Monopoly and Productivity in Cable Television

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IN CABLE TELEVISION

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Abstract

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The paper analyzes the productivity trends of an industry under both monopolistic and competitive market structures. The model differentiates between the contributions to cable television productivity attributable to economies of scale, technology vintage, and operating experience. It traces the trend of vintage adoptions in a competitive environment, and contrasts it with those in established franchise monopolies.

The paper draws on extensive data sets for most of the 5000 cable systems in the U.S., and provides an empirical contribution to the study of a medium that is rapidly becoming the central element of electronic mass communications in America.

The results show, among others, a productivity trend in established monopolistic franchises that is markedly lower than the trend of newly-adopted technology. This indicates a danger that communities which introduced cable television early would fall behind in the communications systems available to them.

I. INTRODUCTION

The empirical evidence for a relation between market power and productivity is ambiguous and contradictory. A good number of studies have pursued this question, primarily through investigations of R&D expenditures of firms of different size, or of their adoption of new production techniques.[1]

Typically, such studies are highly aggregated on the industry level and are estimated across different industries, associating concentration indices with dependent variables such as productivity or patent grants. Such a procedure is usually chosen because it is conceptually and empirically difficult to find different concentration ratios for the same industry. Yet industries vary widely, and their comparison is problematic.[2]

One way to escape the problem of comparison is to use the same industry across different countries; but this only raises new problems.

This study, in investigating productivity trends, can proceed in a very different fashion, in that it is able to look at the rate of productivity changes within one industry and in one country, and to compare the trends under monopoly and competition. This industry--cable television--is characterized by its thousands of local franchise monopolies, by competitive bidding for new franchises, and by a large and steady number of new entrants during the period of observation. This makes it possible to measure the trend of new technology, and to contrast it with the trend of established operations.

II. THE PRODUCTIVITY ISSUE IN CABLE TELEVISION

While the substantial communications potential of cable television is well known, it is less recognized that the *de facto* franchise monopoly structure of the medium may lead to its sub-optimal development. Though this danger has been commented upon for program diversity, which could be lessened by the operator's gatekeeper control over programming (Sloan Commission 1971; Cabinet Committee on Cable Communications 1974), little attention has been paid to productivity and innovation issues. However, the rapid development of cable television technology has been far from uniform in its diffusion. As the *New York Times* reports:

> A pattern is emerging in cable television service across the United States. Large companies that own cable systems, eager to win franchises in unwired cities, are quite willing to spend hundreds of millions of dollars to build modern systems. At the same time, they give much lower priority to rebuilding their older systems in areas where there are no competitive reasons to offer the more lavish services....
>
> In Queens, for example, Teleprompter...is proposing 107 channels.... In Manhattan, by contrast, Teleprompter offers...only 26 channels.
>
> The rates in the new systems, also born in a competitive atmosphere, are far lower than those in New York. The same ATC that charges $11.75 a month in Manhattan for 26 channels is proposing a rate of $3.75 a month for 50 channels in Denver.[3]

The root causes for such discrepancy may be sought in the structure of the industry. The cable television industry consists of a series of parallel local operations, each based on the award of a local franchise that is *de facto* exclusive. In a monopolistic situation, profit maximization does not necessarily lead to adoption of a "best practice" technology, even if such would be economically feasible under competitive conditions. For example, an upgrading of channel capacity may not be undertaken if new program channels would primarily divert viewers from already existing program channels rather than generate new viewers; therefore, a monopolist in the supply of cable program channels would normally have incentives to supply less than the competitive capacity.[4] Within each franchise area, the licensed company is, for all practical purposes, in control of the technical innovation of the transmission system. While it is true that the cable operator is bound by the terms of a local franchise contract and has an incentive not to lose the franchise, such loss has not occurred outside a handful of tiny localities:

> Where cities have tried to spur competition during re-franchising by inviting competitive bidding, they have been unable to inspire even a nibble of interest from any companies other than the incumbent operator. City officials contend that operators are reluctant to enter an already franchised area for fear that the same will happen to them on what they consider their turf.[5]

The Cable Communications Policy Act of 1984 has added further protections to a cable operator's franchise by requiring cities to go through elaborate procedures before denying renewals, and by providing review by courts.

Because of its institutional peculiarities, cable television provides an unusual opportunity to observe and contrast both the competitive and the monopolistic adoption of innovation within the same industry. Operators usually pass through an intensely competitive phase prior to the beginning of any of their new cable systems, when they vie with other companies to gain a local franchise. The usual franchising procedures call for applicant firms to present the merits of their systems; by the nature of the intensive bidding process which ensues, companies compete in the technology that is offered.[6] After a franchise has been awarded, however, there is at present little or no competitive pressure for the operating company to upgrade its system in order to match subsequent technological development.[7] There will be improvements, both due to greater experience and to an adoption of newer equipment, but they are likely to be motivated by considerations other than the presence of intra-industry competition. And there is no reason to expect that established cable systems will match their improvements with the external rate of change that characterizes the industry.

The parts of this paper which follow are an empirical investigation of these issues. In analyzing the production and cost relations of this increasingly significant mass medium, the paper is a contribution to the surprisingly sparse empirical cable literature, which has been characterized in an article authored jointly by a comfortable majority of the economists engaged in cable television research (Besen, Mitchell, Noll, Owen, Parks, and Rosse, 1977) as "...synthetic and eclectic...; no satisfactory data set exists from which to estimate econometric cast or production functions."

III. THE MODEL

Three different causes for shifts in productivity over time are usually left unseparated: (a) internal improvements in operations, i.e., the "maturity" of a system over time; (b) technical progress external to the system--the technological "vintage"; and (c) economies of scale that accrue due to an expansion of size over time. Observations made at successive times could show an apparent productivity trend over time, which could be an aggregate of three distinct rates--that of movement along a function (maturity), that of a shift of the function itself (vintage), and that of change in its underlying size parameter over time (scale).

Past empirical research on cable television cost has focused on economies of scale only (Babe, 1983; Noam, 1985; Owen and Greenhalgh, 1983). Studies of the productivity of various other industries has allowed for scale economies and a time variable, (Christensen and Green, 1976; Denny, Fuss and Waverman, 1982; Nadiri and Schankerman, 1982; Gollop and Roberts, 1981). But they did not distinguish between the separate vintage and maturity rates of productivity increase that are embodied in the time variable. For purposes of the research question--the extent to which existing cable systems, once they have secured the franchise rights, keep up with new systems--this analytical separation is essential.

To do so, consider a model based on the multi-product cost function:

(1) $C(t) = f[P(1t) \ldots P(nt); Q(1t) \ldots Q(mt); V(r); M(t); K(k)]$

where

C(t) - total costs of production at time t;

P(it) - prices for the production factors i, given exogenously;

Q(qt) - output quantities for different products q;

V(r) - vintage of the plant;

M(t) - the plant's maturity at time t;

K(k) - other factors that affect cost of production.

Assuming a cost minimizing behavior by the firm, the cost-price elasticities E(cpi), by Shephard's Lemma, are equal to the share Si of each input factor in total cost. They become part of the model as first-order conditions.

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

where

S_i - share of input i in total cost

E_{CP_i} - cost elasticity w.r.t. price

X_i - quantity of input;

Subscripts for t are omitted for clarity.

The question can be raised whether cable operators may in fact be able to vary output quantities and prices, and this can be answered in the affirmative. Although cable firms are under some regulatory constraint, these are fairly loose on issues of P and Q. The rates for pay-cable have always been unregulated, while basic cable rates have been subject to local approval. But the local regulatory mechanism has been loose and primarily concerned with consumer-protection type issues. In New York City, the regulatory Office of Telecommunications for years had only one professional employee. Furthermore, localities are, through their percentage share in cable revenue, partners in the success of the operation, and have no economic interest in overly constraining it. And where cable has reached only parts of a city, as has been usually the case, cable operators have a politically potent lever to prevent being squeezed on rates by going slow on expansion. In the 1984 cable legislation, local government's power in rate setting was abolished for more than 95% of the population, without strenuous city opposition on that issue. In providing the quantities of service supplied, as measured by subscribers, most cable systems have expanded along a profit-maximization path. The widespread complaints about poorer sections' lack of wiring reflects this pattern. Neighborhoods where losses can be expected are wired, if at all, at a late stage. For these reasons, substantial quantity and price flexibility can be assumed.

For purposes of estimation, let the cost function f be approximated by a multi-product translog cost function. One problem with the application of such a specification is that the observation's value becomes meaningless whenever one of its products is zero. For that reason, one generally specifies an alternative functional form that is well behaved; we therefore substitute for a quantity Q(q) the Box-Cox metric (Q(q) exp(w) - 1)/w, with w the parameter for the power transformation. This expression is defined for zero values of Q(q), and approaches the standard natural logarithm ln Q(q) as w approaches zero. (w is found by choosing that value of w for which $\sigma^2(w)$ is minimum, i.e., the maximum likelihood estimate of w. For details, see Maddala 1977, p. 315 ff.)

A cost function of type (1) can then be specified as the hybrid translog function (3). In that function, subscripts t are omitted for clarity, and coefficients a are subscripted according to the variables they precede.

$$(3) \quad \ln C(P_i, Q_q, M, V, K_k) = a_0 + \sum_i a_i \ln P_i + \sum_q a_q \left(\frac{Q_q^w - 1}{w}\right) + a_v \ln V$$

$$+ a_m \ln M + \sum_k a_k \ln K_k + \tfrac{1}{2} \sum_i \sum_j a_{ij} \ln P_i \ln P_j$$

$$+ \tfrac{1}{2} \sum_q \sum_p a_{qp} \left(\frac{Q_q^w - 1}{w}\right)\left(\frac{Q_p^w - 1}{w}\right) + \tfrac{1}{2} a_{vv} (\ln V)^2 + \tfrac{1}{2} a_{mm} (\ln M)^2$$

$$+ \tfrac{1}{2} \sum_k \sum_\ell a_{k\ell} \ln K_k \ln K_\ell + \sum_i \sum_q a_{qi} \ln P_i (\frac{Q_q^w - 1}{w})$$

$$+ \sum_i a_{iv} \ln P_i \ln V + \sum_i a_{im} \ln P_i \ln M + \sum_i \sum_k a_{ik} \ln P_i \ln K_k$$

$$+ \sum_q a_{qm} (\frac{Q_q^w - 1}{w}) \ln M + \sum_q \sum_k a_{qk} (\frac{Q_q^w - 1}{w}) \ln K_k + a_{vm} \ln V \ln M$$

$$+ \sum_k a_{vk} \ln V \ln K_k + \sum_k a_{mk} \ln M \ln K$$

The elasticities of total cost are the partial derivatives. Price and size elasticities are:

(4) $$E_{CP_i} = a_i + \sum_j a_{ij} \ln P_j + \sum_q a_{iq} (\frac{Q_q^w - 1}{w}) + a_{im} \ln M + a_{iv} \ln V + \sum_k a_{ik} \ln K$$

(5) $$E_{CQ_q} = Q_q^w (a_q + \sum_p a_{qp} (\frac{Q_p^w - 1}{w}) + \sum_i a_{iq} \ln P_i + a_{qm} \ln M)$$

The partial elasticities with respect to M, V and K are obtained similarly:

(6) $$E_{CM} = a_m + a_{mm} \ln M + \sum_i a_{im} \ln P_i + \sum_q a_{qm} (\frac{Q_q^w - 1}{w}) + a_{vm} \ln V + \sum_k a_{mk} \ln K$$

(7) $$E_{CV} = a_v + a_{vv} \ln V + \sum_i a_{iv} \ln P_i + \sum_q a_{qv} (\frac{Q_q^w - 1}{w}) + a_{mv} \ln V + \sum_k a_{vk} \ln K$$

$$(8) \quad E_{CM_k} = a_k + a_{kk} \ln K + \sum_i a_{ik} \ln P_i + \sum_q a_{qk}\left(\frac{Q_q^w - 1}{w}\right) + a_{mk} \ln M + \sum_k a_{vk} \ln V$$

Several standard parametric restrictions are specified, since the cost shares must add to unity, i.e.,

$$(9) \qquad \sum E_{CP_i} = 1$$

Since the cost function must be linearly homogeneous in factor prices at all values of factor prices, output, vintage and maturity, we have

$$(10) \qquad \sum_i a_i = 1; \quad \sum_i a_{ij} = \sum_i a_{iq} = \sum_i a_{im} = \sum_i a_{iv} = \sum_i a_{ik} = 0$$

Furthermore, the symmetry conditions exist

$$(11) \qquad a_{ij} = a_{ji} \quad \text{and} \quad a_{qp} = a_{pq}, \quad \text{where } i \neq j,\ p \neq q$$

The cost elasticity with respect to output, E(CQ), is the reciprocal of scale elasticity. For the multi-product case, local overall scale economies are

$$(12) \qquad E_s = \frac{1}{\sum_q E_{CQ_q}}$$

One can also investigate the economies of scope, S(C). It is the proportion of total cost of joint production [C(Q(1)...Q(N))] that is saved over separate productions [Σ C(Q)] (Bailey 1982)

$$S(C) = [\Sigma\ C(Q) - C(Q(1)...Q(N)]/[C(Q(1)...Q(N))] \tag{13}$$

At the sample mean, given mean-scaling, this simplifies considerably since P(i) = Q(q) = 1 and thus C(Q(1)...Q(N) = exp(a(o)); the separate production functions also simplify analytically. However, for an empirical estimation it would be necessary to have data for the costs of separate and independent production. Since this is not feasible in the case of cable television, we use instead a test for their existence.

As Panzar and Willig (1979) have shown, it is a sufficient condition for economies of scope for the twice differentiable multi-product cost function to have cost complementarities of the form

$$\frac{\partial^2 C}{\partial Q_q \partial Q_g} < 0 \tag{14}$$

which can be expressed by the following (with q and g any combination of outputs, and $g \neq q$):

$$\frac{\partial^2 C}{\partial Q_g Q_q} = \frac{C}{Q_q Q_g}\left(\frac{\partial \ln C}{\partial \ln Q_q}\frac{\partial \ln C}{\partial \ln Q_q} + \frac{\partial^2 \ln C}{\partial \ln Q_q \ \ln Q_g}\right) < 0 \tag{15}$$

At the sample mean of the hybrid translog cost function, this condition is met when

$$a_q a_g < -a_{qg} \tag{16}$$

The model for estimation is the multivariate regression system comprising the cost function (3), N-1 cost share equations of type (4) and the restrictions (9)-(11). The form of estimation is Zellner's iterative method for seemingly unrelated regressions.[9]

IV. DATA

The empirical estimation of this study is based on an unusually good body of data for several thousand cable television systems, all producing essentially the same service,[10] operating and accounting in a single-plant mode, supplying their local market only, reporting data according to the fairly detailed categories of a mandatory federal form,[11] and having very little vertical integration into proprietary technology.

The data covers virtually all 5,000 U.S. cable systems, and is composed of four annual disparate and extensive files for the multi-year period 1976-1982 for technical and programming, financial, local community, and employment information.[12] The financial data includes both balance sheet and income information.[13]

Inputs[14]

Labor factor quantity is the number of employees (with part-timers added at half value); its cost is the average salary of employees.

For capital inputs, accounting data for different classes of assets are reported to the FCC in book value form. Because of the potential inflationary distortion, it was considered as prudent to revalue these assets, and to use both historical and revalued capital figures. To find the latter, the study took advantage of a highly detailed engineering study, commissioned by the federal government, on the pattern of investment in the construction of cable systems. For each observation, we know (a) the first year of operation and (b) the aggregate historical value of capital assets. It is then possible to allocate capital investments to the different years of a construction cycle, and to inflate their value to the prices of the observation year.[15] (As it turns out, using simply the historical figures leads to results that are very close to those of the fairly laboriously revalued capital figures.)

For the total capital stock Z that has been determined, the price P(K) is given by its opportunity cost, consisting of potential returns r on equity H and payments for debt D, with an allowance for the deductibility of interest expenses (tax rate = h).[16]

$$P(K) = r(H)(D - Z)/Z + r(D)(1 - h)D/Z \tag{17}$$

The required return on equity is determined according to the risk premium rho required above the return on risk-free investments, R; that is, $r(H) = R + \rho$. Ibbotson and Sinqefield (1979) found ρ for the Standard & Poor 500 to be 8.8 for the period 1926-1977. Hence, using the capital asset pricing model (Sharpe 1964; Lintner 1965), an estimate 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 is listed by Moody's (1981) as $\beta = 1.42$, resulting in a risk premium of 12.49%, a reasonable rate for the industry.

For r(Q), 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 the observation'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 (Moody's, 1982). This procedure is based on a series of previous studies in the finance literature of bond ratings and their relation to financial ratios.[17]

Tax rate h is defined as the corporate income tax rate (federal and state). Debt is defined as long-term liabilities.

The third production input of the model is the input of programs. A cable system that carries no communications messages would be of no interest to subscribers. By supplying programs, cable operators can sell subscriptions for their services. Cable operators obtain programs from a wide variety of sources as an incentive to the buying of subscriptions, in addition to providing the communications line. These programs are rarely produced by the operators; they are not sold on a quantity basis; with trivial exceptions,[18] programs are supplied by broadcasters and program networks.[19] Costs for such programs are both direct, i.e., direct payments for program services, and indirect, i.e., the advertising earning that is foregone in order to obtain programs from program supplies. A program service such as CNN, for example, is compensated both directly with a per-subscriber payment, as well as indirectly, by permitting CNN to insert advertising into its transmission time for which CNN rather than the cable operator is paid. This "free" advertising time for CNN is a compensation in kind, and an indirect cost for the program supplied by CNN. The unit price of programming inputs is the sum of direct and indirect costs,[21] divided by the total number of program hours, i.e., the aggregate of program hours on the various channels.

It is one of the convenient properties of cable television that it uses very little in inputs beyond those of capital, labor, and programming. Even its energy requirements are quite small, in the order of .7% of total expenses (Weinberg 1979, Table C-1 and C-2).[22] These residual inputs are prorated among K, L, and P.

Outputs

Pay-per-view billing systems are still exceedingly rare, and in their absence there are only negligible marginal costs to the operator for a subscriber's actual viewing of the channels. Interactive communications services, though maybe of future importance, are also rare at present (.1% of systems). Subscriptions are cable operators' predominant revenue-producing source. Hence, the two general types of subscriptions--basic and premium (which is also, somewhat misleadingly, called "pay," as if basic service were provided for free)--are outputs.

There is a third dimension of productive activity. In the industry, the measure of "homes passed," together with the two kinds of subscriptions, defines a cable system. "Homes passed" is a measure for the potential market of subscribers that has been opened. Each such home passed is a unit of potential connection in the technical output sense. The actual subscriptions are a marketing transformation of the potential output (homes passed) into sales (subscriptions). An analogy are airlines, which produce both seat-miles (flights) and passenger-miles (tickets, e.g. for coach and first class.) The two tend to go together, as they do for cable television, but they may diverge, for example at the initiation of a new route, or in bad economic times. Omitting either measure would reduce our information about the airline's productivity. For cable operators to pass more homes than subscribers is a rational profit-maximizing decision, since it is usually cheaper to pass an entire street or neighborhood, rather than come back for individual homes. Once homes are passed, additional "drop-wiring," internal wiring and converter boxes are necessary for actual connection, so that capital is not fixed.

The measure of "homes passed" is conventionally used in industry valuations of a cable system, together with subscriber figures.

Cable television operators' major outputs are then defined along the following dimensions: (a) basic service subscriptions; (b) pay-TV service subscriptions; and (c) homes passed.

Vintage, Maturity, and Other Variables

Vintage is defined according to the year in which the cable operator commenced transmission, relative to the sample mean. System maturity is defined as the relative time lapsed since the commencement of operations.

As an alternative measure for maturity, cumulative output (subscriber-years) was also tested in order to measure the sensitivity of the definition. The results were very similar, as can be expected, given the strong linear correlation of the logs of the cumulated time and cumulated quantity. Because the time trends are important to the paper's question, the cumulated time-measure was used.

Vintage dates the fixed part of the technology, and the starting point of a technology improvement path. Capital is partly fixed, and partly flexible and subject to improvements. Thus, the major investment in hundreds of miles of cable and plant transmission will be rarely altered, whereas the headend equipment may be improved. The upgrading is part of "maturity," which comprises the various ways in which the cable system improves operations over time, including updating of the flexible part of the capital. The variable V increases positively with newness.[23]

Two other variables adjust for differences in the cable systems that may affect costs of production and ability to attract subscriptions: First, density or dispersement of population; the further households are from each other physically, the more capital and labor inputs may have to go into reaching each.[24] We define D as the length of cable trunk line per household passed, i.e. as "dispersement."

A second variable is the number of video channels offered by a cable operator. The more channels offered, the more inputs are required. At the same time, one would expect subscription outputs to be affected positively, since the cable service is more attractive to potential subscribers.

Because the underlying cost function is an approximation around some point, the variables needed to be scaled around that point, in this case the mean.

V. RESULTS

The three-stage estimation of the model yields statistically strong results; system R^2 is .9714. The R^2 for the labor share is .6589; for the capital share is .8244. Most of the parameter estimates have high t-values and are significant at the .01 level, particularly the first-order terms and their squares.[25]

Neoclassical production theory requires concavity and monotonicity in prices P, and monotonicity in outputs. For the translog function with its approximation characteristics these properties of the underlying function are generally only preserved at the point of approximation, in this case the mean. Monotonicity is satisfied if the fitted cost shares are positive, which is the case. Concavity is assured if the cost function's Hessian matrix is negative definite. This is the case at the sample mean. Estimates using the outlying quintiles of observations also found concavity.

We next look at the economies of scale in the system. Using equation (12), we find an overall elasticity of scale of E = 1.064, i.e. positive but moderate economies of scale in the range of a 6.4% average cost reduction for each doubling of output. For a cable system whose subscriber base grows at a rate of 10% annually, this would be a scale-economies based cost reduction of .64% per unit per year.[26]

We next look at the effects of maturity in operation on cost. Here, we find that cost decreases with experience in operation, ceteris paribus, with a cost elasticity of -.2612 (standard error .0971). For an eight year old system, this would translate into a unit cost reduction of about 3.5% per year.

However, these internal productivity increases are considerably smaller than those due to the external changes in technology. Isolating the vintage effect, we find a cost elasticity of -.6495 (standard error .1619), indicating a very substantial cost reduction that accompanies the introduction of new vintages of cable technology. For example, relative to a 1976 vintage, a calculated 1977 vintage would have a unit cost lower by 7%, ceteris paribus. However, the estimate for V may also incorporate factors other than technology that either reduce or increase the costs of cable operations for a new vintage. Among them, foremost is the cost of gaining a franchise, an amount which increased considerably over the late '70s and early '80s. Hence, the estimate for V is not likely to be an overestimate, and may in fact be conservative.

We also test for the robustness of the results. When the capital measure K is used in an unrevalued fashion (i.e. not taking into account inflation that has upvalued earlier capital investments) the vintage elasticity declines slightly to -.6151, with a standard error of .1891.

These results apply to the mean point of observations, since data were mean-scaled. To see whether the observations have been skewed by smaller and older systems, the regressions were also estimated after omitting observations for 12-channel systems, since these tend to be older, smaller, and rural in character. Again, the results are very similar.

The cost elasticity for dispersion has a value of a(D) = .0971 (standard error .0460) 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, the second order term indicates that cost savings decline with density and there are diminishing economies to density. This would conform to the observation that in highly dense city franchise areas costs increase again.

The number of channels is associated with increasing cost; this, too, is as intuitively expected. Cost increases rise with channels, implying increasing marginal cost of channel capacity.

The price elasticities are of fairly similar size and their standard errors range from .034 to .0519. The own-price elasticities of the factors of production, compensated for output, are (standard errors in parentheses) for labor -.88 (.06); for capital -.17 (.04); and for programming -.24 (.1). All but the last coefficients are statistically significant at the 0.05 level and are statistically different from zero.

The Allen-Uzawa partial elasticity E(ij) of substitution between two factors of production i and j is (Binswanger 1974)

$$E(ij) = a(ij)/E(cpi)E(CPj) + 1$$

The results (with standard errors in parentheses) are

E (labor-capital) = .17 (.05)

E (labor-programming) = .23 (.07)

E (capital-programming) = .79 (.13)

In all three cases, statistical significance at the 0.05 level exists. All three factors are moderate-sized substitutes for each other. Capital and programming are the strongest substitutes; a particularly attractive program offering would substitute, to some extent, for less technical features of the system.

We can also test for the existence of economies of scope at the sample mean, using the test of equation (16). All three inequalities are met, fulfilling the sufficient condition for such economies of scope. This is expected for the two types of subscriptions. More interestingly, the existence of economies of scope in production of homes passed and subscriptions indicates--though not proves--that a separation of the transmission and programming functions of cable operators in order to enhance access rights would have a trade-off in that it would lead to some losses of economies of joint production.

Conclusions

What do these results suggest? They show productivity increases--defined as reductions in production cost that are not due to changes in input cost--resulting from economies of scale, technical vintage, and maturity of operations. This, of course, is not surprising. However, the relative contribution of these factors to production cost reduction is important. The effect of economies of scale is moderate, and of a similar order of magnitude as for telephone transmission and cable.[26]

Operating experience, i.e., "internal" innovation, on the other hand, has a much larger effect. But the largest contribution is made by the "external" development of the technology, as expressed by the contribution of new vintages to cost reduction.

Some differential between internal and external contributions to cost reduction could of course be expected. To adapt an existing technology is likely to be more costly and slower than to starting with a brand new system. But when the rates of cost decrease are as far apart as we find them to be, it is a strong indicator that more than natural adjustment lags occur. If cable systems were to compete head-on, a large cost elasticity differential would lead the older systems to be driven off the market, unless they can maintain a very large difference in scale, or unless they have been operating for a substantial time.

Other than in those circumstances, then, a competitive situation would not permit the firm that maintains its slower "internal" rate of cost reduction to survive entry in the face of the rapid change in technology. But, of course, they _do_ survive in the real world. One reason for the paucity of head-on competition--revealingly termed in the trade "overbuilds"--are the protective legal barriers of local and federal regulation, such as _de facto_ exclusive franchises, preferred rights to pole attachment, or preferential access, at nominal cost, to the property of landlords in order to reach tenants.

The existence of strong productivity trend differentials raises a challenge to public policy. It suggests, first, the need for a reduction of legal entry barriers as a way of removing technological protectionism and creating competition or at least contestability. The existence or emergence of alternative media for the delivery of video programs, such as conventional VHF/UHF television, direct satellite broadcasting (DBS), broadcasting micro-wave frequencies (MDS), subscription television (STV) and video-cassette recordings (VCR) exert some comprehensive pressure against cable television operators; but cable is still the technically and economically superior delivery system (see articles in Noam, 1985) and the effectiveness on inter-media competition has its limits. For intra-media competition, i.e. of cable systems with each other, the Cable Communications Policy Act, passed on the last days of the 1984 Congressional session, is not helpful, because it creates a presumption of renewal for franchises, and thus strongly reduces the possibility of another company to bid away the franchise of operators. Under the Act a competing bid may be entertained only after a city goes through an elaborate hearing process and defends a franchise denial in the federal courts.

But while the political process has provided protectionism to established cable operators, legal challenges to franchise exclusivity have emerged from two directions, both launched by cable entrepreneurs. First, a maverick California cable firm has challenged the constitutionality of the mere existence of a franchising process as a barrier to entry, claiming that First Amendment protections preclude local governments from licensing who may transmit "video speech." The Ninth Circuit Court of Appeals agreed with this argument (Preferred Communications, Inc. v. City of Los Angeles, 754 F.2d 1396 (9th Cir. 1985).

The second challenge has come from the operators of Satellite Master Antenna Cable Television (known as "SMATV" or "private cable,") who have, with the help of the FCC, beaten back the attempts of local and state governments to regulate them, e.g., New York State Commision on Cable Television v. FCC, 749 F. 2d 804 (D.C. Cir. 1984). SMATV systems are now emerging in apartment-house complexes across America; but because they cannot cross property lines, their competition is more potential than real at present. But many SMATVs, sitting up as they do in the middle of a franchised operator's territory, are likely entrants into more general cable distribution when the territorial confinements are lifted.

For some time now, concern has been growing as to whether the communication revolution, of which cable television is an important part, would lead to the emergence of a class of "information poor," who could not afford the new offerings (and lose some of the previously "free" ones), either for reasons of low income, or because they live in remote or low-density areas. We can add another concern, that of service differentials between new and older systems. Perversely, some of those communities that welcomed cable television first may find themselves neglected in terms of system innovation, while those that took a long time to permit cable can enjoy the benefits of advanced systems, in some instances financially supported by the revenues generated by the older systems. Furthermore, when most of the desirable locations are cabled, as will soon be the case, bidding for new franchises will cease and improvements will take place internally rather than through competition among firms. This should slow down the momentum of technical innovation in the industry, and this is not a desirable trend, either. Of course, this scenario is painted in somewhat stark colors, but the evidence points to a real problem.

Table 1

Regression Coefficients of Cable Television Cost Function

Coefficients for Variables (in logs)	Parameter Estimate	t-ratio
Constant	-0.3417	(14.5291)
(P1) [Labor]	-0.2876	(17.3946)
(P2) [Capital]	0.3825	(31.5271)
(P3) [Programming]	0.3298	(6.3959)
(Qa) [Basic Subscriptions]	0.2911	(4.7088)
(Qb) [Pay Subscriptions]	0.2890	(3.9561)
(Qc) [Homes Passed]	0.3599	(31.7546)
(D) [Dispersion of Population]	0.0971	(2.1075)
(E) [Channel Capacity]	0.0826	(3.6271)
(V) [Vintage Newness]	-0.6495	(4.0103)
(M) [Maturity]	-0.2612	(4.5716)
(P1)(P1)	-0.0437	(3.8241)
(P1)(P2)	0.2603	(9.1655)
(P1)(P3)	-0.2232	(12.5741)
(P1)(Qa)	0.3287	(7.0590)
(P1)(Qb)	-0.1342	(2.4667)
(P1)(Qc)	0.0709	(4.2999)
(P1)(D)	0.2539	(4.5264)
(P1)(E)	-0.2964	(5.2704)
(P1)(V)	-0.4494	(4.8039)
(P1)(M)	0.3275	(3.1926)
(P2)(P2)	-0.3099	(8.1654)
(P2)(P3)	-0.6702	(2.6591)
(P2)(Qa)	-0.0819	(1.6752)
(P2)(Qb)	0.3925	(4.3291)
(P2)(Qc)	0.5127	(2.6591)
(P2)(D)	-0.1929	(3.3471)
(P2)(E)	-0.6301	(3.5277)
(P2)(V)	0.2069	(2.4916)
(P2)(M)	-0.7095	(4.1272)
(P3)(P3)	-0.4106	(2.5916)
(P3)(Qa)	-0.2468	(4.3752)
(P3)(Qb)	-0.2799	(4.9162)
(P3)(Qc)	-0.5918	(2.1196)
(P3)(D)	-0.0610	(0.0262)
(P3)(E)	0.9265	(1.9659)
(P3)(V)	0.2435	(5.0347)
(P3)(M)	0.3820	(4.2693)
(Qa)(Qa)	-0.0875	(2.2626)
(Qa)(Qb)	-0.3095	(3.1095)
(Qa)(Qc)	-0.2766	(1.5769)
(Qa)(D)	-0.2578	(3.2012)
(Qa)(E)	-0.8520	(6.0888)
(Qa)(V)	-0.4129	(0.3926)
(Qa)(M)	-0.0951	(0.4892)

Table 1 (continued)

Coefficient for Variable	Parameter Estimate	t-ratio
(Qb)(Qb)	-0.0721	(1.4968)
(Qb)(Qc)	-0.1253	(3.2652)
(Qb)(D)	0.1792	(2.1095)
(Qb)(E)	0.2491	(1.7265)
(Qb)(V)	0.6529	(0.3650)
(Qb)(M)	0.0651	(0.3985)
(Qc)(Qc)	-0.2139	(16.5591)
(Qc)(D)	0.0842	(1.9372)
(Qc)(E)	-0.5977	(12.4916)
(Qc)(V)	-1.7320	(3.6527)
(Qc)(M)	-0.2166	(3.2054)
(DD)	-0.0847	(1.9652)
(DE)	0.0104	(0.0765)
(CV)	-1.0026	(0.5103)
(DM)	-1.0802	(4.6929)
(EE)	0.7664	(9.0715)
(EV)	-0.9667	(1.4216)
(EM)	0.1142	(0.0392)
(VV)	0.0729	(5.1444)
(VM)	0.9865	(4.2619)
(MM)	0.4739	(2.9518)
R^2	.9714	

FOOTNOTES

1. Reviews of the literature are Nelson (1981), Kamien and Schwartz (1975), Scherer (1980); Mansfield (1968), Johnston (1966) and Vernon (1972). A recent survey of empirical evidence is Scherer (1984).

2. For example, an important role in productivity changes is played by the presence of basic knowledge ready for application, referred to as "technological opportunity," (Phillips 1971), which varies from industry to industry.

3. New York Times, November 8, 1983, pp. B-1, 29.

4. This would hold true even when access onto cable is leased to outside program syndicators under a system of common carriage, unless regulation forces an upgrading of capacity, or unless perfect price discrimination for access is possible.

5. David Stoller, "The War Between Cable and the Cities," Channels, April/May 1982, p. 36. For a discussion on cable deregulation, see Besen and Crandall (1981).

6. It is of course possible that bids are non-optimal in response to excessive local requirements. In most new franchising, however, bids have been above the minimum requirements. Retrenchment below earlier promises has occurred primarily in a few well-publicized big city franchises with special problems, or where a cable company was in serious financial difficulties. State regulation of cable is minor; federal regulation is mostly concerned with ownership, access rights, and carriage obligations. There is no differential application of federal rules on newer systems.

7. This may change in the future as direct satellite broadcasting (DBS) multipoint distribution systems (MDS), subscription television (STV), and satellite master antenna systems (SMATV) become competitors. Cable operators, however, do not appear to be unduly concerned with potential competition. For example, in an industry survey, 78% of operators responded in the negative to the question whether they thought that DBS would have an inhibiting effect on their growth. Multichannel News, April 26, 1983, p. 46. For several studies on this issue, see Noam (1985).

8. In another line of inquiry, that of "vintage" capital models, capital has been held to embody technical progress, and has been disaggregated according to its age. Those models, very different from the present analysis, go back to the "embodied capital" hypothesis (Abramoritz 1952; Solow 1960; Salter 1966; Solow, Tobin, von Weizaecker, and Yaari 1966; Dhrymes and Kurz 1964). Another approach has been to measure inputs in quality-adjusted units. (Denison 1978; Jorgenson and Griliches 1967).

Starting with Arrow (1962), research considered experience processes or "learning-by-doing" (Kaldor 1962; Alchian 1963; Boston Consulting

Group 1968); but it did not link it with vintage models. A review of functional specifications for estimation is Berndt and Khaled (1979).

9. 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. The parameter w is found by minimizing the residual sum of squares $\sigma^2(w)$. Madalla, 1977, p. 315.

10. Reporting is according to local operations; national cable companies (Multiple Systems Operators, or MSOs) must report their different operations separately.

11. These reports are likely to be fairly accurate due to cable companies' vulnerability to charges of misreporting in a period in which they are actively seeking new franchises. The regulatory environment of cable operators and its enforcement is fairly similar, with some college towns being the notable exceptions.

12. 1983 data are incomplete. 1984 financial file data are yet unavailable. FCC, Cable Bureau, Physical System Files, Community Files, Equal Employment Opportunity Files, and Financial Files. To assure confidentiality, financial data has been aggregated in the publicly available FCC documents; detailed subaggregations--for each state according to seven size categories, and with many categories of financial information--has been made specially available to the author.

13. All variables are standardized around the sample mean in order to overcome the problem of arbitrary scaling. On the statistical aspects of this scaling, which is widespread in translog estimations, see Denny and Fuss (1977).

14. All input prices are assumed to be independent of production level. Input prices are not controlled by cable operators. Even the largest of multiple systems operators (TCI) has only a national market share of 6 %. For programming, some market power may exist in the future if cable should become a dominant medium. As an advertising outlet, cable television has no market power.

15. In the detailed technical study the required investment flow in a medium sized cable system over a period of ten years is calculated. It is used here for the relative distribution of capital investments over time, (Weinberg, 1979, p. 128). We assume that this distribution of investment over the first ten years is proportionally the same for all systems, that investment in the 11th year and further years is identical to that of the 10th year, and that the cost of acquiring capital assets required in a cable television system increases at the average rate of communications and utilities equipment. It is then possible, knowing the start-up date of construction and the total historical value of capital assets, to allocate investment to the various years, and to inflate them to reflect the prices of the observation's year. We use deflation indices of two related industries, Communications Equipment and Public Utilities, available from the Bureau of Economic Analysis, U.S. Department of Commerce. They are quality adjusted, and are derived from

equipment where quality changes are not as rapid as in cable television. We use Weinberg (1979) to obtain the shares in capital of, first, headend, amplifiers, and customer converters, which is the weight applied to the series of communications, and second, the share of transmission system, which is the weight applied to the utilities series. The result is a weighted aggregate index. Investment figures are available before depreciation. This permits a calculation of depreciation from the asset life figures provided by Weinberg rather than relying on divergent company depreciation accounting procedures.

In the end, the complex revaluation yields highly similar results than the unrevealed capital measures. Still, it is the economically superior specification of the variable.

16. Depreciation is already implicit in the measures for β and must not be re-introduced (see Copeland and Weston, 1983). It was not possible to date the debt or equity contributions for purposes of inflating them. But we need to know only their shares in total capital. To find them respectively we assumed their age to be equal, and their total shares of capital Z to be D/Z and (Z-D)/Z.

17. Such models exist since 1966 (Horrigan), and have been refined by Pogue and Saldofsky (1969), Pinches and Mingo (1973, 1975) and Altman and Katz (1976). 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 (> 9) to C (< 1) can then be obtained for each observation point by substitution of the appropriate financial values. Bond rates are those reported by Moody's (1981). For low ratings, no interest rates are reported by the services. For the lowest rating (C), the values estimated by investment bankers specializing in cable television were used (4% above prime); for the next higher ratings, interest rates were reduced proportionally until the reported ratings were reached.

18. Usually restricted to a studio for a low budget public-access channel, and of an automated news/weather display.

19. It would be faulty to view programs as outputs. Neither are they produced by operators, nor are they sold on a quantity basis, nor are there marginal costs per viewer per program. Under the presently existing subscription based system of revenue generation (as opposed to the yet embryonic pay-per-view system) programs serve as an incentive to buy subscriptions, including pay-subscriptions and lower program "tiers," and not as the product itself.

20. Similarly, local broadcasters are carried by cable for free, and the program cost of these "must carry" channels to cable operators, too, is the foregone earnings, largely in advertising revenues.

21. Direct costs include such capital cost as those of origination studios, 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. Actual figures are reported to the FCC; potential revenues are estimated by reference to the average advertising revenue in television broadcasting per household/and viewing time. This is obtained by dividing total TV advertising billing (McCann-Erickson, as reported in Television Factbook 1980, p. 76a) by a number of TV households (Arbitron, as reported in Television Factbook 1980, p. 104a), and by viewing time. Nielsen figures for average weekly viewing of TV households is 42.6 hours; of cable households, 51.7 hours (Nielsen Cable Status Report, May 1981). TV advertising revenues per household viewing hour is found at close to 5.5 cents.

22. Office supplies, telephone, postage, insurance etc., add another 1.8% of costs that include capital inputs. For consistent treatment of inputs and outputs, this small residual input is added to the inputs K, L, and P.

23. The effect estimated for V may overstate or understate the actual contribution of technological vintage on cost reductions, because during the lapsed time factors other than technological development and the variables of the model may have contributed to affect the cost. Local regulatory expectations of franchise contracts had, over time, steadily increased as had the cost of gaining a franchise. Hence, the measure V's coefficient is, if anything, conservative. The problem of overinclusiveness is unfortunately standard in estimates of productivity, which have traditionally relied on a measure of a "residue" to estimate changes.

24. On the other hand, in dense inner city operations, costs may go up, too, because cable must be buried underground.

25. To dispose of concerns about sources of systematic bias: older systems include both small and large operations, as do new ones. It should be noted that although rural systems tend to be small, the reverse is not true. Many suburban systems in metropolitan areas are fairly small. Neither are suburban systems of particularly recent vintage relative to city or rural franchises. It is only in the core of urban media markets that wiring has been slow. The extent of competition to which a cable system is subjected is therefore not a function of size. Nor is there a positive systematic relationship between size of a system and relative amount of channel time that remains unprogrammed, i.e. empty.

26. These are in the general order of magnitude found for telephone communications (AT&T 1976; Charles and Cooper 1984; Christensen et al. 1983; Denny, Fuss, and Waverman 1982; Meyer et al. 1983; Madiri and Schankerman 1982; Sudit 1973; Vinod 1972, 1985), as well as for cable television by Owen and Greenhalgh (1983). The latter study, however, relies on hypothetical cost figures from franchise bid applications in several cities; since these can be frequently tactical or unrealistic, as the many renegotiations subsequent to franchise award show, the real operational figures and the wide range of vintages upon which the present study relies, provide a more reliable estimate.

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