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Title: The Effect of Privatization on Public Transit Costs

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Abstract: In an effort to reduce operating deficits, increase productivity, and improve the quality of services, the public transit sector has been moving away from public ownership and operation towards a franchising arrangement whereby a local government authorizes a private firm to manage and operate the city's public transit system. Profit maximization considerations imply that private managers have stronger incentives for cost efficiency than their counterparts in the public sector. One such example is the city of Indianapolis which privatized its transit operations in January 1996. Based upon monthly data from January 1991 through March 1997, this study examines the effect of privatization on the city's cost of providing transit services. In addition to its contribution on privatization, this study explores the role of serial correlation in translog cost function models. Failure to account for serial correlation has serious implications for hypothesis tests and may lead to incorrect public policy prescriptions.

Keywords: Transit privatization, transit costs, translog functions, serial correlation

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I. INTRODUCTION

Before 1960, urban mass transportation systems in the United States were largely privately owned and operated and received no public financial assistance, although they were still subject to state and local regulations (Orski 1985). The typical privately owned system operated under an exclusive franchise agreement, effectively insulating it from competitive market forces, and received no government financial assistance. Beginning in the early 1960s, however, the private ownership of transit systems was no longer profitable, and public ownership became the norm. Smerk (1974, 1979), and Saltzman (1979) extensively review the trends in transit ridership and the institutional and market forces that contributed to the decline of transit after 1950. Among the most important factors were the increasing availability of automobiles as well as the government assistance in highway building and the suburbanization of housing. As a result, the financial resources of most private bus companies were depleted, leading to an appeal for either public assistance or takeover. Indeed, based on primarily social equity arguments, the government assisted the ailing transit systems by taking over their operation and providing financial assistance in the form of subsidies.

The total operating subsidy from all levels of government (local, state, and Federal) rose from $318 million in 1970 to $9.27 billion in 1990, a 30-fold increase in twenty years (Pucher 1995). Although there may be a returns-to-scale argument that would justify capital subsidies to the industry (Obeng 1987), the increase in operating subsidies was justified by various social arguments. It was expected, for example, that transit would play an important role in preserving and revitalizing cities, satisfying the transport needs of the underpriviledged, creating a better urban environment, and providing a more energy efficient form of transport (Altshuler 1981).

Unfortunately, the effects of operating subsidies on the performance of transit systems have not been encouraging. Many authors contend that subsidies have encouraged productivity declines, lack of innovation and initiative, and financial mismanagement of transit properties. Many studies, using a wide variety of data and methodologies, have examined the effects of government financial assistance on the performance of transit systems (Pucher et al. 1983, Cervero 1984, Pickrell 1985, Bly and Oldfield 1986, Obeng et al. 1995, Karlaftis and McCarthy 1997). While the specific results vary among the studies, the conclusions overwhelmingly support the notion that there are clear links between increases in subsidies, on one hand, and reductions in the performance and productivity, on the other.

To deal with the reality of the degrading effects of subsidies on transit system performance, several authors have suggested three possible solutions:

1. alter the federal and state subsidy programs to reward those systems that raise productivity, increase ridership, or enhance the quality of their services (Fielding 1987);
2. shift subsidy responsibility from federal to more decentralized state and local sources to increase the pressure for cost control and potentially produce efficiency gains in transit systems (Shughart and Kimenyi 1991, Pucher 1995);
3. re-examine the private alternatives to public ownership (Gwilliam et al. 1985a, b, Beesley and Glaister 1985a, b).

This paper contributes to the existing literature by investigating the impact that privatization has had upon a medium-sized public transit system.[1] The Indianapolis Public Transportation Corporation (METRO) was created in 1972 to meet the growing transportation needs of the Indianapolis urban area and to promote travel to and from the Central Business District. While the Indianapolis area continued to grow steadily, the bus service remained virtually unchanged, making no plans to expand service to the rapidly developing surrounding suburban communities. In recent years, METRO's ridership has been declining while at the same time subsidies have been increasing. A total of $1.2 million of local tax funds were used to subsidize METRO in 1982, growing to $6.4 million in 1992. Moreover, while the percentage of the public using METRO decreased, the price of supporting the system steadily increased. By 1992, a $1.2 million budget deficit existed, and the company was forced to lay off a large number of employees as well as reduce service.

To deal with this financial trouble, senior administrative and managerial personnel were replaced, and most express routes were eliminated. In early 1992, METRO, the Indianapolis city government, and

[1] The Indianapolis transit system has operated as a public enterprise since 1972, serving, for the period under study, an average population of 950,000 with an average fleet of 220 buses.

Indianapolis Mayor Steve Goldsmith developed a set of objectives to reverse the decline in the performance of the transit system. First, the city agreed to halt the increase of property taxes to support the failing bus system. Second, METRO would focus on the transit dependent segment of the population, including individuals with disabilities, the elderly, and those without private automobiles. Third, and probably the most important objective, was to create a self-sustaining, customer service driven transit system. With the full support of the Goldsmith administration, it was decided that to achieve these goals METRO should be placed in the competitive market. In a 1994 speech, Goldsmith noted that the goal of Indianapolis' privatization is to increase the efficiency and effectiveness of service.

To examine the prospects of privatization for METRO, a panel of international experts, consultants, and citizens was formed. The outcome of this panel was a Strategic Plan for Public Transit which overwhelmingly supported the private operation of the transit system, to encourage innovation and experimentation and a more market-driven and customer oriented transit system. As a pilot study, a small number of routes was contracted out to a private provider in 1995. Partly due to the successful operation of the privatized routes, 1995 saw the first ridership increase for METRO (2.7% over 1994) in over 10 years. With the success of this pilot program, all of METRO's routes were contracted out to a private firm.[2] Starting on January 1st of 1996, the entire METRO operation was privatized with expectation of increasing operating efficiency and saving Indianapolis $3 million by 1999.

This paper explores the effect of privatization on Indianapolis' system costs by estimating a translog cost function on monthly data for Indianapolis' transit system that spans the period January 1991 through March 1997. Further, in contrast to all other translog cost studies of public transit, we explicitly account for the effects of serial correlation in this analysis. Section II summarizes recent literature on privatization in public transit, Section III develops the translog cost function empirical model, Section IV summarizes the data, and Section V presents the estimation results. Section VI provides concluding comments.

[2] METRO is still a municipally owned operation governed by a board of directors appointed by the Indianapolis City Council. The entire system operation though is contracted out and operated by RYDER logistics.

II. REVIEW OF RECENT FINDINGS

Most researchers supporting the notion of privatization (and deregulation) argue that the government is ineffective and counterproductive in responding to citizens needs. This can be attributed to the inherent inefficiency of government services, the often uncontrollable growth of the public sector, and the reduced personal initiative of individuals and organizations (Berechman 1993). Overall, because the private sector is more sensitive to economic incentives and more responsive to changing market conditions, it is expected to produce a given level of service more efficiently than the public sector.

It is theoretically possible to show that private production of transit services has the potential of being both profitable and welfare-improving (Viton 1982, Dogson and Katsoulakos 1988). Nevertheless, a number of studies of transit deregulation do not unanimously support this theoretical assertion with empirical findings. One of the earlier empirical analyses was Parshigian (1976), who analyzed a cross-section of 40 American transit properties with 10 years of data (1960-1970). This analysis demonstrated that operating costs for publicly owned properties increased faster than those for privately owned ones. Pucher et al. (1983), using time-series data on 35 US bus transit systems from 1970-1979, analyzed the impacts of public ownership, public management, and subsidies, on the operating costs of transit systems. The most important finding from this study was that high subsidy ratios (subsidy/total operating cost) were associated with substantially larger increases in per-hour costs in publicly owned transit systems than cost increases in privately owned systems. Pucher and Marksted (1982) used time series data on four large transit systems (Chicago, Portland, New Jersey, and New Orleans) to examine the impact of subsidies and ownership type on performance. They concluded that increased subsidies and public ownership, in addition to keeping fares low and expanding services, have encouraged wasteful cost increases. Morlock and Viton (1985), in a three country (Australia, England, US) comparison of private versus public costs of providing transit services, offer evidence that private firms do in fact operate at a lower cost than public firms. Perry and Babitsky (1988) used a variety of statistical techniques with 1980-81 Section 15 data to compare five ownership-management structures. One of the important findings of that study was that privately owned and operated systems produced more output per dollar and generated greater revenues than other types of systems. The authors also noted that publicly owned systems managed by contractors performed no more efficiently or effectively than publicly owned and managed systems.

Hensher (1987), using data from urban bus operations in Australia offers evidence that private supply of public transport in general has performed more efficiently than public supply. Similar results were reported by Downs (1988), who found that privately operated transit systems in New York were more cost effective than the public transport agency.

On a different note, Bristow et al. (1991) argue that deregulation is not uniformly beneficial to all users. In particular, low income users for trips to work, users without cars, and the elderly are likely to be hurt. In a related note, Meyer and Oster (1987) claim that privatization will harm inner city low income groups if non-uniform fare structures are adopted.

III. METHODOLOGY

Assuming one output y (vehicle-miles), three variable inputs x_i – labor, fuel, and maintenance – and one fixed input k (number of buses), equation (1) identifies a public transit firm's short-run translog cost function:

$$\begin{aligned} \ln VC = {} & \alpha_0 + \alpha_y \ln y + \sum_{i=1}^{3} \alpha_i \ln p_i + \alpha_k \ln k + \\ & + \sum_{i=1}^{3} \gamma_{iy} \ln p_i \ln y + \sum_{i=1}^{3} \gamma_{ik} \ln p_i \ln k + \frac{1}{2} \sum_{i=1}^{3} \sum_{j=1}^{3} \gamma_{ij} \ln p_i \ln p_j + \\ & + \gamma_{ky} \ln k \ln y + \frac{1}{2} \gamma_{yy} (\ln y)^2 + \frac{1}{2} \gamma_{kk} (\ln k)^2 + u \end{aligned} \qquad (1)$$

where VC is the variable cost of production, p_i = price of variable input x_i (i = 1, 2, 3) and u is the disturbance term. The model's parameters are α_0 , α_y, α_i (i = 1, 2, 3), α_k, and γ_{ij} (i, j = 1, 2, 3, y, k). According to equation (1), a transit firm's fleet size is fixed in the short run which implies that the level of variable inputs the firm employs at any given set of prices and output will depend upon the number of buses available to the system. The associated share equations (using Shephard's lemma) are:

$$s_i = \frac{p_i x_i}{VC} = \alpha_i + \sum_{j=1}^{J} \gamma_{ij} \ln p_i + \gamma_{iy} \ln y + \gamma_{ik} \ln k + u_i \qquad (2)$$

where s_i is the share of input i and u_i is the error term for share equation I (i = 1, 2, 3). Equations (1) and (2) constitute a multivariate equation system with the following restrictions imposed on the parameters to insure homogeneity of degree one in variable input prices, given the fixed factor k and output y:

$$\sum_{i=1}^{3}\alpha_i = 1, \quad \gamma_{ij} = \gamma_{ji} \quad \forall i, j$$
$$\sum_{i=1}^{3}\gamma_{ij} = \sum_{j=1}^{3}\gamma_{ji} = \sum_{i=1}^{3}\gamma_{iy} = \sum_{i=1}^{3}\gamma_{ik} = 0 \tag{3}$$

Following Berndt's (1991) formulation, the multivariate system of share equations can be written as:

$$S_t = X_t\, b + u_t \tag{4}$$

where S_t is an $(n \times 1)$ vector of dependent variables, X_t is an $(n \times m)$ vector of independent variables, b is an $(m \times 1)$ coefficient vector, t denotes a given time period, and u_t is an $(n \times 1)$ vector of random disturbances. Assuming a first-order stationary univariate autoregressive structure for u_t yields

$$u_t = Ru_{t-1} + \varepsilon_t \qquad t = 1, \ldots, T \tag{5}$$

where R is an $(n \times n)$ autocovariance matrix. Combining (4) and (5) results in an equation with uncorrelated disturbances:

$$S_t = RY_{t-1} + (X_t - RX_{t-1})b + \varepsilon_t \qquad t = 1, \ldots, T \tag{6}$$

The usual maximum likelihood estimation methods could be applied to equation (6). However, as Berndt and Savin (1975) show, the constraint that the shares at each observation sum to unity implies that only J−1 equations are independent. The J disturbances must sum to zero at each observation and the $(J \times J)$ disturbance covariance matrices are singular. This singularity of the disturbance covariance matrix imposes restrictions on the autoregressive process. Violation of these restrictions leads to maximum likelihood estimates that are not invariant to the share equation deleted from the system which implies that likelihood ratio test statistics will depend upon the factor share equation deleted.

Berndt and Savin (1975) demonstrate that for equation (6) to be invariant to the share equation deleted, the matrix R has to be diagonal and all the diagonal elements must be equal. They also show that

that equation (6) can be easily generalized to account for higher order vector autoregressive processes. In particular, for an Mth order autoregressive process,

$$\mathbf{u}_t = R_1\mathbf{u}_{t-1} + R_2\mathbf{u}_{t-2} + \cdots + R_M\mathbf{u}_{t-M} + \varepsilon_t \qquad t = 1, \ldots, M \qquad (7)$$

To maintain the system's invariance property to the share equation deleted, each R_i is a diagonal matrix whose diagonal elements must be equal.

IV. DATA

Data for the analysis comes from monthly observations for the city of Indianapolis from January 1991 through March 1997. The data were collected from the Indianapolis Public Transit Corporation accounting, maintenance, and operations reports for fiscal years 1991 – March 1997. Short-run operating costs are estimated by the system's total monthly operating cost, excluding depreciation and amortization of intangibles. Total vehicle-miles provided rather than passengers served was selected as the output measure since bus operations are the primary determinant of costs in a transit system (Savage, 1995).[3] The total number of buses is the number the system owns and operates during a given month.

Similar to many translog cost function models for public transit, there do not exist well defined measures for the input prices. For this study, we follow the price measurement methodology of Berechman and Giuliano (1984), Applebaum and Berechman (1991), and Colburn and Talley (1991) by first allocating the monthly expenses to the various input categories (i.e. labor and maintenance) and then dividing the expenses by paid monthly labor hours per category. The monthly price of labor, for example, was estimated by dividing the total labor expenses (including wages, fringe benefits, and pension payments to operators and administrative employees) by the paid labor hours to operators and administrative employees. Similarly, the price of maintenance was estimated by dividing total maintenance expenses (including wages, fringe benefits, and pension payments to maintenance employees plus total expenditures on parts and maintenance) by the paid labor hours to maintenance employees. This method was not used, however, to estimate the price

[3] From the data it was not possible to separate out revenue vehicle-miles from deadhead miles. Deadhead miles are miles traveled by revenue vehicles when not in revenue service (not available for passengers) and typically include miles traveled to and from storage and maintenance facilities as well as some training mileage.

of fuel since fuel prices were reported on the monthly reports.

Table 1 identifies relevant operating and cost characteristics before and after privatization. From the table, privatization appears to be having a significant positive effect upon operations. Monthly vehicle miles have increased 27% from an average of 536,320 prior to privatization up to 681,938 during the 15 months of privatized operations. Consistent with this, the system is carrying 5.6% more passengers. Yet, relative to the pre-privatized period, the average monthly increase in total vehicle miles and passengers has occurred with 20% fewer total employees, 28% fewer maintenance employees, and 6% fewer buses. Further, in current dollars, average monthly operating costs have increased 2.2% between the pre- and post-privatized periods. Monthly total revenues, on the other hand, have risen 22% between the two periods. During the same period, the average inflation rate increased 16.2%. Thus, in real terms, revenues more than kept pace with inflation between the public and privatized periods while real operating expenses have fallen.

Table 1
Characteristics of the Indianapolis System

	Before Privatization Jan '91 - Dec '95		After Privatization Jan '96 - Mar '97	
Characteristic	Mean	Std. Dev.	Mean	Std. Dev.
Total Vehicle Miles (TVM)	536320	42315	681938	57659
Passengers (PAX)	772535	46894	816340	64853
Total Vehicles (VEH)	228	12	213	4
Total Employees (EMP)	428	30	339	5
Maintenance Employees (MEMP)	92	7	66	3
Total Revenue, Current $	565745	98487	694738	40222
Total Operating Expenses, Current $	1936255	288171	1980383	125087

V. ESTIMATION RESULTS

Table 2 reports the translog estimation results for the model corrected for multiple serial correlation.[4] From the system $\tilde{R}^2$, the model fits the data well. 99.8 % of the generalized variance in the

[4] To explore the possibility that the system faces systematic differences in its operating environment during different months, preliminary runs of the model included peak-base vehicle ratio, average speed of service, and age of fleet. In each case, we accepted the null hypothesis that the variable was not a determinant of short run variable costs.

Table 2
Short-Run Model Parameter Estimates
January 1991 – March 1995

Output Measure: Vehicle Miles
Number of Observations: 75

Parameter[a]		Estimate	t-statistic
α_o	Constant	14.329	231.53
α_y	Output	0.91	4.56
α_l	price of labor	0.64	89.83
α_m	price of maintenance	0.29	45.53
α_k	Number of buses	-0.028	-0.07
γ_{ll}	price of labor	0.15	6.76
γ_{mm}	price of maintenance	0.19	23.26
γ_{kk}	Number of buses	4.97	1.20
γ_{yy}	Output coefficient	0.35	0.53
γ_{lm}	price of labor * price of maintenance	-0.17	-13.67
γ_{lk}	price of labor * no. of buses	0.05	0.46
γ_{mk}	price of maintenance * no. of buses	0.014	0.14
γ_{ly}	price of labor * output	0.08	0.62
γ_{my}	price of maintenance * output	-0.09	-2.16
γ_{ky}	Number of buses * output	1.83	1.27
γ_t	Time trend	-0.004	-1.52
γ_{tt}	Time trend	-0.00006	-0.09
$D_{bef/aft}$	privatization dummy variable	-0.201	-5.79
d_{q1}	dummy for 1st quarter	0.014	1.23
d_{q2}	dummy for 2nd quarter	0.025	2.50
Ar_{c1}	lag 1 autocorrelation coefficient for the cost equation	0.39	4.28
Ar_{c2}	lag 2 autocorrelation coefficient for the cost equation	0.24	2.29
Ar_{sh1}	lag 1 autocorrelation coefficient for the share equations	0.36	4.23
ar_{sh2}	lag 2 autocorrelation coefficient for the share equations	0.25	1.67
ar_{sh12}	lag 12 autocorrelation coefficient for the share equations	-0.16	-1.79
$\bar{R}^2$	system R^2	0.9987	

a Full information maximum likelihood estimates are invariant to share equation deleted (Berndt 1991, p. 463). The estimation results presented in Table 1 normalize on the price of fuel.

variance in the dependent variable is "explained" by the variation in the explanatory variables in the system of equations.[5] Further, the estimated function satisfies the necessary neoclassical conditions of a cost function: linear homogeneity in input prices; monotonicity; and concavity.[6] While linear homogeneity is imposed on the model's parameters, monotonicity and concavity must be checked ex-post. The estimated cost function satisfies each of these conditions at every point in the sample.

Adjusting for first and second order autocorrelation in the cost function and first, second, and twelfth order autocorrelation in the share equations provided the best model fit.[7] It is also important to note that the autocorrelation coefficients for the share equations (ar_{sh1}, ar_{sh2}, ar_{sh6}) are restricted to being equal across share equations to satisfy the diagonality requirement of the R_i matrices (Berndt and Savin 1975). The estimated pattern of the autocorrelation coefficients indicate a positive first and second order correlation and a negative twelfth order correlation for the share equations. While the sources of such correlations are unclear, the first and second-order terms suggest that the effects of service and policy decisions made during a given month affect cost and input demands for the subsequent two months.

In general, the estimation results are consistent with expectations. The price coefficients are positive and strongly significant. Further, the coefficient for output indicates that the Indianapolis mass transit system operates under mildly increasing returns to density at mean production level. A 10% increase in output increases short run variable costs 9.1%.[8] It is important to note, however, that we cannot reject the

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[5] Most studies that estimate flexible cost functions for public transit report the R^2 for the individual equations. This is misleading in an equation system context for two reasons (Berndt 1991): first, the R^2 could be negative since it is not required in equation systems that within each equation the sum of residuals is zero; second, single equation least-squares maximizes R^2 but equation systems estimation methods do not maximize individual equation R^2s. The system R^2 reported in the table is computed as (Berndt 1991):

$$\tilde{R}^2 = 1 - \frac{|EE'|}{|y'y|}$$

where $|EE'|$ is the determinant of the residual cross-product matrix of the full model, and $|y'y|$ is the determinant of the residual cross-product matrix of a model in which all slope parameters are simultaneously set to zero.

[6] Monotonicity requires that the cost function be non-decreasing in input prices and is satisfied if the fitted factor shares are positive at each observation. Concavity of the cost function in input prices is satisfied if the Hessian matrix based on the fitted factor shares is negative semidefinite.

[7] To test for serial correlation, the model was initially estimated under the constraint that the R_i matrices (from equation (6)) equal zero and then re-estimating the model for R_i not equal to zero. The usual likelihood ratio test is based upon the sample maximized log-likelihood functions obtained from the previous models (Berndt 1991). The null hypothesis of no autocorrelation was rejected at the .01 level.

[8] Based upon annual time series data from Belgium, de Borger (1984) found a similar result.

hypothesis of constant returns to density. The t-statistic for the null hypothesis of constant returns to density is –.45, well below the 1.67 critical value. We also see that the estimated coefficient for 'Number of buses', the fixed factor of production is negative but not statistically significant.

Holding all else constant, the coefficient for Time Trend indicates that monthly public transit costs have been declining on the order of .004% during the sample period, which translates into a .048% annual reduction. And relative to the latter part of the year, Indianapolis' transit system experiences higher costs during the winter and spring quarters of the year.[9]

In addition to output, input prices, and the fixed factor of production, the empirical model reported in Table 2 also includes a dummy privatization variable, $D_{bef/aft}$, which equals zero for the period of public transit ownership and operation (1991 – 1995) and one for the period of public ownership but privatized operation (January 1996 – March 1997). From Table 2, the coefficient for this variable is negative and highly significant. Holding all else constant, the –.201 estimated coefficient for $D_{bef/aft}$ indicates that transferring operations from the public to the private sector has reduced monthly operating costs .201% which reflects a 2.4% annual cost savings from privatization.

Further Analysis of the Model

Tables 3 presents test results for homotheticity and Cobb-Douglas production technologies for the estimated model.[10] Consistent with other studies, a Cobb-Douglas production technology is strongly rejected in each case.[11] In addition, the model rejects the hypothesis of homotheticity implying that the cost function is not separable in output and that changes in a factor's price will not only affect an input's demand but also the cost elasticity with respect to output.[12]

[9] In earlier model runs, a full complement of monthly dummy variables were included but likelihood ratio tests could not reject the null hypothesis that the monthly dummy variables in a quarter were equal.

[10] Testing for homotheticity is equivalent to testing the null hypothesis that $\gamma_{iy} = 0$ (i = labor, maintenance) versus the alternative hypothesis that at least one of these parameters is non-zero.

[11] A Cobb-Douglas technology characterizes the production of transit trips if we can accept the null hypothesis that $\gamma_{yy} = \gamma_{ij} = \gamma_{iy} = 0, \forall i$. Viton (1981) and Obeng (1984) reject a Cobb-Douglas technology in short-run analyses while Williams and Hall (1981), Williams and Dalal (1981), Berechman and Giuliano (1984), and de Rus (1989) reject a Cobb-Douglas technology in long run analyses.

[12] The literature provides mixed evidence on homotheticity. Berechman and Giuliano (1984), de Borger (1984), Berechman (1987), and de Rus (1989) also found a non-homothetic production structure. However, Williams and Dalal (1981), Williams and Hall (1981), and Berechman (1983) could not reject the null hypothesis of a homothetic production structure. However, in none of the time series models did the authors correct for autocorrelation.

Table 3
Test Statistics for Homotheticity and Cobb-Douglas Production Technologies

Null Hypothesis	$-2(\ln L_R - \ln L_U)$[a]	Number of Restrictions (n)	$\chi^2(n)$ at 0.01 level	Result
Homotheticity	82.11	2	9.21	Rejected
Cobb-Douglas	233.47	10	23.21	Rejected

[a] $\ln L_U$ is the sample maximized log-likelihood value without restrictions (unconstrained) And $\ln L_R$ is the sample maximized log-likelihood with restrictions imposed (constrained)

Table 4 presents the own price (e_{ii}) and Allen elasticities of substitution (σ_{ij}) evaluated at the sample mean for Indianapolis' public transit system during the publicly operated and privatized periods. As expected, the own price elasticities have the correct negative sign. During both periods, and consistent with

Table 4
Short-Run Own Factor Demand Elasticities
and Elasticities of Substitution

Period	Price Elasticity[a]					
	e_{ll}	e_{ff}	e_{mm}	s_{lf}[b]	s_{lm}	s_{mf}
Before	-0.114	-0.311	-0.018	0.541	0.089	-0.341
After	-0.118	-0.307	-0.035	0.568	0.110	-0.353

[a] e: own-price elasticity of demand, s: Allen partial elasticity of substitution, where l = labor, f = fuel, m = maintenance
[b] Elasticities of substitution are symmetric

other studies, the elasticities are relatively small for labor and maintenance while the demand for fuel is more elastic. Although privatization did not have a demonstrable effect upon the demand for labor or fuel, we see that the demand for maintenance has become more elastic during privatization. This is consistent with the 28% reduction in maintenance employees since the system privatized its operations. The Allen elasticity results indicate that privatization has had little effect upon substitution elasticities. During both periods, labor is a substitute for maintenance and fuel while maintenance and fuel are complements in the production of public transit services.

Optimal Fleet Size

In this section, we use the estimation results to estimate optimal fleet size in order to evaluate the extent to which privatization has affected capital investment in Indianapolis' public transit system. Long-run total costs are always less than short-run total costs, except at the output level at which the fixed factor is appropriate for long-run cost minimization. Thus, the *optimal* level of the fixed factor (optimal number of buses) solves the following equation:

$$\frac{\partial VC}{\partial x_F^*} = -p_F \qquad (7)$$

where the subscript F refers to the fixed factor, VC is short-run total variable cost, p_i is the price of input i, and x_F^* is the optimal level of the fixed factor (optimal number of buses). Since there is not a closed form solution for x_F^*, the optimal level of rolling stock, given p_i and y, was obtained through a numerical procedure.[13]

Table 5 presents actual and optimal fleet sizes along with long-run cost estimates for the pre-privatized and post-privatized periods. During the 5 year period when the public transit system was publicly operated, we see in the table that the estimated long run marginal cost is greater than long run average cost indicating that the system is operating under decreasing returns to scale. Further, in comparison with an average fare of \$.95 per vehicle-mile, long run marginal cost pricing implies a subsidy of \$2.04 per vehicle-mile. During the privatized period, on the other hand, the system's cost structure is lower. Long run marginal cost, for example, has fallen to \$1.62 per vehicle mile. Further, the system is operating close to constant returns. Since privatization, long run marginal cost is on average 5.8% higher than long run average

[13] To compute the economic cost of capital to the firm, the present study uses the modified Nelson (1972) approach (Berechman and Giuliano (1984)). The formula for the annual cost of capital for bus category i in year t, P_{it}, is

$$P_{it} = N_{it}\,(1 - .08)\,V_{it}\,\delta \exp(-\delta A_{it})$$

where i is size of bus (e.g. 40 foot bus, 35 foot bus, or other bus category), N_{it} is fleet size for bus category i in year t, V_{it} is the price for a new bus in category i in year t, δ is the depreciation rate, A_{it} is average fleet age for bus category i in year t. The annual cost of capital for a given year is $P_t = \sum_i P_{it}$. The depreciation rate was calculated using the double-declining balance method over an assumed twelve-year economic life (based on Federal Transit Authority standards of a 12 year 500,000 mile minimum bus life). The constant depreciation rate assumed by this method is determined from the formula δ=2/N, where N is the assumed depreciation life. For N equal to 12, δ is 1/6. V_{it} for the sample was obtained from the American Public Transit Association (1994).

Table 5
Long-Run Costs and Capital Optimality
January 1991 – March 1997

Period	Actual Fleet	Optimal Fleet	LRAC[b]	LRMC[c]
Before	227	201	2.37	2.99
After	215	209	1.53	1.62

[a] Long Run Average Cost - Estimate based on optimal fleet size
[b] Long Run Marginal Cost - Estimate based on optimal fleet size

cost compared with a 26.2% difference during the pre-privatized period. Also, given the $1.00 fare per vehicle-mile during this period, long run marginal cost pricing implies a per-mile subsidy of $.62, which is 32% of the per vehicle-mile subsidy required during the publicly operated period.[14]

Complementing these results, the system was overcapitalized during the 1991-1995 period. For an average month during the 1991-1995 period, fleet size was 227 buses which compares with an estimated optimal fleet of 201 buses which reflects a 13% rate of overcapitalization. Since privatization, however, optimal fleet size is higher, 209 buses, while actual fleet size is on average lower at 215 buses. Although there is still some inefficiency, the rate of capitalization is relatively small at 2.8%. One could easily argue that this rate of overcapitalization is within acceptable tolerances for operating efficiency.

VI. CONCLUSIONS

This paper offers two contributions to the public transit literature. First, in contrast to all other time series translog cost analyses of public transit operations, the model estimated in this paper corrects for serial correlation. Not correcting for serial correlation biases standard errors of coefficient estimates, invalidates the associated hypothesis tests, and can have important implications for public transit policy.[15]

[14] We also observed similar differences with respect to short run costs. Prior to privatization, estimated short run marginal cost was $3.091 per vehicle mile which implies a $2.14 operating subsidy. Since privatization, however, short run marginal cost is estimated to be $1.63, implying a smaller $.63 operating subsidy.
[15] As an example, Karlaftis and McCarthy (1997) estimate a translog cost model for Indianapolis based only upon the pre-privatized period January 1991 - December 1995. In this analysis, the authors demonstrate that, when unadjusted for serial correlation, the extent to which Indianapolis' transit system is overcapitalized is considerably greater than when the model adjusts for serial correlation. In other words, when not accounting for serial correlation, the mis-specified model suggests that Indianapolis' operations are less efficient than may actually be the case.

Second, this paper contributes to the literature on privatization. Consistent with other studies, the results of this analysis indicate that Indianapolis' 15 month experience with privatization of its mass transit system has reaped economic fruit. In general, during the privatized period, Indianapolis is producing more vehicle-miles and serving more passengers but doing so with the expenditure of fewer resources. According to the translog cost function results presented in this paper, privatization of Indianapolis' public transit system has led to an annual 2.4% decrease in operating costs. Further, estimated long run marginal costs have fallen 45.8%, from $2.99 per vehicle-mile to $1.62 per-vehicle mile, and the system is more efficiently using its bus fleet. This is particularly important in today's environment in which there are increasing calls for significant reductions in operating subsidies to public transit systems. Overall, the positive initial results imply that Indianapolis continue with privatized management and, more generally, suggest that other publicly run systems take a hard look at private-sector alternatives for managing their transit operations.

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