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I. The Research Issue

The U.S. television industry is presently undergoing rapid change. Where once there was a limit on viewing options imposed by the scarcity of electromagnetic spectrum, confining most viewers to a handful of channels, cable television is emerging as "the television of abundance," (Sloan Commission 1971). Yet ironically, the market structure of "abundant" cable television is more restrictive than that of "scarce" broadcast television, since the present franchising system has arranged the medium into parallel local distribution monopolies, one for each franchising area. This raises concern about a cable operator's ability, if left unconstrained, to charge monopolistic prices to subscribers, and, more significantly, to control the content of dozens of program channels. A variety of reform proposals have therefore been made, seeking to impose some form of either conduct regulation, public ownership, common carrier status, or competitive market structure. The latter approach, in particular, has been taken by the Federal Communications Commission,

whose philosophy it has become to permit entry and encourage inter-media competition between cable and other video technologies.

A second and distinct competitive approach is to rely on intra-medium competition among cable companies. In New York State, for example, a Governor's Bill, based on recommendations by Alfred Kahn and Irwin Stelzer, had sought to open each cable franchise area to additional cable companies, thereby reducing their local economic power. The likelihood of such entry, however, is based on the assumption that more than one cable company could successfully operate in a territory. But such competition is not sustainable if cable television exhibits strong economies of scale and economies of scope, i.e., cost advantages of diversified production.

The question of cable television's economies of scale also has implications on the scope of local regulation and on the treatment of the medium as a "public utility," issues that have arisen in a number of court cases. In one decision, for example, the court declared that "CATV is not a natural monopoly. Thus, the scope of regulation which is necessary in the natural monopolies is not here necessary ... (and) CATV is not a public utility"... (Greater Fremont, Inc. v. City of Fremont, 302 F. Supp. 652 (N.D. Ohio 1968)). Information on scale elasticities is also important in assessing the likelihood of future consolidations into regional or national cable systems, finding the economically most efficient subdivision of large cities into franchise zones, and in analyzing the price structure of cable television.

Despite the relevance of the question of cable television economies of scale and scope, it has not received much empirical investigation.

Previous studies of cable television have typically centered on questions of demand analysis and of audience diversion. They are also mostly dated, since their impetus was the 1966 FCC rules restricting CATV.

As pointed out in an article jointly authored by a comfortable majority of the economists engaged in cable television research (Besen, Mitchell, Noll, Owen, Park, and Rosse, in MacAvoy 1977): "All of these models are synthetic and eclectic, drawing their cost data for the specific components of a system from engineering specification and field experience; no satisfactory data set exists from which to estimate econometric cost or production functions" (p. 66).[1]

Since that observation, several empirical studies on the demand for pay-cable services were undertaken (Block and Wirth 1982; Dunmore and Bykowsky 1982; Smith and Gallagher 1980). However, no comparable research on the production side was undertaken, with the exception of Owen and Greenhalgh (1982), which relies on projected rather than actual data.

II. The Model

For purposes of analysis and estimation of economies of scale, consider the multi-product cost functions of firm i, uniquely corresponding to the production function under duality assumptions,

$$(1) \qquad C_i = f_i\ (P_1 \ldots P_n;\ Q_1 \ldots Q_q;\ M)$$

where C_i are total costs of production, Q_q is the output vector, P_i are the prices for input factors i, assumed to be independent of output, and M is the maturity of the system in terms of operating experience. Under the assumption of cost-minimization, we have from Shepherd's lemma an identity of the cost-price elasticities E_{CP}; with the share of each input factor in total cost, i.e.,

$$(2) \qquad S_i \equiv \frac{P_i X_i}{C} = \frac{\partial \ln C}{\partial \ln P_i} = E_{CPi}$$

where X_i is the quantity of input i.

Furthermore, let the cost function f be given by the translog function, a second-order logarithmic approximation to an arbitrary twice-differentiable transformation surface. A major problem with the application of a multiproduct specification of a cost function is that if even one of the products has the value zero, the observation's value becomes meaningless. For that reason, it is necessary to specify an alternative functional form that is well behaved, and we can substitute the Box-Cox metric

$$(3) \qquad g_i(Q_q) = \frac{Q_q^w - 1}{w}$$

which is defined for zero values, and which approaches the standard natural logaritha $\ln Q_q$ as $w \longrightarrow 0$. Using this expression, we can define the "hybrid" multiproduct translog cost function.

$$(4) \qquad \ln C\,(P_i, Q_q, M)_m = a_0 + \sum_i a_i \ln P_i + \sum_q a_q \left(\frac{Q_q^w - 1}{w}\right) + \sum_m a_m \ln M + \frac{1}{2}\sum_i\sum_j a_{ij} \ln P_i \ln P_j$$

$$+ \frac{1}{2}\sum_q\sum_p a_{qp} \left(\frac{Q_q^w - 1}{w}\right)\left(\frac{Q_p^w - 1}{w}\right) + \frac{1}{2}\sum_m a_{mm} (\ln M)^2 + \sum_i\sum_q a_q \ln P_i \left(\frac{Q_q^w - 1}{w}\right) + \sum_m\sum_i a_{im} \ln P_i \ln M$$

$$+ \sum_m\sum_q a_{qm} \left(\frac{Q_q^w - 1}{w}\right) \ln M$$

Several parametric restrictions must be put on the cost function. The cost shares must add to unity which implies that $\sum E_{CPi} = 1$; hence, the cost function must be linearly homogeneous in factor prices at all values of factor prices, output and maturity.

Furthermore, the function is homogeneous at the sample mean if overall cost

$$a_{qp} = a_{iq} = a_{qm} = w = 0 \tag{5}$$

For a test of constant returns to scale to exist. we add the independent restriction,

$$a_q = 1 \tag{6}$$

Finally, for a neutrality of technical change, we impose the n-1 independent restrictions, for an M that measures time,

$$a_{im} = 0 \tag{7}$$

For the multinroduct case, local overall scale economies. as shown by Fuss and Waverman (1982),

are

$$E_S = \frac{1}{\sum_q E_{CQq}} \tag{8}$$

so that

$$E_S = 1/ \sum_q (Q_q^w (a_q + \sum_p a_{qp} (\frac{Q_p^w - 1}{w}) + \sum_i a_{iq} \ln P_i + \sum_m a_{qm} \ln N)) \tag{9}$$

Product specific economies of scale are, using the definition in Baumol, Panzar,

and Willig (1982)

$$(10) \qquad E_{Sq} = \frac{IC_q}{Q_q \frac{\partial C}{\partial Q_q}}$$

(where IC_q are the incremental costs of producing product q) which is

$$(11) \qquad E_{Sq} = \frac{IC_q}{C} / Q_q^w \left(a_q + \sum_p a_q \left(\frac{Q_q^w - 1}{w}\right) + \sum_i a_{iq} \ln P_i + \sum_m a_{qm} \ln M\right).$$

For the hybrid translog function, sample mean values are $P_i = Q_q = M = 1$; so that equation (11) for the product-specific economies of scale becomes

$$(12) \qquad E_{Sq} = \frac{\exp(a_o) - \exp(a_o - \frac{a_q}{w} + \frac{a_{qq}}{2w^2})}{\exp(a_o) \cdot a_q}$$

The form of estimation that is used to determine this system follows Zellner's (1962) iterative method. That technique is a form of generalized least squares, shown to yield maximum likelihood estimates (Dhrymes 1964) that are invariant to which of the cost-share equations is omitted (Barten 1969). In estimating such a system, it is generally assumed that disturbances in each of the share equations are additive, and that they have a joint normal distribution. These assumptions are made here too.

Effects of Regulation

The model has so far assumed the absence of regulation, by treating each cable operator as an unconstrained profit maximizer. However, cable firms may operate under a set of constraints. Of these, the most frequent are restrictions on profitability, the usual corollary to the franchise-awarded monopoly status. These constraints will now be incorporated into the model.[2]

We first assume the existence of a rate of return regulation in the prices of cable television services. Such regulation exists explicitly in a number of jurisdictions, and implicitly in many others by the regulating authority's restriction of basic rates to result in a "reasonable" overall return, including pay-channel revenues, that does not discourage further investments in the cable system.

Let total cost be given by

$$C = \sum_i X_i P_i, \tag{13}$$

where, as before, X_i and P_i are the quantities and prices of input factors. Total differentiation with respect to time in operating experience yields

$$\frac{dC}{dm} = \sum_i X_i \frac{dP_i}{dm} + \sum_i P_i \frac{dX_i}{dm} \tag{14}$$

We define, for any variable A, the term $\dot{A}$ as the change $\frac{dA}{dm}$ proportional to its size, to its size.

We also recall that the cost shares S_i were defined as $S_i = \frac{X_i P_i}{C}$. Therefore, the previous expression becomes, after some manipulation,

$$\dot{C} = \sum_i S_i \dot{P}_i + \sum_i S_i \dot{X}_i \tag{15}$$

Suppose now that cable operators minimize cost subject to a constraint z of return on capital.

Under the constraint z, Shephard's lemma leads to modified optimization conditions (Fuss and Waverman 1981). With unconstrained inputs i, constrained capital input K, and Lagrangean multiplier λ, these conditions are

$$\frac{\partial C}{\partial P_i} = (1-\lambda)\, X_i \tag{16}$$

$$\frac{\partial C}{\partial P_K} = X_K \tag{17}$$

$$\frac{\partial C}{\partial z} = -\lambda K \tag{18}$$

A total differentiation of the cost function yields

$$(19) \qquad \frac{dC}{dm} = \sum_i \frac{\partial C}{\partial P_i} \frac{dP_i}{dm} + \sum_q \frac{\partial C}{\partial Q_q} \frac{dQ_j}{dm} + \frac{\partial C}{\partial m} + \frac{\partial C}{\partial z} \frac{dz}{dm}$$

and, after substitutions,

$$(20) \qquad \dot{C} = \sum_i (1-\lambda) \; S_i \dot{P}_i + S_K \dot{P}_K + \sum_q E_{Qq} \dot{Q}_q + \dot{C}_m - \frac{\lambda z X_K}{C} \dot{z}$$

The shift in the cost function is hence, after equating the previous expression with (15),

$$(21) \qquad \dot{C}_m = \sum_i S_i \dot{X}_i + S_K \dot{X}_K - \sum_q E_{Qq} \dot{Q}_q + \sum_i \lambda S_i \dot{P}_i + \frac{\lambda z X_K}{C} \dot{z}$$

We now define total quantity changes as the sum of the component changes, weighted by their share in total cost C. That is, let

$$(22) \qquad \dot{Q} = \sum \dot{Q}_q \frac{IC_q}{C}$$

and let equation (21) then be rewritten, after substituting for the elasticities E_{Qq}, and rearranging

$$(23) \qquad \dot{TFP} = \dot{Q} - \dot{I} = -\sum_q \frac{\dot{Q}_q \cdot Q_q}{C} \left(\frac{\partial C}{\partial Q_q} - \frac{IC_q}{Q_q}\right) + \lambda\left(\sum_i S_i \dot{P}_i + \frac{z X_K}{C} \dot{z}\right) - \dot{C}_m$$

This expression now shows changes in total factor productivity as composed of the effects of falling average costs and of rate-of-return regulation, as well as of the more conventional effect of technical progress in operations.

What is the interpretation of the first term of the right hand side equation? The terms inside the parenthesis are, respectively, the marginal cost and the average cost of product q. We will later observe that marginal costs tend to be below average costs. Hence, the entire term is likely to be positive, and the observed growth in total factor productivity, if this effect is not considered, is likely to overstate the contributions of maturity in operations $\dot{C}_m$.

The second expression (preceded by the λ term) shows the effect of rate-of-return regulation. If no negative rate of regulation exists, ($\lambda = 0$), TFP growth is measured by maturity progress $\dot{C}_m$. However, if rate-of-return regulation is effective, and if--as is reasonable to assume under inflation--for each factor i, $\dot{X}_i \geq 0$, and $\dot{z} \geq 0$, then the measured total factor productivity growth, too, overestimates the contribution of operating experience.

The following section is an empirical estimation of the model (1) - (10). For the regulated model, sufficient data is not available at this point; their generation and use is the subject of further research.

III. Data

The empirical estimation of this study is based on an unusually good body of data for cable television systems, all producing essentially the same service, operating and accounting in a single-plant mode, supplying their local market only, and reporting data according to the fairly detailed categories of a mandatory Federal form.

The data covers virtually all 4,200 U.S. cable systems, and is composed of four disparate and extensive files for the year 1981 for technical and programming, financial, local community, employment information.[3] The financial data includes both balance sheet and income information.[4]

All variables are standardized around the sample mean in order to overcome the problem of arbitrary scaling that can become an issue in translog functions.

Labor Inputs[5]

The factor quantity is the number of full-time employees (with part-times added at half value).

Capital Inputs

Accounting for the different classes of assets is reported to the FCC in book value form. Although the great bulk of assets in the cable television industry have been acquired within the past decade, thus limiting the extent of inflationary distortion, it was considered prudent to revalue these assets. To do so, the study took advantage of a highly detailed engineering study, commissioned by the Federal Government, on the cost and pattern of investment in the construction of cable systems (Weinberg 1972). In that report, the required investment flow in a medium-sized cable system over

a period of ten years was calculated. We assume that this time distribution of investment over the first ten years holds proportionally for all systems, with investment in the 11th year and further years identical to that of the 10th year in real terms, and that the cost of acquiring capital assets required in a cable television system increases at the rate of a weighted index of communications and utilities equipment.

For each observation, we know the first year of operation and the aggregate historical value of capital assets. It is then possible to allocate capital investments to the different years and different types of investment, and to inflate their value to the prices of the observation year. The input price P_K of this capital stock K is determined by its opportunity cost in a competitive environment, consisting of potential returns r on equity E and payments for debt D, with an allowance for the decuctibility of interest expense (tax rate = t).

$$P_K = r_E \cdot \frac{E}{K} + r_D \, (1-t) \, \frac{D}{K} \tag{24}$$

The required return on equity is determined according to the risk premium ρ required above the return on risk-free investments, R_F; that is, $r_E = R_F + \rho$. Ibbotson and Sinquefield (1979) found ρ for the Standard & Poor 5000 to be 8.8 for the period 1926-1977. Hence, using the capital asset pricing model, an estimate of ρ for a specific firm is 8.8 times β, where β is the measure of non-diversifiable (systematic) risk. The average β for cable companies listed by Moody's is, for 1980, β = 1.42, resulting in a risk premium of 12.49% over the treasury bill rate

For r_D, the return on long-term debt, the following method was employed: for each observation it was determined, using several financial measures, what its hypothetical bond rating would have been, based on a com-

pany's financial characteristics. These "shadow" bond ratings for each observation were then applied to the actual average interest rates existing in the observation years for different bond ratings. This procedure is novel, but is based on a series of previous studies in the finance literature of bond ratings and their relation to financial ratios.[6]

Tax rate w is defined as the corporate income tax rate (federal and average net state). Debt is defined as long term liabilities.

Programming Inputs

The third production factor of the model is the input of programming. A cable system that carries no communciations messages would be of no interest to subscribers. Therefore, cable operators supply programs in addition to providing the communication wire. These programs are not produced or generated by the operators; with trivial exceptions, programming is supplied by broadcasters and program networks. Program costs are both direct and indirect. Direct costs are the outlays for program services, for example to pay-TV networks and to suppliers such as Cable New Network (CNN), which charge operators according to the number of their subscribers, plus the cost of program importation and its equipment. Direct costs, however, are only part of the programming cost; indirect costs that must also be considered are the foregone net earning from advertising. For example, CNN is able to sell some of its "air" time to advertisers. This time is in effect a compensation in kind by the cable operator to CNN for the supply of the program. Similarly, local broadcasters are carried by cable for free,

and the programming cost of these "must carry" channels to cable operators, too, is the foregone earnings, largely in advertising revenues.

Direct costs are reported to the FCC and are available. Included are also such capital cost as those of origination studios and signal importation equipment and cost to carriers. The indirect cost of foregone advertising revenue is defined as the potential minus the actual advertising revenue obtained by cable operators net of cost. Actual figures are reported to the FCC; potential revenues are estimated by reference to the average net advertising revenue in television broadcasting per household/and viewing time. The unit price of programming inputs is their total divided by the number of program hours and channels.

Output

Costs and revenues in cable television are nearly entirely for subscription rather than actual use. Pay-per-view billing systems are exceedingly rare, and in their absence there are only negligible marginal costs to the operator for a subscriber's actual viewing of the channels. Active communications services, though maybe of future importance, are very rare at present. Advertisements, simularly, are largely supplied by program providers as part of an exchange arrangement; as discussed above, they are an input. Hence, the number of actual and potential subscribers -- as opposed to their viewing -- are the measures of the operator's outputs.

Cable television operators' major outputs are then of the following dimensions: (a) basic service subscriptions; (b) pay-TV service subscriptions; and (c), the size of the market developed, measured by the number of potential subscribers that are reached. The latter is reflected by the number of "homes passed" by cable. The larger this number, the more subscribers can be potentially enrolled. Cable trunk lines or feeder lines pass their houses; only drops need to be added for their inclusion as paying customers. Subscriptions as share of homes passed vary widely.

Other Variables

M, maturity in operation, is one variable that is introduced to allow for the period that a cable operator had to improve operations and to establish himself in the local market. It is defined by the number of years of actual operation.

This variable may be thought of as if it were an input factor. Quite possibly, it is substitutable for the more conventional input factors of capital and labor, reflecting improvements in productivity of a firm whose experience shifts the cost function downwards.

Two additional variables are introduced in order to adjust for differences in the cable systems that may affect costs of production and ability to attract subscribers. The density of population has a role in determining cost. The further houses are from each other physically, the more capital and labor inputs must go into reaching each. To allow for density variations, we define D as the length of cable trunk lines per household passed. The resultant ratio is used as a proxy for density.

A third variable is the number of video channels offered by a cable operator. Clearly, the more channels offered, the more inputs are required. At the same time, one would expect subscription outputs to be affected positively, ceteris paribus, since the cable service is more varied and hence probably more attractive to potential subscribers.

IV. Results

Table 1 represents the parameter estimates for the five models (A - E), for the multipoint specification, for the year 1981. Results for the unrestricted model are discussed.

The system has a good fit, with system R^2 values above .97 for the models. Similarly, the coefficients are generally significant at the .05 level, and common parameters are of similar size. High R^2 values are found for the cost share equations, when these are estimated seperately.

Overall elasticity of scale is calculated, using equ. (14), as $E_S = 1.096$ That is, a 10% increase in size is associated with a unit cost decrease of about 1%.

We are also able to calculate, using equ. (19), measures for the product-specific economies of scale for the four outputs. They are:

E_S (Homes Passed) = 1.020

E_S (Basic Subscriptions) = 1.054

E_S (Pay Subscriptions) = 1.072

Economies of scale are thus observed for three outputs: basic and pay subscriptions, and channel capacity. However, for "Homes Passed," these are relatively smaller and significant; it may be recalled that this output description refers to a physical measure, namely the extent of the cable network in accessing a market. These results do not change markedly when the small, old, and low-capacity systems are omitted from the observations.

The implication from this result is that scale economies do not appear to reside primarily in the technical distribution aspects of cable television, as reflected by "Homes Passed." Instead, they are observed for the output definitions that include a strong element of marketing success.

It is particularly interesting to observe that the overall economies of scale are larger than the product-specific economies of scale. There are then economies to joint production, or of "scope."

The product-specific scale elasticity measures listed above also provide another insight. Since they are the ratio of average to marginal cost, their being generally above unity reflects marginal costs that are below average costs. This suggests that in a hypothetical competitive environment, where subscriber prices are driven to marginal cost, total costs will not be recovered.

It is also interesting to look at the estimates for the effects of operational maturity M. This factor, it may be recalled, measures the effects of experience in operation. We find the elasticity of costs with respect to such maturity to be $E_{CM} = -.01$, suggesting a small downward shift of the cost function with experience, with inputs and outputs held even.

that several rivals coexit in a market, even in the presence of subadditivity, if they enter into some form of oligopolistic agreement to assure their mutual survival. However, such interaction is less likely with a single incumbent, as is the case in cable television. A hostile entry, on the other hand, is costly: since many of the cable companies operate multiple systems across the country, a hostile entry would under normal circumstances invite retaliation or a protective price cut (Milgrom 1982).

The likelihood of competitive entry could also be affected by sunk cost of the incumbent cable operator. Sunk cost--the difference between the ex ante cost of investment and its ex post sale value--may permit strategic investment behavior in order to create entry barriers (Dixit 1979).

It differentiates the cost of incumbents from those of contestants, and imposes and exit cost on a contestant. Knieps and Vogelsang (1982) have shown that entry and a multifirm equilibrium may still be possible in a sunk cost situation under Cournot assumptions, provided demand is high relative to cost, but that under a Bertrand behavioral assumption entry can be deterred if a sufficiently high share of cost is sunk. It is not clear which of the assumptions better reflects a hypothetical oligopolistic interaction in cable television, or even if one can accept the simplistic assumption of invariable post-entry behavior. As an empirical matter, it is very hard to assess the existence of sunk cost and to separate it from good will in cable television, although there are indications for its existence. In a sale of cable assets, the physical cable network may be acquired by other communication

It should be noted that the maturity effect M actually embodies two separate effects, that of experience, given a technology, and that of changes in the technology itself. Conceptually, it is the difference between a movement along a curve, and the shift of the curve. To separate between these effects is a question for further research.

A look at the other control variables is interesting, too. Here, we can observe the coefficient for density (trunk length/homes passed) to have a value of a (D) = .19, with a good statistical significance. That is, costs are declining with density, which is an expected result, though its magnitude is not particularly great. Furthermore, cost savings decline with density and there are diminishing economies to density. This would confirm the observation that in dense city franchise areas costs increase again, since underground ducts are necessary.

The number of channels, on the other hand, is associated with increasing cost; this, too, is as intuitively expected. Here, cost increases rise with channels, implying increasing marginal cost of channel capacity beyond the mean.

While this paper deals with scale economies of cable, such conditions are not the only factor pertinent to entry. Theoretically, it is for example possible

carriers as a broadband transmission facility, possibly as a "by-pass" to telephone companies, but such use is only in its beginning, and probably not profit-generating for some time. In any event, it has been shown (Panzar and Willig 1977) that competitive entry can be deterred where sunk costs are zero, if average cost is continuously diminishing; in the presence of sunk costs this result should hold all the more.

Beyond the theoretical arguments, there is also the reality of competitive entry, or rather the lack thereof. In practice there are no second entrants, apart from minor cream skimming instances. Competitive cable television services (known in the industry as "overbuild") exist in less than ten franchises our of 4,200, and are usually caused by disputes about the scope of the initial franchise award. Of these operations, only those in Allentown, Pennsylvania, and Phoenix, Arizona are of appreciable size. Despite rivalry, subscriber rates in Allentown are above the national average.

The rivalry among cable operators is thus primarily for the right of first entry. Being first

assures a head start and thus the advantages of economies of larger size; this, together with the likely existence of sunk costs, the ability of the incumbent to cut prices fairly rapidly, and consumers' conservative adjustment to new offerings, violates the criteria for actual or potential contestability.

If the estimation results are accepted, their implications are that large cable corporations have cost advantages over smaller ones when they function as more than a mere distributor. Under the results, a pure distribution network with no programming or marketing role, such as a passive common carrier, is not likely to have a major cost advantage over potential rivals. The imposition of such a common carrier status would therefore be doubly injurious to the cable television industry (which strenuously opposes it): it would not only eliminate operators' control over and profit from non-transmission activities such as program selection, but it would also reduce the cost-advantage protection of incumbents against entry.

On the other hand, the conclusions require a subtle change in the pro-separations argument. That position--held by institutions as disparate as the Nixon White House and the American Civil Liberties Union--is normally presented as one of protection against a vertical extension of the natural monopoly in one stage of production (transmission) upstream into other stages such as program selection. The implications of our estimation, however, do not support the view that such advantages are primarily derived from a naturally monopolistic

distribution stage. Instead, the cost advantages appear to lie in the integration of transmission and marketing activities. It is this integration which appears to provide cable television firms with protection against rivalry in the distribution phase of their operations.

FOOTNOTES

1. Two earlier attempts at cost studies of cable television have been chapters in two doctoral dissertations on the economics of Canadian television (Good 1974; Babe 1975), which include simple regressions of cost per size for several Canadian systems and which come to conclusions that are contradictory to each other.

2. While the effect of regulation was investigated for other industries, no such investigation exists for cable television. Industry studies are for trucking (Friedlaender 1978); air transport (Gollop and Jorgenson 1980); railways (Caves et al. 1980); environmental regulation (Denison 1978); electric power (Christensen and Greene 1976); and gas pipelines (Callen 1978). Closest to the present study is an investigation of Canadian telephone service (Fuss and Waverman 1981), to which credit is due.

3. FCC, Cable Bureau, Physical System File; Special financial data printout; Community File; Equal Employment Opportunity File.

4. To assure confidentiality, financial data had been aggegated in the publicly available FCC documents; particularly detailed subaggregations--for each state according to seven size categories, and with many such catagories of financial information--had been made specifically available to the author.

5. All input prices are assumed to be independent of production level. Furthermore, input prices are not controlled by cable operators. This seems unexceptional in light of the mobility of capital and labor. For programming, some market power will exist in the future if cable should become a dominant medium. As an advertising outlet, cable television has no particular market power.

6. The model used here is taken from the Kaplan and Urwitz survey (1979, Table 6, Model 5) which determines bond rating with a fairly high explanatory power(R^2 = .79). The financial variables used in that model are: (a) cash flow before tax/interest charges; (b) long term debt/net worth; (c) net income/total assets; (d) total assets; (e) subordination of debt. Bond ratings ranging from AAA (Model values $\geq$ 9) to C ($\leq$ 1) can then be obtained for each observation point by substitution of the appropriate financial values. Bond rates are those reported by Moody's. For low ratings, no interest rates are reported by the services. For the lowest rating (C), the values estimated by an investment banker specializing in cable television were used (4% above prime); for the next higher ratings, interest rates were reduced proportionately until the reported ratings were reached.

Table 1

Cost Function Parameters

Output Definition: Multiproduct

Parameter	Model A Unrestricted	Model B Homotheticity	Model C Homogeneity	Model D Constant Returns to Scale	Model E Neutrality
a(0) Constant	-0.4295 (21.0098)	-0.3551 (16.3044)	-0.2669 (14.1049)	-0.4353 (9.2915)	-0.3780 (18.4553)
a(P1) Labor Cost	0.3349 (12.4595)	0.2824 (9.4205)	0.2150 (8.2853	0.4507 (13.3905)	0.2889 (11.2621)
a(P2) Capital Cost	0.3417 (10.2453)	0.2490 (7.2420)	0.1584 (6.3529)	0.3947 (11.5193)	0.2831 (8.6899)
a(P3) Programming Cost	0.3233 (7.6582)	0.4685 (10.1526)	0.6265 (27.2923)	0.1545 (4.9320)	0.4278 (10.3827)
a(Qa) Basic Subscriptions	0.2920 (4.1001)	0.3219 (5.4185)	0.5476 (12.7492)	0.5399 (12.6206)	0.2858 (4.0156)
a(Qb) Pay Subscriptions	0.1211 (1.5862)	0.1629 (2.0956)	0.1972 (3.7183)	0.2977 (2.0495)	0.2762 (3.5872)
a(Qc) Homes Passed	0.4987 (13.5994)	0.3622 (9.2298)	0.1970 (11.5557)	0.5585 (22.4069)	0.4314 (11.8519)
a(D) Trunk/ Households	0.1927 (2.4782)	0.0844 (1.0149)	-0.2019 (2.8993)	-0.1778 (0.9504)	0.0029 (0.0407)
a(E) Channel Capacity	0.4407 (6.1587)	0.4219 (5.4698)	0.5284 (7.2090)	0.0204 (0.1173)	0.4089 (6.0793)
a(M) Maturity of System	-0.0092 (2.0556)	-0.0587 (1.6472)	-0.0296 (0.6157)	0.0209 (0.1649)	0.0552 (1.1232)

Table 1 (Continued)

Parameter	Model A Unrestricted	Model B Homotheticity	Model C Homogeneity	Model D Constant Returns to Scale	Model E Neutrality
a(P1)(SQ)	0.0192 (1.2457)	0.0169 (1.2603)	0.0653 (5.0556)	0.1096 (5.4497)	0.0318 (2.1764)
a(P1)(P2)	0.1757 (4.5319)	0.0126 (0.5000)	-0.0996 (4.4764)	-0.1322 (3.6293)	0.0297 (0.8589)
a(P1)(P3)	-0.2142 (5.1888)	-0.0464 (4.3946)	-0.0309 (3.4134)	-0.0870 (6.1643)	-0.0935 (2.5117)
a(P1)(Qa)	0.0814 (0.9600)	-----	-----	-----	0.2007 (2.7285)
a(P1)(Qb)	0.2438 (2.8283)	-----	-----	-----	0.0231 (0.3134)
a(p1)(Qc)	0.0094 (0.2667)	-----	-----	-----	-0.0807 (2.4471)
a(P1)(D)	-0.1481 (1.7573)	-0.0095 (0.1166)	0.1114 (1.7598)	0.1900 (2.2280)	-----
a(P1)(E)	-0.4059 (3.8088)	0.2317 (2.3676)	-0.0369 (0.4621)	0.0406 (0.3447)	-----
a(P1)(M)	-0.0478 (0.9377)	0.1963 (4.6775)	0.0493 (1.3034)	0.0750 (1.2297)	-----
a(P2)(SQ)	0.4082 (12.4739)	0.0332 (2.4624)	0.0750 (6.6422)	0.1204 (6.4273)	0.2905 (9.3819)
a(P2)(P3)	-0.9922 (13.4510)	-0.0792 (5.9905)	-0.0504 (5.4034)	-0.1086 (7.4886)	-0.6109 (10.0694)
a(P2)(Qa)	-0.2334 (2.1867)	-----	-----	-----	0.1112 (1.1449)
a(P2)(Qb)	0.4235 (3.7497)	-----	-----	-----	-0.0737 (0.7668)
a(P2)(Qc)	0.7728 (12.0940)	-----	-----	-----	0.4742 (8.7495)

Table 1 (Continued)

Parameter	Model A Unrestricted	Model B Homoethnicity	Model C Homogeneity	Model D Constant Returns to Scale	Model E Neutrality
a(P2)(D)	-0.2435 (2.2640)	-0.2612 (2.7856)	-0.0077 (0.1290)	0.0252 (0.2989)	-----
a(P2)(E)	-0.5717 (3.8874)	0.3377 (3.0053)	0.0485 (0.6524)	0.0625 (0.5585)	-----
a(P2)(M)	0.3278 (4.7756)	0.2077 (3.3537)	-0.0280 (0.8139)	0.0314 (0.5559)	-----
a(P3)(SQ)	0.6032 (12.5321)	0.0628 (7.8259)	0.0406 (14.8110)	0.0314 (0.5559)	0.3522 (9.1544)
a(P3)(Qa)	0.1520 (1.1172)	-----	-----	-----	-0.3120 (2.5455)
a(P3)(Qb)	-0.6674 (4.7819)	-----	-----	-----	0.0505 (0.4287)
a(P3)(Qc)	-0.7823 (9.8163)	-----	-----	-----	-0.3935 (6.0579)
a(P3)(D)	0.3916 (2.9928)	0.2708 (2.2879)	-0.1037 (3.5403)	-0.2152 (2.8686)	-----
a(P3)(E)	0.9776 (5.4791)	-0.5694 (3.8618)	-0.0115 (0.3923)	-0.1031 (1.3260)	-----
a(P3)(M)	-0.2800 (3.7788)	-0.4041 (5.8027)	-0.0213 (1.1789)	-0.1065 (2.3104)	-----
a(Qa)(SQ)	0.1509 (0.9408)	0.2967 (1.7608)	-----	-----	0.1634 (1.0060)
a(Qa)(Qb)	-0.5721 (1.6672)	-0.7997 (2.2508)	-----	-----	-0.4138 (1.2027)
a(Qa)(Qc)	-0.1156 (0.9659)	0.0691 (1.6512)	-----	-----	0.2345 (2.0869)
a(Qa)(D)	0.2968 (1.2781)	0.4290 (1.7567)	-----	-----	0.2673 (1.1416)
a(Qa)(E)	0.0502 (0.1517)	-0.0498 (0.1501)	-----	-----	-0.4212 (1.2502)
a(Qa)(M)	0.0305 (0.1895)	0.0410 (0.2419)	-----	-----	-0.2483 (1.5042)

Table 1 (Continued)

Parameter	Model A Unrestricted	Model B Homoethnicity	Model C Homogeneity	Model D Constant Returns to Scale	Model E Neutrality
a(Qb)(SQ)	-0.0337 (3.3132)	0.0334 (0.4302)	-----	-----	-0.3023 (3.3153)
a(Qb)(Qc)	0.2981 (2.4572)	-0.2418 (5.5954)	-----	-----	-0.2545 (2.3535)
a(Qb)(D)	-0.5525 (2.2777)	-0.5936 (2.3360)	-----	-----	-0.4203 (1.7505)
a(Qb)(E)	-0.5389 (1.6146)	0.2512 (0.7674)	-----	-----	0.3580 (1.0777)
a(Qb)(M)	-0.0251 (0.1617)	0.0802 (0.4982)	-----	-----	0.2326 (1.4746)
a(Qc)(SQ)	0.0319 (9.4927)	0.0292 (4.1997)	-----	-----	0.1710 (6.0260)
a(Qc)(D)	-0.2008 (1.9116)	-0.1169 (1.2390)	-----	-----	0.0794 (2.1344)
a(Qc)(E)	-0.5338 (3.7968)	0.5509 (4.4980)	-----	-----	0.1880 (5.1626)
a(Qc)(M)	0.2751 (4.2650)	0.3351 (5.3635)	-----	-----	0.0190 (0.9946)
a(D)(SQ)	-0.0316 (0.3699)	0.0862 (0.9853)	0.0972 (2.0793)	0.1290 (1.0478)	0.0117 (0.1594)
a(D)(E)	0.5141 (2.0282)	0.4598 (1.7958)	0.4015 (2.7186)	0.9788 (2.4377)	0.3799 (1.6409)
a(D)(M)	0.1819 (1.5034)	0.2374 (1.8710)	0.1653 (1.5121)	0.2217 (0.7486)	0.1005 (0.8209)
a(E)(SQ)	1.0449 (4.8100)	-0.1151 (0.5416)	0.1148 (0.6843)	0.5262 (1.1270)	0.2549 (1.4826)
a(L)(M)	0.5639 (3.0229)	-0.0926 (0.4949)	0.4372 (2.8572)	1.1679 (2.8955)	0.6205 (3.3830)
(M)(SQ)	0.1849 (3.7133)	0.0779 (1.4725)	0.1309 (2.9945)	0.3789 (3.4417)	0.2041 (44.0412)
R^2	0.9771	0.9816	0.9707	0.8714	0.9772

REFERENCES

Babe, Robert E., Cable Television and Telecommunications in Canada. East Lansing: Michigan State University Graduate School of Business Administration, 1975.

Barten, A. P., "Maximum Likelihood Estimation of a Complete System of Demand Equations," Eur. Econ. Rev. 1 (Fall 1969): 7-73.

————, John C. Panzar, and Robert D. Willig, Contestable Markets and the Theory of Industry Structure, N.Y.: Harcourt Brace Jovanovich, 1982.

Baumol, William J., "On the Proper Cost Tests for Natural Monopoly in a Multiproduct Industry," American Economic Review 67 (1977a): 809-22.

————, Elizabeth E. Bailey, and Robert D. Willig, "Weak Invisible Hand Theorems on the Sustainability of Multiproduct Natural Monopoly," American Economic Review 67 (1977b): 350-68.

Besen, Stanley M., Bridger M. Mitchell, Roger M. Noll, Bruce M. Owen, Rolla E. Park, and James N. Rosse, "Economic Policy Research on Cable Television: Assessing the Costs and Benefits of Cable Deregulation," in Paul W. MacAvoy, ed., Deregulation of Cable Television, AEI, 1977.

Bloch, Harry and Michael Wirth, "Demand for Pay Television and Its Impact on Expansion of Cable Availability," University of Denver Center for Mass Communications Research and Policy, June 1982.

Cable Television Information Center (CTIC), Cable Television Options for Jacksonville. (Washington, D.C.: Urban Institute, 1972).

Callen, J. L., "Production, Efficiency, and Welfare in the Natural Gas Transmission Industry, Amer. Econ. Rev. 68 (June 1978): 311-23.

Caves, D. W., L. R. Christensen, and M. W. Tretheway, "Flexible Cost Functions for Multiproduct Firms," Review of Economics and Statistics 62 (August 1980): 477-81.

Christensen, Laurits R. and William H. Green, "Economies of Scale in U. S. Electric Power Generation," J. of Political Economy 84 (1976): 655-76.

Denison, E. G., "Effects of Selected Changes in the Institutional and Human Environment Upon Output Per Unit of Input," Survey of Current Business 58 (Jan. 1978): 21-44.

Denny, Michael and Melvyn Fuss,"The Use of Approximation Analysis to Test for Separability and the Existence of Consistent Aggregates," Amer. Econ. Rev. 67 (June 1977): 492-97.

————, Melvyn Fuss, C. Everson, and Leonard Waverman, "Estimating the Effects of Diffusion of Technological Innovations in Telecommunications: The Production Structure of Bell Canada," Canadian Journal of Economics, (Feb. 1981a): 34-43.

————,Melvyn Fuss, and Leonard Waverman, "The Measurement and Interpretation of Total Factor Productivity in Regulated Industries, with an Application to Canadian Telecommunications," in Thomas Cowing and Rodney Stevenson (eds.), Productivity Measurement in Regulated Industries. New York: Academic Press, (1981b).

Dhrymes, Phoebus J. and M. Kurz, "Technology and Scale in Electricity Generation," Econometrica 32 (1964): 287-315.

Dixit, Avinash, "A Model of Duopoly Suggesting a Theory of Entry Barriers," Bell Journal of Economics 10 (Spring 1979): 20-32.

————, "The Role of Investment in Entry-Deterrence," Economic Journal 90 (March 1980): 95-106.

————, "Recent Developments in Oligopoly Theory," Amer. Econ. Rev. 72, Papers and Proceedings (May 1982): 12-17.

Dunmore, Kenneth R. and M. M. Bykowsky, "Cable Television Demand and Its Implications for Cable Copyright," Office of Policy Analysis and Development, Nat. Telecomm. and Info. Admin., Dept. of Commerce, (July 1982).

Federal Communications Commission, New Television Networks: Entry, Jurisdiction Ownership and Regulation, Washington, (October 1980).

Friedlaender, Ann F., "Hedonic Costs and Economies of Scale in the Regulated Trucking Industry," In Motor Carrier Economic Regulation. Washington, D. C.: National Research Council, (1978).

Fuss, Melvyn and Leonard Waverman, "Multi-Product Multi-Input Cost Functions for a Regulated Utility: The Case of Telecommunications in Canada," in G. Fromm (ed.), Studies in Public Regulation. Cambridge, Mass.: MIT Press, (1982).

————, "The Regulation of Telecommunications in Canada," Technical Report, No. 7, Economic Council of Canada, March 1981.

Gollop, Frank M. and Dale W. Jorgenson, "United States Productivity Growth by Industry 1947 - 1973," in New Developments in Productivity Measurement and Analysis, (J. W. Kendrick and B. N. Vacarra, eds.), Studies in Income and Wealth, National Bureau of Economic Research, University of Chicago Press, Chicago, Ill., (1980).

Gollop, Frank M. and Mark J. Roberts, "The Sources of Economic Growth in the U. S. Electric Power Industry," in Thomas G. Cowing and Rodney E. Stevenson (eds.), Productivity Measurement in Regulated Industries. New York: Academic Press. (1981).

Good, Leonard, "An Econometric Model of the Canadian Cable Television Industry and the Effects of CRTC Regulation," Unpublished Ph.D. thesis, University of Western Ontario, (1974).

Ibbotson, Roger G. and Rex A. Sinquefield, Stocks, Bonds, Bills, and Inflation: The Past (1926-1976) and the Future (1977-2000), (Charlottesville, VA.: Financial Analysis Research Foundation, (1979).

Kahn, Alfred E., The Economics of Regulation: Principles and Institutions, (New York: John Wiley & Sons, 1971), Vol. 2,: 119-23.

Kahn, Alfred E. and Irwin M. Stelzer, "Communications Regulation in New York State," Appendix 2 of Telecommunications In New York State: Redefining the Role of Government. N.Y.S. Executive Chamber, Office of Development Planning, (April 1981).

Kaplan, Robert S. and Gabriel Urwitz, "Statistical Models of Bond Ratings: A Methodological Inquiry," Journal of Business 52 (1979): 231-61.

Knieps, Guenther and Ingo Vogelsang, "The sustainability concept under alternative behavioral assumption," Bell Journal of Economics (Spring 1982): 234-41.

Milgrom, Paul and John Roberts, "Predation, Reputation and Entry Deterrence," Journal of Economic Theory 27 (August 1982): 280-312.

Moody's Bond Survey, Moody's Investor Services, (1981).

Nielsen Cable Status Report, (May 1981): 14.

Noam, Eli, "Towards an Integrated Communications Market," forthcoming in the Federal Communications Bar Journal (1982).

Owen, Bruce M. and Peter K. Greenhalgh, "Competitive Policy Considerations in Cable Television Franchising", Washington, D. C.: Economists, Inc., Draft, (Oct. 1982).

Panzar John, "Free Entry and the Sustainability of Natural Monopoly," Bell J. of Econ. (1977): 1-22.

————,"Economies of Scope, Product-Specific Economies of Scale, and the Multiproduct Competitive Firm," Bell Laboratories Economic Discussion Paper No. 152, (August 1979).

Shephard, Ronald W., Theory of Cost and Production Functions. Princeton: Princeton University Press, (1970).

Shepherd, William G, "The Competitive Margin in Communications," in William M. Capron, ed., Technological Change in Regulated Industries, Brookings, (1971).

————,"Concepts of Competition and Efficient Policy in the Telecommunications Sector" forthcoming in Noam (1983),

Sloan Commission, On the Cable: The Television of Abundance. New York: McGraw Hill, (1971).

Smith, Ralph Lee and Raymond B. Gallagher, The Emergence of Pay Cable Television. Washington, D. C.: U. S. Dept. of Commerce, National Technical Information Service, (July 1980): PB 80-209-968.

Standard & Poor's, Fixed Income Investor,(November 1981): 70.

Weinberg, Gary, Cost Analysis of CATV Components, Washington, D.C.: U. S. Department of Commerce, National Technical Information Service, (June 1972): PB 211-012.

Zellner, A., "An Efficient Method of Estimating Seemingtly Unrelated Regression and Tests for Aggregation Bias," J. Amer. Statist, Assoc. 57 (1962): 348-68.