OPERATIONAL EFFICIENCY IN TELECOMMUNICATIONS

PART I: A Pilot Inter-Firm Comparison

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The opinions and statements expressed in this paper represent views of the authors. These views are not necessarily those of the federal Department of Communications or of any other department or agency of the Government of Canada.

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Introduction*

This portion of the final report discusses our work on inter-firm comparison. The primary empirical basis for the pilot project was the public data bases developed by the companies. The substantial work by the companies in producing these data bases and making them public has made this pilot study of intra-firm comparison possible. The procedures used by the companies to generate the data differ. In a separate section of this report we have documented (a) the current methods used by the firms (b) specifications for an interim data base and (c) proposal for a common methodology for the future. For the purposes of the pilot inter-firm comparison, we have used the public data base. This was necessitated by the absence of any alternative. The material for the interim data base was only partially available and could not be fully incorporated into out current inter-firm comparison. Additional data has been provided by the companies as part of the interim data base and we have used that data to supplement the public data base. This extra data, while not directly used in the comparison, has been very useful to evaluate the results obtained from the pilot comparison. However, it is still true that as further data become available the quality of our comparison can be improved at what we believe are reasonable costs.

The comparison was undertaken for three of the four companies for which we had data. Teleglobe Canada, one of the North American pioneers in the use of productivity has been exceedingly helpful with this project. The international services which Teleglobe produces are quite similar to the domestic services which BC Tel., AGT and Bell Canada produce. However, the production methods, via broadband satellite and multi-channel undersea

* We wish to thank John Veitch whose talent and persistence made this task much easier and the results better.

cable with no local distribution, are distinctly different. For this reason, we have not integrated Teleglobe into the inter-firm comparison. In the early portion of our analysis we do consider Teleglobe briefly. During our further work it would be interesting to compare some aspects of the domestic toll network with the overseas network of Teleglobe. Alternatively a comparison of Teleglobe with other Overseas networks would be very useful.

The pilot comparison for the three domestic firms was undertaken using the methodology discussed in last year's report (Denny, de Fontenay, and Werner 1980a). Since this is a departure from many earlier attempts at comparisons, we have also made the comparison using alternative methods. The first section of this report provides a non-technical introduction to the methods that we have used for the comparison. This is followed by a critical analysis of the alternative methods. A more sympathetic although incomplete discussion of alternatives may be found in Kravis (1975, 1976). The results from the alternative methods are contained in an appendix.

The first empirical section considers regional, not company, variations in the use of different transmission systems, the calling rates and the number of telephones in service. Data is compared for the provinces of British Columbia, Alberta and a Central region comprised of Ontario and Quebec.

The following section provides the core results on the inter-firm comparison. In brief, these results state that there is a very small efficiency differential between BC Tel. and Bell Canada in any given year from 1972-79 and no prevailing trend is evident. AGT had a lower relative efficiency level than Bell in 1967 or BC Tel. in 1972. However, the average productivity growth rate at AGT has exceeded that of either BC Tel. or Bell. By 1979, AGT's relative efficiency level exceeded those of the other two firms.

How seriously should we take these results. The remainder of the report is devoted to this question and some introductory remarks are required. First, we have purposively concentrated on the adequacy of the data which our method (or any of the alternatives) require. This is a sensible choice since it integrates the work on the pilot comparison with the task of specifying a desirable data base. The cost of this choice is that we have not explored the non-economic factors that might influence the results. We believe that the economic factors are important, perhaps predominant,but geographic, demographic and social factors should be expected to play some role. The relative efficiency level, like relative profitability, does not describe the complete relative health of a firm. Neither is it insignificant.

Our explorations of the data bases have clarified several problems that require further work. As the interim data base becomes available in more complete form and we integrate it into the comparison, a more secure set of results will be deduced. The current results do not portray enormous differences between the companies. Professor Denny's prediction of the impact of the new data is an improvement in relative performance for BC Tel. and perhaps a decline for AGT relative to the other companies in each case.

We will close this introduction with a word of caution. Telecommunications is a very political industry and comparisons such as ours are potentially subject to abuse. We hope that the reader will remember that this is a pilot project. More importantly, if one wishes to understand what we have to say there is no substitute for careful reading without any grasping at sharp final conclusions. We are satisfied that this is a very good beginning but we do not believe the task is complete.

2. Comparing the Efficiency of Firms

This section of the report is intended to be a non-technical introduction to the comparison of firms' efficiency. A more technical discussion is contained in last year's report, Denny, de Fontenay and Werner (1980) and in Denny and Fuss (1980). In particular, the development of new methods which we will be using in our telecommunications study are discussed. We will distinguish two broad approaches to comparative efficiency. The accounting method attempts to derive from data on the prices and quantities of inputs and outputs a measure of relative efficiency. It is a segment of economic index number theory. The simplicity of this method makes it very appealing and it will undoubtedly be widely used. Properly understood these methods can be very helpful and our discussion will concentrate on these methods.

The alternative econometric approach requires much more information but holds out the potential of a far richer interpretation and understanding. If sufficient data is available, statistical procedures exist which will permit the estimation of the production technology of the firm. With these statistical results comparisons are possible which are more diverse than those available from the accounting procedure. The difficulties with this method are rooted in the veracity, sensitivity and reliability of the econometric results. Since these are not specifically problems associated with comparing efficiency levels and there is a very large literature associated with these problems, we will not discuss these problems in this section.

We will begin with an interpretation of the meaning of the relative efficiency of firms. Crucial to this interpretation is the concept of the production function which implicitly appears in all our work. This will be followed by a discussion of the particular accounting method we prefer. Since our method is relatively new, we will include a critical discussion of the possible alternatives.

2.1 The Production Technology

Underlying any method of measuring productivity are some implicit or explicit assumptions about the production technology. This technology can be represented by either a production function or a cost function.[1] The production function is a construct that represents in abstract fashion the simple ideas that (1) outputs cannot be produced without inputs, (2) different input bundles permit you to produce different output bundles (3) the same output bundle may be produced by different input bundles (and vice versa) and (4) for any input bundle, there is an upper limit as to how much of any output(s) can be produced.

Measures of productivity or efficiency are related to the production technology in several ways. First, all efficiency measures involve a comparison of the output level produced relative to the inputs used. Therefore these measures are concerned with the relationship between the volume of output that firms can produce with various input bundles. This is obviously related to the production technology. More formal relations can be developed by noting that any particular efficiency measure implies some assumptions about the production technology.[2] We know for example that the use of a particular index number formula implies that the production technology must have a particular form. Often the particular form of the technology can be written down explicitly although this need not be true for our argument. Similarly, efficiency formulas that use only an incomplete list of inputs or reduce output to value-added can be interpreted as implying specific restrictions on the technology in the latter case and implicit assumptions about the role of other inputs in the former case.[3]

The production technology provides a framework to interpret all work on productivity. We will retain it throughout this discussion since without this structure very little can be said about the measurement of efficiency.[4]

2.2 Comparing Firms

Suppose we knew the production function (or cost function) for each firm. Algebraically we can represent this function by,

$$Q_i = f_i(K,L) \qquad\qquad i \text{ - indexes the firm}$$

where output Q is produced using inputs capital (K) and labour (L). Select any input bundle $X_0 \equiv (K_0, L_0)$ and calculate

$$Q_{i0} = f_i(K_0, L_0) \qquad ,$$

for all firms. A particular firm i is defined to be more efficient at this input bundle X_0 than firm j if $Q_{i0} > Q_{j0}$. That is the more efficient firm i produces more output for a given input bundle than the other firm j. For any number of firms one can rank the firms using this procedure. If desirable, the proportional difference in the output levels between any two firms may be defined as the relative efficiency level. An index can be constructed by choosing any single firm as having an efficiency level of 100 and all other firms can be compared to this firm.

Notice carefully that we chose a particular input bundle X_0 for the comparison. Is the comparative ranking independent of this choice? In general the answer is no, although many methods implicitly assume the opposite. The methods we prefer permit the answer to depend on the input bundle chosen. While this complicates the comparison it is a desirable feature. Some firms may be more efficient than others for some input bundles and not for others. This is a sensible possibility that we do not wish to eliminate. To illustrate this situation, consider Figure 1. Output is produced with labour only in this two dimensional example. Firm Two is more efficient at input levels less than H while Firm One is more efficient at higher input levels. While the geometry becomes complex, the extension to more outputs and inputs can be done algebraically.

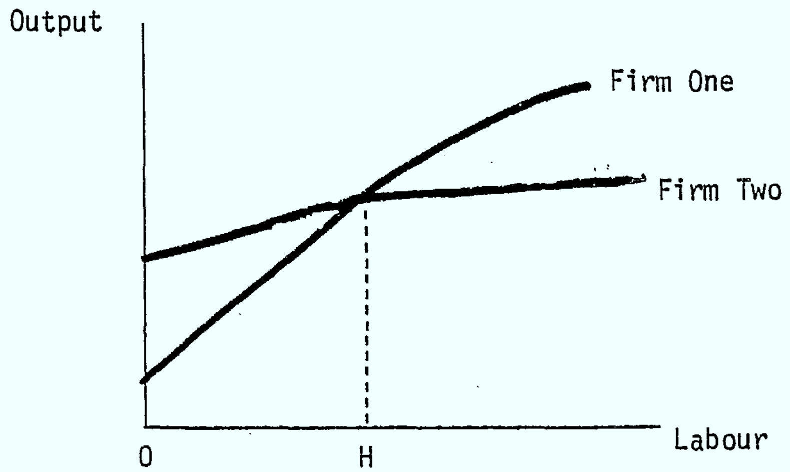

Figure 1

If we want to use cost functions, a similar procedure must be used. Assuming that we know the cost functions, $g_i(w_K, w_L, \bar{Q})$ for each firm, choose a particular input price for capital, w_{K0}, and labour, w_{L0} and an output level Q_0 and calculate total costs,

$$C_{i0} = g_i(w_{K0}, w_{L0}, Q_0)$$

for each firm. The firm with the <u>lowest</u> cost is most efficient. The remarks made about the input vector, X_0, pertain here to the input prices w_{j0} and output level, Q_0.

Provided we have enough information on the technology, our general methodology is very simple. At any specified input bundle, the firms' output level produced from those inputs is compared. The efficiency ranking and levels may be different for different input bundles. We do <u>not</u> have all the required information and most of our efforts must be directed towards using the limited information available.

Two broad types of methods can be distinguished. There is the index number or accounting method on which we will concentrate here. Second there is the econometric method which we will only briefly discuss.

The econometric method requires a sufficient quantity of quality data to permit the estimation of the production and/or cost function. With these estimates, one can directly calculate the comparisons discussed above. There are a number of difficulties in obtaining the estimates of the technology. These will not be discussed in this portion of our work. When this method is used a discussion of any problems will be included.

The accounting method requires that we extract from limited information a measure of relative efficiency without knowing the complete production technology. With this method there is no requirement that we know the details of the production function. How are we going to attain a comparison without knowing the specific technology of the firms?

The accounting method we prefer can now be outlined. The basic requirement is that we must be able to measure the relative efficiency of the firms using only data on the quantities and prices of the inputs used and outputs produced. This is a relatively weak data base but we wish to eliminate the necessity of using complex statistical procedures or a reliance on other people's estimates.[5] The technology of any firm is to be represented by a second-order approximation. As noted above, all methods must make some implicit or explicit assumption about the production technology. In this case, we will assume that a second order approximation to the true unknown technology is adequate. This does not presume a knowledge of the exact function, only the general type of second order function which can approximate <u>any</u> true unknown technology to the second order. In particular, an approximation in the logarithms of the outputs and inputs will be used in the case of production function. There are specific reasons for these decisions. The second-order approximation is used because it will not be possible to use the limited data available with a higher order approximation. In fact we will use a quadratic function as the second-order approximation. This is also required by the limited data as we will explain more completely below. The choice of the logarithmic form is not necessary but it has one major advantage. We will be able to directly link our method to the most prevalent measure of productivity and to the pioneering method of measuring intra-firm efficiency.[6] However for some purposes one may wish to give up these links.

The next few pages may be excessively technical for some readers. However it is suggested that the algebra be omitted and the text read in order to perceive in non-technical terms our procedures. Assume that the technology of the firm can be approximated by a quadratic form in the logarithms of the variables of the cost or production function. In this case, Diewert's Quadratic Lemma[7] states that the difference in the logarithm of output between two firms can be expressed <u>exactly</u> as a weighted sum of the differences in the logarithms of the inputs and a term which we will interpret as the difference in the productivity level between firms.

Let the production function for all firms be written

$$Q = f(K, L, D) \tag{1}$$

where D is a discrete variable indexing the firm. This representation restricts the differences in the approximation to each firm's technology. That is each firm's technology is approximated by a function which cannot be completely different for each firm. This is required for our method and a similar restriction is required for any accounting method.

Given the production function for each firm equation (1), we assume that we may approximate this production function by a quadratic function in the logarithms of the output and inputs. The Quadratic Approximation Lemma states that,

$$\log Q^i - \log Q^j = \tfrac{1}{2}[f_D^i + f_D^j][D^i - D^j] + \tfrac{1}{2}[f_K^i + f_K^j][\log K^i - \log K^j] + \tfrac{1}{2}[f_L^i + f_L^j][\log L^i - \log L^j] \quad (2)$$

where f_z^i is the partial derivative of the production function with respect to the z-th argument evaluated at the i-th firms input vector.

The approximation to the production technology must be quadratic if equation (2) is to hold. The key property of (2) which requires the quadratic assumption is the presence of <u>only</u> first order derivatives. If non-quadratic approximations are used then the correct replacement for (2) will involve terms which include the second order derivatives of the production function. These second order derivatives are related to the curvature of the production function and consequently to the prices elasticities of factor demand. Unless one knows the price elasticities, which is very unlikely, it will not be possible to use accounting methods with expressions that include these second order derivatives. Since we cannot see any reasonable possibility of including more complex information requirements, the quadratic assumption is strongly recommended as a practical necessity.

The differences in the firms inputs and technology are weighted by the average of the first order derivatives. For the accounting method we must relate these derivatives to observable data. In the logarithmic case the derivatives are the shares of the inputs in total cost under the assumption that firms minimize costs in competitive markets. If one did not make the logarithmic assumption then one would find that these weights are not the average shares. In that case one might or might not be able to relate the weights to price and quantity data. It will depend on the particular case. One must be careful not to choose some alternative to the logarithmic case which is impossible to apply with observations on only the prices and quantities of inputs and outputs.

In the logarithmic case, equation (2), the assumptions of constant returns to scale and competitive markets will permit us to rewrite the expression

$$\log Q^i - \log Q^j = \theta_{ij} + \tfrac{1}{2}[s_K^i + s_K^j][\log K^i - \log K^j] + \tfrac{1}{2}[s_L^i + s_L^j][\log L^i - \log L^j] \quad , \qquad (3)$$

where s_h^i is the cost share of input h in firm i and θ_{ij} is the raw measure of the efficiency differential between firms i and j. To provide an easier interpretation of the efficiency differential, we prefer to define

$$E_{ij} = \exp(\theta_{ij}) \quad .$$

The transformation to E_{ij} permits us to make the following interpretation. The efficiency differential, E_{ij}, is the output level in firm i relative to that in firm j after accounting for differences in the levels of inputs used by the two firms.[8]

Recall that in the beginning we stated that we wished to consider the output levels produced by each firm with a given input bundle X_0. Our actual observations on input bundles are unlikely to be identical. To adjust for differences in the input levels across firms, some of the observed differences in the output levels are attributed to the observed differences in the input levels. It is not possible to compare the firms at identical input quantities unless we know the particular technologies of the firms. Our method is an alternative which states that for certain classes of technologies we know exactly how differences in output levels must be allocated between efficiency differences and differences in the quantities of inputs.

An intuitive indication of how this method works can be given using Figure 2.

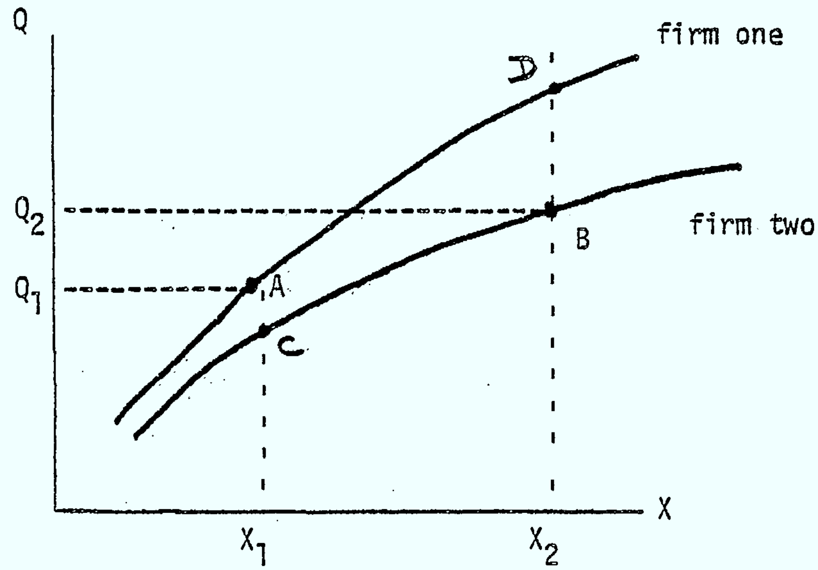

Figure 2

The production function for two firms is shown in an example in which there is only one input, X. Suppose we observe firm one using input quantity X_1 and firm two using the quantity X_2. Since we also observe the output quantities Q_1 and Q_2, our observations may be represented by the points A and B in Figure 2. We only know these two points and we do not know the production functions themselves. We would like to compare the output levels of the two firms when they were both using exactly the same input quantities. For example, if both firms were using the input quantity X_1, the difference in the output levels is AC. Alternative BD is the difference in the output levels when both firms use input quantity X_2. Since we do not know the production functions and cannot observe the points C and D what does our method measure?

Our method measures the average of AC and BD with one qualification. Since we are only approximating the true production functions, we are measuring exactly the average of AC plus BD if the curves in Figure 2 are the approximations to the production function. If they are the true productions firms then our method approximates the average of AC and BD.

With only data on the prices and quantities of inputs or outputs, alternative methods are unlikely to dominate this method. We will now consider some of these alternatives.

2.3 Alternative Methods

Since the procedure we have been discussing has only recently been developed, I will consider the alternatives that have often been applied. It is possible to argue that there has only been one alternative measure although it has been applied in a number of variations. The major studies by Gilbert and Kravis (1954), Gilbert et. al. (1958) and Kravis et. al. (1975, 1978) have used variants of this methodology. In Canada, comparisons of the U.S. and Canada have also used this method, West (1971), and Walters (1968, 1970).

It will be useful[9] to define a revenue function, $R(p,X)$, where $p = (p_1,\ldots p_n)$ and $X = (X_1,\ldots X_m)$ are vectors of output prices and input quantities. The revenue function is defined as the maximum revenue that a producer can obtain at output prices, p , when using input quantities, X . For example, if we observe a firm which produces at output levels, Q_i, and sells output at prices p_i then $R(p,X) = \sum_i p_i Q_i$. This assumes that firms attempt to maximize revenue in the markets in which they sell.

Consider an efficiency comparison between two firms. Each firm is observed to produce outputs Q_i^j which are sold at prices, p_i^j where $j = 1,2$, indexes the firms. Suppose we define a relative efficiency variable, LP, measured as aggregate output (Q^j) per manhour (L^j). How are we going to aggregate outputs for each firm? A common procedure is to calculate two aggregate outputs for <u>each</u> firm. One uses the output prices of the other firm and the other aggregate uses its own prices. Define Q_j^k, the aggregate output,

$$Q_j^k = \sum_i p_i^k Q_i^j \quad ; \qquad j = 1,2; \qquad k = 1,2 \ .$$

This formula will provide the basis for two productivity comparisons, Firm One's Prices: $LP_1^1 = Q_1^1/L^1$ vs $LP_2^1 = Q_2^1/L^2$

Firm Two's Prices: $LP_1^2 = Q_1^2/L^1$ vs $LP_2^2 = Q_2^2/L^2$

where the first pair use firm one's price weights and the second pair firm two's price weights. Is it possible to interpret these results to provide some understanding of what they mean?

Consider the output aggregates Q_1^1 and Q_2^2 . These can be interpreted as $R_1(p^1,X^1)$ and $R_2(p^2,X^2)$, the revenue functions for firms one and two evaluated at their actual output prices and input quantities. The output aggregates Q_1^2 and Q_2^1 are not equal to any revenue function but do satisfy the following inequalities,

$$Q_1^2 \leq R_1(p^2,X^1)$$

$$Q_2^1 \leq R_2(p^1,X^2) \quad .$$

These inequalities must hold since in calculating Q_1^2 for example, firm two's prices are used to aggregate firm one's observed outputs. However if firm one actually had the opportunity to sell at firm two's prices, it would probably choose a different output vector than the actual observed output vector chosen at the actual prices for firm one. Given the definition of the revenue function, $R_1(p^2,X^1)$ must be the maximum revenue attainable at these output prices and input quantities. Consequently it must be at least as large as Q_1^2 .

Rewrite the first comparison, LP_1^1 vs LP_2^1 , as

$$R_1(p^1,X^1)/L^1 \quad \text{vs} \quad Q_2^1/L^2 \leq R_2(p^1,X^2)/L^2 \quad .$$

Using firm one's prices we have aggregated the output of both firms and divided by the respective labour input quantities. Firm two will do relatively poorly in this comparison since $Q_2^1 \leq R_2(p^1, X^2)$. I would argue that it is the unobserved $R_2(p^1, X^2)$ that should be used as aggregate output. Since it is not observed it is replaced with Q_2^1 which is probably smaller. The relative performance of the firm whose prices are not used will be underestimated by this method.

The other comparison, at firm two's prices has similar problems associated with the underestimate of firm one's efficiency when evaluated at firm two's prices.

A possible conclusion might be based on the following argument. Suppose firm one is more efficient when both its own prices and firm two's prices are used as weights. Can we conclude that firm one is more efficient? At firm two's prices, firm one's performance is underestimated. If it is more efficient as measured then it certainly must be more efficient when correctly measured at these prices. However the bias goes against firm two when firm one's prices are used. Consequently even if firm one is measured as more efficient it may not be so if correct methods were used. At best this method can establish which firm is more efficient only if the firm whose prices are not used is more efficient (as measured) than the firm whose prices are used. This implies that the only joint outcome of the two comparisons which is unambiguous must be conflicting. Each firm is more efficient at the others prices.

This method generates two comparisons which do not correctly evaluate the efficiency of firms whose prices are not used. What is the difference between the two comparisons? In general, an empirical comparison may give different answers at every set of data for the firms. There is no sensible way of comparing the two relative efficiency measures. Each is as good as the other since they purport to compare the firms at different output prices. In neither case do we have the required data on the revenue functions and even if we did the relative efficiency levels may change as one selects different input and output vectors.

Our example was simplified by choosing a labour productivity measure. This was done because most of the previous comparisons, particularly the international ones (Kravis, 1976), have made labour productivity comparisons. Similarly the focus has often been on the multitude of outputs. As we will discuss later, we are not yet satisfied with our comparative output measurement. Suppose we shift to TFP with either one or many outputs. The procedure under discussion aggregates inputs in a manner comparable to the output aggregation and results in similar problems. Define input aggregates X_j^k; j,k = 1,2

$$X_j^k = \sum_{i=1}^{m} w_i^k X_i^j$$

and TFP measures,

$$PR_j^k = Q_j^k / X_j^k$$

The input aggregates X_1^1 and X_2^2 can be interpreted as the value of the cost functions $C_1(w^1,(Q_i^1))$ and $C_2(w^2,(Q_i^2))$. The other input aggregates X_1^2 and X_2^1 must satisfy inequalities

$$X_1^2 \geq C_1(w^2,(Q_i^1))$$

$$X_2^1 \geq C_2(w^1,(Q_i^2)) \quad .$$

That is, the aggregate input is too large when one firm's inputs are evaluated at the other firm's input prices.

Combining the problems of input and output aggregation two points can be observed. First if revenues equal costs, then the productivity index using own prices will always equal one, $PR_1^1 = PR_2^2 = 1$. To the extent that they do not, we are either measuring economies of scale, measurement error or some behavioral misspecification. The important point is that we may be mis-measuring efficiency.[10] Second, the value of PR_j^k for $j \neq k$ reflects the overestimate of X_j^k , $j \neq k$ and the underestimate of Q_j^k , $j \neq k$ which implies an underestimate of PR_j^k .

The same type of conclusions may be reached in this case. If the firm, whose output and input prices are not being used as weights, is more efficient than the firm whose prices are used then it is certainly more efficient if one could correct for bias. In all other cases no unambiguous conclusion can be reached and this includes all cases in which a third firm's prices are used.

The other most popular variant of this method of making comparison can be discussed as an example of using a third firm's prices. One can find examples in which outputs and inputs are priced at world prices when making comparisons. That is , no particular country's or country industry's prices are used. A third set of prices called world prices are used which will result in all the biases discussed above.

Both of the variants most commonly used suffer conceptual flaws even when used for a single year. Just as serious is their lack of any conceptual basis for linking intertemporal with interspatial measures of efficiency. While it is conceivable that measures could be developed they do not exist currently.

I have been fairly blunt in attacking the conceptual weakness of these methods and yet I intend to calculate such measures. What is a reasonable defense of these calculations. First, we want to see how the results compare with those of our preferred procedure. Second, the empirical magnitude of the errors may be small. This will occur when either (a) the quantities of outputs produced and inputs consumed are insensitive to differences in relative output and input prices or (b) relative input and output prices are very similar for the two firms. The first condition is never likely to occur although any approximation to it combined with relatively small differences in relative prices may make the biases quite small. For these two reasons, we will calculate the alternative measures. The results of these alternative calculations are given in Appendix A.1.

3. Variations in the Regional Networks

This section analyzes the regional data on the physical characteristics of the transmission networks.[11] The data is reported by province only and so any attempt at examining the profile of individual telephone comanies is at best an approximation to reality. With this in mind results are reported for British Columbia, Alberta and a Central region, constructed by aggregating data from Ontario and Quebec. In each region there are some independent telephone companies included with the major companies we are studying. The major difference between the companies and the regions occurs in Alberta where Edmonton Tel. currently provides about 15% of the dollar value of telecommunications services in the province.

The transmission network can be divided in a number of ways and the available data determines the particular division that we have used. The network is divided into toll and exchange lines.[12] Within each of these categories, data are divided into;

a) single aerial wire

b) aerial cable

c) buried and underground cable

d) carrier systems

e) microwave.

The purpose of considering these alternatives is to understand the differences in utilization across the regions and through time.

3.1 Some Introductory Definitions and Remarks

To clarify some terminology, definitions of some of the variables under discussion will be useful.

Cable: an assembly of individually-insulated conductors protected by an outer covering called a sheath.

Conductor: a single wire forming part of a communication circuit

Sheath Miles: a measure of the physical length of a cable of some type, without reference to the number of individual conductors the cable contains.

Conductor Miles: measure of the sum of all the physical lengths of the individual conductors which are contained in the cable.

Pole Line Miles: measures the physical distance spanned by all the telephone poles which the company owns. Mileage along rented poles is not included. Pole Line miles is measured without reference to either sheath or conductor miles.

A simple example may help sharpen the differences between these three measures of distance. Assume that two towns, A and B, are one mile apart and are directly connected by a line of telephone poles, then;

1. if A and B have a length of single aerial wire joining them

   sheath miles = 1 mile
   conductor miles = 1 mile
   pole line miles = 1 mile

2. if A and B are joined by a single cable containing ten conductors

   sheath miles = 1 mile
   conductor miles = 10 miles
   pole line miles = 1 mile

3. if A and B are joined by two cables each containing ten conductors

sheath miles = 2 miles
conductor miles = 20 miles
pole line miles = 1 mile

There are some difficulties with the data series. Up to 1970, whenever toll and exchange calls travelled over the same line[13] or cable, the mileage was included in the toll category. After 1970 the practice was changed so that shared mileage was put into the exchange category. The small absolute size of the toll categories means that a significant break occurs in each toll series between 1970 and 1971. A number of other series exhibit some very erratic behaviour.[14] In the tables that follow, we will indicate the breaks that occur.

3.2 The Fate of Aerial Transmission

The use of aerial transmission systems has declined in all telephone companies. In our data we have information on single aerial wire and aerial cable. The former represents the oldest and simplest method for serving low density areas. The latter incorporates the technical possibilities of placing more than one wire or conductor within a cable.

Table 1 summarizes the information on the use of single aerial wire in the three regions. The unit measure is sheath miles. Recall that sheath miles equals route[15] and conductor miles for single aerial wire.

For the exchange network almost all the mileage was in single aerial wire in 1963 for all regions. By the end of the 1970's a very sharp reduction had taken place as this system was replaced by newer technologies.

Table 1

Single Aerial Wire as a Proportion of Total Sheath Miles

<u>EXCHANGE</u> - break in 1970-71 in CEN, AT 1970 High, 1971 Low
- unusually high observation 1971 BC

<u>Trends</u>:

Strong downward trend in all three regions
CEN oscillates until 1970 then falls (68% to 30%)

<u>Means</u>:

Means		RANKING BY LEVEL 1963	RANKING BY LEVEL 1979
AT = 58%	High	BC (99%)	BC (39%)
BC = 63%		AT (97%)	CEN (30%)
CEN = 67%	Low	CEN (90%)	AT (9%)

<u>TOLL</u> - break in CEN between 1970-71 1970 High, 1971 Low

- break in AT between 1976-77 1976 High, 1977 Low

<u>Trends</u>:

CEN moderate rise 1963-70, no trend thereafter
AT very slight decline 1963-76, rapid decline 1977-79
BC steady moderate decline between 1963-79

<u>Means</u>:

Means		RANKING BY LEVEL 1963	RANKING BY LEVEL 1979
AT = 92.4%	High	AT (99.1%)	CEN (85.6%)
BC = 94.4%		BC (98.1%)	BC (84.7%)
CEN = 88.3%	Low	CEN (90.9%)	AT (62.9%)

Alberta, in particular, reduced its use of aerial single wire to only 9% in 1979 from 99% in 1963. The other regions used a substantially higher proportion of single aerial wire transmission in the late 1970's.

The use of single aerial wire declined in the toll network during this time period. However, the declines were not as substantial as those experienced in the exchange networks. In B.C. and the Central region the proportion of single aerial wire sheath miles in the toll network was still 85% in 1979 down from 99% in 1963. Alberta has reduced their use of single aerial wire very rapidly during the late seventies and had reached a much lower level than the other regions in 1979.

The other use of aerial systems is in aerial cable which packages more than one conductor within a sheath. It is to be expected that the decline of single aerial wire was substantially a shift to aerial cable or buried cable. In Table 2 the data on the proportion of sheath miles contained in single wire plus cable is shown. In both the exchange network and in the toll network, the use of aerial systems has declined for all companies. However for the toll network the decline is very modest in British Columbia and the Central region. This is consistent with the slightly larger declines in the proportion of sheath miles in single wire. Alberta has had the larger declines coming in the late 1970's.

In the exchange network the very steep declines in single wire apparently involved substantial shifts to aerial cable in British Columbia and to a lesser extent the Central region. Once again Alberta has the unique situation with much sharper declines.

The sheath miles that are not in aerial systems are buried. The data in Table 2 can be interpreted as indicating that the burial of transmission

Table 2

Single Aerial Wire and Aerial Cable as a Proportion of Total Sheath Miles

<u>EXCHANGE</u> - break in 1970-71 for CEN, AT (1970 High, 1971 Low)
- break in 1972-73 for AT

<u>Trends</u>:

CEN - no trends before 1971, gentle decline 1971-79
AT - noticeable downward trend, accentuated by 2 data breaks
BC - uniform downward trend over entire period

<u>Means</u>:

AT = 62.5%
BC = 90.4%
CEN = 85.7%

RANKING BY LEVEL

	1964		1979
High	BC (99.9%)	→	BC (80%)
	AT (99.3%)	↘ ↗	CEN (69%)
Low	CEN (96.3%)		AT (14%)

<u>TOLL</u> - break in CEN 1970-71 (1970 High, 1971 Low)

- break in AT 1976-77 (1976 High, 1977 Low)

<u>Trends</u>:

CEN - slight upward growth 1963-70, no trend after 1970
AT - slight irregular downward trend, large declines 1977-79
BC - slight, but constant, downward trend throughout period

<u>Means</u>:

AT = 92.5%
BC = 97.1%
CEN = 92.7%

RANKING BY LEVEL

	1963		1979
High	BC (99.3%)	→	BC (91.2%)
	AT (99%)	↘ ↗	CEN (90%)
Low	CEN (94.6%)		AT (62.9%)

systems has proceeded much more quickly for exchange lines than for toll. This is to be expected due to the concentration of exchange lines in urban areas. All companies have been increasing the quantity of buried sheath miles but Alberta companies has proceeded much more rapidly than the companies in the other regions.

Sheath miles is only one of the two mileage measures that we have used. Conductor miles is the alternative to which we will now turn. Conductor miles is a measure of the capacity available and this capacity is allocated within the transmission system in a sharply different pattern than the sheath miles. Table 3 presents the data on the proportion of conductor miles that are in single aerial wire.

In all three regions, there has been a very low and declining proportion of exchange conductor miles in single aerial wire. The mean proproportions for conductor miles ranges from 1.5% to 3.7% which contrasts sharply with the mean proportions for sheath miles that ranged from 58% to 67%. This is not surprising since almost all of the high capacity exchange trunks are buried.[16]

The situation in the toll network is a little different since the initial proportions of single aerial wire tended to be higher. The declines during the period have eliminated the importance of single aerial wire in the toll network.

The details of the situation for both networks when considering both types of aerial systems is provided in Table 4. In general, the use of all aerial systems is declining and the conductor miles in aerial systems are smaller proportion than the sheath miles.

Table 3

Single Aerial Wire as a Proportion of Total Conductor Miles

EXCHANGE - break in series 1970-71 in Central and Alberta 1970 High / 1971 Low

- artificially high observation in 1971 for B.C.

Trends:

Alberta (AT) has most marked rate of decline
British Columbia (BC) has moderate rate of decline
Central (CEN) gentle rate of decline

Means:

AT = 1.96%
BC = 3.71%
CEN = 1.46%

RANKING BY LEVEL

	1964		1979
High	BC (5.3%)	→	BC (.19%)
	AT (2.4%)	→	CEN (.13%)
Low	CEN (1.7%)	→	AT (.056%)

TOLL - break in all series between 1970-71
- break between 68-69 in BC
- break between 65-66 in AT

Trends:

CEN marked downward trend after 1971
AT downward trend after 1966, reinforced by breaks
BC stable, downward trend through whole period

Means:

AT = 13.8%
BC = 21.3%
CEN = 6.2%

RANKING BY LEVEL

	1964		1979
High	BC (45%)	→	BC (4%)
	AT (12%)	→	AT (.8%)
Low	CEN (5%)	→	CEN (.2%)

Table 4

Single Aerial Wire Plus Aerial Cable
as a Proportion of Conductor Miles

EXCHANGE - break in series 1970-71 in Central & Alberta (1970 High, 1971 Low)
- artificially high observation in 1971 for B.C.

Trends:

AT has most marked rate of decline 34% to 9.5%
CEN has noticeable rate of decline over period
BC rises to 59% in 1967 then falls to 40% in 1979

Means:

		RANKING BY LEVEL 1964		1979
AT = 21.6%	High	BC (57%)	→	BC (40.5%)
BC = 50.8%		CEN (35%)	→	CEN (27%)
CEN = 30.1%	Low	AT (34%)	→	AT (9.5%)

TOLL - break in all series 1970-71 (1970 High, 1971 Low)
- break between 1969-69 in CEN
- break between 1965-66 in AT

Trends:

- marked decline in BC, though not as steep as single aerial wire
- noticeable downward trend in CEN over most of period
- AT series is too irregular, no consistent trends

Means:

		RANKING BY LEVEL 1963		1979
AT = 16.4%	High	BC (81%)	→	BC (22%)
BC = 45.9%		CEN (40%)	→	CEN (8%)
CEN = 27.3%	Low	AT (15%)	→	AT (0.5%)

For conductor miles, the mileage that is not in aerial systems can be in buried systems, physical carrier systems or microwave systems. In the exchange network there is no significant microwave. The largest proportion of the capacity in the exchange network is in buried cable. The use of carrier systems in the exchange network has been very limited except in Alberta. There it has become roughly 15% of total exchange conductor miles.

In the toll network the data for all regions seems to vary erratically for the alternatives to aerial conductor miles. The following conclusions are sustained by the data. The backbone of the toll network in all regions has been buried cable. The importance of carrier systems has been growing particularly in the Central region. Microwave systems form a fairly small proportion of the toll network.

3.3 The Density of the Transmission Networks

The changing use of alternative types of transmission media does not indicate the rapid movement in the network density. There are many alternative measures of density and we have chosen to use miles of transmission system per main telephone. The miles will be either sheath or conductor miles. The available data show considerable variability and the results are presented as representative values for a time period. They should not be interpreted as precise values but rather they are believed to show the relative levels across companies and time periods.

The density in terms of sheath-miles is shown in Table 5 . The predominant result is a sharp decline in the quantity of sheath-miles per main telephone for both the exchange and the toll networks for all regions.

In the exchange network, British Columbia had a much lower density than Alberta or the Central region in the mid-60's. The density was reduced 40% by the late 70's. At that time the Central region had a roughly equal density based on a rate of decline that was more than twice that in British Columbia. Alberta began with a very high density relative to the other regions. Although the density has declined very quickly it is still substantially larger than elsewhere.

The decline is predominantly due to a consolidation of separate lines and the continued urbanization. The very high density for Alberta reflects the rural nature of the province. The very low density in British Columbia probably arises from high urban density combined with the use of non-wire facilities for isolated areas.

The density of the toll network has shifted downwards in all regions. Relative to the exchange network, the toll network density is much smaller.

Table 5

Sheath-Miles per Main Telephone

1. Exchange Network

	British Columbia	Alberta	Central
Mid-60's	.080	.330	.150
Early 70's	.060	.120	.080
Late 70's	.045	.070	.045

2. Toll Network

	British Columbia	Alberta	Central
Mid-60's	.070	.190	.038
Early 70's	.050	.070	.015
Late 70's	.015	.002	.008

The Central region has had a very low density through the period which has only been surpassed by Alberta in the late 70's.

An entirely different trend occurs in conductor mile density in Table 6. There has been an upward trend in the conductor mile density in the exchange network for all companies. The quantity of conductor miles per main telephone has roughly doubled from the mid-60's to the late 70's. The levels remain higher in Alberta and the Central region than in British Columbia. This growth in capacity per main telephone is not easily explained but we will return to this issue below.

The toll network displays a similar pattern in B.C. and Alberta. Conductor miles per phone has doubled in each. The Central region's density has not risen. It has remained relatively stable with perhaps a slight decline.

It is not possible to apply these results directly to our comparisons. However the following interpretation is suggestive but no more than that. British Columbia has a network whose toll and exchange components are characterized by relatively high sheath miles per telephone. Alberta which had an exceptionally high initial sheath-mile density has lowered it significantly. British Columbia's high sheath-mile density is accompanied by a low conductor-mile density. This is not true for Alberta where the conductor-mile density is high.

Table 6

Conductor Miles per Main Telephone

1. Exchange Network

	British Columbia	Alberta	Central
Mid-60's	4.8	6.0	6.8
Early 70's	7.4	8.0	9.3
Late 70's	9.5	13.0	11.0

2. Toll Network

	British Columbia	Alberta	Central
Mid-60's	.15	.38	.66
Early 70's	.26	.80	.67
Late 70's	.33	.60	.60

3.4 Regional Growth in Stations and Usage

The network may be described by the number of main stations that it services. In our case, the networks are of quite different sizes and have experienced very different rates of growth. In 1963, the Alberta network had 416 thousand main stations, the British Columbia network had 563 thousand and the Central network had 3,697 thousand.

The rates of growth of main stations are reported in Table 7 for each region. The average annual rates of main station growth prior to 1972 were 5.4% in Alberta, 6.0% in British Columbia and 4.8% in the Central region. After 1972, these average rates changed to 7.5% in Alberta, 5.4% in British Columbia and 4.0% in the Central region. Over the total period the growth rates were 6.38%, 5.68% and 4.43% for Alberta, British Columbia and the Central region. There were substantial differences in the growth of main stations across the regions although the size differentials remained large. In 1979, the number of main stations was 1,112 thousand in Alberta, 1,362 thousand in British Columbia and 7,393 thousand in the Central region.

The usage per main station is a basic indicator of the demand for network services. The patterns for toll and local calls is strikingly different. Indexes of local and toll calls per main station are shown in Table 8. In all regions, toll calls per main station grew swiftly. The average rate of growth from 1964-78 was 6.7%, 5.35% and 4.33% in British Columbia, Alberta and the Central region respectively. After 1971, the average annual rates of growth were higher at 7.2%, 6.3% and 5.9% respectively.

Table 7

Rate of Growth of Main Telephones

	British Columbia	Alberta	Central
1964	4.5	4.7	4.4
1965	6.3	5.6	5.2
1966	6.5	5.7	5.2
1967	5.9	4.0	5.1
1968	4.9	3.5	4.3
1969	5.7	6.8	4.5
1970	5.4	5.7	4.0
1971	5.8	4.3	4.3
1972	6.1	7.4	4.6
1973	7.0	6.4	5.2
1974	6.5	8.5	5.1
1975	5.9	7.8	4.4
1976	4.0	6.1	3.7
1977	3.2	6.5	2.9
1978	4.9	8.0	3.6
1979	5.5	7.5	2.5

Table 8

Indexes of Calls per Main Telephone
(1971 = 1.00)

	Local			Toll		
	British Columbia	Alberta	Central	British Columbia	Alberta	Central
1964	.94	1.04	.99	.66	.74	.83
1965	.94	1.05	.98	.76	.65	.84
1966	.97	1.05	.98	.80	.72	.84
1967	.93	.89	.96	.75	.85	.88
1968	.94	.92	.99	.81	.87	.91
1969	.93	.91	.98	.89	.91	.99
1970	.93	.91	.99	.95	.93	.98
1971	1.00	1.00	1.00	1.00	1.00	1.00
1972	1.05	1.16	1.01	1.06	1.13	1.10
1973	1.04	.87	1.00	1.19	1.25	1.18
1974	1.09	.86	1.03	1.35	1.41	1.27
1975	1.04	.89	.98	1.50	1.48	1.33
1976	1.02	.86	.99	1.55	1.45	1.38
1977	1.00	.88	1.00	1.62	1.54	1.42
1978	.96	.90	.98	1.63	1.53	1.50
1979	.94	.90	.98	1.96	1.81	1.56

Local calls per main station do not show any persistent trends. Prior to 1971, there was a decline in Alberta and British Columbia and stability in the Central region. After 1971, modest declines seemed to occur in all regions. However, there appear to be some breaks in the series around 1971 which are not explained. It is clear that there has been no upward trend in local calls per main station although the existence of a decline may be doubtful except in Alberta.

The explorations into the structure of the network have been quite tentative. We have tried to use the regional data published by Statistics Canada to determine if there have been sharp differences in the types of, or changes in, the regional transmission systems. We have not had time to link the observed differences to our comparative results and we do not believe that a formal linking is a pre-requisite for further investigation. We would like to obtain the survey data from the companies in order to focus on the firms we are studying and to clarify the breaks that appear in the series. More generally we expect that the companies will be interested in exploring other sources of data that may provide a more useful comparison of the transmission networks. We expect that we will be able to obtain a breakdown of the capital stock into five broad categories. The two largest categories are outside plant and central office equipment. The outside plant class contains the transmission systems that we have been comparing here. Ultimately, we would hope to link the quantity of outside plant to some of the characteristics of the transmission system discussed here.

The other large category is central office equipment. We are in the process of assembling the available data on the regional characteristics of this class and we intend to pursue the investigation of this category further. Since capital is by far the largest input and the one most directly affected by geography, we believe that a more detailed investigation deserves our energy.

4. Inter-Firm Comparisons

4.1 An Introduction to the Companies

At a later stage of this paper, an analysis of the efficiency of Bell Canada (BELL), Alberta Government Telephones (AGT), British Columbia Telephones (BC Tel.) and Teleglobe (TG) will be presented and discussed. In this section we want to provide a descriptive analysis of the four companies. Three of the companies, Bell, BC Tel. and AGT, are the largest common carriers in Canada and provide a very wide range of telecommunications services within their geographic service area. Teleglobe provides overseas service almost exclusively and produces a more limited and specialized service mix. Bell and BC Tel. are private companies whose rates and rates of return are federally regulated. AGT is a crown corporation, i.e., a public enterprise in the Province of Alberta. Teleglobe is a federal crown corporation.

In 1978, AGT, Bell and BC Tel. provided about 75% of the dollar value of domestic telecommunications services in Canada. In Table 9, the structure of revenue and costs for these companies in 1978 is presented. Bell is by far the largest company with revenues that are roughly four to five times larger than either of the other two firms.

The operating revenue of the three firms is derived from local, long distance and other services. The revenue proportion of these services is quite different for each company. Bell receives over one-half of its revenue from local services while AGT receives less than one third. BC Tel. generates about 43% of its revenue from local services.[17] The observed differentials are partially the result of AGT's long distance revenue received for transit traffic that neither originates nor terminates in AGT's

Table 9

Revenues and Costs in 1978
(millions of dollars, percentages in brackets)

		AGT	BELL	BC Tel.
1.	Operating Revenue	444	2497	551
2.	Local	138 (31)*	1263 (51)	242 (43)
3.	Long Distance	292 (66)*	1153 (46)	319 (57)
4.	Other	17 (4)*	94 (4)	-2.3 (0)
5.	Operating Cost	339	1785	393
6.	Maintenance	87 (26)**	420 (23)	109 (28)
7.	Depreciation	125 (37)**	474 (27)	113 (29)
8.	Traffic	24 (7)**	127 (7)	40 (10)
9.	Marketing	29 (9)**	141 (8)	46 (12)
10.	Other	64 (19)**	481 (27)	58 (15)
11.	Non-Income Taxes	9 (3)**	141 (8)	28 (7)

* percentage of operating revenue

** percentage of operating costs

Source: Statistiques Financières sur les Sociétés Exploitants territory. This is a more important source for AGT than the other companies. AGT also provides long distance services for Edmonton Telephone Co.[18] The latter firm provides local services for one of the largest urban areas in Alberta. If one combined AGT with Edmonton Tel., the revenue shares would be very similar to those of BC Tel. Consequently, it may be suggested that AGT's high long distance revenue share is due to both transit traffic and the existence of a large local service company within AGT's territory.

The 1978 operating costs for the companies have also been broken down in Table 9. For all companies maintenance and depreciation are over 50% of total operating costs. Bell appears to have a lower share of costs devoted to maintenance than the other companies. AGT has an enormously high depreciation cost share which will be discussed further below. Bell has tended to have a larger share of other costs than BC Tel. and AGT.

The static situation portrayed in Table 9 may disguise rapid shifts in the importance of the revenue and cost components due to growth through time. To characterize shifts through time, Table 10 shows the 1978 values of revenue and cost component indexes with base year 1972. Revenue growth has been much faster for AGT than for Bell and BC Tel. There is a tendency for long distance revenue to grow faster than local revenue in telephone companies. This is not true in Alberta.

Total costs have grown with revenue for AGT but have exceeded revenue growth in Bell and BC Tel. For all companies traffic costs have grown more slowly than total costs. For AGT, the growth in depreciation and maintenance costs has been higher and in non-income taxes lower, than total costs. Bell's other costs grew much more while depreciation and marketing grew less than the firm's average costs. Marketing and non-income tax costs grew faster

Table 10

1978 Indexes of Operating Revenue
and Operating Costs, 1972 = 100

	AGT	BELL	BC Tel.
Local Revenue	319	201	227
Long Distance Revenue	315	248	278
Total Revenue	314	222	242
Total Cost	314	233	246
Maintenance	329	217	222
Depreciation	342	208	260
Traffic	217	192	201
Marketing	311	203	315
Other Costs	309	310	236
Non-Income Taxes	248	261	321

Source: See Table 9.

than average and maintenance costs grew slower in BC Tel. While there is some diversity in the growth and shares of revenue and costs it is not sensible to conclude anyting about efficiency from these data. They will provide some questions which we will attempt to explore in more depth later in the paper.

A further simple comparison of these companies can be based on the number of telephones per employee. Very roughly this measures the magnitude of the network served by each employee. The companies differ enormously in the value of this measure as one can see in Table 11. Of the three major companies, Bell has the largest number of telephones per employee followed by BC Tel. and AGT. There are some sharp fluctuations in the annual series and perhaps a very slight trend upwards.

What do these differences signify? First, the AGT numbers are extremely low and this appears to be a function of the low average density of the AGT area served. Edmonton Telephones is included in Table 11 to provide a contrast. Their urban network has a very high number of telephones per employee. If we combine Edmonton Tel. with AGT the results are very similar to those for BC Tel. If this interpretation is correct the high numbers for Bell may only signify a more densely packed network.

Table 11

Telephones per Employee

	BC Tel.	AGT	BELL	EDMON. Tel.
1972	109	85	166	240
1973	98	87	165	250
1974	99	84	162	230
1975	112	82	176	222
1976	112	86	173	220
1977	121	90	171	220
1978	121	95	168	245

Source: See Table 9.

4.2 Productivity as Measured by the Companies

All four companies have produced productivity measures[19] and for reference purposes we have included some of their estimates here. In Table 12, some company estimates are shown. BC Tel., Bell Canada and Teleglobe have calculated estimates of total factor productivity growth rates. Teleglobe has had exceptionally fast increases in productivity. Bell has had an average rate of growth of TFP of 3.1% compared to the lower BC Tel. average of 2.6% from 1972-79. Given the difference in the methods used the Bell-BC Tel. results cannot be easily compared but Telglobe's productivity has clearly grown more swiftly.

AGT and Bell produce estimates of value-added productivity. AGT's productivity has grown at 7.2% a year which is substantially higher than Bell's average of 4.0%. Without any serious investigation of methodology, the ranking using these measures would be Teleglobe, AGT and Bell and BC Tel. tied. There is no doubt that these are very high rates of productivity growth relative to other industries. Our task is to evaluate why these results were achieved and to provide a more detailed underpinning for these results.

Measured productivity growth is often correlated with output growth. This is expected since accurate measures of utilization of quasi-fixed inputs is seldom possible. In periods of slow output growth, productivity growth is low since the input measurement incorrectly overestimates utilization which falls as firms maintain input levels over fluctuations in demand growth. This may be a more serious problem in telecommunications due to the high weight of relatively fixed capital and the labour required to maintain it.

Table 12

Company Measures of Productivity Growth
(produced independently by the companies)

	TFP			Value-Added Productivity	
	BC Tel.	BELL	TELEGLOBE	BELL	AGT
1967	—	5.7	—	6.6	—
1968	—	3.9	—	4.5	6.9
1969	—	2.9	—	7.4	6.8
1970	—	3.5	—	4.2	5.5
1971	—	-1.0	—	-1.0	4.7
1972	0.3	3.8	12.7	4.5	11.5
1973	2.8	4.8	16.7	5.7	9.0
1974	5.7	4.7	8.9	5.6	14.2
1975	5.9	6.9	10.7	8.2	9.9
1976	4.7	1.0	14.3	1.2	0.7
1977	-3.6	0.7	11.3	0.8	7.2
1978	2.5	2.0	—	2.5	2.7
1979	2.4	1.3	—	1.5	—

Source: See footnote 19

In Table 13, the companies' output growth rates are shown. First one can see that Teleglobe and AGT have had very high rates of output growth underlying their high rates of productivity growth. BC Tel.'s output grew at 10.2% compared to Bell's output growth of 8.8% from 1972-79. These are less than 60% of AGT's output growth rate. For all companies relatively high average rates of output growth have accompanied relatively high rates of growth of productivity. It is not yet clear why this relationship exists.

If fluctuations in productivity and output growth are considered for individual companies, there is no consistent pattern. It is easy to find exceptions to any but weak relationships that tie ups and downs in the two measures together.

Table 13

Company Measures of Output Growth Rates
(produced independently by the companies)

	BC Tel.	BELL	AGT	TELEGLOBE
1967	—	9.1	—	—
1968	—	9.1	10.5	—
1969	—	10.4	13.7	—
1970	—	9.5	12.1	—
1971	—	5.6	10.6	—
1972	9.0	9.1	15.7	14.8
1973	11.0	10.7	13.9	24.3
1974	14.3	11.0	20.1	24.3
1975	10.3	11.0	19.0	27.9
1976	9.2	7.6	12.2	17.5
1977	6.3	6.9	13.6	18.6
1978	9.8	8.7	19.2	—
1979	11.7	6.3	—	—

Source: See footnote 19

4.3 Labour Productivity Growth and Levels

To begin our comparison, we have measured labour productivity and compared the companies on their levels of labour productivity. Output is the aggregate of the output disaggregation provided by the firms and discussed elsewhere in the report.[20] For reasons of comparability, labour is measured as unweighted man-hours of labour worked in each company.

In Table 14, indexes of labour productivity for AGT, BC Tel. and Bell are shown. Labour productivity in AGT and BC Tel. have grown at approximately 8% a year since 1972 compared to about 4.5% in Bell. Prior ot 1972, labour productivity was growing at an annual rate above 10% at AGT and 7.7% in Bell Canada.

Output growth was slightly lower at Bell than BC Tel. after 1972. Labour input must have grown faster at Bell than at BC Tel. in order to convert the minor output growth disadvantage into a significantly lower labour productivity growth performance. AGT had the fastest rate of growth of output after 1972 but this was not translated into a higher labour productivity growth relative to BC Tel. has managed a superior performance relative to Bell and AGT in achieving labour productivity growth.

The levels of labour productivity are reported in Table 15. Bell has consistently had a higher level of labour productivity. The gap was very large in 1972 but it has been reduced substantially during the 1970's. AGT has had the lowest levels.

Table 14

Labour Productivity
(1972 = 100.00)

	BC Tel.	AGT	BELL
1967	—	61.7	66.3
1968	—	70.7	74.4
1969	—	76.7	80.8
1970	—	81.4	86.2
1971	—	88.2	92.5
1972	100.0	100.0	100.0
1973	104.2	107.2	105.4
1974	111.9	121.8	109.7
1975	131.4	143.8	122.3
1976	150.8	149.3	125.5
1977	159.9	164.1	129.6
1978	157.1	159.3	131.7
1979	149.2	—	133.9

Table 15

Levels of Labour Productivity
(Index, Bell 1972 = 100.0)

	BC Tel.	AGT	BELL
1967	--	43.6	66.2
1968	--	50.0	74.6
1969	--	54.3	80.6
1970	--	57.5	86.2
1971	--	62.5	92.6
1972	82.0	70.9	100.0
1973	84.7	75.6	105.2
1974	91.7	86.2	109.9
1975	107.2	102.0	121.9
1976	123.4	105.3	125.0
1977	129.8	116.3	129.8
1978	128.2	112.3	131.6
1979	121.9	--	133.3

4.4 Total Factor Productivity: An Initial Comparison

To begin our comparison, we will measure total factor productivity for AGT, Bell and BC Tel. using a common methodology and data which i partially standardized. Define the rate of growth of productivity,

$$\dot{TFP} = \dot{Q} - \dot{F}$$

where the aggregate output growth rate $\dot{Q}$ is defined by,

$$\dot{Q} = \sum_j r_j \dot{q}_j$$

and the aggregate input growth rate, $\dot{F}$ is defined by,

$$\dot{F} = \sum_j s_i \dot{x}_i \quad .$$

The disaggregate output $(\dot{q}_j)$ and input $(\dot{x}_i)$ growth rates are weighted by the revenue (r_j) and cost (s_i) shares respectively. This standardizes the methodology for the three companies.

The data are partially standardized by the choice of input variables. At this stage, we will not standardize the output measurement. This process will require a separate section below. For each company, labour input is measured as man-hours worked without any adjustment for skill levels. Capital is measured as the gross capital stock which is aggregated from detailed disaggregates. Material inputs are not completely comparable but this is not believed to be a problem. Finally, the assumption is made that the value of capital services can be measured as a residual component in total realized costs. Each of these measurement choices will be discussed below.

Given the limitations of the public data, we cannot directly move to an improved data set. Our strategy has to be more indirect.

For the three companies, the rates of growth of total factor productivity are shown in Table 16 and a productivity index (1972 = 100) appears in Table 17. The rough standardization does not alter our earlier comments based on the companies published results. AGT has had a faster rate of growth of TFP than Bell and BC Tel. during any time period when comparable data is available. From 1972-78, AGT's productivity grew at an average annual rate of 6.6% compared to a rate of 3.9% for Bell and for BC Tel.

Recall that AGT and BC Tel. had almost identical rates of growth of labour productivity. The TFP results indicate that BC Tel. achieved the labour productivity results through faster rates of growth of the capital-labour and the materials-labour ratio relative to AGT. The latter company was more successful at achieving high rates of labour productivity growth via high rates of TFP growth.

Bell had a substantially lower rate of growth of labour productivity than BC Tel. but TFP grew at least as quickly. Relative to Bell as well as AGT, BC Tel. must have had a faster rate of growth of capital and materials to labour intensities in order to achieve the results portrayed above.

Table 16

Annual Rates of Growth of TFP

	BC Tel.	AGT	BELL
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

Table 17

TFP Indexes
(1972 = 100)

	BC Tel.	AGT	BELL
1967	—	74.9	86.8
1968	—	78.9	90.6
1969	—	83.4	93.3
1970	—	87.3	96.8
1971	—	91.1	96.3
1972	100.0	100.0	100.0
1973	102.9	108.0	104.8
1974	109.1	121.7	109.5
1975	115.9	132.3	117.3
1976	121.0	132.8	118.5
1977	118.4	141.8	119.4
1978	122.0	144.8	122.2
1979	125.1	—	124.9

Using the data underlying our calculations of total factor productivity, an initial comparison of the firms' relative levels of efficiency was made. Relative efficiency will be measured in the following ways. Define[21] the relative total factor productivity level, of firm k relative to firm h, E_{kh}

$$\log E_{kh} = \log (Q_k/Q_h) = \tfrac{1}{2} \sum_i (s_{ik} + s_{ih}) \log (X_{ik}/X_{ih}) , \qquad (4)$$

where s_{ik} is the cost share of factor i in firm k and X_{ik} is the equivalent quantity.

From the cost function, one may define a relative cost efficiency level, CE_{kh}

$$\log CE_{kh} = \log(C_k/C_h) - \tfrac{1}{2} \sum_i (x_{ik} + x_{ih}) \log(w_{ik}/w_{ih}) - \log(Q_k/Q_h) , \qquad (5)$$

where C_k is the total cost and w_{ik} the price of input i in firm k.

Tables 18 and 19 present the results, E_{kh} and CE_{kh}, of measuring both of these relative efficiency measures for the three companies. Consider the results of comparing Bell and AGT in Table 18. In 1967 Bell's relative TFP level was 124.8 compared to AGT's 100. Alternatively, one may state that the quantity of output produced by Bell was approximately 25% greater than that produced by AGT after accounting for differences in input quantities. For the companies to be equally efficient, the E value for Bell would have to be 100.

The results are roughly equivalent when measured from the cost side. Bell's cost efficiency in 1967 was 80.3 relative to AGT's 100. Bell's costs were only 80.2% of AGT's after accounting for differences in input prices and output levels.

Table 18

Relative Efficiency of Bell Compared to AGT

	Productivity BELL	AGT	Cost Efficiency BELL
1967	124.8	100	80.2
1968	123.9	100	80.7
1969	120.9	100	82.7
1970	120.4	100	83.1
1971	115.6	100	86.5
1972	109.7	100	91.2
1973	106.4	100	93.9
1974	98.8	100	101.2
1975	98.3	100	101.7
1976	98.9	100	101.1
1977	93.3	100	107.1
1978	93.4	100	107.1

Through time AGT has eliminated the relative efficiency gap. In 1978 AGT had a 7% relative efficiency advantage. In our explorations below we will try and indicate what led to this sharp improvement in AGT's relative efficiency.

In Table 19, AGT and Bell are compared to BC Tel. for the years 1972-78. In 1972, BC Tel. and Bell had approximately equal efficiency and BC Tel. was 10% more efficient than AGT. Since BC Tel. and Bell had equal average productivity growth during this period there is no substantial change in their relative efficiency levels during the 70's. Since AGT had a very rapid growth in TFP relative to the other companies, the initial efficiency disadvantage of AGT relative to BC Tel. has been sharply reversed. AGT began in 1972 with a 10% cost disadvantage and finished with a 7% cost advantage.

These results with the public data base depend critically on the quality of the data. In the remainder of this report, considerable attention will be devoted to differences in the data. It is quite possible that when, and if, a more comparable data base is constructed, the results may shift.

Table 19

Relative Efficiency of AGT and Bell Compared to BCT

	Productivity			Cost Efficiency	
	AGT	BELL	BCT	AGT	BELL
1972	89.6	98.8	100	111.7	101.2
1973	94.1	100.7	100	106.3	99.4
1974	100.0	99.5	100	100	100.5
1975	102.4	101.0	100	97.6	99.0
1976	98.6	98.1	100	101.4	102.0
1977	108.2	101.2	100	92.4	98.8
1978	107.5	100.5	100	93.0	99.4

4.5 Interpreting the Results

Our investigation is limited by the data that we have available publicly. The results suggest that in 1978, Bell and BC Tel. use more real resources to produce a given output level than AGT. To clarify this possibility, we will study the use of each factor and the production of outputs for the three companies. To begin, consider the indexes of the input-output ratios for each factor and company presented in Table 20. The indexes are normalized to 100 for Bell Canada in 1972.

For Bell Canada, the labour to output ratio has declined throughout the period. However the decline was more rapid prior to 1972 than after. BC Tel. had a much larger labour-output coefficient in 1972 but the ratio declined more quickly for BC Tel. than Bell after 1972. There was still a slightly lower labour coefficient in Bell in 1979. AGT had a very high labour coefficient relative to Bell in 1967 but this coefficienct has declined more rapidly for AGT than Bell. Most of the large difference had disappeared by 1979. For the input labour, both BC Tel. and particularly AGT have done better than Bell in reducing the coefficient. Bell's level has been consistently lower throughout all of the period.

The capital-output ratio has fallen for Bell but the temporal pattern is reversed. Prior to 1970 the capital coefficient fell very slowly and after 1972 its rate of decline increased. The rate of decline was always much slower than the decline in the labour coefficient. The capital-labour ratio has increased in Bell throughout this period.

In 1972, the capital coefficient at BC Tel. was lower than at AGT or Bell. The very slow reduction in the BC Tel. capital coefficient has

Table 20

Input-Output Ratios

Indexes: BELL 1972 = 1.00

	Labour			Capital			Materials		
	AGT	BCT	BELL	AGT	BCT	BELL	AGT	BCT	BELL
1967	2.29	–	1.51	1.25	–	1.06	0.92	–	0.97
1968	2.00	–	1.34	1.25	–	1.05	0.91	–	0.94
1969	1.84	–	1.24	1.19	–	1.02	0.87	–	1.01
1970	1.74	–	1.16	1.15	–	1.00	0.84	–	0.94
1971	1.60	–	1.08	1.13	–	1.01	0.81	–	1.05
1972	1.41	1.22	1.00	1.06	.92	1.00	0.72	0.81	1.00
1973	1.32	1.18	0.95	0.98	.90	0.96	0.64	0.79	0.96
1974	1.16	1.09	0.91	0.87	.87	0.91	0.58	0.70	0.91
1975	0.98	0.93	0.82	0.83	.88	0.88	0.60	0.65	0.81
1976	0.95	0.81	0.80	0.82	.88	0.88	0.66	0.66	0.82
1977	0.86	0.77	0.77	0.80	.90	0.87	0.57	0.84	0.86
1978	0.89	0.78	0.76	0.74	.88	0.84	0.61	0.72	0.86
1979	–	0.82	0.75	–	.83	0.82	–	0.66	0.82

eliminated the gap relative to Bell and AGT at the end of the period.

At AGT, the capital coefficient has fallen throughout the period at a rate faster than either of the other companies. The large (50%) gap relative to Bell that existed in 1967 has been substantially reduced by 1978. While the capital to labour ratio increased sharply prior to 1972, its growth has been much slower absolutely and relative to the other companies after 1972.

For materials the pattern is different since at the beginning of the period Bell did not have a substantially lower materials coefficient. Instead it was modestly higher. At Bell, the materials coefficient has fallen by less than the other coefficients. The other two companies have maintained their lower materials' coefficient throughout the period and after 1972 there has been little change in the relative coefficients. Prior to 1972 AGT's materials coefficients did fall more than Bell's coefficient. The advantage held by BC Tel. and AGT over Bell does not result in a very large impact on the comparison for two reasons. Materials are the least important input due to their smaller cost share and the differences across companies is smaller than the differences in the other two inputs.

There are two major questions raised by these results. First, the rapid growth of output at AGT relative to input growth has been the source of their spectacular gains. How inadequate is that output measurement? Second, the capial coefficient at all companies must be investigated.

The initial results on the levels of relative efficiency may be interpreted in terms of the components of equation (4), p. 57. Consider the comparison between AGT and BC Tel.. In Table 21, the relative quantities of the inputs and output are presented from 1972-78. AGT's output quantity grew sufficiently rapidly that by the end of the period, the levels in the two companies were approaching equality. During the same period the relative quantities of capital changed very little. In 1972, AGT used more capital relative to its output level than BC Tel.. Given the rapid changes in the relative output level, AGT had an advantage by 1975 which steadily increased for the remainder of the period. The difference in the measured capital used is crucial to the difference in measured performance.

Labour inputs at AGT have tended to be larger relative to output than at BC Tel. and this has continued throughout the time period. There are some sharp jumps in the relative quantities of materials used. However AGT has an advantage in the use of this input relative to BC Tel..

The relative quantities of inputs enter into the calculation of efficiency as an average share weighted difference in the logarithms of the quantities. The comparison between AGT and BC Tel. depends very heavily on the capital component. This portion remains roughly constant throughout the period and is the major factor in explaining the rise in relative efficiency as the difference in output levels declines. The weighted difference in labour input declines in relative importance and the materials component remains a significant factor but not of the magnitude of the capital component.

The comparison can be calculated using the concept of relative cost efficiency. The components underlying the cost efficiency differential are given in the second half of Table 21 for AGT relative to BC Tel.. Average

Table 21

Relative Quantities and Prices: AGT/BC Tel.

Relative Quantities

	Labour	Capital	Materials	Output
1972	0.752	0.751	0.573	0.651
1973	0.750	0.730	0.550	0.670
1974	0.746	0.704	0.590	0.704
1975	0.805	0.716	0.706	0.763
1976	0.918	0.732	0.789	0.787
1977	0.946	0.745	0.572	0.842
1978	1.030	0.768	0.766	0.906

Relative Prices

	Labour	Capital	Materials	Output
1972	0.804	0.863	1.000	0.957
1973	0.805	0.898	0.995	0.931
1974	0.783	0.958	1.007	0.898
1975	0.848	0.847	1.006	0.845
1976	0.722	0.939	1.008	0.878
1977	0.813	0.983	1.013	0.857
1978	0.741	0.970	1.013	0.834

wage rates are lower at AGT than BC Tel. and this difference has remained throughout the period as one reason for lower costs at AGT. The relative price of capital services was initially lower at AGT than at BC Tel.. This difference has been almost eliminated in recent years. There is relatively little difference in the materials' price.

The relative price of output is included in Table 21 although it is not used directly in the calculation of relative efficiency. Indirectly, the rate of growth of the aggregate price level determines the rate of growth of aggregate output given the rate of growth of total revenue. The output price for AGT relative to BC Tel. has fallen by roughly 15% during 1970's. For the same hypothetical rate of growth in revenue this would imply a faster rate of growth of output for AGT. Alternatively, methodological differences may underlie some of the differences in the growth in output prices. This will be considered more fully below.

In Table 22, similar material is presented for Bell and BC Tel.. The relative output quantities fall slightly during this time period and the decline in the relative materials use is consistent with the relative output pattern. However, the level of materials usage by Bell remains consistently high. Capital usage at Bell relative to BC Tel. is initially higher compared to the relative output levels. However, the relative advantages held by BC Tel. disappears over the years. For labour usage, the trend is in the opposite direction. Bell had an initial advantage which declines to almost nothing through time.

The relative price levels and trends for Bell relative to BC Tel. have some similarity to those between AGT and BC Tel.. Like AGT, Bell has a lower relative price of labour and capital initially. Both relative

Table 22

Relative Quantities and Prices: BELL/BC Tel.

	Relative Quantities			
	Labour	Capital	Materials	Output
1972	4.23	5.64	6.37	5.18
1973	4.17	5.49	6.30	5.17
1974	4.18	5.27	6.59	5.02
1975	4.44	5.08	6.38	5.07
1976	4.92	4.99	6.22	5.01
1977	5.08	4.87	5.17	5.04
1978	4.85	4.76	5.99	4.98

	Relative Prices			
	Labour	Capital	Materials	Output
1972	0.909	0.95	1.000	0.96
1973	0.913	0.97	0.96	0.94
1974	0.878	0.95	0.92	0.93
1975	0.870	0.90	0.92	0.88
1976	0.760	0.86	0.91	0.85
1977	0.823	0.82	0.93	0.83
1978	0.859	0.83	0.94	0.85

prices decline through time. Moreover, the relative output price declines steadily.

It is not necessary to discuss in detail the same material comparing AGT and Bell. It is presented in Table 23. A few highlights for emphasis will suffice. AGT tends to use more labour but less materials relative to output than Bell. The basic point is that the very rapid decline in the relative output level has exceeded the declines in any of the relative input usages and this is the basis for AGT's large relative efficiency gain.

One does not observe any trend in the relative output price levels which is strikingly different from the two previous cases. However, there is a sharp trend in the capital service price which is much larger than in our earlier cases.

The relative quantities and prices of inputs and outputs are the underlying components of the efficiency differentials. In the next section we will assess some alternative methods of measuring the price and quantity of capital services.

Table 23

Relative Quantities and Prices: BELL/AGT

Relative Quantities

	Labour	Capital	Materials	Output
1967	6.43	8.29	10.23	9.77
1968	6.42	8.05	9.82	9.56
1969	6.23	7.91	10.73	9.29
1970	5.96	7.80	9.96	8.93
1971	5.75	7.63	11.13	8.51
1972	5.62	7.51	11.10	7.94
1973	5.56	7.52	11.46	7.71
1974	5.60	7.47	11.13	7.13
1975	5.52	7.10	9.04	6.64
1976	5.36	6.81	7.88	6.37
1977	5.37	6.53	9.04	5.99
1978	4.71	6.19	7.82	5.50

Relative Prices

	Labour	Capital	Materials	Output
1967	1.01	1.36	1.02	0.95
1968	1.12	1.16	1.02	0.91
1969	1.11	1.13	1.02	0.91
1970	1.14	1.18	1.01	0.95
1971	1.07	1.21	1.02	0.98
1972	1.13	1.10	1.00	1.00
1973	1.13	1.08	0.96	1.01
1974	1.12	0.99	0.92	1.03
1975	1.03	1.05	0.91	1.04
1976	1.05	0.92	0.91	0.97
1977	1.01	0.84	0.92	0.97
1978	1.16	0.86	0.93	1.02

4.6 Capital Stocks and Capital Service Pricing

In our initial comparison we emphasized the importance of the capital stock measure and the pricing of capital services as a determinant of the relative efficiency of the three firms. This section will explore the changes in relative efficiency when different measures of the quantity and price of capital services are used.

Recall that we used the individual company's measures of capital stocks in constant dollars as the input quantity. Given this choice one may either choose an independent price of capital services or a total value (cost) of capital services.[22] The initial comparison used a residual calculation to obtain the value of capital services. The latter was defined to equal total operating revenue minus the sum of total labour compensation and total material expenses. The price of capital services must then be defined as the value of capital services divided by the quantity of capital inputs. This procedure produces the relative prices of capital services for each company shown in Tables 21 to 22 . BC Tel. had a higher price of capital services than either Bell or AGT. Moreover, the relative prices were increasing for AGT and falling for Bell (relative to BC Tel.) during the period. These results imply that the high relative price for Bell compared to AGT rapidly declined and became a lower relative price for Bell in the last half of the 70's.

There are alternative methods of measuring the price and quantity of capital services and two were chosen to illustrate the sensitivity of our results to the method chosen for these measurements. First, we can construct an independent price of capital services and use this in conjunction with the company measures of the capital stock. This was done in the following simple but illustrative manner. Define the price of capital services p_{KS},

$$p_{KS} = p_K(r + \delta)$$

where p_K is the price of the capital stock, r is the opportunity cost of holding the asset and δ is the economic depreciation rate. For simplicity let $(r+\delta) = .11$ for all companies and calculate the price of capital services using the formula given above. For AGT and Bell, asset price data is available which permits p_K in the formula to vary by company. The public data base does not contain a capital stock price for BC Tel. and Bell's capital stock price was used for BC Tel.[23]

The consequence of this change is to practically eliminate the difference in the capital service price across companies in each time period. Using this data the relative efficiency differences were recalculated. The new results are shown in Table 24. <u>The main results are NOT altered</u>. Bell is as efficient as BC Tel. and there is no change through time. AGT is less efficient than BC Tel. in 1972 but the difference is reversed by the end of the period. The similarity in the results may seem surprising. It occurs because the change in the price of capital services results in a change in total cost and consequently the cost shares. For example, when comparing AGT and BC Tel., this has the effect on relative efficiency measures (equations (4) and (5), p. 57) of increasing the importance of the difference in the unchanged quantity of capital inputs and decreasing the differences in labour and materials input when comparing AGT and BC Tel.. The net effect is very small.

Table 24

Relative Efficiency - Alternative Capital Service Prices and Company Capital Stock

	Productivity			Cost Efficiency	
	AGT	BELL	BC Tel.	BELL	AGT
1972	89.5	98.9	100.0	101.2	111.7
1973	94.0	100.8	100.0	99.3	106.4
1974	100.0	99.5	100.0	100.5	100.0
1975	102.5	101.0	100.0	99.1	97.6
1976	98.6	98.1	100.0	101.9	101.4
1977	108.2	101.3	100.0	98.7	92.5
1978	107.2	100.6	100.0	99.4	93.3

	Productivity		Cost Efficiency
	BELL	AGT	BELL
1967	124.7	100.0	80.2
1968	123.9	100.0	80.7
1969	120.9	100.0	82.7
1970	120.3	100.0	83.1
1971	115.3	100.0	86.7
1972	109.5	100.0	91.3
1973	106.3	100.0	94.0
1974	98.7	100.0	101.3
1975	98.1	100.0	102.0
1976	98.7	100.0	101.3
1977	93.3	100.0	107.2
1978	93.3	100.0	107.1

The second alternative used the explicit capital service price developed in the first alternative and a new alternative capital stock. The latter was generated by dividing the actual value of capital services by the capital service price. This method may be interpreted in the following manner. The derived capital stock is consistent with the actual expenditure on capital services at the chosen price of capital services.

The comparative efficiency results in this case are different and are reported in Table 25. In the comparisons of AGT-BC Tel. and Bell-BC Tel. there are several comments relative to our initial comparison. First, the initial efficiency levels are raised, to the disadvantage of BC Tel. Second the intertemporal gains made by AGT still occur although at a slightly slower rate. Third, the Bell-BC Tel. comparison now has a trend in favour of Bell which was not evident in the earlier comparisons.

There are several changes in the Bell-AGT comparison. The 1967 relative efficiency advantage held by Bell is much smaller. The trend against Bell is still evident but it is neither as consistent nor as strong.

The alternatives that we have presented should be understood as examples of the sensitivity of our results to alternative measures of capital. We have shown that the relative efficiency levels may change although the broader conclusions do not disappear.

What is required in the next stage is a careful construction of a capital service price to be used in conjunction with the capital stocks. This will be a more complex variant of our second alternative and will permit a much more satisfactory understanding of the differences between countries.

Table 25

Relative Efficiency - Alternative Capital
Service Prices and Capital Stocks

	Productivity			Cost Efficiency	
	AGT	BELL	BC Tel.	BELL	AGT
1972	96.8	101.4	100.0	98.6	103.3
1973	99.6	102.3	100.0	97.8	100.4
1974	102.2	102.3	100.0	97.8	97.8
1975	110.9	107.2	100.0	93.3	90.2
1976	102.1	106.1	100.0	94.2	97.9
1977	110.0	112.2	100.0	89.1	91.0
1978	108.7	111.0	100.0	90.0	92.0

	Productivity		Cost Efficiency
	BELL	AGT	BELL
1967	106.9	100.0	93.6
1968	114.5	100.0	87.3
1969	114.0	100.0	97.9
1970	110.2	100.0	90.8
1971	103.8	100.0	96.4
1972	103.9	100.0	96.3
1973	101.8	100.0	98.2
1974	99.3	100.0	100.7
1975	96.1	100.0	104.0
1976	103.3	100.0	96.8
1977	101.9	100.0	98.1
1978	102.0	100.0	98.0

The methodology will permit a sharper distinction to be made between inter-firm variations in (1) the capital asset price, (2) the opportunity cost of funds, (3) the rate of depreciation and (4) the tax systems. These may be all important sources of differences in the capital service price and we are working on clarifying the role of each.

4.7 The Price and Quantity of Labour Inputs

The comparison of the firms was undertaken with the available data from the public data base. The quantity of labour equalled the unweighted total of manhours used by the firm. The price of labour was the implicit price given the total expenditure on labour by the company. Other studies[24] have used weighted manhpurs and a brief investigation of the consequences of weighting will be usefu.

Both BC Tel. and Bell have data on disaggregated labour costs and manhours. It is possible, for these two companies, to evaluate the consequences of weighting. Alternative price indexes for labour are given in Table 26. The columns labelled 'unadjusted manhours' are the unweighted price indexes used in our comparison. BC Tel. experienced a very rapid rate of price increase from 1974-76 while Bell has had a very rapid increase from 1976-79.

Bell Canada produces data on weighted manhours based on the use of 1967 relative wages as weights for each year. The resulting price index is shown under the column labelled 'adjusted manhours'. The movement of the price index for Bell's adjusted manhours is identical to the unadjusted manhours. This is purely a specific result for this set of data. Prior to 1972, there was a divergence in the prices of adjusted and unadjusted manhours for Bell Canada. From 1972-79, the choice between adjusted and unadjusted manhours is irrelevant for the measurement of Bell's efficiency.

For BC Tel., this is not true. A labour price index for adjusted manhours, using 1972 relative wages as weights for each year, was calculated. It is reported in Table 26, column two. There is a slower rate of price increase and a faster rate of quantity increase using adjusted manhours.

Table 26

Labour Price Indexes

	Divisia Index	Adjusted Manhours		Unadjusted Manhours	
	BC Tel.	BC Tel.	BELL	BC Tel.	BELL
1971	.92	.92	.89	.91	.89
1972	1.00	1.00	1.00	1.00	1.00
1973	1.07	1.07	1.08	1.07	1.08
1974	1.24	1.24	1.21	1.25	1.20
1975	1.48	1.48	1.45	1.51	1.45
1976	1.90	1.90	1.63	1.95	1.63
1977	1.88	1.87	1.81	2.00	1.81
1978	1.91	1.87	1.90	2.03	1.92
1979	1.98	1.94	2.18	2.07	2.18

For BC Tel. the switch to adjusted manhours will slow down the rate of growth of productivity.

There is no reason to use fixed weights and for BC Tel., a Divisia labour price index is presented in column one of Table 26. The variable weights result in a price index which is very close to the fixed weight index until 1977. Form then on the Divisia index grows more slowly.

Our use of unweighted manhours probably underestimates the rate of growth of labour input and overestimates the rate of growth of total factor productivity. From our limited data, the change to weighted manhours might penalize BC Tel. more than Bell. However, our evidence is very limited at this time. No information is available for AGT.

The proper treatment of weighted manhours might require a different procedure than the companies currently use. Bell forces the weighted and unweighted manhours to be identical in the year from which the weights are chosen. This is fine for their purpose but it would be useful to permit variation in the total quantity across companies in the common base year between the weighted and unweighted cases.

4.8 Material Inputs

It was noted earlier that Bell Canada's cost share for material inputs was higher than the other two companies. At this stage we do not have any evidence about the reasons for this observation. In the continuation of this work, the underlying disaggregated series will be examined to try to understand the implications of this higher materials usage.

4.9 The Price and Quantity of Local Service Output

Local service output includes the basic local services provided at a flat rate for main telephones and extensions as well as numerous special equipment items. Data is not yet available on a consistent disaggregated basis and we will have to struggle with incomplete comparisons. Our major tasks can be easily stated. To what extent does the existing data on the price and quantity of local services (a) provide an adequate measure of local output and (b) provide comparable data across companies. For present purposes we will concentrate on (b) although elements of (a) will appear. This choice is predicated on our previous work on task (a) in last year's report and our continuing efforts contained in the sections on documentation.

To concretely illustrate the possible problems we can use the companies' reported local service price indexes presented in Table 27. From 1968-74 AGT's price showed no increase. This is because there were no explicit rate increases. There were however changes in the relative quantities of outputs which are not reflected in the AGT local service price index. From 1972 to 1974, there were no explicit rate increases for BC Tel. Yet, the BC Tel. price index rises by 5%. This increase for BC Tel. is due to differences in the methodology used at BC Tel. relative to that used at AGT and Bell in measuring price indexes. During the 1970's most of the increases in the price indexes for all companies are due to explicit rate increases. However, it is likely that the BC Tel. price index increased more rapidly than it would have if the AGT or Bell methodology had been used.

Table 27

Local Service Price Indexes
(1972 = 100.0)

	BC Tel.	AGT	BELL
1967	--	94.1	92.1
1968	--	100.0	92.1
1969	--	100.0	92.3
1970	--	100.0	93.6
1971	--	100.0	97.2
1972	100.0	100.0	100.0
1973	102.2	100.0	102.7
1974	105.5	100.0	105.0
1975	120.0	101.6	110.1
1976	137.5	123.2	116.9
1977	153.0	137.7	124.3
1978	162.4	137.7	135.8
1979	166.9	137.7	145.1

We do not have the data to measure the price index for local service on a common methodology across all three companies. However, we can provide some evidence on the likely consequences of changing methodologies. There are a large number of specific items in local services. BC Tel.'s procedure uses five major categories to account for most of local services. These are: (1) monthly contract-business main, (2) monthly contract-business extensions, (3) monthly contract-residential main, (4) monthly contract-residential extensions and (5) monthly contract-PBX and Centrex. The BC Tel. price index for this subset of local services rises slightly more slowly than the price index for all local services. The unweighted (or simple average revenue) price index for these services rises slightly more slowly than the weighted one. In summary, shifting from the Divisia price index of all local services presented in Table 27 to an unweighted price index of the five major items listed above lowers the price index but not by a major amount. The unweighted price index is reported in Table 28.

In this same table we have presented an unweighted local price index for almost the same group of services for Bell. Notice that the 1979 price indexes for the companies are now very close. Moreover, prior to 1972 the Bell price index was increasing faster than the local service price index in Table 27. Most of the difference occurs in the 1972-75 period. The Bell local service price index for 1975 has risen from 110.1 in Table 27 to 118.1 in Table 28. The comparable difference in the two Bell price indexes after 1975, with 1975 = 100, is only 132 to 136. This evidence suggests that the difference in the rate of growth of the local service price index is significantly affected by the methodological differences between BC Tel. and the other two companies.

Table 28

Unweighted Local Price Indexes: BC Tel. and Bell

	BC Tel.	BELL
1967	--	85.6
1968	--	86.7
1969	--	88.6
1970	--	91.2
1971	--	97.0
1972	100.0	100.0
1973	101.8	105.2
1974	104.6	110.0
1975	117.3	118.1
1976	133.2	126.4
1977	148.9	136.2
1978	158.3	149.7
1979	162.6	160.1

One might wonder if the new Bell unweighted price index (Table 28) misrepresents the Bell price index for all local services. There is one bit of limited evidence reported in Table 29 .

Table

Local Price Indexes for Bell

	Bell Contract	All Local	Our Contract
1975	100.0	100.0	100.0
1976	105.3	106.2	107.1
1977	111.9	112.8	115.4
1978	121.8	123.2	126.9
1979	129.5	131.8	135.7

The first two columns are Bell-produced price indexes. Column one contains the price index for contract services only derived from Bell Canada, Memorandum on Demand and Operating Revenues. The second reports the standard Bell Canada price index for local services and the third column contains our unweighted Bell Canada price index for contract services. The price index for local contract services rises more slowly than the price index for all local services. This was also observed for BC Tel. Second, Bell's contract price index rises significantly more slowly than our unweighted contract price index. This confirms two points. First, for both companies, the price index for contract services rises more slowly than the price index for non-contract local services. Second, most of the difference in the local service price indexes produced by the companies is probably a result of different methodologies.

Table 30

Alternative Output Indicators

1. Constant Dollar Quantity	BC Tel.	AGT	BELL
(a) 1972 value, 1967 = 1.00	--	1.62	1.41
(b) 1979 value, 1972 = 1.00	1.50	2.69	1.52
(c) 1979 value, 1967 = 1.00	--	4.36	2.16

2. Main Telephones	BC Tel.	AGT	BELL
(a) 1972 value, 1967 = 1.00	--	1.58	1.40
(b) 1979 value, 1972 = 1.00	1.44	1.66	1.31
(c) 1979 value, 1967 = 1.00	--	2.62	1.84

It is useful to consider more directly the evidence on the quantity measures of local service output. One could consider number of phones, local calls and main stations as alternatives to the constant dollar local output. For simplicity we will limit ourselves to the number of main telephones. Various index values for constant dollar local service output and the number of main telephones are reported in Table 30 .

From 1967-1972, main telephones grew at almost the same rate as constant dollar local service output for AGT and Bell. The same was not true from 1972-79. For BC Tel., the two indicators were quite similar but for AGT and Bell this was not true. AGT provides the most spectacular case. The 1979 value of the index of constant dollar output was 2.69 (1972 = 1.00) compared to 1.66 for main telephones. This very sharp difference needs an explanation but we do not have one. While the divergence for Bell Canada (1.52 vs. 1.31) is not as large it is still much larger than the earlier period.

These results suggest that the local service output growth at AGT and Bell needs more investigation before a final comparison can be satisfactory.

To provide some detail on the growth of the major components of local services, we report, without comment, the rates of growth of five components in Tables 31, 32 and 33.

Table 31

Change in Monthly Contract Quantities
(in %)

	Business Main			Residence Main		
	BC Tel.	AGT	BELL	BC Tel.	AGT	BELL
1968	-	4.4	4.2	-	7.9	4.7
1969	-	4.9	4.6	-	7.5	4.4
1970	-	3.9	3.3	-	7.2	3.7
1971	-	6.6	4.4	-	8.4	3.9
1972	-	6.1	5.5	-	8.8	4.6
1973	7.7	3.9	6.0	5.9	3.5	4.4
1974	8.3	8.8	5.3	6.0	7.5	4.3
1975	7.9	15.4	5.9	5.0	6.4	3.8
1976	6.1	8.6	5.1	4.4	5.3	3.5
1977	4.5	9.5	4.5	3.7	6.6	3.0
1978	5.0	10.2	4.4	3.8	6.2	2.9
1979	6.8	10.9	4.7	4.6	6.8	2.1

Table 32

Change in Monthly Contract Quantities
(in %)

	Business Extension			Residence Extension		
	BC Tel.	AGT	BELL	BC Tel.	AGT	BELL
1968	-	10.2	10.0	-	19.4	5.6
1969	-	7.3	8.2	-	11.2	6.0
1970	-	6.9	6.8	-	16.5	3.7
1971	-	7.8	7.7	-	18.3	4.6
1972	-	8.5	16.7	-	18.0	6.0
1973	8.1	6.4	5.9	13.8	7.3	6.3
1974	8.9	10.0	8.4	12.8	19.3	5.4
1975	7.1	-3.3	7.1	10.4	16.9	4.6
1976	6.5	9.0	11.6	8.1	13.6	4.5
1977	4.9	9.2	5.9	6.1	12.6	3.9
1978	3.9	11.2	5.7	5.3	12.9	3.5
1979	5.5	11.5	4.2	7.2	12.4	4.0

Table 33

Change in Monthly Contract Quantities
(in %)

PBX Service

	BC Tel.	AGT	BELL
1968	-	9.1	6.3
1969	-	13.5	7.0
1970	-	8.6	5.3
1971	-	3.2	4.9
1972	-	8.0	6.0
1973	8.6	9.0	6.6
1974	6.0	13.9	7.9
1975	8.1	13.1	5.3
1976	5.7	12.3	3.2
1977	3.8	7.3	3.0
1978	4.8	9.6	3.5
1979	5.8	6.0	3.2

4.10 The Price and Quantity of Toll Output

The methodology used to measure toll output is different for each company. In particular, BC Tel. has used a simpler and potentially less useful technique. To provide some evidence on the consequences of varying methodologies some alternatives have been tried for message toll.

BC Tel. divides message toll into ten categories and an implicit toll price may be defined by dividing settled revenues for each category by the number of calls. Using a discrete approximation to the Divisia index an aggregate message toll price index is calculated from these ten toll output categories. The price index is shown in column A of Table 34. An extreme alternative is to simply divide total message toll revenue by total toll calls to obtain a simple aggregate price index. Column B in Table 34 reports this index. The rate of price increase is smaller when all calls are treated equally. The corresponding output will grow slightly quicker since total revenue is fixed. Instead of eliminating all the distinctions between types of calls, we have calculated the price index when the distinction between operator-assisted and DDD is eliminated, column C, and in column D, one that includes this constraint plus a simple combining of Overseas, Trans-Canada and U.S. calls. The price index in column C rises much more slowly than those in columns A and B. That is the failure to distinguish between operator-assisted and DDD calls reduces the price index substantially. The addition of a second constraint that combines some jurisdictional categories (Overseas, Trans-Canada and U.S.) does not lead to a major change in the index. The key variable for BC Tel. message toll pricing is the distinction between operator-assisted and DDD calls.[25]

Table 34

Alternative Toll Prices: BC Tel.

	A	B	C	D
1972	100.0	100.0	100.0	100.0
1973	109.0	102.4	100.5	101.3
1974	111.7	104.3	100.6	102.0
1975	119.5	112.3	105.9	108.3
1976	127.6	120.7	113.4	115.6
1977	132.3	126.6	116.9	119.8
1978	137.2	132.6	120.9	124.6
1979	137.0	135.2	121.2	125.1

To link this variation to the toll price indexes of the other companies, Table 35 reports the message toll price indexes for all three companies. The question we would like to answer about toll prices is similar to the enquiry into local prices. Do the methodological variations dominate the true results. We have much less information about toll pricing but certain things can be indicated.

First, a simple unweighted message toll price index for Bell rises to 145.5 in 1979 in contrast with 128.5 for the Bell message toll price index in 1979. The unweighted price index for BC Tel. has risen by less than the unweighted price index for Bell. Unfortunately, we have not been able to use any common weighting scheme for both companies. We do know from Table 34 that changed weighting alter the message toll prices index for BC Tel. but we cannot duplicate the Bell procedure for BC Tel. We hope to duplicate the BC Tel. procedure approximately for Bell. It is likely although not certain that the BC Tel. procedure tends to increase the rate of price increase relative to the Bell procedure for both companies.

Table 35

Price Indexes for Message Toll
(Company Produced)

	BC Tel.	AGT	BELL
1967	--	98.7	89.9
1968	--	101.4	89.3
1969	--	101.1	89.6
1970	--	100.1	97.0
1971	--	100.1	98.6
1972	100.0	100.0	100.0
1973	109.0	100.3	102.1
1974	111.8	100.2	103.2
1975	119.5	103.5	106.9
1976	127.6	117.4	113.0
1977	132.3	121.7	116.1
1978	137.2	122.9	122.1
1979	137.0	123.5	128.5

5. Future Work

In the separate sections we have tried to indicate briefly the type of work that must be done if an improved set of estimates are to be calculated. At this stage, we have completed a highly useful set of estimates whose quality probably surpasses that of most empirical economic work. The problems that remain attest to the quality of the comparison that we can attain provided we assemble the required data. This does not seem an insurmountable task.

The major improvement must come in the reconciliation of the output data and an improved treatment of capital. At the moment, there is too much uncertainty about the consequences of the methodological differences. BC Tel. is the company whose methods differ the most from the other two but there is some variation between AGT and Bell.

We will end as we began with our thanks for the assistance of the companies. We hope that this report will assist all of us in finishing the project with a comparison that satisfies almost everyone.

Footnotes

1. The cost function defines the minimum cost of producing any output level of any set of relative input prices.
2. See Diewert (1976).
3. See Denny, Fuss and Everson (1979).
4. Kravis (1976) provides a different perspective.
5. These estimates might include information about scale or demand or supply elasticities for example,.
6. See Jorgenson and Nishimizu (1978).
7. See Diewert (1976).
8. Remember that we are accounting for the effects of differences in input usage. The remaining efficiency differential may be caused by many things.
9. Almost all the studies have been concerned with multiple outputs which is why we have begun with the revenue function.
10. That is, we force the measures with own price weights to equal one and deviations from this may not include efficiency differentials that have been defined away.
11. The data is taken from Statistics Canada, Telephone Statistics (56-203).
12. The exact dividing line is not specified in detail although for our purposes this is not very important.
13. The change was associated with the introduction of a new survey.
14. In some cases, one would have thought that better editing of the survey would have clarified the problems.
15. Route miles equal the geographic distance over which circuits are laid out.

16. Most of the single aerial wire in the exchange netwrok must be in the very low density areas.

17. For all three companies, the revenue shares for local services were much higher fifteen to twenty years ago.

18. Almost all of the toll revenue is allocated to AGT.

19. The sources for AGT, Bell and BC Tel. are contained in Appendix A.2. For Teleglobe the estimates are found in Teleglobe Canada, Total Factor Productivity, Users Manual and Historical Perspective.

20. It is contained in a separate publication entitled part III, Data Documentation.

21. An extensive discussion of this measure is contained in Denny, de Fontenay and Werner (1980) and Denny and Fuss (1980). A non-technical discussion is contained in section two of this report.

22. That is, the value of capital services is defined to equal the price of capital services times the quantity of capital services. Only two of the three variables may be chosen independently.

23. Our guess is that this is not a serious distortion but we will check this assumption and use the BC Tel. plant price index when it is available.

24. For example, Denny, Fuss and Everson (1979), as one among many.

25. This is conditional on the distinctions that they do make and ignores certain other ones that they do not make, e.g. mileage bands and time of day.

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Appendix A.1

Alternative Measures of Relative Efficiency

In the text of the report we discussed the possibility of using alternative measures of TFP and relative efficiency. In this appendix we report the results of carrying out that task. Our primary estimates are based on the common approximation to a Divisia index for TFP and on the Denny-Fuss extension of the Jorgenson-Nishimizu methodology for comparing efficiency levels. The particular alternatives we have used for a comparison are similar to commonly used alternatives which we have argued (in the text) have conceptual weaknesses which may lead to empirical differences.

The primary method for computing an index of a firm's TFP was based on the growth formula

$$\log Q_t - \log Q_{t-1} = \dot{TFP} + \frac{1}{2} \sum_i (s_{it} + s_{it-1})(\log X_{it} - \log X_{it-1})$$

where X_{it} is the quantity of input i used in year t to produce output level Q_t and $\dot{TFP}$ is the rate of growth of the total factor productivity. The cost shares s_{it} are calculated at the firm's own prices. The alternatives use the prices of one firm for calculating the productivity index for all firms. The results are reported by company in Tables A-1.1 to A-1.3. It is not necessary to analyze the differences in detail. For each company the first column presents the results using our primary method. The second and third columns provide estimates for the given company evaluated at the prices of the other two.

The ranking of the firms by their TFP index is basically the same whichever method is used. AGT's productivity level has reached a higher

Table A-1.1

Alternative Measures of TFP Indexes

	B.C. Telephone		
Prices	BC Tel.	AGT	Bell
1972	100.0	100.0	100.0
1973	102.9	102.9	102.9
1974	109.1	109.1	109.0
1975	115.9	115.4	115.6
1976	121.0	120.0	120.4
1977	118.4	116.5	117.2
1978	122.0	120.6	121.1

Table A-1.2

Alternative Measures of TFP Indexes

	Alberta Government Telephone (AGT)		
Prices	AGT	BC Tel.	Bell
1967	74.9	—	75.4
1968	78.9	—	79.1
1969	83.4	—	83.5
1970	87.3	—	87.5
1971	91.1	—	91.2
1972	100.0	100.0	100.0
1973	108.0	108.0	107.9
1974	121.7	121.7	121.7
1975	132.3	132.9	132.7
1976	132.7	133.7	133.3
1977	141.9	143.2	142.8
1978	144.8	145.6	145.0

Table A-1.3

Alternative Measures of TFP Indexes

	Bell Telephone		
Prices	Bell	AGT	BC Tel.
1967	86.8	86.7	—
1968	90.6	90.7	—
1969	93.3	93.3	—
1970	96.8	96.9	—
1971	96.3	96.2	—
1972	100.0	100.0	100.0
1973	104.8	104.8	104.8
1974	109.5	109.5	109.5
1975	117.3	117.3	117.4
1976	118.5	118.5	118.6
1977	119.4	119.4	119.7
1978	122.2	122.2	122.6

level than either BC Tel. and Bell. The latter two are very close although the use of the alternative methods clearly tends to place Bell slightly further ahead of BC Tel. than the primary method. This is because BC Tel.'s productivity index changes more sharply using the alternative methods than either of the other companies. Since Bell's and BC Tel.'s TFP index is very close no matter what method is used, there is really no significance to this variation.

The productivity indexes do not change by a large amount but will the productivity levels? The answer is 'No' as the evidence to be presented will demonstrate. First, the alternative method of measuring relative efficiency should be explained carefully. In contrast with the primary methods the alternative method for measuring regional efficiency was not derived in a manner that integrates it with the alternative method of measuring the TFP index. Instead we have followed the common practice of using a separate procedure for relative efficiency.

Our alternative procedure for the computation of the relative efficiency level is very simple. For any two firms we have calculated an aggregate output and an aggregate input index. The ratio of aggregate output to aggregate input for one firm divided by the same ratio for the other firm equals the alternative relative efficiency measure. Algebraically we have,

$$E^A_{i0} = \frac{Q_i/F_i}{Q_0/F_0}$$

where Q_k and F_k, $k = 1,0$, are the aggregate output and input quantities in firm k. This method was applied using the prices of one firm in both firms. The results are presented for each company in Tables A-1.4 to A-1.6. The first column in each table shows the results from our primary method

Table A-1.4

Alternative Measures of TFP Levels

AGT vs. BC Tel.

	Primary	BC Tel. Prices	AGT Prices
1972	89.6	89.3	89.8
1973	94.0	93.7	94.3
1974	100.0	99.7	100.2
1975	102.4	102.4	102.9
1976	98.6	98.7	99.3
1977	108.2	108.1	109.4
1978	107.5	106.6	107.8

Table A-1.5

Alternative Measures of TFP Levels

Bell vs. BC Tel.

	Primary	BC Tel. Prices*	Bell Prices
1972	98.8	99.0	98.6
1973	100.7	100.8	100.4
1974	99.5	99.4	99.0
1975	101.0	100.3	100.0
1976	98.1	97.1	97.0
1977	101.2	100.1	100.4
1978	100.5	99.4	99.5

Table A-1.6

Alternative Measures of TFP Levels

Bell vs. AGT

	Primary	AGT Prices	Bell Prices
1967	124.8	126.5	126.9
1968	123.8	125.6	126.2
1969	120.9	122.2	122.9
1970	120.4	121.2	121.9
1971	115.6	115.5	116.4
1972	109.7	109.3	110.1
1973	106.4	106.0	106.8
1974	98.8	98.3	99.1
1975	98.3	96.9	97.4
1976	98.9	97.6	97.9
1977	93.3	91.9	92.1
1978	93.4	92.2	92.8

discussed in the body of the report. The second two columns show the alternative measure calculated using the prices of one of the two firms. That is, the same prices are used for both firms in evaluating the inputs and output.

The major conclusions do not change when one uses the alternative method. Bell began with an efficiency level that was higher than AGT's and equal to BC Tel.'s. AGT's efficiency level was lower than BC Tel.'s level. The rapid growth of productivity in AGT resulted in the highest relative efficiency level in AGT at the end of the period. Bell maintained its efficiency level relative to BC Tel.

As the theoretical discussion indicated, a given company should do better when its own prices are used rather than when another company's prices are selected. This is certainly confirmed empirically in Tables A-1.4 to A-1.6.

In this particular application it would seem that the use of the alternative methods would not have changed the qualitative results. The quantitative magnitudes are shifted but by quite small percentages. We remain convinced that the knowledge of the theoretical underpinnings for our primary measure gives it a definite advantage over the alternatives. The latter lack any firm basis for an interpretation.

Our comparisons using all methods are limited at this stage due to the limited public data. As further data becomes available, new results on alternative measures will emerge.

Appendix A.2

Data Base for Efficiency Comparison

The comparisons that have been made are based on the public data bases of the three companies. In a small but crucial number of incidents the companies have provided extra data which was very helpful. The purpose of this section is to identify the exact public data series which were used.

For Bell Canada, the data were taken from the most recent productivity submission to the CRTC:

> Bell Canada, Information Requested by National Anti-Poverty Organization, March 30, 1981, Bell (NAPO) 30 Mar. 81-612, CRTC.

For BC Telephone the data were taken from the submission to the CRTC:

> BC Telephone, Total Factor Productivity Study: Data Description and Methodology, by J.T.M. Lee, BC Tel. (NAPO) 80-08-01-406, CRTC.

For AGT, data in current dollars was supplied by the company and the corresponding constant dollar data appear in the CRTC submission by AGT, Saskatchewan Telecommunications and Manitoba Telephone Systems in the CNCP-Bell Canada inter-connect case:

> Some Economic Aspects of Interconnection, Evidence in Chief, H. Harris, economic witness.

BELL CANADA

Labour

- uses unweighted man-hours (unadjusted man-hours from Table 6 of NAPO 30 Mar. 81).
- generates price index PL by dividing total labour compensation (Table 6 NAPO 30 Mar. 81) by unadjusted man-hours
- PL = TLE/MH $

Materials

- uses current $ cost of materials, services, rents and supplies divided by constant $ cost of materials, etc. (from Table 3 NAPO 30 Mar. 81) to arrive at a price index. This price series is re-normalized in 1972. The re-normalized series is divided into the current $ cost of materials to provide a constant $ material series.

Capital

- use total average gross stock of physical capital in current $ divided by constant $ series (Table 7 NAPO 30 Mar. 81) to generate an asset price series. This asset price series was re-normalized in 1972 and the re-normalized price was divided into current $ total average gross stock of capital to yield a constant dollar gross capital series in 1972 $.

The value of capital was generated residually by subtracting total labour compensation (Table 6 NAPO) and current $ cost of materials (Table 3 NAPO) from Total Revenue (Table 1 NAPO 30 Mar. 81)

$$VK = TR - PM * M - PL * L$$

The service price of capital was arrived at by dividing the 1972 constant $ gross capital series into the value of capital services generated residually.

Output

- the output series is a divisia index with price = 1.0 in 1972. The components in the divisia index are the prices and quantities of local service message toll, other toll, directory advertising and miscellaneous. Current and constant $ amounts for these categories appear in Tables 1 and 2 of NAPO 30 Mar. 81. The price series for each classification were found by dividing current $ series by the corresponding constant $ series.

B.C. TELEPHONE

Labour

- Table A-13 of (BC Tel. NAPO 80-08-01-406) provides expensed labour hours and expensed wages, benefits and taxes for the following classifications; management, clerical operators, occupational, engineers, salesmen, service rep., technicians and draftsmen. The quantity of labour is the simple, unweighted sum of the expensed labour hours of all these categories. The price of labour was found by dividing this quantity of labour into the unweighted sum of the expensed wages of all the categories.

$$PL = \frac{\sum_i \text{wages}_i}{\sum_i \text{labour hours}_i}$$

Output

- the output price and quantity series is a divisia index (price = 1.0 in 1972) of the disaggregated output categories given in Tables A-1 and A-2. The quantity series is given in Table A-2 while the corresponding revenues are given in Table A-1. A price series is generated for each category by dividing the quantity series into the revenue series.

Capital

- the value of capital services was found as the sum of the financial charges (Total line in Table A-4), depreciation (Total line in Table A-5), property tax (Total line in Table A-6) for Okanagan Tel. and the financial expense (Total line in Table A-7), depreciation expense (Total line in Table A-8) and property taxes (Total line in Table A-9) for B.C. Tel.

The capital series was found as the reproduction cost of capital in Table A-11, adjusted to 1972 $.

The price of capital services was generated by dividing the value of capital services series by the capital series:

Materials

- the value of materials is generated residually. It is found by subtracting total expensed wages (see above) and the value of capital services (see above) from total revenue (see above).

This value of materials series is deflated by a re-normalized (1972) materials price index equal to the Stats Can GNE deflator to yield a constant 1972 $ series for materials.

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Materials

- the current dollar value of materials (in Harris letter of Dec. 4, 1980) is divided by the constant 1971 $ value of materials (provided in Interconnection Evidence Appendix 4, Table 1) to arrive at a price series. This price series is re-normalized in 1972 and a constant $ material series is found by dividing current $ value materials by the re-normalized price series.

Labour

- current $ value of labour (from Harris letter) is divided by the man-hour series (Interconnection Evidence, App. 4, Table 1) to arrive at a price series for labour. No normalization is performed on these series.

Capital

- the value of capital services in current $ (from Harris letter) is divided by constant 1972 $ average gross capital series to yield a price of capital services. This series is constructed by dividing the current $ gross capital series (Harris letter) by the constant 1971 $ gross capital series (Interconnection Evidence) which yields an asset price series. The asset price series is re-normalized in 1972 and then divided into current $ gross capital to arrive at the constant 1972 $ gross capital series. The price of capital services is arrived at in this manner.

<u>Output</u>

- the output quantity series is produced by dividing gross revenue in current $ (Harris letter) by gross revenue in constant 1971 $ (Inter. Ev.) to yield an output price series. The output price is re-normalized in 1972 then divided into current $ gross revenue to yield a constnat 1972 $ output series.

Table A-2.1

Cost Shares: BC Tel.
(percentage of operating costs)

	Labour	Capital	Materials
1972	35.5	52.0	12.5
1973	35.3	52.0	12.7
1974	36.7	51.0	12.3
1975	34.6	53.8	11.6
1976	35.3	53.0	11.7
1977	31.8	53.5	14.7
1978	31.3	55.9	12.8
1979	33.3	53.7	13.0

Table A-2.2

Cost Shares: AGT
(percentage of operating costs)

	Labour	Capital	Materials
1967	39.7	47.8	12.5
1968	33.3	54.4	12.3
1969	33.4	54.3	12.3
1970	34.5	53.0	12.4
1971	36.7	50.9	12.3
1972	34.4	54.1	11.5
1973	34.1	54.7	11.1
1974	33.9	54.5	11.6
1975	36.6	50.6	12.8
1976	33.8	52.7	13.5
1977	33.8	54.3	11.8
1978	31.6	55.2	13.2

Table A-2.3

Cost Shares, Bell Canada
(percentage of operating costs)

	Labour	Capital	Materials
1967	27.8	58.1	14.1
1968	27.4	58.5	14.1
1969	27.2	57.0	15.8
1970	27.6	57.7	14.7
1971	27.0	56.3	16.7
1972	27.5	56.5	16.0
1973	27.5	56.8	15.7
1974	28.9	54.9	16.2
1975	29.9	54.9	15.2
1976	31.0	53.4	15.6
1977	31.8	51.2	17.0
1978	30.7	52.3	17.0
1979	32.2	51.3	16.5

Table A-2.4

B.C. Telephone

Quantities

	Output	Labour	Capital	Materials
1972	218.2	13.0	1040.9	28.4
1973	241.5	13.9	1130.7	30.4
1974	276.1	14.7	1250.1	30.7
1975	303.3	13.8	1387.6	31.4
1976	329.9	13.1	1516.9	34.8
1977	350.7	13.1	1644.0	46.9
1978	385.3	14.7	1756.0	44.3
1979	431.0	17.3	1854.8	45.9

Prices

	Labour	Capital	Materials
1972	6.21	.114	1.00
1973	6.66	.121	1.09
1974	7.74	.127	1.25
1975	9.39	.145	1.38
1976	12.11	.157	1.52
1977	12.43	.167	1.61
1978	12.62	.188	1.72
1979	12.84	.192	1.88

Table A-2.5

Alberta Government Telephones

Quantities

	Output	Labour	Capital	Materials
1967	78.8	8.8	511.8	11.7
1968	87.1	8.5	563.8	12.7
1969	99.0	8.9	614.3	13.9
1970	111.0	9.4	663.2	14.9
1971	122.8	9.6	721.5	15.9
1972	142.1	9.8	781.6	16.3
1973	161.8	10.4	824.9	16.7
1974	194.4	11.0	880.6	18.2
1975	231.4	11.1	993.6	22.2
1976	259.8	12.0	1109.6	
1977	295.2	12.4	1225.0	
1978	348.9	15.1	1349.1	

Prices

	Labour	Capital	Materials
1967	3.44	.071	.814
1968	3.42	.084	.841
1969	3.73	.088	.879
1970	4.07	.089	.924
1971	4.70	.087	.951
1972	5.00	.089	1.000
1973	5.36	.108	1.088
1974	6.06	.122	1.259
1975	7.96	.123	1.393
1976	8.75	.147	1.527
1977	10.10	.164	1.633
1978	9.35	.183	1.737

Table A-2.6

Bell Telephone

Quantities

	Output	Labour	Capital	Materials
1967	769.7	56.6	4240.9	119.5
1968	832.8	54.6	4540.6	125.0
1969	919.7	55.5	4858.5	149.0
1970	991.7	56.1	5169.5	176.8
1971	1046.1	55.2	5507.9	181.0
1972	1129.3	55.1	5869.2	191.7
1973	1248.7	57.8	6205.3	202.6
1974	1385.3	61.6	6582.6	200.7
1975	1536.8	61.3	7053.3	216.4
1976	1653.9	64.3	7551.4	242.4
1977	1768.4	66.6	8000.9	265.7
1978	1919.1	71.1	8354.5	267.7

Prices

	Labour	Capital	Materials
1967	3.46	.097	.834
1968	3.82	.098	.862
1969	4.15	.099	.898
1970	4.64	.105	.932
1971	5.00	.105	.968
1972	5.64	.109	1.000
1973	6.08	.117	1.048
1974	6.79	.121	1.153
1975	8.17	.130	1.271
1976	9.21	.135	1.383
1977	10.24	.137	1.500
1978	10.85	.157	1.610