint significance of excluded predetermined variables for the three equations are reported. Because λ_2 does not appear in the second equation (8b), only one result is appropriate in that case, that for λ_1. Given a reduced form equation $\lambda_i = \beta_i' X_i + \beta_i'^* X_i^*$, where X_i^* refers to those X's excluded in the relevant equation in (8), we test whether $\beta_i'^*$ is significantly different from zero. The results are summarized as follows (significance level in parenthesis): Equation (8a): F_1 = 2.06 (0.02), F_2 = 1.87 (0.04); Equation (8b): F_1 = 2.30 (0..03); and Equation (8c): F_1 = 1.86 (0.04), F_2 = 2.65 (0.061). These results provide relatively strong support for the assumptions necessary for rank identification of the model. Coefficient-by-coefficient evaluation using t-tests are encouraging, though slightly weaker. For λ_1, the *P* and *C* equation requires four non-zero coefficients among its omitted *X*s, while the *PR* equation requires only three. The largest t-scores in the λ_1 reduced-form equation corresponding to these equation-by-equation requirements are: for *P*, *MEDAGE* (-2.17), *CAP* (-2.23), AGE^2 (-2.09), and *AGE* (1.81); for *C*, *MEDAGE* (-2.17), AGE^2 (1.58), *AGE* (1.81), and *DENSE* (1.58); and for *PR*, *CAP* (-2.23), *DENSE* (1.58), and *HPASS* (-1.57). For λ_2, the results are: for *P*, *DNE* (-2.33), *AIRCHAN* (2.13), *MEDAGE* (-1.72), and *AGE* (-1.30); for *C*, *DNE* (-2.33), *AIRCHAN* (2.13), *HPASS* (1.84), and *MEDAGE* (1.81); and for *PR*, *DNE* (-2.23), *HPASS* (1.84), and *DENSE* (1.17). On balance, these results are supportive of the assumptions underlying identification. For a very enlightening discussion, see Wooldridge (2002, pp. 90-94).

1. EVALUATION OF THE STRUCTURAL EQUATIONS

Results from the estimation of equations (8a-c) are summarized in Table 2. The equations for price and quality are interpreted as (approximations to) optimal behavioral rules for the sample firms, while the penetration equation represents the demand relationship.

First, consider the dependencies between the three endogenous variables: P, *PR*, and *C*. The observed pattern (*C* does not depend on *P* or *PR*; *P* depends only and positively on *C*; *PR* depends negatively on *P* and positively on *C*) is economically sensible and intuitive, and is consistent with the notion that quality is determined "first," prices then reflect this choice, and quantity demanded reflects both price and quality in the expected manner.

From the estimated demand relationship, demand is found to be elastic (-2.7) at the sample means. This result is consistent with previous findings. Service quality positively and significantly influences demand: an increase of one satellite channel (at the sample means) increases subscription by about eight-tenths of one-percent. Penetration is slightly lower in dense market areas, and the result is statistically significant. Older systems enjoy higher subscription rates, other things equal, a result consistent with the notion that diffusion occurs. No evidence is found that local broadcast channels present much of a challenge to cable sales, or that area population, incomes, age, or region of the country matter much when all other variables are taken into consideration. The insignificant result for income is surprising, but the discussion below on service quality sheds light on this finding.

The price equation is also relatively intuitive. Besides service quality, there is weak evidence of a cost component in prices. System density (*DENSE*) is marginally relevant, and appears to reduces prices. These results suggest that service costs affect prices.

Quality, *C*, appears to reflect decisions that, in an informal causal sense, are "prior" to pricing and subscription. There are significant income effects, and greater area population leads to greater quality offerings, perhaps reflecting the proliferation of "specialized" channels that may lack an adequate constituency in smaller markets. Channel capacity (*CAP*) also significantly affects channel offerings, but the absolute effect is small.

A primary focus of the is paper is the role of system overlaps in cable provider performance. The variables λ_1 and λ_2 measure the monopolized proportions of the target firm and its (potential) competitor (if any). Turning to the simplest case first, the estimates indicate that penetration is significantly greater, all else equal, when more consumers have no alternative, an unsurprising result. The quality results are more interesting: greater monopoly by the rival firm reduces channels offered in a significant fashion but "own" monopoly has no effect. As for prices, consumers pay more when their provider enjoys a greater monopoly segment, although the extent of the rival firm's monopoly segment has no direct effect. This finding, combined with those previous discussed, suggests that the "price effect" of competitive suppliers arises partially and indirectly through service quality – an issue addressed more fully below.

2. Evaluation of Equilibrium Effects

The structural analyses offered above are interesting, but any complete assessment of the impact of cable system overlap on consumers requires that the total equilibrium effects of changes in the extent of overbuilding be evaluated. Computing point estimates of the equilibrium effects is relatively straightforward, requiring only that the three variable, three equation system estimated above be solved for price, demand, and service quality. These "reduced form" equations are then used to find the total (mutatis mutandis) effects of changes in the degree of geographic monopoly.

It is important to note that these mutatis mutandis effects represent estimates of the net consequence of the change in market structure. For example, while an increase in the extent of monopoly raises prices and subscriptions directly, and may lower quality, the increase in price has a "feedback" effect on subscription rates and service quality. Therefore, a calculation of the total equilibrium effects is of policy relevance.

Equilibrium analysis reveals the following total effects. If λ_i, the extent of the seller's monopolized segment of the market, rises by ten percentage points, then (i) price will rise by about $1.63 per month; (ii) the firm's penetration rate decreases by about 4.5 percent; (iii) the number of channels offered ("quality") increases by about 0.9 channels. These effects differ from the "direct" effects analyzed earlier because these latter values seek to include the simultaneous, equilibrium adjustments of price, demand, and quality.

These calculated effects, if even modestly accurate, are quite important. There is no question that monopoly leads to higher prices: a rise of $1.63 represents an increase about a 8.8 percent in customer expenditures on cable service. This is a substantial effect.

3. Empirical and Theoretical Specifications

Although the estimation results presented here are sensible, an important question arises as to the generality of the model adopted. In particular, does the fragmented duopoly framework produce results usefully different from other models? Somewhat curiously, most common alternative formulations of duopolistic competition either are not applicable to fragmented competition when a firm's prices must be the same over both monopoly and "competitive" segments, or else do not produce useful results. For example, the case of undifferentiated Bertrand price competition may admit no pure strategy price equilibria with partially overlapping markets.[15] Since it is directly observed that prices (and service qualities) vary in overbuilt markets, only models consistent with these facts need be considered. The undifferentiated Bertrand model, therefore, is not a meaningful alterative specification of the theoretical model.

Differentiated quantity competition (Cournot) is likewise problematic. In this case, one could imagine that each firm produces two quantities, one for sale in the monopoly segment, and the other for sale in the contested segment. However, prices must be the same in both segments regardless of the quantities sold or selected by sellers. This restriction is impossible in an equilibrium model when all demands are continuous in quantities. Adding an external constraint that quantities must be selected to satisfy the uniform price requirement is both complex and artificial.

Perhaps the most obvious alternative view to fragmented price competition is the supposition that firms facing some overlap collude. If all firms facing overlap collude, however, the expectation is monopoly pricing throughout the cable industry, with no obvious differences between prices and qualities arising from variation in the degree of overlap. The results reported here strongly indicate that the extent of overlap, and not its mere presence, significantly affects price and quality outcomes.[16] It appears that among familiar oligopoly models, therefore, the fragmented price-setting model is the best choice.

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[15] Complete details are available from the authors on request. However, this result is easy to see by noting that, with equal prices, a tiny price cut allows the discounter to capture the entire overlap segment. Alternatively, if prices differ and are not beyond monopoly market profit maximizing levels, then the firm with the lower price has an incentive to raise price.

[16] To evaluate this proposition, the regressions were estimated with a dummy variables indicating overlap and a variables measuring its degree. The degrees of monopoly remain significant, despite the relatively small number of total sample firms experiencing overlap competition.

V. Conclusion

The primary contributions of this paper are twofold. First, the paper points out the potential utility of the theory of fragmented duopoly in assessing the effects of emerging competition in the communications and energy industries. While the intuition of fragmented duopoly is present in many policy debates, no formal conceptual framework has been established in this arena.[17] The framework presented in this paper is a simple yet potentially powerful tool for competition and antitrust analysis in an important class of industries receiving increased attention due to deregulation.

Second, empirical evidence on fragmented competition in the communications and energy industries, and in other industries generally, is virtually non-existent. This paper provides empirical support for the theory using a sample of prices from monopoly and duopoly cable markets. On balance, the empirical analysis suggests that the competitive effects of overbuilding are consequential and in accord with economic intuition. There is no question that overbuilds reduce prices. In the policy arena, this contribution to the literature is decidedly relevant. Even the most intuitively obvious concepts carry little weight with regulators and lawyers absent empirical support (Brennan 1992).

It is hoped that the results presented here will foster additional examination into the empirics of "fragmented duopoly," as such a market structure will be an ubiquitous feature of emerging competition in electricity, local telecommunications, wireless telecommunications, and other markets with partially overlapping distribution plant. Of particular potential interest will be studies that seek to gauge the effects of "multiple" (i.e., more than two) overlaps, and work on this problem is encouraged.

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[17] The idea of fragmented competition has surfaced in many settings, though never formalized conceptually. For example, regulatory relief of regulated cable systems (multichannel video programmers) is tied to the existence of 'effective competition.' The term 'effective competition', as defined by the 1992 Cable Act, means that a) fewer than 30 percent of the households in the franchise area subscribe to the cable service of a cable system; b) the franchise area is served by at least two unaffiliated multichannel video programming distributors each of which offers comparable video programming to at least 50 percent of the households in the franchise area; c) the number of households subscribing to programming services offered by multichannel video programming distributors (meeting requirement (b)) other than the largest multichannel video programming distributor exceeds 15 percent of the households in the franchise area; or c) a multichannel video programming distributor operated by the franchising authority for that franchise area offers video programming to at least 50 percent of the households in that franchise area. The uniform pricing condition proposed in the Echostar/Directv merger is another example (McConnell 2002).

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Table 1. Variable Definition and Descriptive Statistics

Variable	*Definition*	*Mean*	*Stan. Dev.*
P	Log of the tier-weighted price of firm *i*'s cable service including converter box [exp(*P*)]	2.892 [18.47]	0.245 [4.10]
PR	Logistic transformation of firm *i*'s penetration rate *W*, given as the number of subscribers divided by homes passed [*W*]	0.735 [0.65]	0.907 [0.17]
C	Log of the total number of satellite channels [exp(*C*)].	3.193 [27.7]	0.411 [9.30]
FIBER	System miles of fiber distribution plant installed	1.713	14.030
DENSE	Density of system, defined as the number of homes passed divided by miles of cable installed.	78.86	4.10
MSO	Number of systems owned and operated by the system's parent company	254.93	425.82
HPASS	Homes passed by the cable system	31,685	61,102
INCOME	Per-capita income at the county level	18,244	4,106
$INCOME^2$	Square of INCOME.		
AGE	The number of years the system has been in operation	17.67	9.82
AGE^2	Square of AGE.	408.54	426.44
AIRCHAN	Over-the-air broadcast stations retransmitted by the cable system	7.96	3.26
POP	Population at the county level	92,603	181,368
CAP	Cable system channel capacity	43.86	13.26
DNE	Dummy for Northeast Region.	0.142	0.35
DMW	Dummy for Midwest Region.	0.336	0.473
DSTH	Dummy for South Region.	0.365	0.482
MEDAGE	Median age of the population in the market	33.46	3.58
λ_i	Percentage of total cable market monopolized by firm *i*	0.89	0.28
λ_j	Percentage of total cable market monopolized by firm *j*	0.04	0.16

Table 2. Results
(t-values in Parenthesis)

	Dep. Variable: P_i	Dep. Variable: PR_i	Dep. Variable: C_i
P_i	…	-7.98**	0.607
		(-2.61)	(0.77)
PR_i	-0.045	…	-0.029
	(-1.13)		(-0.48)
C_i	0.0237**	1.03*	…
	(4.14)	(1.71)	
FIBER	0.0001	…	…
	(0.28)		
DENSE	-0.003	-0.003**	…
	(1.60)	(-2.61)	
MSO	…	…	-0.0001
			(-0.30)
HPASS	3.315E-7	…	…
	(1.55)		
INCOME	…	12.092	25.507**
		(0.31)	(2.02)
$INCOME^2$	…	-0.593	-1.309
		(-0.29)	(-2.03)
POP	…	0.130	0.075*
		(1.05)	(1.65)
AIRCHAN	…	-0.105	…
		(-0.47)	
MEDAGE	…	-0.006	…
		(-0.03)	
AGE	…	0.056*	…
		(1.80)	
AGE^2	…	-0.0008	…
		(-1.18)	
CAP	…	…	0.011**
			(4.91)
FFEE	0.346	…	…
	(0.61)		
DNE	…	0.301	…
		(1.32)	
DMW	…	-0.171	…
		(-0.97)	
DSTH	…	0.132	…
		(0.77)	
λ_i	0.717**	4.605**	-0.214
	(4.44)	(2.31)	(-0.71)
λ_j	0.074	…	0.780**
	(0.36)		(2.16)
CONSTANT	1.564	-48.314	123.935**
	(6.09)	(-0.25)	(-2.00)

** Statistically significant at the 5 percent level.
* Statistically significant at the 10 percent level.