PROBLEMS IN APPLYING PRODUCTIVITY MEASUREMENT TO PRICE CAP REGULATION OF TELECOMMUNICATIONS SERVICES

by

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I. Introduction

In the last few decades, revolutionary developments in electronics have slashed the costs of switching and other forms of telecommunications equipment. As Huber (1987) pointed out, the telecommunications network has evolved from a pyramid[1] to something more like a geodesic dome, as a result of network nodes developing new links.[2]

The restructuring of the network due to the new electronic technologies in the 1970s and 1980s was one of the major driving forces of both AT&T's divestiture in 1984 and regulatory "reform" such as price cap regulation in the late 1980s. Rapid development of digital electronics and transistor technology blurred the line between computers and communications and lowered economic barriers for non-telephone companies to enter into the telephone business.

Traditionally, federal and state regulatory agencies have used rate-of-return regulation to set rates and profits for utilities. Under this type of regulation, prices are set so that the utility is allowed to earn a specific return on its investment after recouping its operating costs. Critics of rate of return regulation allege that, since the utility's rates are reduced in response to decreases in its costs, the utility may have little incentive to minimize its costs or engage in product innovation. In addition, Averch and Johnson (1962) have shown that theoretically under rate-of-return regulation, the utility may have an incentive to overuse capital.

Under a "price cap" form of regulation, the regulatory agency sets a ceiling on the price rather than on the rate of return. The utility has pricing flexibility below this ceiling, e.g., the regulated utility can raise or lower prices as long as the prices stay below the cap.

This approach is then proposed as being more efficient than rate-of-return regulation. Under this new form of regulation, the utility is expected to have stronger incentives to make profits from cost-reducing innovations, since its rates would not automatically be adjusted downward. A utility that improves efficiency and responds to consumer demand effectively would see its profits rise. Therefore, it

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[1] When switching was expensive and transmission was cheap, the efficient network looked like a pyramid.

[2] Today's private branch exchanges (PBXs), micro- and mainframe-computers, and other intelligent "terminals" have many ports. Network "terminals" no longer terminate, they interconnect.

would help strengthen the competitiveness of American industry in domestic and international telecommunications markets and help ensure that consumers share in the benefits of the information age through lower rates and a wide array of high quality services.[3]

Since 1989,[4] the Federal Communications Commission (FCC) has concluded that price cap regulation is superior to rate-of-return regulation for certain dominant carriers. Price cap regulation for AT&T was first adopted by the FCC on July 1, 1989 and price cap regulation for the local exchange carriers[5] (LECs) will be implemented by Jan. 1, 1991.

In the price cap formula adopted by the FCC to determine the price ceiling for carriers, a productivity index is one of the major factors to modify allowable increases in production costs. In this paper we focus on the use of productivity in the price cap regulation of telecommunications services. We first discuss the basic definitions and concepts of productivity and technology in Section II and the approaches of productivity measurement in Section III. Productivity measures in price cap regulation are discussed in Section IV. Based on the theoretical framework in Sections II and III, the problems of using productivity in the price cap formula are evaluated and discussed in Section V. Our conclusions are presented in Section VI.

II. Definitions and Concepts of Productivity and Technology

Technology is closely related to productivity, but it is not the same thing. The technology of production is a complete specification of the inputs and operations to be performed on them to create output of a given quality. Productivity change is an important characteristic of technological change. Productivity measurement thus plays a crucial role in assessing the effects of technological change.

In the past, productivity was often expressed as the ratio of output to the scarcest or otherwise most critical input, with other cooperating inputs ignored. Agricultural productivity was expressed, for example, in bushels of wheat or corn per acre. As skilled craftsmen became important in medieval Europe, output per worker per day or week was a common productivity concept. A petroleum refinery may be

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[3] See FCC Second Further Notice at 5

[4] See FCC Second Further Notice, 4 FCC Rcd at 2931.

[5] Not all LECs will be eligible to participate. Only the eight largest LECs - the seven Regional Bell Operating Companies (RBOCs) and General Telephone and Telegraph Company (GTOC) will be required to participate. Price cap regulation will be optional for mid-sized and smaller LECs.

rated in barrels per day; an auto assembly line in terms of vehicles per day or per shift; a steel mill in terms of tons per day.

Total factor productivity (TFP), the productivity of all purchased inputs, is the broadest measure of productivity. It is also the only measure whose increase is unambiguously beneficial, in the sense that it corresponds to a decline in the total unit cost of production.

The U.S. Bureau of Labor Statistics' Office of Productivity and Technology produces a variety of productivity measures: quarterly labor productivity for the private business sector, manufacturing and other large National Income and Products Account (NIPA) aggregates; annual labor productivity measures for a variety of U.S. three- and four-digit manufacturing and service industries; annual total factor productivity (value added) measures for the above-mentioned sectors in the NIPA; and true TFP measures for two-digit industries, selected four-digit industries and aggregate manufacturing (BLS, 1988). While productivity in service industries is very important, particularly in international trade, the absence of sufficient data to support reliable measures of their productivity growth has hampered economic policy. The productivity effects of obvious technological change in many service industries are unmeasured chiefly because output measures are so poor. Banking, construction, health services, and telecommunications are key areas where the effects of large investments in new technology are widely debated and genuinely in doubt because the measures of productivity growth that can be created for those industries from official economic statistics are virtually meaningless.

In a serious study of productivity, it is crucial to carry out the analysis in terms of the "right" set of inputs and outputs. In the U.S. in the 1970s this generally meant capital, labor, energy and materials for manufacturing industries especially: energy, being scarce and partially regulated, was an object of special concern.

The problems of the late 1980s and prospectively, the 1990s, however, are likely to be more concerned with technology and competitiveness. Many high technology firms use little energy: rather, analytic emphasis is placed on specific materials inputs (e.g., semiconductors), capital inputs (e.g. computers and flexible manufacturing systems), and labor inputs, particularly nonproduction workers. The "best" representation of technology in terms of inputs, given the limitations of the data sources, will vary by industry.

III. Approaches in the Measurement of Productivity

A. Measurement of Productivity: Growth Accounting Approach

This section discusses the techniques for measuring the level and growth rate of TFP -- output per unit of total factor input -- for an industry or plant.

TFP is defined as <u>the ratio of aggregate gross output to aggregate purchased input</u>, with both expressed in real terms. It aggregates unlike inputs in terms of their marginal products, and unlike outputs in terms of current year marginal costs of production. TFP is the weighted average productivity of all purchased inputs, where the weights are the shares in the total cost of production. Thus

$$(1) \qquad TFP = \Sigma_j\ w_j\ y_j\ /\ \Sigma_i\ v_i\ x_i$$

where y_j is the physical quantity of output j
x_i is the physical quantity of input i
w_j is the share of output j in total revenue
v_i is the share of input i in total cost
and $w_j = q_j\ y_j\ /\ \Sigma_j\ q_j\ y_j$
$v_i = p_i\ x_i\ /\ \Sigma_i\ p_i\ x_i$
where q_j = the price of output j j = 1,...,J
p_i = the price of input i i = 1,...,I.

The enterprise is assumed to maximize profits subject to the constraint of the production function

$$(y_1,\ldots,y_J) = F(x_1,\ldots,x_I)$$

where profits are given by

$$\pi = \Sigma q_j\ y_j - \Sigma p_i\ x_i.$$

The equilibrium condition is that economic profits are zero; hence

$$\Sigma q_j\ y_j = \Sigma p_i\ x_i.$$

That is, total revenues are equal to the total cost of production.

The equality between total costs and total revenues is insured by the assumption that all inputs are purchased in competitive markets so that their prices are equal to their marginal revenue products. All outputs are produced under conditions of constant returns to scale, and the price of output j is equal to its marginal cost. All inputs are adjusted to their equilibrium levels.

Competitive conditions in the output market do not hold in the case where prices are determined in a regulatory process. Because the enterprise is required to meet demand effective at the regulated prices, revenue weights based on administered prices are inappropriate for the construction of an output aggregate because the relationship q_j(price) = mc_j(marginal costs) does not hold. Fisher and Shell (1972) have demonstrated that the appropriate weights for output aggregation to measure the real output of a producing establishment, industry or enterprise are the respective marginal costs of producing each output. Where q_j is not equal to mc_j, we may specify an appropriate approximation to a cost function as discussed in Section III.B below and estimate that cost function. The marginal costs, mc_j, of producing each output y_j may then be determined from the estimated cost function. The resulting real output measure for a firm or an industry is thus

(2) $$y_R = \Sigma_j \, mc_j \, y_j.$$

This technique has been used by Caves, Christensen and Swanson (1980) for U.S. railroads; Gollop and Roberts (1981) for U.S. electric power generation; Denny, Fuss and Waverman (1981) for Canadian telecommunications; and Norsworthy and Jang (1989) for the U.S. Postal Service. An "appropriate" aggregation of outputs by using the estimated marginal costs as the weights through an econometric model would result in a better measurement of TFP and a basis of output grouping for "baskets" in the telecommunications price cap regulation[6].

Unmeasured quality change in an input or output is another important factor in productivity measurement. If this unmeasured quality change is ignored, then its quantity will be misstated, and the TFP measure will be correspondingly biased. An unmeasured increase in the quality of an input will result in a downward bias in measured TFP. Similarly, an unmeasured increase in the quality of an output will result in a upward biased TFP.

Determination of quality for inputs and outputs is part of the deflation process. It involves the separation of changes in the value of a good or service into price or quantity components, based on the characteristics of that good or service. For particular goods or services, small changes in quality can be fairly reliably determined on the basis of small changes in performance characteristics. At any particular time, the characteristics most closely related to performance of a particular good are usually easy to identify. However, when there is rapid technological change, or model changes that entail many simultaneous changes in performance characteristics, quality differences are harder to measure.

The rapid technological changes in the last two decades have made the task of price deflation more difficult in consumer goods and producer goods, while the resources available to the cognizant statistical agencies -- primarily the Bureau of Labor Statistics in the U.S. -- to carry out the studies have not increased commensurately. In addition, more technological expertise is required now than in the past to identify and quantify the changing characteristics of products that are most important to their performance.

The growth of TFP is equal to the aggregate rate of growth of output less the aggregate rate of growth of inputs.

(3) $$\frac{dTFP}{dt} = \Sigma_j \, w_j \, \frac{dy_j}{dt} - \Sigma_i \, v_i \, \frac{dx_i}{dt}.$$

Equivalently, it can be shown that

(4) $$\frac{dTFP}{dt} = \Sigma_i \, v_i \, \frac{dp_i}{dt} - \Sigma_j \, w_j \, \frac{dq_i}{dt}.$$

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6 It is discussed in more detail in Section V.

That is, the growth of TFP is equal to the average rate of growth of input prices less the average rate of growth of output prices.

B. Using Information from Econometric Model in Growth Accounting

The structure of production for a firm or an industry can be examined by estimating a cost function or production function. For example, a typical cost function can be defined as

$$(7) \qquad TC = f(P_k,\ P_l,\ P_e,\ P_m;\ y_1,\ y_2, \ldots .y_J)$$

where P_i is the price of input i; i = K, L, E, M representing capital services K; hours of labor L; energy E; materials M and the level of gross output y_j, j = 1....J. Under the given output quantity and the given input prices, a firm is assumed to minimize its production costs, TC. The functional forms of a cost function as models of production can be specified either as simple as a log-linear functional form[7] or as complicated as a second-order or higher order nonlinear functional form.[8] The choice of functional form ultimately depends on the characteristics of production for the firm or the industry which is studied.

From the estimation of a cost function for a firm or an industry, its marginal costs and economies of scale can be computed. The marginal costs of output y_j can be estimated by

$$(8) \qquad MC_j = \delta TC \ / \ \delta y_j \qquad j = 1.....J.$$

The estimated marginal costs of outputs are used as the weights of output aggregation in the computation of TFP growth.

Since the scale elasticity is identical to the reciprocal

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[7] For example, a Cobb-Douglas production function is a log-linear functional form specified as $Y = K^a + L^b$ (or $\ln Y = a * \ln K + b * \ln L$.)

[8] For example, the translog cost function is generally considered to be a second-order approximation to a function where exact form is unknown. The translog cost function can be specified as

$$\begin{aligned} \ln TC = {} & a_o + a_Y \ln Y + 1/2\ a_{YY} \ln Y^2 \\ & + \Sigma_i\ b_i \ln P_i + 1/2\ \Sigma_i\ \Sigma_j\ b_{ij} \ln P_i \ln P_j \\ & + \Sigma_i\ c_{iY} \ln P_i \ln Y \end{aligned}$$

of the elasticity of cost with respect to output (Hanoch, 1975), we use the latter as a measure of economies of scale. The scale elasticity of a cost function is therefore:

$$SE = (\delta \ln TC / \delta \ln Y)^{-1}. \quad (9)$$

Once the information of economies of scale is obtained from the estimation of an econometric model, the constraint of constant returns to scale in growth accounting approach then can be released by an adjustment discussed in the following section.

Important sources of growth in TFP such as economies of scale cannot be derived directly by growth accounting techniques. Econometric models can lead to estimates of these effects, however, which can then be incorporated in the growth accounting framework by partitioning the TFP growth term:

$$TFP_R = TFP - TFP_{SE} .$$

Then the equation for output growth may be rewritten

$$Y = \Sigma_i \ v_i \ X + TFP_{SE} + TFP_R . \quad (10)$$

That is, output growth is "explained" in terms of the growth in inputs, scale effects (TFP_{SE}), and residual or unexplained growth in TFP (TFP_R).

Equation (10) also illustrates a most important principle of productivity measurement and growth accounting: TFP growth is normally measured as a residual after the effects of other factors have been accounted for. This fact can lead to confusion, especially when one compares the results of different investigators.

IV. Productivity Measures and Price Cap Regulation

The price cap regulatory approach adopted by the FCC for tariff review purposes for AT&T and proposed for the LECs operates according to the following process. A carrier's services are grouped together in accordance with common characteristics, and the weighted prices in each group are adjusted annually pursuant to the following formula designed to ensure that rates are based on the cost of providing service.

The price cap formula is as follows:

$$PCI_t = PCI_{t-1} [1 + w (GNP\text{-}PI - X) + Y/R + Z/R] \quad (11)$$

where

GNP-PI = the percentage change in the GNP-PI between the quarter ending six months prior to the effective date of the new annual tariff and the corresponding quarter of the previous year,

X = productivity factor,

Y = (new access rate - access rate at the time the PCI was updated to PCI_{t-1}) x (base period demand),

Z = the dollar effect of current regulatory changes when compared to the regulations in effect measured at the base period level of operations,

R = base period quantities for each rate element "i", multipled by the ratio of the price for each rate element "i" at the time of the PCI to updated to PCI_{t-1},

w = R - (access rates in effect at the time the PCI was updated to PCI_{t-1} x base period demand) + Z, all divided by R,

PCI_t = the new price cap index (PCI) value, and

PCI_{t-1} = the immediately preceding PCI value.

The formula in (11) reflects

(a) changes in the costs of input factors of production through use of the Gross National Product Price Index (GNP-PI);

(b) a productivity offset (X) representing the historical difference between AT&T's (or LECs) productivity improvements and productivity gains in the economy as a whole;

(c) certain specific cost changes beyond the carrier's control. These "exogenous costs" consist of cost changes due to changes in laws, regulations, or rules, or due to other administrative, legislative, or judicial changes <u>beyond a carrier's control</u>;

(d) a consumer productivity dividend: an additional 0.5 percent productivity offset that exceeds the historical productivity of the telephone industry due to the additional efficiencies from the improved incentives created by price cap regulation.

In most respects, this price cap formula is applied to both AT&T and the LECs. Because of the possible variability of individual LEC productivity around the industry average, the FCC has proposed some additional "backstops" such as a shared earnings and lower end adjustment mechanism in price cap regulation for the LECs. These backstops are designed to assure that the LECs would have strong financial incentives to improve productivity and their rates charged to customers would fall inside the zone of reasonableness.

The productivity index is one of the essential factors in the price cap formula. Productivity gains in a firm or industry represent increases in outputs from the same amount of factors of production, or equivalently, the same amount of output from decreases in input factor utilization. In either case, the unit cost of output declines due to the diminished factor requirement per unit of output. Therefore, productivity gains would offset the price of output.[9] We discuss how the FCC determines the magnitudes of the productivity offset in the price cap formula for both AT&T and the LECs in the following section.

A. Productivity Offset in the Price Cap for AT&T

To determine a value for the productivity offset, the FCC first reviewed existing productivity studies for AT&T. On the basis of these studies, it found that the productivity differences between the telecommunications industry and the whole economy ranged from 1.9 percent to 4.09 percent.[10] The FCC then decided a productivity factor of 2.5 percent was appropriate in the price cap formula for AT&T, based on the long term historical studies of Bell System productivity, as well as its analysis of AT&T cost and revenue changes since 1984.[11] This productivity offset did not include a 0.5 percent consumer productivity dividend.

B. Productivity Offset in Price Cap Regulation for the LECs

In the FCC's proposal, the productivity of the LECs for the price cap regulation was not measured directly. Instead, productivity was measured by two indirect approaches: (1) output price difference between the telephone services and the entire economy;[12] and (2) "break-even" productivity approach.[13]

In the output price difference approach, productivity was measured by the difference between the telephone service price increases and the price increases of the entire economy as

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[9] This is why productivity factor is reduced by subtracting price cap index in the price cap formula.

[10] 1.9 percent in AT&T's own study for the years 1947-78; 4.09 percent in Nadiri & Schankerman (1981) for the years1947-76; 2.2 percent in the American Productivity and Quality Center for the years 1948-85; 2.48 percent in the FCC's study for the post-divestiture period and 3.35 percent in Denny, Fuss and Waverman (1981) for Canadian Telecommunications.

[11] See the FCC Second Further Notice at 106.

[12] i.e. the FCC so called "long term historical productivity study" by its staff T. C. Spavins and J. M. Lande. See Appendix D in the FCC Supplemental Notice of Proposed Rulemaking and Appendix D in the FCC Second Report and Order.

[13] i.e. the FCC so called "short term historical productivity study" by its staff J. C. Frentrup and M. I. Uretsky. See Appendix C in the FCC Supplemental Notice of Proposed Rulemaking and Appendix C in the FCC Second Report and Order.

measured by the CPI or the GNP deflator. In the "break-even" productivity approach, the FCC computed a productivity factor such that rates would have been the same under a price cap regime as they are under rate of return regulation. The problems in using these two indirect approaches are discussed in the Section V.D below. Based on these studies primarily, the FCC decided to proceed with a 3.3 or 4.3 percent productivity factor in the price cap formula for the LECs, depending upon the level of shared earnings.[14]

When using a 3.3 percent productivity offset to establish prices, LECs must share with their customers 50 percent of their earnings between 1 to 5 percent above the 11.25 percent level, and share 100 percent of their earnings above 16.25 percent. If a LEC chooses to lower its set prices further by using a higher productivity offset of 4.3 perent, the LEC can retain more of its earnings if it subsequently is able to earn higher profits through improved efficiency. In this case, the LEC can retain all of its earnings up to 2 percent above 11.25 percent. LECs would share with their customers 50 percent of their earnings between 2 to 6 percent above 11.25 percent, and share 100 percent of their earnings above 17.25 percent. The FCC also proposes a lower end adjustment mechanism. If a LEC's earnings drop below the lower end figure established, i.e. 11.25 percent, the LEC is entitled to a prospective automatic upward adjustment to its cap.

V. Problems in Using Productivity in Price Cap Regulation

A reasonable and acceptable productivity growth rate to be used in the price cap formula for the telecommunications service industry should be computed by a direct measurement approach with an appropriate measurement of the prices and quantity of the inputs and outputs.

A. Difficulty in Measuring Productivity for the Telecommunications Industry

As we discussed in the Section II above, specifying a "right" set of inputs and outputs is an important step in the direct measurement of productivity for an industry or a firm. Determination of the aggregation level of inputs and outputs is subject to the production technology and data availability for the specific industry or firm. The more disaggregation there is in inputs and outputs, the better the productivity measure.

For example, in the production process of local telephone services, a local exchange carrier transports subscribers' telephone calls over copper wires to a centrally located switching point, establishes computer-controlled connections to other subscribers, and transports calls to neighboring

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[14] See the FCC Second Report and Order at 36-46.

switching points over high-capacity cables or microwave radio links. Mitchell (1990) has divided the functions of local exchange production into: the local loop, the central office switch, and interoffice transport. He then categorized the local loop into feeder, distribution and structures[15]; digital switches into the 5ESS switch (AT&T), the DMS100 switch (Northern Telecom), and the GTD-5 switch (AG Communication Service); interoffice transport facilities into metallic cable, fiber optic cable, and microwave radio links. Duncan (1990) has defined the inputs and outputs for GTE's telephone service in his productivity study as:

fixed input K2:	switching equipment;
fixed input K3:	transmission equipment;
fixed input K4:	land, buildings, furniture and office equipment, vehicles and other equipment, organization, and materials and supplies;
variable input W1:	non-maintenance labor;
variable input W5:	maintenance labor;
variable input W7:	non-labor variable inputs;
output:	sum of local and toll calls;
output:	the average call duration;
output:	the number of lines.

Oniki, Oum and Stevenson (1989) measured the Nippon Telephone and Telegraph Company's (NTT's) productivity by defining its inputs as capital (equipment and circuits, buildings and other equipment), labor, and materials and its outputs as toll and public phone, private lines and telegrams and telexes.

These different specifications of inputs and outputs in the productivity studies are expected to have different results. Particularly, the non-homogeneity of outputs in the telephone service industry due to the variety of its telephone services have made it harder to measure its productivity precisely. Another important dimension of output, i.e. the network, is usually ignored in service industries as telecommunications. The outputs in the service industry are dispensed or delivered through its network. There may be economies of scale in expanding outputs on a given network, but diseconomies of scale associated with network expansion. Both of these scale effects should be separated from other sources of productivity growth.

B. Weakness in Direct Measurement of Productivity: Ignoring Quality Change

In most of the previous productivity studies reviewed by the FCC as listed in Footnote 10, total factor productivity

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[15] Structures here include poles, conduit, manholes, and associated equipment.

growth was measured directly. The major sources of input and output prices in these productivity studies have been taken from either the U.S. Department of Labor, Bureau of Labor Statistics (BLS) or the U.S. Department of Commerce, Bureau of Economic Analysis (BEA). The price indices from these sources were developed by the so called "matched model method." This method assumes the quality of products remains the same through time and ignores quality changes due to rapid technological change. Since there is no quality change adjustment in these studies, their results overstate prices and understate output. The resulting estimates of TFP growth must be much lower than the true productivity growth, after quality-change adjustments.

The importance of a quality-change adjustment in the measurement of productivity, particularly for information-technology industries and their associated service industries, is demonstrated clearly in Jang and Norsworthy (1988a and 1988b) and Norsworthy and Jangs' (1991) productivity study. The study is based on an analysis of the computer industry which is a useful proxy for the telecommunications industry. Jang and Norsworthy computed the TFP growth for the U.S. computer industry by a direct measurement approach, with a quality-adjusted price index developed by Cole et al. (1986) at IBM and Triplett (1989) at BEA. This quality-adjusted price index for computers is the first official price index in the National Income and Product Accounts, taking account of the changes in the performance characteristics of computer systems[16].

The quality-adjusted price index for computers has dramatically declined from 2422.7 in 1959 to 20.4 in 1982. In contrast, the official price index for semiconductors, without quality adjustment, has slightly increased from 129.5 in 1959 to 142.6 in 1982. The price decline for computers is mainly due to rapid technological change which has a significant effect on its productivity growth. Based on the quality-adjusted price index, Jang and Norsworthy[17] measured the average annual rate of productivity growth for computers. It is about 26.31% during the period 1959-81 as shown in Table 1.

Semiconductors, computers and telecommunications equipment are major inputs in the telecommunications services industry. The rapid albeit unmeasured technological change incorporated in these inputs has played a critical role in the decision to deregulate in the telecommunications service

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[16] No other studies have made comparable modifications to the price indices of other high-tech products such as semiconductors, telecommunications equipment and service etc.

[17] See Jang and Norsworthy (1988a) and Norsworthy and Jang (1991).

industry. To measure a reasonable and acceptable productivity growth used in the price cap formula for the telecommuncations service industry, it is thus necessary to measure the prices and quantity of its inputs and outputs properly so that the likely impacts on future productivity due to technological change on the inputs and outputs can be considered.

C. Approaches for Developing Quality-Adjusted Price Index:

There are several approaches to developing a quality-adjusted price index. An hedonic regression approach is used to estimate quality-adjusted price index for computers in the Cole et al. study, in which the computer performance characteristics such as speed and memory capacity etc. are incorporated. Another approach is cost function estimation of quality change developed by Norsworthy and Jang (1990). They have applied this approach to build the quality-adjusted price indices of semiconductors as an input used in the various industries in Table 2. Based on their quality-adjusted price index for semiconductors, the associated productivity growth for the U.S. microelectronic industry during the period 1960-80 is computed in Table 3. The average annual rate of total factor productivity growth for the microelectronic industry, after quality adjustment of its output price, is 49.34%, which is substantially higher than those before quality adjustment of 5%. More important, the study provides an estimate of how much productivity growth in the computer industry derived from changes in semiconductors: about 60 percent. A forecast of productivity growth for the computer industry can therefore be based on reasonable projections of the productivity effects of technological change in semiconductors and scale effects based on reasonable output growth expectations.

Studies of this nature have not yet been performed for the telecommunications service industry. However, the results of these studies suggest the productivity growth for the telecommunications service industry should be very different from the results in the previous productivity studies. They are analogous to the telecommunications industry, although no such study has been conducted to date.

D. Weaknesses in the Indirect Measurement of Productivity:

There are weaknesses in both indirect measurement approaches on which the FCC's proposed productivity offset for the LECs is based. The indirect measurement of output price difference refers to the method whereby the telecommunications productivity growth is defined as the difference between the rate of growth in telephone prices and the growth in the entire economy. The objection to this output price difference approach is based on the fact the growth rate for telephone prices can be attributed to both productivity gains and increases in input prices. Thus, one can use output price differences to estimate productivity growth differences for two entities only under the assumption that (1) excess profits are zero in every period and (2) input price growth is the same for the two entities. These assumptions are clearly not valid in the telecommunications industry, where wage gains have exceeded the national average.

The "break-even" productivity approach starts from the assumption that price, set under a rate of return regulation regime, is based on efficient costs. This is a paradoxical assumption because the demand to alter the current regulatory regime is founded on the notion that rate of return regulation does not provide incentives that insure that firms act efficiently. It assumes that price changes are caused either by input price change, other exogenous forces, or productivity gains as shown in the above price cap formula. The unknown productivity factor then can be computed by subtracting the price changes occurring under rate of return regulation from the sum of both inflation estimate and exogenous factors.

These two indirect approaches are based on unreasonable assumptions. Therefore, the productivity factors computed from these indirect approaches are very likely to be biased. A direct measurement of productivity growth is inherently superior to the indirect estimates.

E. Other Problems of Applying FCC Price Cap Formula

After a productivity factor is measured by a direct approach with the incorporation of quality change as discussed above and applied to FCC price cap formula, one still cannot be certain that an appropriate price cap for telecommunications products is developed. The reason for that is there are other problems with this formula. These problems are: (1) imported materials are excluded from computation of GNP-PI; (2) it is questionable how best to define the appropriate "baskets" for price capping; (3) using simple projections of historical productivity growth to forecast future productivity may create expectations that cannot be fulfilled.

1. GNP-PI Excludes Imported Materials The FCC used the Gross National Product Price Index (GNP-PI) as a measure of changes in the costs of input factors of production for the whole economy. The GNP-PI does not include prices for the imported materials. Since the importance of international trade has increased substantially in the last few decades in the U.S., particularly in the manufacturing sector, the fact that the price ceiling derived from the price cap formula does not reflect the costs of the imported materials and subassemblies has become more important. Further, prices of inputs change in response to exchange rate fluctuation as well as production costs in foreign countries, and are thus more volatile than domestic prices.

2. Grouping "Baskets" In order to simplify the administrative work, the FCC divided all of AT&T's services into three baskets, divided the LEC's services into four baskets and implemented its price cap formula separately for each of them. The three baskets for AT&T services are the residential and small business basket, the 800 service basket and the business services basket. The four baskets suggested by the FCC for the LEC's services are common line services, traffic sensitive services, special access services and interexchange services. The FCC believes that imposing an aggregate cap on a basket of services instead of using one cap on all of services would assure regulatory control over prices charged to the class of consumers of services within the basket, and prevent cross-subsidization of services across different baskets.[18]

Putting other issues such as cross-subsidization and competition aside and focusing only on the productivity factor in the price cap, the FCC's implementation of the aggregate price caps on the various baskets has implicitly assumed that the services within the basket are homogeneous and have the same productivity factor. This assumption is not reasonable because the services within each basket vary substantially. For example, the residential and small business basket for AT&T services can be further divided into six service categories[19]: (1) Domestic day; (2) Domestic evening; (3) Domestic night/weekend; (4) International MTS; (5) Operator and credit card services; and (6) Reach Out America. There are seven service categories in the AT&T's business services basket: (1) Pro America I, II, and III; (2) WATS; (3) Megacom; (4) SDN; (5) other switched; (6) voice grade private line and below; and (7) other private line. Grouping baskets improperly has a significant impact on the measurement of productivity for each basket in the price cap regulation.

Further, grouping services into baskets and projecting productivity gains at historical rates for these baskets implicitly projects historical productivity gains from economies of scope (as well as scale) into the future. Past productivity gains from economies of scope are the result of the patterns of technological change in plant, equipment and organization of the past. It is dubious that their future

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[18] See the FCC Second Furhter Notice at 166.

[19] The FCC also divides the LEC's services in the traffic sensitive basket into three service categories: (1) local switching; (2) local transport; and (3) information and divides special access basket into four service categories: (1) voice grade / WATS / metallic / telegraph; (2) audio / video; (3) high capacity / digital data service; and (4) wideband data / wideband analog. According to the FCC's price bands, it allows the prices for these service categories to move on a streamline basis by plus or minus 5 percent per year based on its own existing rate element.

effects even on the aggregate of all baskets of services will be the same as in the past; it is highly unlikely that their effects will persist for any particular grouping of services into three or four baskets. While the desire to avoid undesirable cross-subsidies among baskets is well-intentioned, this particular means of achieving it is likely to produce far more contention and litigation than equity.

3. <u>Historical Productivity Growth as a Forecast of Future Productivity</u> The FCC's productivity factors for both AT&T and the LECs are drawn from several empirical studies which are mainly based on historical data series. Their use implies that the patterns of productivity growth and technological change in the telecommunications industry are assumed to be the same as those in the future, and that the earlier studies are sufficiently accurate for the purpose. Granting the latter proposition, the former assumption is not likely to be true. For example, the decade of the 1980s was a period of significant change in the structure of the industry. These changes included the AT&T divestiture, the introduction of the concept of equal access, and the perceived threat of competition. Each of these changes had impacts on productivity.

The AT&T divestiture divided a complex corporation into eight parts, seven regional holding companies and AT&T. Duplication of some administrative costs may have a negative impact on productivity in the short term, but may have a positive effect on productivity in the long run due to the increase in competition. In response to the Modified Final Judgment (MFJ) mandate to provide equal access, telephone companies accelerated the replacement of electro-mechanical switches by electronic switches. This replacement program increased the ratebases of the companies, and therefore, increased the revenue requirement associated with rate of return regulation.

The productivity of the telephone companies may well differ in the 1990s from in 1980s. The two major factors for this trend are the absence of the unique nonrecurring circumstances of the 1980s and the productivity gains embodied in the recent investment such as fiber optics transmission facilities and digital switches[20].

The purpose of applying productivity factor in the price cap formula is to estimate (or "forecast") future productivity for the telecommunications industry so that FCC can set up a future price cap on the regulated telephone companies. Therefore, it is obvious that the FCC's use of historical

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[20] Note that realization of these gains may require faster than scheduled depreciation of existing facilities and switching equipment. This depreciation due to obsolescence will require larger depreciation allowances or higher nominal rates of return to allow recovery of capital costs. (Jang and Norsworthy, 1990)

productivity performance fails to meet this objective credibly.

VI. Conclusions

In the price cap formula adopted by the FCC to set up the price ceiling for AT&T and the LECs, productivity is one of the major factors to offset the production costs. After reviewing the FCC's determination of productivity factor, several problems in using productivity in the price cap are indicated and discussed. In the FCC's proposal, the productivity of the LECs is measured indirectly by two approaches: (1) output price difference approach and (2) "break-even" productivity approach. These two approaches are based on unreasonable assumptions. Several previous studies in AT&T productivity, reviewed by the FCC for price cap regulation, used a direct measurement of productivity. Although the direct approach is superior to an indirect approach, the FCC's method is still flawed because it ignores the adjustments for quality change of inputs and outputs due to rapid technological change. Therefore, the productivity factors from these studies are biased. In this paper we not only illustrate the concepts and measurement of productivity by growth accounting approach and econometric approach, but we also discuss two approaches, i.e. hedonic approach and cost function estimation approach, for developing a quality-adjusted price index for productivity measurement. A reasonable and acceptable productivity growth rate to be used in the price cap formula for the telecommunications service industry should be computed by a direct measurement approach with an quality-adjusted measurement of the prices and quantity of the inputs and outputs.

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TABLE 1
AVERAGE ANNUAL RATES OF PRODUCTIVITY GROWTH
IN U.S. COMPUTER INDUSTRY (SIC 357)

	Total Factor Productivity Including Scale Effect		Capital Productivity		Prod. Workers Productivity		Nonproduction Workers Productivity		Materials Productivity	
	SIC 357	Manuf.	SIC 357	Manuf.	SIC 357	Manuf.	SIC 357	Manuf.	SIC 357	Manuf.
1959-67	31.23	0.58	31.08	1.12	37.56	1.48	34.98	1.07	27.66	0.20
1967-75	29.42	0.87	15.50	-2.12	24.88	2.64	18.97	0.81	20.95	0.55
1975-81	26.60	1.39	24.75	-0.45	31.03	2.56	25.58	1.57	26.87	1.27
AVERAGE	26.31	0.91	24.11	-0.48	31.45	2.20	26.90	1.11	25.27	0.66

	Total Factor Productivity Including Scale Effect	Scale-Adjustment Factor	Scale-Adjusted Total Factor Productivity
	SIC 357		
1959-67	31.23 (100%)	27.82 (89.08%)	3.42 (10.92%)
1967-75	20.42 (100%)	14.87 (72.82%)	4.90 (27.28%)
1975-81	26.60 (100%)	26.25 (98.68%)	2.23 (1.32%)
Average	26.31 (100%)	22.68 (86.20%)	3.63 (13.80%)

Source: This is Table 5.12 in chapter 5 of Appendix A, Empirical Measurement and Analysis of Productivity and Technology Change: Application in High Technology and Service Industries, J.R. Norsworthy and Show-Ling Jang, to be published by North-Holland.
The annual rates of productivity growth for U.S. computer indu are computed on the basis of quality-adjusted price index of computers developed by Rosanne Cole et al (1986) and J.E. Trip (1989).

Table 2: Semiconductor Price Indexes After Quality Adjustment for Three Industries, 1977=100

Year	PPI	Quality Adjusted Prices Based on Technological Characteristics of Semiconductors Used In		
		SIC 3661	SIC 3662	SIC 3573
		Telephone & Telegraph Equipment	Other Telecomm. Equipment	Computers
1969	108.2	4912.9	5074.5	11458.3
1970	103.5	2845.1	2825.0	3576.1
1971	105.3	1673.0	1511.2	2884.0
1972	103.2	987.2	934.3	1539.6
1973	103.1	607.1	571.7	866.3
1974	103.0	406.5	383.0	528.0
1975	102.2	256.8	247.2	300.4
1976	103.2	158.1	154.0	170.4
1977	100.1	100.0	100.0	100.0
1978	101.4	63.4	65.5	59.0
1979	101.9	41.4	33.9	36.3
1980	104.7	29.0	33.2	23.8
1981	111.9	19.0	23.2	15.0
1982	111.2	12.3	16.1	9.2
1983	110.4	8.8	12.4	6.3
1984	111.7	6.2	9.7	4.4
1985		4.2	7.3	2.9
1986	119.5	3.0	5.7	2.1

TABLE 3
Average Annual Rate of Output and Productivity Growth in
U.S. Microelectronics Industry: 1959-1981
Before and After Quality Adjustment of Output

Time Period	Total Factor Productivity		Capital Productivity		Production Worker Productivity		Nonproduction Worker Productivity		Materials Productivity		Output	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	Afte
60-67	5.02	64.31	0.03	49.83	9.09	58.89	9.66	59.47	2.54	52.34	14.51	54.
67-73	5.62	45.43	3.70	43.13	6.61	46.03	5.81	45.24	5.35	44.78	5.00	45.
73-80	5.24	53.05	3.04	45.35	8.47	50.79	5.44	47.76	4.62	46.93	10.74	53.
60-80	5.00	49.34	2.45	46.25	7.87	52.20	5.62	51.10	4.06	48.18	10.61	54.

Source: This is Table 6.17 in chapter 6 of Appendix, Empirical Measurement and Analysis of Productivity and Technological Change: Application in High Technology and Service Industries, J.R. Norsworthy and Show-Ling Jang, to be published by North-Holland.

The annual rates of productivity growth for U.S. microelectronics industry are computed on the basis of the quality-adjusted price index of microelectronics developed by J.R. Norsworthy and Show-Ling Jang.