5

PRODUCTIVITY AND PRICE CAPS IN TELECOMMUNICATIONS

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1. Introduction

Although proposals for price caps are numerous and varied, all subscribe to the common purpose of strengthening incentives for cost efficiencies. Indeed, at this level of generality, few question the potential for price caps to improve upon conventional rate of return regulation. Major complexities—and disagreements—arise in the process of moving price caps from the economic drawing board to actual practice. This paper will discuss one of the central implementation issues of most price-cap plans, namely, the need to adjust prices for increases in firm productivity.

The paper proceeds as follows. The next section sets out the relevant considerations for adjusting prices under price-cap plans, followed by a discussion of appropriate productivity measurements. Subsequent sections detail and evaluate the actual productivity adjustment in the Federal Communications Commission's price-cap plan for dominant telecommunications carriers, which is the leading operational example of such plans. A summary section concludes the paper.

2. The Need for Productivity Adjustment

In terms of strengthening incentives, completely fixed prices maximize the regulated firm's efforts to reduce costs. Adjustments to price, on the other hand, are necessitated by the fact that, over time, any fixed price will diverge from underlying cost conditions, create profit windfalls or losses, and result in prices that may not even be superior to those under rate of return regulation. To maintain breakeven operation, therefore, prices must change in accordance with changing unit costs.

In principle, the appropriate corrections to price are straightforward. Consider a firm selling a single product Q at price P, in a production process employing a

M. A. Einhorn (ed.), *Price Caps and Incentive Regulation in Telecommunications*

Table 1. Annual Rate of Growth in Total Factor Productivity

Year	A BLS- Private Domestic Business	B APC- Communica- tions	C Christensen- Bell System	D AT&T- Bell System
1948	—	—	3.3	0.8
1949	-0.8	8.0	-1.1	0.6
1950	7.8	9.4	4.5	4.8
1951	3.6	8.6	4.8	5.1
1952	2.2	3.4	2.3	0.1
1953	3.1	6.0	0.9	-0.6
1954	-0.1	3.3	0.8	1.6
1955	3.3	9.2	5.2	5.3
1956	0.6	2.5	1.4	1.1
1957	1.1	7.1	5.2	6.1
1958	0.7	8.9	1.6	2.4
1959	4.0	7.2	5.8	5.4
1960	0.8	3.4	3.9	4.4
1961	2.3	4.0	2.2	2.2
1962	3.2	4.6	3.0	3.2
1963	3.2	4.6	2.3	3.3
1964	3.7	2.0	3.1	2.9
1965	2.6	2.7	2.9	2.7
1966	1.7	3.3	4.3	5.2
1967	0.9	4.1	3.3	3.5
1968	1.8	3.8	4.4	5.2
1969	-0.6	2.6	3.8	3.6
1970	-1.2	3.2	0.6	3.0
1971	1.8	3.9	1.1	0.3
1972	2.9	3.7	4.0	0.0
1973	1.8	2.6	4.3	4.3
1974	-3.6	1.2	3.7	3.2
1975	-0.5	3.6	2.8	4.9
1976	3.1	3.6	4.4	3.8
1977	2.1	1.9	3.6	4.7
1978	1.2	3.3	4.8	3.8
1979	-1.5	0.8	4.2	4.9
1980	-2.2	3.1	—	—
1981	0.3	1.4	—	—
1982	-2.5	0.4	—	—
1983	2.5	8.3	—	—
1984	3.4	-3.0	—	—
1985	1.2	-1.8	—	—
1986	1.2	-0.3	—	—

Sources: A - Bureau of Labor Statistics, Multifactor Productivity Measure 1986.
B - American Productivity Center, Multiple Input Productivity Indexes.
C - L.R. Christensen Testimony in U.S. v. AT&T.
D - AT&T, Bell System Productivity Study 1947-78.

single input Z that it purchases at price R. Initially, we assume that the firm exactly breaks even, so that

$$P\,Q - R\,Z = 0, \tag{1}$$

and that the regulatory objective is to set price so as to maintain breakeven operation over time. Denoting the time rate of change of a variable X by X, this in turn requires

$$(\dot{P} + \dot{Q}) - (\dot{R} + \dot{Z}) = 0, \tag{2a}$$

or,

$$\dot{P} = \dot{R} - (\dot{Q} - \dot{Z}). \tag{2b}$$

Equation (2b) gives the necessary price trajectory for breakeven operation.[1] Price P must change in each period by the proportional change in input price R, offset by the difference between the growth rates of output Q and input Z. The latter difference represents the changing number of units of input relative to the changing number of units of output, i.e., productivity growth.

An increase in the number of units of output per unit of input may occur as the result of technological change, increased realization of scale economies, and/or improved usage of existing resources. Regardless of the source, measuring such increases in a one-input, one-output case is trivial. An index T of such change may be defined simply as

$$T = \frac{Q}{Z}. \tag{3}$$

The time rate of change in T is given by the derivative of the natural logarithm of the above expression, or

$$\dot{T} = \frac{d\left\{\ln\left(\frac{Q}{Z}\right)\right\}}{dt}, \tag{4a}$$

$$= \dot{Q} - \dot{Z}, \tag{4b}$$

Equation (4b) demonstrates that the rate of growth of output per unit input—productivity—is simply the difference between the rates of growth of Q and Z. By equation (2b), however, that difference was shown to be the necessary adjustment to input price change for establishing new output prices over time. In the humblest terms, if input prices are rising by five percent per annum, but productivity (output per unit input) increases by two percent, then continued breakeven operation by the firm would require only that output prices rise by the difference, or three percent.

This case of a single input used to produce a single output is not at all typical. All firms of interest employ multiple inputs and produce multiple outputs. The now-standard technique for handling such cases, originally developed by Kendrick (1961),[2] is so-called total factor productivity. Total factor productivity measures Q and Z in equation (3) by indexes of the firm's multiple outputs and multiple inputs. Assuming, for example, that the firm produces n distinct outputs $\{q_1,..., q_n\}$, some common metric for combining these quantities is required. That metric is the corresponding vector of prices $\{p_1,..., p_n\}$. Thus, the initial quantity is expressed in dollar terms as:

$$Q^0 = \sum^{\infty} p_i^0 q_i^0. \tag{5}$$

Using the same (base-period) prices as weights, this methodology implies the following output index in year 1:

$$Q^1 = \sum^{\infty} p_i^0 q_i^0. \tag{6}$$

The ratio of equation (7) to equation (6) is an index of output, and can be written

$$\frac{Q^1}{Q^0} = \sum^{\infty} w_i \left(\frac{q_i^1}{q_i^0} \right) \tag{7}$$

where

$$w_1 = \frac{\sum p_i^0 q_i^0}{p_j^0 q_j^0}. \tag{8}$$

This technique expresses changes in aggregate output Q as the weighted average of changes in individual product quantities, with weights the revenue shares of each product in the base period. This is a Laspeyres index of output change. Precisely the same approach is employed to account for multiple inputs. That is, a Laspeyres index of input change is constructed, using base period cost-shares as weights. The difference between the rates of change in the output index Q^1/Q^0 and the input index Z^1/Z^0 yields total factor productivity, in accordance with equation (4b).

This description is essentially the original formulation of total factor productivity. Diewart (1976, 1978) has shown that the Laspeyres, base-weighting procedure yields exact results only for a linear homogenous production function in which all inputs are perfect substitutes. Otherwise, changing input prices induce changes in factor proportions, which in turn cause growing divergence from the path given by the Laspeyres assumption of constant cost and revenue shares.

The theoretically superior formulation for more general production technologies is provided by the so-called Divisia index. That index is exact for a translog production function, and since the translog form provides a second-order approximation to any arbitrary production function, the Divisia index has quite general applicability. The Divisia index, however, is defined on continuous-time variables, whereas economic data basically come in discrete-time form. As a result, a discrete-time approximation to the Divisia index is generally employed, the most useful being that due to Tornqvist and given by

$$\ln\left(\frac{Q^1}{Q^0}\right) = \sum^{\infty} \overline{w}_i \ln\left(\frac{q_i^1}{q_i^0}\right). \tag{9}$$

Here $\overline{w}_i = .5(w_i^1 + w_i^0)$, that is, the simple average of the base-period and the current-period weights.

The need for current period data for construction of the weights in the Tornqvist approximation represents a practical obstacle to its use. Moreover, the constantly changing weights imply that the Tornqvist index changes even when the values of the underlying quantity variables do not, a feature often at odds with intuition about such indexes. For these reasons, most—but not all—empirical estimation has employed the base-weighted, Laspeyres methodology.

Actual indexes of total factor productivity may take several forms. The most common variants involve either two or three factors—labor and capital, and possibly purchased materials. Two-factor productivity is most often employed for more aggregated, economy-wide measurement, in which materials purchases largely (except for imports and exports) cancel out. For individual industries or firms, however, materials usage may be subject to productivity differences and changes, and are more appropriately included. Two- and three-factor productivity measures are not directly comparable, since the exclusion of materials tends to make two-factor values larger.[3]

Each input, as well as the multiple outputs, typically requires subaggregation of various types of the factor. For example, several different occupational groups and skill levels may be separately accounted for in constructing the labor input variable. Capital input measurement, however, is undoubtedly the most complicated component of the task. Different capital of different vintages and technology comprise current stock, which stock, in turn, is subject to different utilization rates. A host of procedures is required to adjust these data and ultimately to derive a measure of the current flow of capital services.[4]

3. Price Caps in Telecommunciations

Perhaps the major example of the use of price-cap regulation with productivity adjustment is the Federal Communications Commission plan to cap AT&T's long-distance telephone rates and the access prices charged by local exchange carriers. The FCC inquiry opened in August, 1987, and concluded for AT&T in April, 1989 (FCC, 1987, 1988, 1989). The heart of the plan is a cap on a set of price indexes of its various services, subject to limitations on individual service price movements. The cap changes over time in accordance with changes in certain "exogenous" costs that are regulatory-determined (e.g., AT&T's access charges), input cost inflation, and productivity increases.

The role of these factors is made clear from equation (2) above. For the inflation measure, the FCC adopted the fixed-weight GNP deflator, sometimes called the GNP Price Index or GNP-PI. With respect to productivity, the FCC decided against actually undertaking its own ongoing calculation of productivity. The reasons were twofold. First, the procedures involved in estimating productivity are so complex and judgmental that controversy would inevitably attend any results. Little or nothing would be accomplished if the parties that previously contested key parameters of rate-of-return regulation simply redirected their attention to periodic productivity measurement.

Secondly, an accurate measure of current productivity could not in any event be used to adjust prices directly, since full contemporaneous adjustment would diminish the firm's incentive to conserve on costs. The alternative to direct estimation of the productivity offset is use of some benchmark estimate of telecommunications carrier productivity, i.e., a long-term average or evidence from comparable firms. This has the advantages of once-and-for-all determination, and of exogeneity from the regulated firm's behavior so that (as with fixed prices) incentives are maximized.

Two methodological issues concerning this benchmark approach deserve mention. If the productivity of AT&T and the local exchange carriers is similar to that of the economy as a whole, then no explicit productivity adjustment would be required in a price formula. The reason is that inclusion of an index of price inflation would already correct for economy-wide average productivity gains, i.e., it would be measuring precisely those price changes that remain after such productivity gains are realized.

As a result, it is necessary first to determine the economy-wide average productivity and then whether the productivity of the price-capped firm or sector diverges from that standard. As we shall see, a considerable body of undisputed literature exists indicating that telecommunications in general and AT&T in particular have long achieved above-average productivity. Therefore, reliance on economy-wide averages would understate this sector's actual productivity, understate the appropriate offset to cost inflation, and lead to excessive prices.

A second methodological issue arises from the fact that all measures of the productivity of telecommunications firms or the industry are necessarily calculated in a rate-of-return environment. Not only does such regulation lower the absolute level of productivity, but it appears that under some circumstances it may also lead to incorrect estimates of the rate of change. Denny, Fuss, and Waverman (1981) derive results showing the nature of the possible bias, but Cowing, Small, and Stevenson (1981) perform some simulations that suggest the magnitude of distortion is quite small. Their results depend on the degree of regulatory stringency and the gap between the cost of capital and the allowed rate of return, but never exceed

0.3 percent of measured productivity. Hence, it appears safe to ignore this possible discrepancy.

For comparison with telecommunications productivity, the appropriate reference may be taken as the Bureau of Labor Statistics Multifactor Productivity Index for the private business sector (BLS, 1987). Annual percentage changes in this measure are given in Column A of table 1. They show that economy-wide productivity rose by an annual average of 1.4 percent from 1949 to 1986, although the rate of increase dropped to 0.4 percent in the post-1973 period. Telecommunications industry productivity measures were sought for comparison with this standard. The BLS itself has indicated plans to develop a multifactor productivity measure for telecommunications, as it has already done for other major business sectors. But this index does not yet exist and persistent data difficulties suggest that it will not be available for some time.

For the telecommunications industry in particular, the only existing index of productivity is one constructed by the American Productivity Center, a private group that uses governmental data for two-factor productivity indexes of numerous sectors of the economy (American Productivity Center, various issues). The productivity increases that it calculates for this sector are in Column B of table 1. They average 3.9 percent over the 1948-85 period, declining steadily from 5.6 percent in 1948-65, to merely 1.3 percent in 1979-85. There are, however, several concerns with the APC index. These include some nontelecommunications activities included within its "Communications" sector, its use of the narrower two-factor productivity, and the peculiar behavior of its index in the past few years (declining rather sharply, when other evidence suggests otherwise). In terms of its utility for the FCC price-cap plan, it is also relevant that its sponsors include major telecommunications firms.

For these reasons, the FCC placed principal reliance on a number of studies of AT&T's own productivity. Two of these studies were submitted by AT&T in the context of the antitrust suit brought by the Department of Justice, and one other represents its own internal productivity study. Each deserves brief description.

One study, performed by Christensen (1981), measured total factor productivity for the Bell System as a whole for the years 1947-79. Christensen defined five output variables—local service, interstate toll, intrastate toll, directory assistance, and miscellaneous services—and examined labor services, capital services, and raw materials as factors. All outputs and inputs were aggregated according to the Tornqvist approximation to the Divisia index. Christensen's results are reproduced in Column C of Table 1. They show Bell System productivity averaging 3.2 percent per year between 1948 and 1979, with annual increases ranging from -1.1 to 5.8 percent. In order to determine the differential relative to the overall economy, Christensen cites his work with Jorgensen that estimated annual productivity growth for the entire private U.S. economy, akin to the BLS measure described above. Based on those figures, he deduces a productivity differential of 2.1 percent for the Bell System.

The data also reveal a notable trend. From 1947 through 1966, the differential favoring the Bell System was 1.6 percent, whereas from 1966 to 1978, it grew to fully 3.0 percent. Most of the differential was due the collapse of productivity in the private economy in the later period.[5] Bell System productivity was 3.4 percent—slightly higher than its long-term average—but the private economy as a whole achieved only 0.4 percent growth in productivity.

Christensen performed an essentially parallel study of Bell System productivity using less precise public data on SIC 481, the Telephone Industry. From these, he deduced Bell System total factor productivity of 3.2 percent for the 1947-79 interval, identical to his direct estimate. The disaggregation of SIC 481, while involving difficult procedures, permitted an estimate of the non-Bell portion, largely the independent local exchange carriers. For these, Christensen estimated a considerably smaller productivity of 1.9 percent during the same period.

A second study filed in the antitrust suit was performed by Kendrick himself (Kendrick 1982). This study used the same five output definitions as above, but examined only two factors—labor and capital. Between 1948 and 1979, Bell System productivity increases were found to average 4.9 percent annually. Relative to the economy-wide average of 2.0 percent that Kendrick reports as comparable, this implies an annual differential of 2.9 percent.[6] Although somewhat greater than the results reported above, most of the discrepancy is undoubtedly due to the use of two-factor productivity, as previously discussed.

AT&T has routinely conducted its own internal study of Bell System total factor productivity, using methodology originally developed for it by Kendrick. One such study was put on the record of the FCC's price-cap proceeding (AT&T, 1979). It reports both two-factor productivity as well as the more inclusive three-factor version. The AT&T study concluded that, over the 1947-78 period, three-factor productivity grew at an average annual rate of 3.2 percent, whereas two-factor productivity averaged 3.7 percent annual growth. The latter figure was compared to an economy-wide benchmark of 1.9 percent reported by AT&T, implying a 1.8 percent differential favoring the Bell System.

As with preceding estimates, AT&T's study showed that the differential grew over this interval. From 1948 to 1965, AT&T two-factor productivity averaged 3.5 percent, compared to 2.4 percent for the economy as a whole. From 1965-72, the analogous figures were 3.7 percent and 1.6 percent, and for 1972-78, they were 4.9 percent and 1.0 percent. Therefore, the differential favoring the Bell System initially was 1.1 percent, rising to 2.1 percent and ultimately to 3.9 percent. In contrast to the two previous studies, more of the growing differential reflects rising Bell System productivity and not simply declining productivity in the economy as a whole.

To varying degrees, three other published studies of productivity corroborate these findings. The first, due to Nadiri and Schankerman (1981) distinguishes four inputs, adding research and development to the conventional three, and four outputs—local service, interstate toll, intrastate toll, and miscellaneous. Using proprietary data for the period 1947-76, they estimated that total factor productivity grew at an annual average rate of 4.1 percent, rising from 3.5 percent in 1947-57, to 3.6 percent in 1958-67, and to 5.0 percent in 1968-76. These estimates differed slightly for various assumptions concerning demand elasticity.

Two studies have been conducted for productivity in Bell Canada, but because of differences in both scale economy realization and regulatory environment between Canada and the U.S., the results need to be interpreted cautiously. Denny, Fuss, and Waverman (1981) found annual increase in total factor productivity averaging 3.4 percent from 1952-76. Productivity grew steadily from 1.3 percent in 1952-57 to 4.5 percent in the last five years of the period. Kiss's econometric approach found Bell Canada productivity growing at an annual average rate of 3.44 percent, with more varied gains by subperiod (Kiss 1983). Despite the caveats, the similarity of these results to those reported for the U.S. Bell System is striking.

Further evidence concerning the productivity of the Bell System emerges from an alternative measurement technique. By combining equations (2b) and (4b), one observes that

$$\dot{T} = \dot{R} - \dot{P}. \tag{10}$$

That is, the change in total factor productivity *(Q - Z)* can equivalently be stated as the difference between the rate of growth of input prices ($\dot{R}$) and the rate of growth of output prices ($\dot{P}$) in the industry. Recalling the earlier example, if input prices rise by 5 percent but output prices increase only 3 percent, then implied productivity is 2 percent, holding other things constant.[7]

This "implied productivity" approach was also employed by the FCC. The BLS data series on the prices of local and long distance telephone services dating back to 1935 shows an annual average increase of 2.25 percent through 1985.[8] Overall CPI—as a benchmark measure of input price increases, since GNP-PI does not exist that far back—rose by 4.20 percent per year, implying a productivity differential of 1.95 for that period. This number is remarkably similar to results such as Christensen's.

Moreover, as do the direct productivity studies, the price data show rising differentials in more recent periods. For example, from 1955 to 1985, telephone prices rose by 2.53 percent annually, compared to overall CPI averaging 4.74 percent. The differential therefore rose to 2.21. In the last ten-year period, the differential increased further, to 2.64 percent, as telephone prices rose by 4.53 percent but overall prices climbed 7.17 percent. All of this evidence is strongly corroborative of the direct productivity estimates.

However consistent these results, little of the evidence bears on the question of the productivity in long-distance service relative to local exchange or access services. Indeed, for most of this period, such a distinction cannot be drawn from existing data, because of the confounding role of separations in the economics of local vs. long-distance service. Starting in 1943, a certain percentage of the costs associated with the local loop was assigned to interstate Message Toll Service (MTS). By the early 1980s the percentage grew to about 33 percent, and these costs comprised nearly one-half of the per minute charge for MTS. As a result, all indexes of interstate or local rates in this period have embedded within them an essentially arbitrary allocation of very large system costs, and are unreliable guides to underlying cost or productivity changes.

The FCC price-cap plan, however, contemplates eventually capping the prices of LEC interstate services as well as AT&T's. Apart from Christensen's result for the independent telephone companies, the only result at all relevant to this disaggregation is again for the Canadian telecommunications system. Denny, de-Fontenay and Werner's results (1983) are given in table 2, showing that Bell Canada (primarily a provider of long-distance service) achieved 3.2 percent annual productivity growth, whereas two provincial companies, over slightly different time periods, achieved 3.2 percent and 6.2 percent, respectively. These numbers suggest the possibility of significant differentials between long-distance and local telecommunications service, and indeed, among firms providing the latter.[9] More direct evidence on productivity differentiation was sought by the FCC, focusing on the post-divestiture period in which meaningful disaggregation of local and long distance service is more feasible. One piece of such evidence was the FCC's own calculation of AT&T's implied productivity in the price-cap order (FCC, 1989, Appendix C).[10] In the four-year period from divestiture to early 1988, the FCC calculated that AT&T's MTS rates declined by 34 percent. Most of that, however, was due to FCC-mandated reductions in access charges, costs not subject to productivity gains.[11] Thus, the procedure netted out the effects of various regulatory cost changes, resulting in an annual MTS price change of (positive) 1.28 percent. Since GNP-PI rose by 3.60 percent per year during this interval, AT&T's implied productivity gain was 2.32 percent.[12]

Table 2. Annual Rate of Growth of Total Factor Productivity

Year	British Columbia Telephone	Alberta Government Telephone	Bell Canada
1967	—	—	5.9
1968	—	5.3	4.3
1969	—	5.5	2.9
1970	—	4.6	3.7
1971	—	4.2	-0.5
1972	—	9.3	3.7
1973	2.9	7.7	4.7
1974	5.9	11.9	4.4
1975	6.0	8.3	6.9
1976	4.4	3.3	1.0
1977	-2.2	6.6	0.7
1978	3.0	2.0	2.3
1979	2.5	—	2.2

Source: Denny, de Fontenay, and Werner. "Comparing the Efficiency of Firms." In *Economic Analysis of Telecommunications*, edited by Courville, de Fontenay, and Dobell.

Table 3. Annual Rate of Growth of Implied Total Factor Productivity (1984-88)

Unit	TFP
Ameritech	1.28
Bell Atlantic	-1.26
BellSouth	-2.61
NYNEX	-0.19
Pacific	0.35
Southwestern	0.99
US West	6.59
7 RBOC Average	0.62
Total Industry	-0.70

Source: Bell Communications Research. 1988. "Impact of FCC Proposed Price Cap Plan on Interstate Consumers-Regional Disaggregation."

The FCC requested the Bell Operating Companies to conduct and provide similar studies of their individual productivity experiences since divestiture to determine whether their productivity adjustment should differ. Initially, the BOCs provided only a study of their combined productivity, calculated as 0.67 percent after correction for regulatory cost changes (Bellcore, August 1988). A subsequent submission disaggregated this result, all the while disputing the reliability and significance of the very large reported differences among the regional Bell holding companies (Bellcore, September 1988). Those productivity estimates are reproduced in table 3.

Both of these studies were subject to intense controversy and criticism in the FCC proceeding. It became clear that the process of correcting revenue flows for various regulatory cost changes can be as difficult and contentious as the direct calculation of productivity. Nonetheless, it is clear that the evidence does not support the view that AT&T and BOC productivity are the same, or even that productivity *among* the BOCs is similar. We will return to some of the implications of these observations below.

4. Evaluation of the FCC's Evidence

Based on these studies, the FCC concluded that the long-term productivity increases of the telephone industry have averaged approximately 2 percent per year in excess of the overall private economy. However, since this differential has been rising in more recent periods, a better prediction of likely future productivity was taken to be 2.5 percent. Further, in order to ensure net consumer benefit from greater productivity increases, the FCC proposed that prices[13] be adjusted by an additional 0.5 percent per year, for a total of 3.0. In terms of the original formulation, therefore, the FCC's price cap plan would change prices each year in the amount of the change in GNP-PI less 3.0 percent.

This general conclusion seems well supported by the evidence. Most of the productivity studies, plus the price evidence, all suggest a differential favoring the Bell System of between 2.0 and 3.0 percent, the larger numbers characterizing more recent years. Although there are some differences in the detailed results of these studies, their similarities predominate. For example, perhaps the most closely matched series—those due to Christensen and AT&T in table 1—are highly correlated, with a simple correlation coefficient of .91. They appear to be estimating similar phenomena in a consistent fashion, providing a sound basis for such a conclusion.

The productivity number is a long-term average, of course, subject in any year to a variety of forces that may yield larger or smaller changes. From a policy perspective, annual discrepancies are important since they represent temporary over- or under-payments by consumers to telephone companies, and corresponding windfalls or shortfalls in current revenues to the regulated companies. The revenue consequences of even modest discrepancies are strikingly large. Consider the following stylized example: Let the regulated company's revenue requirement be 100, consisting of operating cost of 70, taxes of 10 (based on a tax rate of one-third of operating profit of 30), and accounting profit of 20. With total invested capital of 200, this implies achievement of an assumed authorized rate of return of 10 percent (20 on 200).

Now let revenue requirements be reduced by 3 percent per year, based on long-term average productivity gains and assuming no demand expansion. But in some particular year, assume actual costs fall by 5 percent, that is, two percentage points more than the long-term average. If all costs, including total invested capital, are subject to such gains, the realized rate of return immediately rises to 10.7 percent. If this differential persists, then within five years the company earns 13.7 percent on invested capital, 37 percent in excess of the authorized rate of return.[14]

The extent of variation in the actual data series is illustrated in table 1. For example, the standard deviation of Christensen's annual estimates is 1.6 percent.[15] The average absolute value of deviation is 1.3 percent, ranging from positive 2.6 percent to negative 4.3 percent. This degree of variation is clearly substantial.

The more relevant test of deviations would be a comparison of the FCC formula—the change in GNP-PI minus 3.0 percent—with "actual" values of the productivity differential. The latter can only be estimated, but certain results are nonetheless suggestive. Figure 1 presents the FCC formula as well as an approximation of actual values given by the difference between AT&T's own productivity calculation (column 4 in table 1) and the BLS economy-wide figure (column 1 in table 1).

The series differ in absolute magnitude, with the formula averaging 1.3 percent and actual values averaging 1.8 percent. The average annual absolute value of the difference between the "actual" values and the FCC formula values underlying figure 1 is 2.2 percent, although for the 1970s, this declines to 1.3 percent. Actual values tend to move more smoothly, while the formula is more strongly affected by wide swings in the inflation rate. Overall, the series exhibit a simple correlation of .62.

These discrepancies are obviously not trivial, particularly in light of the stylized example above. Yet one might respond that the relevant standard of comparison for policy purposes is not this discrepancy per se, but how this discrepancy compares to that that arises under rate-of-return regulation. The FCC formula would undoubtedly fare better in that comparison.

Further problems attend the effort to apply price caps to the local exchange carriers. To the extent that the LECs have persistently different rates of productivity change, application of the average—or any single number—will result in persistent excess profits to some and losses to others. As the above numerical illustration shows, the realized rate of return of a carrier achieving 5 percent productivity but subject to a 3 percent productivity adjustment will rise by several percentage points in a very few years.

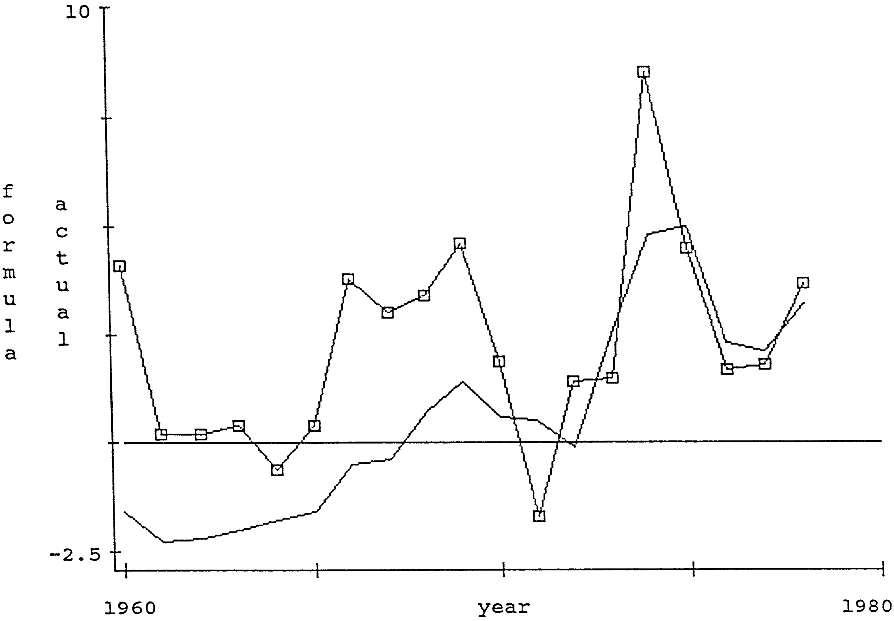
For this reason, capping the prices of differentiated firms requires either firm-specific productivity factors, or alternatively, some feedback mechanism by which errors are identified and rectified. Unfortunately, reliable estimation of firm-specific productivity factors for the 1400 local exchange carriers, or even the seven regional holding companies, is a virtually intractable problem. The controversy surrounding the efforts of the RBOCs thus far makes clear that such estimates will have difficulty standing up to scrutiny.

The alternative is to establish some initial common productivity value for all the carriers, and then to adjust it (or equivalently, directly adjust prices) in accordance with evidence regarding each firm's individual productivity. For example, the so-called "sliding scale" is a long-recognized device by which realized profits (or rate of return) are used as a guide for adjusting prices in a subsequent period of time, high profits indicative of high productivity and the need for price reductions, and low profits the reverse.[16] Versions of the sliding scale are present—or at least implicit—in the fixed price plan adopted by the New York State Department of Public Services for New York Telephone and in other price-cap-type plans.

The FCC's proceeding with respect to the local exchange carriers has proposed a similar adjuster, termed an "automatic stabilizer" (FCC, 1989). Whenever a firm's realized rate of return falls outside a 2 percent band around the target rate, the price cap in the following period would be adjusted so as to return the firm's earnings to that band. Thus the firm bears the full profit consequences—positive or negative—up to two percentage points in its rate of return, and the consequences of further deviations for precisely one year, after which its earnings are restored. Whether this represents the optimal structure for firm and consumer sharing of risk and benefit is doubtful, although the principle of the automatic stabilizer is well suited to the problem of LEC productivity differentiation.[17]

5. Conclusion

Price caps have considerable promise as a regulatory tool. As with most public policies, however, implementation of price caps requires careful analysis and judgment concerning important policy parameters. The productivity adjustment is an example of such a parameter. The choice of productivity factor plays a crucial role in maintaining correspondence between price and cost. It affects large revenue flows and realized rates of return. And it is visible and readily understood. The choice is, therefore, both important and public.



Comparison of FCC Formula Adjustments and 'Actual' Values

This article has used the Federal Communications Commission's price cap plan as an extended case study of the issues involved in selecting an appropriate productivity offset for telecommunications carriers. Among the alternatives available to the FCC, its chosen approach seems sound, although we have remarked on issues that arise as the result of normal variation in annual productivity, inflation, and cost changes, as well as discrepancies among carriers whose productivity experience appears to differ significantly. Attention to these various concerns will ensure the realization of the potential of price-cap regulation.

Notes

The author is Professor of Economics, George Washington University, and has served as Special Assistant to the Chief, Common Carrier Bureau, Federal Communications Commission, on the FCC price-cap proposal. The opinions in this article should be construed as reflecting views of the FCC.

1. If the firm initially was not breaking even, equation (2) would still hold so long as the magnitude of profits did not change. A change in profits would require modifying equation (2b) to read

$$\dot{P} = \dot{R} - (\dot{Q} - \dot{Z}) - \dot{\Pi}$$

where $\dot{\Pi}$ represents the rate of change in profits.

2. See also Denison (1962) for early development and Cowing and Stevenson (1981) for recent discussion and references.

3. This is true even though two-factor measures exclude materials from their output definition. That is, they employ value added instead of total output as the relevant variable.

4. For illustrative discussion of the complexities, see, for example, Christensen (1981).

5. The forces responsible for this collapse are much in dispute, and in any event appear to have been arrested and slightly reversed in the mid to late 1980s.

6. Kendrick's testimony did not report results by year, although some detail was later published in his book, *Improving Company Productivity* (Kendrick, 1984).

7. Also noted previously, among the other things that must be held constant is the level of profit, i.e., the degree of regulatory stringency.

8. These and other data employed in this paragraph are conveniently gathered in J. Lande and P. Wynns (1987).

9. One possible reason for differentials among provincial companies in Canada, and among the LECs in the U.S., is differing rates of demand growth in various regions. Persistent productivity differentials characterize other regulated industries. See, for example, Caves, Christensen, and Trethway (1981) and Gollop and Roberts (1981).

10. Slightly different numbers appeared in the FCC's *Second Notice*, (FCC, 1988).

11. As previously noted, access charges and certain other regulatory-imposed costs are not included within the FCC price-cap plan, since they represent uncontrollable cost factors not subject to cost-saving efficiencies.

12. Kiss objects to this calculation, asserting that it is inconsistent with the simultaneous use of GNP-PI in the FCC formula (F. Kiss, 1989). This calculation, however, is a separate exercise designed to corroborate other productivity estimates. It does not, and need not, presume the various corollary conditions Kiss asserts.

13. As noted previously, the actual FCC plan involved movements of weighted average prices, with some secondary limits on individual price changes.

14. One might contend that capital stock is not subject to the same productivity improvement possibilities as other factors. This example can be modified to reflect alternative assumptions, for example, that productivity gains are limited to operating costs, or to operating costs plus new investment. These alternatives, of course, must imply proportionally larger productivity gains on those other factors if total factor productivity rises by 5 percent.

15. Christensen's data are taken as typical for this exercise. Similar results would emerge using most of the other candidates.

16. The sliding scale is originally discussed in Bussing (1936) and more recently in Schmalensee (1979).

17. For discussion of sharing formulas, see Kwoka (1988).

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