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An Initial Analysis of Total Factor Productivity for Public Transit

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ABSTRACT

Improvement of transit performance depends first on the ability to measure performance levels. Introduced is the concept of total factor productivity as a unified measure of transit performance. This concept uses the shift in the cost function as the measure of change in productivity. A three-stage least-squares estimation procedure was used to estimate model parameters. The technique was applied to 20 transit systems. Data were analyzed for the most recent 26-year period. Results indicate that there are no consistent trends in total factor productivity. Productivity appears to increase and decrease in similar amounts year by year, indicating that there is little change. This supports the hypothesis that little technological improvement has occurred in the industry and that management decisions tend to compensate for productivity changes so that productivity remains stable over time when total inputs and outputs are investigated.

The ability to improve transit performance relies to a great extent on the ability to measure it. This need for performance measures has led to the development of a large number of ad hoc productivity, efficiency, and effectiveness measures. A measure of productivity is suggested that (a) is derived from economic theory, and (b) consistently traces changes in productivity (which includes all the relevant inputs and outputs). The method is total factor productivity and its application in this paper is based on the cost function approach and not the production function approach, which assumes constant returns to scale.

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REVIEW OF LITERATURE

Among the pioneering work in transit performance analysis is Tomazinis's research, which specifies a set of indicators to be used in measuring partial productivity and efficiency (1). Following Tomazinis, a number of studies have been conducted, all of which attempt to offer explanations for productivity changes and suggestions for productivity improvement. Meyer and Gomez-Ibanez after a detailed analysis of productivity changes in transit systems, suggest elimination of parking, discontinuation of less productive services, and specialization of service as possible approaches to improve productivity (2). In addition to explaining productivity changes, other research has focused on developing relationships between productivity and policy variables. For example, weak statistical relationship has been found between organizational structure and transit performance (3).

These relationships between productivity measures and policy variables are more meaningful if a single measure of productivity can be developed. Although Stokes contends that no one indicator of transit performance (partial productivity) will reveal the relative or absolute performance of a system's management (4), recent research indicates that total factor productivity, defined as total output per unit of total resources expended, is the single best measure of productive efficiency (5). Two approaches can be used to measure total factor productivity: the first utilizes the production function and the second is based on the cost function. The cost function approach is the dual of the production function approach. In both cases, the rate of growth of output, which is unexplained by input growth, is the technical change or productivity. This method of analyzing productivity has been used to calculate and determine the sources of total factor productivity growth for U.S. railroad systems (5).

Concerning measurement of total factor productivity in transit systems, little research exists in this area except that of Meyer and Gomez-Ibanez (2). The absence of research in the application of the total factor productivity method to transit systems makes this current research timely and useful.

METHODOLOGICAL FRAMEWORK

The derivation of the total factor productivity formula begins by assuming that the production of transit services requires the least-cost combination of the various inputs. Thus if the transit inputs are fuel, labor, vehicles, and materials, the transit manager must select combinations of these inputs to produce a given level of output at least cost. If the exact form of the production function is known, the underlying cost function can be derived. The resulting cost function can be used to calculate total factor productivity. The cost function, as noted earlier, will be the dual of the production function. Thus, total factor productivity can be determined from either the production or cost function. However, a major disadvantage in the production function approach is that it assumes constant returns to scale and, as a result, recent trends indicate that the cost function approach is the most appropriate method to use.

Caves, Christensen, and Swanson (5) have demonstrated that the index of total factor productivity based on a homogeneous, concave, and nondecreasing cost function is given by

$$-(\partial \ln g/\partial T) = \sum^{j} (\partial \ln g/\partial \ln Y_j) \cdot (\partial \ln Y_j/\partial T) - \sum^{i} S_i \; (\partial \ln X_i/\partial T) \qquad (1)$$

where

g = cost function,
T = time,
Y_j = output j,
S_i = cost share of input, and
X_i = input i.

Thus, total factor productivity is the difference between the weighted growth of output and the weighted growth of inputs. Total factor productivity defined in Equation 1 is for marginal changes in the outputs and inputs only. For discrete changes, an approximation to Equation 1 is used. The difference in natural logarithms is used to approximate the logarithmic derivatives, and the arithmetic average of the weights at the beginning and end of a period is used to approximate the instantaneous weights. Thus, total factor productivity is

$$-(\ln g_T - \ln g_{T-1}) = \sum^{j} \{1/2\,[\partial \ln g/\partial \ln Y_j]_T + 1/2\,[\partial \ln g/\partial \ln Y_j]_{T-1}\}\{\ln Y_{j,T} - \ln Y_{j,T-1}\} - \sum^{i} \{1/2\, S_{iT} + 1/2\, S_{i,T-1}\}\{\ln X_{i,T} - \ln X_{i,T-1}\} \qquad (2)$$

All of the variables in Equation 2 are observable except for the cost elasticities ($\partial \ln g/\partial \ln Y_j$), which must be obtained by using statistical estimation methods. If the cost elasticity is greater (less) than one, there are diseconomies (economies) of scale, whereas a value equal to one indicates constant returns to scale.

To estimate the cost elasticity with respect to output, a modified Cobb-Douglas cost function in which the elasticity of output is variable is specified and used. This is essential to the current analysis, which requires the cost elasticity with respect to output to vary from year to year. Although other functions such as the generalized Leontief, generalized quadratic, or the translog model could have been used, the modified Cobb-Douglas is flexible enough to permit tests of economies of scale for the entire period. To derive this cost function, it is assumed that the production function underlying the cost equation is the Zellnar-Revankar type. That is,

$$Y^{\alpha_Y} \; \exp\{\alpha_{YY}\,[(\ln Y)^2/2]\} = L^{\alpha_L}\, K^{\alpha_K}\, F^{\alpha_F} \qquad (3)$$

where the exponent is the base of natural logarithm and F, L, and K are the quantities of fuel, labor, and vehicles, respectively, and α_Y, α_{YY}, α_L, α_K, and α_F are the parameters of the production function equation. Minimizing the cost equation $C = P_F \cdot F + P_L \cdot L + P_K \cdot K$, where P_F, P_L, P_K are the prices of fuel, labor, and capital, subject to the production function Equation 4 and taking the natural logarithm gives

$$\ln C = B + \theta(\alpha_L \ln P_L + \alpha_K \ln P_K + \alpha_F \ln f) + \alpha_Y \ln Y + 0.5\alpha_{YY}(\ln Y)^2 \qquad (4)$$

where B is the constant term in the cost equation when it is estimated.

Equation 5 is homogeneous of degree plus one in input prices, implying that the coefficients of the input prices sum to one. That is, $\theta(\alpha_L + \alpha_K + \alpha_F) = 1$. This is a restriction that must be imposed on the cost function if it is to be estimated and holds true even in the absence of homogeneity because the price coefficients are also input cost shares. The cost elasticity with respect to output from Equation 4 is given by

$$\partial \ln C/\partial \ln Y = \theta(\alpha_Y + \alpha_{YY} \ln Y) \qquad (5)$$

The results of applying Equation 5 are substituted into Equation 2 along with values for all Y, S_j, and X_i to calculate estimates of productivity over a period of time and to compare total productivity growth for a cross section of transit agencies. Although the advantages of this method have already been pointed out, it is appropriate to emphasize its flexibility and methodological superiority as the overriding factors in using it.

It is also possible to use Equation 2 to analyze productivity growth of each factor. For example, holding the quantities of all inputs except one constant at their mean levels allows changes in productivity to be attributed to the input whose quantity is variable. In this paper, such an approach is adopted to determine productivity growth for each factor.

DATA

The total factor productivity approach was applied to urban transit by analyzing relevant measures for major transit agencies. Secondary data were selected for the past 26 years for the 25 largest agencies that consistently recorded required information during that period.

Two major sources of secondary data have been identified: the Annual Operating Reports for Motor Bus Operations by American Public Transit Association (APTA) (6) and the Section 15 data summary published by UMTA, U.S. Department of Transportation (7).

Although a thorough review of the validity of the APTA data was not found, discussion with UMTA personnel and other university researchers revealed serious problems with the Section 15 data. Problems were found with definitions and reporting of data, particularly related to system evaluation and outputs. Definitional problems were reported for outputs such as capacity miles and passenger miles. Financial measures that are collected routinely for other purposes were found to be most reliable.

The original measures considered were the following:

Output: Number of vehicle miles
Number of passenger trips (unlinked)
Input: Labor operating cost (salaries and wages)
Fuel price (gasoline, diesel, oil, and propane)
Number of vehicles (substitute for capital expenditures)
Cost: This is not adjusted for inflation because only cost shares are used, as discussed.

Another problem was to find a consistent data set for the entire 26-year period. Transit systems were reviewed for consistent reporting both in APTA and UMTA. Only systems with at most 3 years missing were accepted. A total of 71 systems were identified, which had more than 25 vehicles and which reported regularly.

Of the qualifying systems, it was determined that a minimum of 25 systems was needed to accommodate the degrees-of-freedom requirement of the cost model in a cross-sectional analysis. Table 1 gives a list of these systems.

Subsequent analysis identified data missing on the key variables used in the productivity analysis for some of these systems. A total of 20 systems were ultimately analyzed.

ESTIMATION OF COST FUNCTION

Appropriate measures of the variables over the analysis period having been obtained, Equation 4 was

TABLE 1 Qualifying Agencies and Years Reporting

System No.	Agency Name	Years Missing	Inclusion in Final Analysis
1	Kanawha Valley Regional Transportation Authority, Charleston, W. Va.	0	Yes
2	Savannah Transit Authority, Ga.	1	Yes
3	Charlotte City Transit System, N.C.	2	Yes
4	Southeastern Pennsylvania Transportation Authority, Philadelphia	2	No
5	City Transit Service, Fort Worth, Tex.	3	No
6	Greater Cleveland Regional Transit Authority, Ohio	3	No
7	New Orleans Public Service, Inc., La.	3	Yes
8	New York City Transit System, N.Y.	4	Yes
9	San Diego Transit Corporation, Calif.	4	No
10	Lehigh and North Hampton System, Allentown, Pa.	4	Yes
11	Baltimore Mass Transit Administration, Md.	4	Yes
12	Jacksonville Transportation Authority, Fla.	4	Yes
13	Sun-Tran, Albuquerque, N. Mex.	4	No
14	Southwestern Ohio Regional Transit Authority, Cincinnati	4	Yes
15	Chicago Transit Authority, Ill.	4	No
16	Grand Rapids Transit Authority, Mich.	5	No
17	Central Ohio Transit Authority, Columbus,	5	Yes
18	Niagara Frontier Transit System, Inc., Buffalo, N.Y.	5	Yes
19	Southeastern Transit Authority, Detroit, Mich.		No
20	Springfield City Utilities, Missouri	5	Yes
21	C.N.Y. Centro Inc., Syracuse, N.Y.	5	Yes
22	Metro Regional Transit Authority, Akron, Ohio	5	Yes
23	Memphis Area Transit Authority, Tenn.	6	Yes
24	Capital Area Transit Authority, Harrisburg, Pa.	6	Yes
25	Sacramento Regional Transit Authority, Calif.	6	Yes

estimated by using constrained least-squares methods. The first restriction imposed on this equation is the nonnegativity of the price coefficients. Each price coefficient measures the share of cost and hence cannot be negative. Furthermore, the shares cannot be zero because it is assumed that transit managers choose fuel, labor, and capital to produce a given level of output.

The price coefficients were restricted such that they fell within the observed ranges of the cost shares of the various inputs. Thus, the restriction $a_i < B < b_i$ was imposed, where a_i and b_i are the lowest and highest shares of cost of Input i, respectively. This restriction ensures that the cost equation is continuous and nondecreasing in input prices. The second type of constraint imposed is the homogeneity restriction, which ensures that the sum of the price coefficients is one.

A three-step approach was adopted in estimating the coefficients. The first step involved least-squares estimates of the coefficients without any restrictions. Next, the inequality constraints were imposed on the coefficients by using the mixed estimation method discussed by Kmenta (8). The final step in the estimation process involved imposing the linear homogeneity restriction on the coefficients.

The validity of the estimated parameters can be tested by conducting comparative statics on the coefficients. A well-behaved cost function must have positive price coefficients. Because of the sequential method of imposing the constraints, this constraint may be violated in certain cases. In cases when this occurs, the affected system is eliminated from the sample.

Another property of the cost function is that marginal cost should be continuous in output. That is, the marginal cost cannot be negative. Again, it is possible that in rare cases this constraint may be violated. When the coefficients of the linear and quadratic output terms interchange signs, a possibility exists for marginal cost to be negative. For example, if the coefficient of the linear output term is small and positive and the coefficient of the quadratic output term is large and negative, the cost function will not be well behaved and a negative marginal cost will be obtained, a result that is inconsistent with theory. A system exhibiting this characteristic is also eliminated from the sample. Thus, the number of transit systems is further reduced when these results are obtained.

The results of the estimation led to the elimination of six systems from the sample when vehicle miles is used as output and the elimination of five systems when passenger miles is used as output. These systems did not have the appropriate data structure to allow econometric cost functions to be developed. It is possible that a detailed analysis of the data base could pinpoint the sources of inconsistencies in the data structure, but budget and time limitations did not allow further analysis of the data to be performed.

RESULTS

The results from the estimation process are given in Tables 2 and 3. In these tables, the effects of different sources of data can be observed in Column 8. Of all the systems, only in System 14 did changes in the sources of data have a statistically significant impact on the estimated coefficients. This result indicates that although changes in data sources occurred for all systems, in virtually all systems except one, these changes have an insignificant effect on cost. As a result of this finding, the equation could have been estimated without accounting for changes in data sources.

For each system, more than 95 percent of the variations in costs are explained by variations in input prices and output if vehicle mile is used as output. When passenger mile is used as output the corresponding figure is 89.7 percent. By comparing the equations, a glaring result is that the equations with passenger miles as output can be used to explain a smaller percentage of the variations in cost. Tests of significance of each coefficient in

TABLE 2 Cost Coefficients

System No.	R^2	$\ln P_F$	$\ln P_L$	$\ln P_K$	$\ln Q$	$0.5(\ln Q)^2$	Data Source
18	0.966	0.01764	0.2798	0.70126	-0.636*	-0.08274	0.00656*
		(0.00297)	(0.00911)	(0.00942)	(0.4382)	(0.02694)	(0.0043)
21	0.944	0.2786	0.1166	0.6048	0.6739	-0.02144	-0.0081*
		(0.00624)	(0.0165)	(0.0227)	(0.01887)	(0.00131)	(0.0079)
1	0.958	0.08279	0.5071	0.4101	0.6494	0.0052	-0.000098*
		(0.00642)	(0.0118)	(0.01675)	(0.01146)	(0.00046)	(0.005789)
22	0.986	0.1628	0.3005	0.5367	0.7551	-0.0040	-0.00251*
		(0.0018)	(0.0033)	(0.0066)	(0.0046)	(0.000053)	(0.00175)
2	0.986	0.1143	0.3974	0.4883	0.7638	-0.01429	-0.00217*
		(0.00204)	(0.0047)	(0.00712)	(0.00508)	(0.00027)	(0.00169)
3	0.967	0.0843	0.6088	0.307	0.7372	-0.0172	0.000316*
		(0.00285)	(0.00732)	(0.00777)	(0.00615)	(0.00074)	(0.00559)
7	0.971	0.1073	0.6875	0.2052	0.7799	-0.00331	0.00366*
		(0.00276)	(0.00717)	(0.00602)	(0.00739)	(0.00044)	(0.00379)
12	0.986	0.1077	0.3321	0.5602	0.7063	0.00020	-0.00076*
		(0.00177)	(0.00446)	(0.00651)	(0.00468)	(0.000032)	(0.00219)
24	0.981	0.0777	0.4405	0.4818	0.6584	0.0066	0.000903*
		(0.00266)	(0.00702)	(0.00955)	(0.00544)	(0.00021)	(0.00355)
10	0.974	0.6193	0.3342	0.6039	0.57	0.00608	0.00132*
		(0.00353)	(0.01058)	(0.01397)	(0.0084)	(0.00028)	(0.00531)
11	0.956	0.02213	0.3999	0.5779	0.6582	-0.01277	0.00539*
		(0.00292)	(0.0092)	(0.00985)	(0.00928)	(0.00042)	(0.00723)
14	0.951	0.03378	0.6219	0.3444	00.8443	-0.00541	0.01323
		(0.00333)	(0.0092)	(0.00985)	(0.00928)	(0.00042)	(0.00512)
23	0.989	0.03614	0.3047	0.6592	0.7085	-0.0067	0.000732*
		(0.00139)	(0.00429)	(0.00506)	(0.00327)	(0.00013)	(0.00171)*
20	0.971	0.2553	0.7068	0.03791	0.6936	0.00571	-0.00196
		(0.0019)	(0.0059)	(0.0051)	(0.0074)	(0.00027)	(0.0028)

Note: The standard error is shown in parenthesis under each coefficient. The t-values can be obtained by dividing each coefficient by its standard error. Data source is a dummy variable indicating APTA data or UMTA Section 15 data as the source. In the last column, asterisks represent those data sources that are statistically significant.

TABLE 3 Coefficient of Cost Equation with Passenger-Miles as Output

System No.	R^2	$\ln P_f$	$\ln P_L$	$\ln P_K$	lnY	$0.5(\ln Y)^2$	Data Source
18	0.9292	0.002404	0.3592	0.6384	-0.36	0.2528	0.009255
		(0.005195)	(0.01869)	(0.01705)	(0.6176)	(0.0353)	(0.007044)
21	0.9549	0.2493	0.3936	0.3571	0.6068	-0.000364	-0.008542
		(0.00315)	(0.00892)	(0.00887)	(0.00641)	(0.00031)	(0.00372)
1	0.9507	0.5996	0.5648	0.3752	0.5028	0.007201	0.001436
		(0.00617)	(0.01343)	(0.01628)	(0.00909)	(0.00035)	(0.006522)
22	0.9697	0.08369	0.3362	0.5802	0.4834	0.004633	-0.003615
		(0.003313)	(0.00549)	(0.00821)	(0.00493)	(0.000149)	(0.002413)
2	0.9281	0.184	0.4031	0.4129	0.5599	-0.00155	-0.00106
		(0.00763)	(0.02735)	(0.03388)	(0.01659)	(0.000771)	(0.00833)
3	0.9562	0.0767	0.5581	0.3652	0.8121	-0.0119	0.00106
		(0.00419)	(0.01075)	(0.01169)	(0.01013)	(0.000544)	(0.00742)
7	0.9647	0.1198	0.7314	0.1488	0.6866	-0.00893	0.00117
		(0.0036)	(0.01075)	(0.00728)	(0.00889)	(0.00031)	(0.00451)
8	0.901	0.1441	0.8332	0.02267	0.6947	-0.00915	0.00272
		(0.00888)	(0.02856)	(0.0382)	(0.01917)	(0.00105)	(0.05201)
12	0.9561	0.1176	0.2881	0.5943	0.5864	0.000181	0.00105
		(0.003793)	(0.01189)	(0.01471)	(0.0079)	(0.00009)	(0.006002)
23	0.9314	0.09264	0.2531	0.6542	0.5297	0.00064	0.001341
		(0.006912)	(0.02421)	(0.02581)	(0.01362)	(0.000841)	(0.01804)
24	0.9411	0.05924	0.3125	0.6283	0.4436	0.00526	0.000974
		(0.006353)	(0.02003)	(0.02502)	(0.01491)	(0.000444)	(0.01133)
25	0.8965	0.599	0.1884	0.2125	0.8584	-0.03868	0.006059
		(0.00377)	(0.00167)	(0.00367)	(0.00548)	(0.000356)	(0.00467)
10	0.9025	0.126	0.2722	0.6018	0.5019	0.0001223	0.001643
		(0.01134)	(0.04221)	(0.04593)	(0.01999)	(0.000485)	(0.02055)
11	0.9054	0.04187	0.4159	0.5422	0.5256	-0.01864	0.003753
		(0.003725)	(0.01055)	(0.00919)	(0.007743)	(0.00049)	(0.00825)
14	0.9128	0.03095	0.6771	0.2919	0.7633	-0.001091	0.01717
		(0.00496)	(0.01377)	(0.01491)	(0.0101)	(0.0003871)	(0.007572)

Note: The standard errors are shown in parentheses. The t-values can be obtained by dividing each coefficient by its standard error.

the cost equation can also be obtained by dividing the standard error shown in parenthesis into each coefficient. The result of this division indicates that, in Table 2, all the estimated coefficients are statistically significant at the 95 percent confidence level except the linear output term in System 18. The same cannot be said of Table 3; some of the coefficients in this table are statistically insignificant.

INITIAL PRODUCTIVITY

By using the estimated coefficients, total factor productivity was calculated for each of the 26 years and for each of the 14 systems that was determined to have sufficient data for analysis. (The data criterion is discussed in another section of this paper.) Tables 4 and 5 present total factor productivity for System 14 in Cincinnati. The results are typical of those obtained and indicate that little change occurs in total factor productivity. The relative lack of change in total productivity is underscored by the average change for each system given in Table 6. A comparison of means to standard errors indicates that the means are an order of magnitude smaller than the standard error in every case but one. In all cases, they are not significantly different from zero at the 0.05 significance level. This indicates a lack of growth in total factor productivity for the period of the study and is true for both vehicle miles and passenger miles.

To investigate short-term periods of productivity growth, the overall period of the study was divided into approximate 5-year intervals. The results indicated that in virtually all cases, average productivity changes were not significantly different from zero at the 5 percent significance level. This is true for all systems for all time periods.

The consistency from system to system and period to period indicates that national trends and events have had little effect on system productivity. For example, systems were equally productive before and after the introduction of federal operating subsidies during the period from 1970 to 1975. It could be hypothesized that such changes would be negative as a result of passive supervision of subsidy programs and the influx of large amounts of additional monies. However, this is not the case. Each year there is a mixture of productivity gains and losses all of which are not significantly different from zero. The same trends occurred during the periods of the fuel crises (1973 and 1978). Apparently, the changes in demand for service were compensated for by changes in cost.

TABLE 4 Performance of Cincinnati System Calculated Using Vehicle-Miles

Year	Total Factor Productivity	Labor Productivity	Capital Productivity	Fuel Productivity
1956	-0.0026	0.0242	0.0178	0.0364
1957	0.0276	0.0575	0.0171	0.0386
1958	0.0155	0.0476	0.0264	0.0480
1959	0.0126	0.0230	0.0176	0.0257
1960	-0.0002	0.0134	0.0055	0.0155
1961	0.0052	-0.0695	0.0046	-0.0610
1962	-0.0274	-0.1042	-0.0282	-0.0954
1963	0.0043	-0.0132	0.0074	-0.0080
1964	0.0268	0.0127	0.0320	0.0147
1965	0.0494	-0.0071	0.0508	-0.0014
1966	-0.0428	-0.0378	-0.0385	-0.0332
1967	0.1352	0.1520	0.1228	0.1304
1968	-0.0952	-0.0492	-0.0760	-0.0262
1969	-0.0071	0.0114	0.0096	0.0278
1970	-0.0250	-0.0221	-0.0177	-0.0130
1971	0.0393	0.0509	0.0544	0.0544
1972	-0.1205	0.0252	-0.0637	0.0782
1973	0.1070	0.0305	0.0983	0.0201
1974	0.0311	-0.0614	-0.0252	-0.1006
1975	-0.0303	-0.0278	-0.0701	-0.0546
1976	0.0644	-0.0437	0.0359	-0.0572
1977	0.0182	0.0311	0.0105	0.1065
1978	-0.2464	-0.1313	-0.1089	0.0151
1979	0.0276	0.0077	0.0217	-0.0194
1980	-0.0277	0.0112	-0.0340	0.0042
1981	-0.0151	-0.0065	-0.0072	-0.0075

TABLE 5 Performance of Cincinnati System Calculated Using Passenger-Miles

Year	Total Factor Productivity	Labor Productivity	Capital Productivity	Fuel Productivity
1956	-0.38	0.15	-0.16	0.23
1957	-0.02	0.004	-0.002	0.02
1958	-0.007	0.04	-0.004	-0.02
1959	-0.01	0.02	-0.002	0.02
1960	-0.02	-0.01	-0.02	-0.008
1961	-0.06	-0.05	-0.05	-0.04
1962	0.08	0.007	-0.08	0.02
1963	0.08	-0.03	0.05	-0.02
1964	0.007	-0.01	0.01	-0.005
1965	0.02	0.07	0.03	0.01
1966	0.05	-0.01	0.05	-0.004
1967	-0.01	-0.007	-0.007	-0.002
1968	-0.05	0.07	0.04	0.04
1969	-0.09	-0.04	-0.07	-0.02
1970	-0.03	-0.007	-0.009	0.01
1971	-0.02	-0.02	-0.01	-0.01
1972	-0.08	0.08	0.09	0.01
1973	-0.19	-0.05	-0.14	0.0007
1974	0.103	0.03	0.04	0.02
1975	0.01	-0.02	0.02	-0.06
1976	0.01	0.01	-0.03	-0.01
1977	-0.12	-0.002	-0.08	-0.02
1978	-0.02	-0.005	-0.03	-0.02
1979	0.26	-0.15	-0.113	-0.008
1980	-0.05	0.01	0.04	0.003
1981	-0.07	-0.03	-0.07	1.103

TABLE 6 Average Change in Total Factor Productivity for All Systems

System No.	Vehicle Miles Avg Change	Vehicle Miles Standard Error	Passenger Miles Avg Change	Passenger Miles Standard Error
1	-0.005	0.015	0.0168	0.064
2	-0.009	0.012	-0.0003	0.092
3	0.002	0.014	0.003	0.873
7	0.007	0.189	-0.006	0.083
10	-0.003	0.221	-[a]	-[a]
11	0.000	0.124	0.086	0.426
12	-0.002	0.131	-0.012	0.110
14	-0.003	0.142	-0.020	0.113
18	-0.013	0.011	-0.012	0.055
20	-0.002	0.036	0.146	0.029
21	0.007	0.038	0.026	0.165
22	-0.020	0.116	-0.016	0.476
23	-0.023	0.014	-0.014	0.175
24	-0.003	0.013	-0.022	0.114

Note: Agencies corresponding to system numbers are given in Table 1.
[a]Insufficient data.

Another alternative hypothesis was that productivity has been declining because of reduced demand for public transport. However, these measures indicate that reduced demand has been met by reduced service level in a way that results in little change in productivity over an extended period of time. Thus, these systems have responded to alternate pressures to provide service and do so efficiently.

Finally, it must be noted that there was no significant effect of changes in reporting on costs during the period from 1978 to 1981 when the new Section 15 data were utilized. Further, isolated examination of trends during 3 selected years when major national trends had an impact on transit (1973, 1974, and 1978) reveal no trends, either positive or negative. Only during 1978 did the majority of systems show a decrease in productivity. This could indicate a reduction in productivity during a brief, highly inflationary period. However, the trend is not true for systems in Springfield, Missouri (System 20), and Akron, Ohio (System 22). Further, these results are confounded by the change in data sources at that time.

In sum, the results of the total factor productivity analysis indicate that systems tend to adjust and compensate, keeping inputs and outputs in balance in the long run for both dependent variables. For example, there is a compensatory process occurring in which capital, labor, and fuel productivity are substituted alternately, thus creating an overall balance over time. This process is evidenced by the average changes in total factor and partial productivity that are given in Table 6. Furthermore, the data in Table 7 indicate that total factor productivity has decreased on average; this is compensated for by increases in average productivity of capital and fuel. However, these changes are small and are not significantly different from zero at the 5 percent level. This pattern of negative total factor productivity and labor productivity but positive capital and fuel productivity is experienced by four systems (1, 14, 18, and 22). The other systems indicate other compensating patterns. One interesting pattern is demonstrated in Memphis, Tennessee (System 23). There, the negative growth in total productivity is the result of positive partial contributions, which is the result of the definitions of productivity with inputs combining to overcome the contribution of the output to productivity growth.

Detailed Analysis of Productivity

A detailed analysis of productivity was performed on two systems for 3 separate years (1956, 1974, and 1981). These 3 years were chosen because of the following reasons. First, the beginning and ending periods in the data set are 1956 and 1981. Second, in 1974, a major event--the introduction of federal operating subsidy under Section 5 of the Urban Mass Transportation Act--was having an impact on transit. Also, because the two transit systems, Charleston, West Virginia, and Charlotte, North Carolina, indicated patterns typical of the results obtained for all the transit systems analyzed, they were singled out for detailed analysis.

Productivity for Charleston, West Virginia

In 1956, there was an overall increase in productivity. In 1974, the year of increased subsidies, productivity decreased in all categories. In 1981, an overall increase was once again observed. Of interest is the across-the-board pattern observed in each of these years.

Productivity in Charlotte, North Carolina

In contrast to Charleston, Charlotte indicates a pattern of compensation. In 1956, there was an across-the-board decrease in productivity but in 1974 a decrease in capital productivity was compensated for by increases in labor and fuel productivity. In 1981, a decrease in labor productivity was compensated for by increases in the productivities of the other inputs.

Patterns of Increases and Decreases

The question of similarities of increases and decreases in productivity between partial and total factor productivity was investigated by calculating correlations between increases and decreases in each measure for each system. Two patterns were identified. The first pattern is a compensatory pattern in

TABLE 7 Total Factor and Partial Productivity

System No.	Agency Name	Total Factor	Labor	Partial Capital	Fuel
1	Kanawha Valley Regional Transportation Authority	-0.005	-0.002	0.000	0.005
2	Savannah Transit Authority	-0.010	-0.001	-0.002	0.007
3	Charlotte City Transit System	-0.005	-0.009	-0.004	-0.003
7	New Orleans Public Service, Inc.	0.002	-0.005	0.004	-0.003
10	Lehigh and North Hampton System	-0.003	0.014	0.015	0.029
11	Baltimore Mass Transit Administration	0.000	-0.001	-0.002	-0.002
12	Jacksonville Transportation Authority	-0.002	-0.007	-0.006	-0.004
14	Southwestern Ohio Regional Transit Authority	-0.013	-0.001	0.002	0.002
18	Niagara Frontier Transit System, Inc.	-0.013	-0.001	0.005	0.017
20	Springfield City Utilities	-0.002	0.0035	0.007	0.010
21	C.N.Y. Centro, Inc.	-0.004	0.004	0.007	0.006
22	Metro Regional Transit Authority	-0.019	-0.009	0.003	0.012
23	Memphis Area Transit Authority	-0.023	-0.019	-0.015	-0.009
24	Capital Area Transit Authority	-0.003	0.008	0.013	0.022
Average total		-0.007	-0.002	0.002	0.006

which capital productivity was compensated for by labor and fuel productivity changes. Systems 2, 3, 14, and 24 exhibited this pattern. The correlation matrix of this pattern is exhibited by System 2 (Savannah, Georgia). (* = significant at the 5 percent level.)

	Total Factor	Labor	Capital	Fuel
Total factor	1.0	0.51*	0.82*	0.10
Labor		1.0	0.36*	0.80*
Capital			1.0*	0.29
Fuel				1.0

From this table it can be observed that capital and total factor productivity are highly correlated as are labor and fuel. This point is better illustrated by a principal components analysis. The factor scores for an analysis of these data are given in the following table.

Productivity Measure	Factor 1	Factor 2
Total factor	0.55	-0.12
Labor	0.02	0.49
Capital	0.51	-0.08
Fuel	-0.19	0.61

By using the criterion of the eigenvalue greater than 1, this is a two-factor solution. The first factor accounts for 62 percent of the variance and is most closely related to total factor and capital productivity. Factor 2 accounts for 30 percent of the variance and is most closely related to labor and fuel productivity. This factor is therefore labeled operating resources. These factors are unrelated (orthogonal) and the measures indicate that for this agency capital decisions and operating decisions are not related. Compensatory activities therefore occur, for the most part, within factors over time. The other systems in this group behave similarly.

The other group indicates a high degree of across-the-board increases or decreases in productivity. In this case, all variables increase or decrease at the same time and compensation takes place year by year instead of within years. Systems that behave in this way are Systems 1, 10, 11, 12, 18, 20, and 22. System 22 is typical of this group and the correlations for partial and total factor productivity are given in the following table.

	Total Factor	Labor	Capital	Fuel
Total factor	1.00	0.995	0.992	0.982
Labor		1.00	0.996	0.994
Capital			1.00	0.996
Fuel				1.00

All coefficients are significant at the 5 percent level. All measures are highly correlated, and a principal components analysis reveals that they represent one overall productivity factor. Compensation therefore occurs within the overall factor over time.

Two systems (7 and 21) were unique in their patterns. No system characteristics were found that adequately explained these variations.

Similarities Between Systems

Finally, the similarity between increases and decreases in total factor productivity between systems was investigated. Initial analyses using analysis of variance resulted in no significant differences in changes between systems because they were all not significantly different from zero. Instead, by using vehicle miles as the output measure, systems whose productivity measures were highly correlated were grouped together.

By using principal components analysis and a criterion of an eigenvalue greater than one, seven factors were obtained. Further, by using only factor scores with significant correlations between factors and systems, no consistent pattern emerges. At most, three systems correlate highly with any single factor. Factors 1, 4, and 7 are related to System 18 (Buffalo, New York), System 19 (Detroit, Michigan), and System 1 (Kanawha Valley, Ohio), respectively. The systems related to Factor 2 are 20 (Springfield, Missouri), 22 (Akron, Ohio), and 24 (Harrisburg, Pennsylvania). Factor 3 is related to Systems 10 (Allentown, Pennsylvania) and 22 (Akron, Ohio). Factor 5 is related to Systems 12 (Jacksonville, Florida) and 14 (Cincinnati, Ohio). Factor 6 is related to Systems 11 (Baltimore, Maryland) and 23 (Memphis, Tennessee).

Although these indicators do not contain sufficiently detailed information to describe the mechanisms by which compensatory activities occur, it might be possible to find predictors of productivity changes. Because the systems for the most part have orthogonal changes in productivity, one is led to the conclusion that no such predictors exist. For the few agencies that do cluster together, there appears to be little in common. The predictors that were considered were size, density, geographical region, and degree of state subsidy contribution. Only Factor 3 appears to have a relationship in size, geographical location, and state assistance; however, other similar systems (e.g., Allentown, Pennsylvania) do not cluster there. In short, of the predictors considered, there are no clear predictors of cluster membership and thus of changes in total factor productivity.

CONCLUDING REMARKS

There are two overriding conclusions from this study. First, the total cost function approach applied provides a close fit to public transit cost data. The second conclusion is that the change in total factor productivity over time is not substantial.

These conclusions have implications for management and policy issues; they lead to the further conclusion that management decisions have over time resulted in little change in the level of productivity. This can be observed by using both vehicle miles and passenger miles as output measures. The indicators developed here demonstrate a compensatory effect within partial factors over time. However, the data available to this study are not sufficient to describe and test hypotheses about the causes and effects.

It is also observed that the results of this analysis contradict those of previous research that examines partial productivity. Those results have indicated an overall trend toward decreasing productivity. On the other hand, Meyer and Gomez-Ibanez found a contradiction for both partial and total measures of productivity when revenue passenger was the output measure (decreasing productivity) and when vehicle miles was the output measure (increasing productivity).

In the case of partial measures, the contradiction between the results of this study and those of previous efforts is due to the approach of this paper, which considers all inputs, whereas those based on partial productivity do not. Also in the current study, both total and partial measure take into account (dis)economies of scale. Further, the partial measures are determined by holding the other inputs at their mean levels. In other words, the indicators utilized in this study account for changes in productivity that result solely from changes in specified inputs. For total factor productivity, changes in the complete set of inputs (labor, capital, and fuel) are used. This unique modeling approach also accounts for the differences between the Meyer and Gomez-Ibanez results, which do not account for (dis)economies of scale, and the results of this study.

Future research will examine the root causes (i.e., geographic, organizational, contractual) and their influence on productivity in the hope of developing guidelines for planning and management decisions.

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