Comparison of Supply, Demand and Cost Models using UMTA Section 15 Data

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ABSTRACT

To assess the usefulness of the UMTA Section 15 transit data for research, econometric models estimated from previous data sets were replicated. Estimates were prepared for supply, demand and cost equations. Relationships were compared for magnitude, sign and significance. It was found that the 1978-79 Section 15 data can not be used to replicate previous studies. Incomplete returns together with the absence of variables reduce the value of the data set for research. Recommendations are made for improvement of Section 15.

Availability of the National Mass Transportation Statistics, 1978-79 (Section 15) for the first time provides national data collected in a standard format.(1) Operating and financial information submitted by transit properties pursuant to Section 15 of the Urban Mass Transportation Act of 1964, as amended, is reported in aggregate and by individual property. Transit performance indicators are reported for motor bus operators grouped by fleet size. Using the new data, researchers now have an opportunity to examine the production and consumption of transit service and the factors which affect demand, supply and cost. This paper assesses the suitability of the 1978-79 data for policy analysis by replicating demand, supply and cost equations from previous research.

Section 15 had its origin in a proposal by several transit associations in 1971 to develop a uniform financial reporting system known as FARE. The FARE reporting system was designed to meet the needs of: individual transit systems for comparing their performance with other transit systems with similar characteristics; transit industry associations for monitoring industry performance; and Federal, State, and local government agencies for transit industry analysis and for financial assistance program administration.(2)

One year after the completion of Project FARE, in 1973, the Urban Mass Transportation Act of 1964 was amended to include Section 15, which requires a uniform system of accounts and records as well as a uniform reporting system. The modifications presented under Section 15 were of a practical nature. It was recognized that for an accounting system to function effectively its data requirements should not overburden its data suppliers. In addition limits had been placed upon the level of detail that could be mandated by a Federal agency under the Federal Reports Act of 1941. A reconciliation was needed between the two dimensions of acquiring useful information while not being overly burdensome. The solution was to minimize the required data under Section 15 but to allow transit organizations the option of substituting more detailed reports. The basic objectives of a uniform account and reporting system were not altered, but much data useful for the analysis of factors affecting transit supply, demand and cost was eliminated.

The purpose of this research was to conduct a preliminary assessment of the first year's output from Section 15 to judge the reliability of the new data set before using the data for performance analysis.[(3)]

METHODOLOGY

Data was obtained on tape from the Transportation Systems Center. Some 324 properties are represented, although only data from 259 single mode motor bus properties were used for this research. Data omissions and difficulty in obtaining data for each variable caused the deletion of additional properties so that the number of cases in each equation varies between 75 and 121. Supplementary data was obtained from Census reports and from a survey of transit operators. This was necessary because not all the variables used by previous researchers were available from Section 15 reports.

Using census data to replicate demographic and environmental variables used in earlier econometric studies proved difficult and is given as an explanation for some differences in magnitude. As transit systems often serve suburbs beyond the city, city population may be too small to realistically represent the transit service area, whereas the county is too large. Urbanized area (the contiguous built up area) comes closest to many transit areas and was used as the statistical base unit. However, transit systems only serve a portion of their urbanized area. Also, the urbanized area statistics are based upon the 1970 Census Population. Population density and percent of population over 65 have been calculated for 1975, but the remainder are eight years dated.

Requests for demographic data and the size of the service area should be included in future revisions of section 15 regulations.

Two econometric studies were selected for replication. Both had used data from carefully selected, but smaller, data sets to develop equations for urban bus transit. Nelson developed equations for supply, demand and cost.(4) Parameters were estimated from two cross-sections of data on single-mode bus firms in urbanized areas: 51 transit firms in 1968 and 44 in 1960. We have chosen to replicate the 1968 results.

Veatch used 1970 data collected from 29 bus transit firms operating in small and medium sized cities.(5) Veatch was primarily interested in the environmental variables affecting cost and whether or not economies of scale were present, but he also estimated supply and demand equations. Replication of the equations has an advantage because he used demographic data from the 1970 Census which we also used for several variables.

Assessment of comparability of the coefficients in each data set is subjective. No tests were performed to determine whether the data sets used by Nelson, Veatch and Section 15 are samples from the same population or whether the coefficients in each study are equal. Differences in the magnitude of coefficients was expected because of the changes that have occurred in the transit industry the last decade. The sign and significance of the variables are therefore more important in assessing the usefulness of the Section 15 data than magnitude of coefficients.

In order to test whether previous econometric models can be replicated using Section 15 the components of transit are grouped into three classes: 1) supply of transit service represented by vehicle miles 2) demand for transit represented by passengers carried, and 3) cost of transit operation including models of operating cost, as well as total cost per unit of output.

TRANSIT SUPPLY

For transit management, the level of service provided is the most important decision. Management has less influence over demand and cost and, in the short run, is likely to take them as given. There is agreement between Nelson and Veatch as to which variables affect supply (4, p. 84 and 5, p. 104). The level of demand, and the cost of providing that service are statistically significant in each study (Table 1). Also significant was log of urban population in Nelson and urban area in Veatch.

Nelson attempted to determine whether firms tend to maximize the level of service, as expressed in vehicle miles, or maximize the level of ridership. He was not able to find a single objective function that fit well his cross-sections of transit properties. However, he found that the supply function (vehicle miles) is proportional to the quantity of trips demanded and not affected independently by size of the urban area. Furthermore, vehicle miles was inversely proportional to the cost per mile. Supply also decreased as the cost-revenue ratio increased, but not as sharply as it had in Nelson's 1960 data.

The ownership variable that appears in the Veatch study is a surrogate for whether the transit system was receiving a subsidy from a state or local government. Veatch found that his measure for service level was significantly related to all but the federal subsidy variable. He indicated that higher levels of demand were associated with higher levels of service, and those systems that received subsidies provided a higher level of service than those that received no subsidies. The relationship between area served and level of service was direct and positive. The cost per vehicle mile relationship was negative and significant, indicating that those systems with a lower average cost were able to operate more vehicle miles of service, other things being equal. The fact that no systematic relationship was found between federal aid and level of service could be attributed to the date of the study. Federal aid to transit had just begun when Veatch conducted his study.

Section 15 Replication

The Section 15 data for single mode operators is consistent with the results Nelson obtained using 1968 APTA data: there is a positive relationship between vehicle miles and passengers and a highly significant negative relationship with cost. When the 52 multimode operators were added to the data set, the positive relationship with urban population increased and was significant at the 0.01 level. Deletion of the multimode operators eliminated many regional transit operators whose positive correlation between population and service supplied was expected.

Veatch measured supply by total vehicle miles, which is positively related to total passengers in both 1970 and 1979. However, the effect of passengers upon supply has decreased. The much larger and significant effect of the federal subsidy variable in 1979 was expected. Veatch had hypothesized this but did not find it in his 1970 data, although his private/public ownership variable was, in fact, a subsidy dummy variable.

The Section 15 data seems consistent with the data from the two earlier studies using established data bases and a smaller number of observations. Inconsistencies occur with population size and urban area variables but these can be explained by changes in the nature of transit supply and the difficulty in obtaining demographic statistics for 1979 which matched transit service areas. However, lack of significance of the cost data deserves attention. It could be caused by increased subsidies based upon population rather than service supplied. The coefficient in the replication of the Veatch equation is very large although insignificant. The cause is unknown and the hypothesized effect of subsidies upon variance of the transit cost/supply relationship deserves additional analysis.

TRANSIT DEMAND

The Nelson and Veatch demand equations (Table 2) have four variables in common: auto availability, population and size of urban area, and bus miles. Nelson also used fare, highway capacity, household income and age as explanatory variables. Nelson had revenue passengers per annum as the dependent variable and Veatch total passengers. The only variable that was too difficult to replicate was highway capacity.

Nelson found that level of service had a significant effect on demand for transit service. He further found that bus patronage was lower in the urbanized areas where higher percentages of household earned less than $3,000 in 1960 or where there were higher percentages of old or young persons. This, he concluded, lent support to the notion that most transit riders are members of the work force. That is, most of those who demand transit services do so because they must travel to or from a work place. The availability of automobiles was found to have no significant effect, in contrast to Veatch's results.

Veatch found that demand for transit was significantly related to the unavailability of automobiles, service levels supplied and population. Service area had little effect. Veatch was not able to acquire a transit fare variable for his data, although he did include this variable in his theoretical model.

Section 15 Replication

Replication of the Nelson equation with 1979 data yields in consistent results. The magnitude of average fare and the youth and elderly groups on demand is much lower and statistically insignificant. Between 1968 and 1979 fares have increased by only 75 percent whereas transit operating expenses have increased by 230 percent. Fares now have less negative effect on demand and more non-employed persons are using transit. The negative correlation between bus miles per capita and demand in the Section 15 data was unexpected and probably due to our inability to match transit service areas with demographic data. The specification of the income variables was changed since Nelson's $10,000 upper and $3,000 lower income levels, defined for 1960, did not represent reasonable divisions for the 1970 census data. Both per capita income and per capita income squared are very significantly related to demand. Demand for transit is negatively related to per capita income, although the decline in demand decreases slightly as income increases. In contrast to Nelson's results, low income families use transit more frequently than do higher income families.

The positive coefficients of log of urban population and log of urban area are similar in size to Nelson's and, like Nelson, we found population to be the most statistically significant measure of market demand.

Using Section 15 data to replicate the Veatch equation yields two inconsistencies. Families with no auto is defined differently, using available census data, which may explain the insignificance of this variable. The positive and highly significant relationship between vehicle miles and demand is consistent with Veatch's findings, as are the negative relationships found for both urban population and urban area. However significance of the two urban size measures switched from urban population to urban area.

Inability to replicate the earlier demand equations using 1979 data was expected. Demand for transit has both increased and changed since 1968 and 1970. Central city work trips by transit have been maintained but other work trips have been lost to automobiles. And in the largest cities, transit ridership has declined for all except the lowest income workers. Difficulty in obtaining comparable demographic statistics also affected the results. Section 15 provides consistent data on neither the population accessible to transit nor the size of the transit service area. The data on number of passengers was missing for more than 50 percent of the data and passenger miles ratios, if used, would have been missing for 75 percent of the cases. Data on fares was not collected so we have used surrogate measures or data collected from other sources. Collection of data on service area size and population as well as the fare schedules should be included in any revision of the Section 15 requirement. Relating urbanized area statistics to transit performance proved unsatisfactory. The effort devoted to the collection of passenger mile data seems to be unwarranted. Accurate data on passenger revenue, fares, and number of passengers would be sufficent for bus transit systems.

TRANSIT COSTS

Transit cost studies are of two types: cost-allocation studies based upon the accounts of individual properties and regression studies which are longitudinal or cross-sectional studies. Nelson and Veatch use the latter approach.

The Nelson study is important in several respects. The first is that his dependent variable was total cost, which includes interest and depreciation expenses, in contrast to other studies which explain operating cost, exclusive of capital charges. Second, Nelson found that the amount of bus-miles supplied had a proportionate effect on the cost, and concluded that no economies of scale exist. Miller (6, p. 24) had earlier demonstrated that there were slight diseconomies of scale but this was questioned by both Nelson and Veatch. Veatch suggested that there is a "U" shaped cost curve: costs decrease, then level out and then increase with increasing bus miles. The Nelson sample excluded very large and very small cities and therefore captured only the flat middle section of the U-shaped cost curve. Labor costs and miles per bus-hour (speed) did have a major impact on the cost of operations in Nelson's equation. He also found that newer buses, larger buses and buses which were not subsidized by capital grants, did not have statistically significant relationships with cost.

Veatch was primarily concerned with whether economies or diseconomies of scale exist and secondarily with the relationship between costs of the transit firm and the characteristics of the city. He estimated several equations in his attempt to test Miller's hypothesis of diseconomies of scale. Veatch concluded that average costs vary with the size of the firm and with characteristics of the community. This suggests that valid cost equations can only be developed when the sample is disaggregated by size of firm as well as by characteristics of the operating environment such as city structure, operating speed, and concentration of central city employment.

Section 15 Replication

Results consistent with the Nelson 1968 data were found for those variables which were significant. Costs increase proportionately with vehicle miles, seating capacity and as buses travel more slowly.

The lessened importance of wage rate and its lack of significance in the 1979 data was not expected.

Veatch found only the top operators' wage to be significant. When compared with the 1979 Section 15 data, two additional variables are significant and the R^2 is slightly better than that achieved by Veatch. The puzzling result is the negative sign on the inverse of vehicle miles which is significant in the Section 15 results. However, its small size represents no important diseconomies of scale and is consistent with the constant returns to scale suggested by Nelson and Miller but rejected by Veatch.

USEFULNESS OF SECTION 15 FOR RESEARCH

Our attempt to replicate previous studies can be described as only a limited success. There are a number of reasons for this, some of which are not related to Section 15. For example, the difference in size and composition of the samples of systems. Also changes in the industry have occurred such as the increased importance of subsidy and the increase in number of multimode (bus/demand responsive) systems.

Although Section 15's uniform method of accounts potentially increases the comparability of systems, the existence of much missing data in the inaugural report tends to reduce the data set by half, even for the relatively simple models considered in this paper. Greatest difficulty was encountered with the demand equations. Only two of the independent variables used by Nelson and Veatch were available from Section 15 and the missing variables were difficult to establish using Census data. Inclusion of population and size of the area served would be extremely useful addition for each transit system.

Other useful additions would be numbers of revenue passengers and transfer passengers, base fare, top operator wage rate, route miles (miles of line is the nearest proxy), and peak-to-base pay hours. Other information could be deleted: complete details of the balance sheet (Form 101) are unnecessary for comparative study. The three summary statistics for "total assets," "total liabilities," and "accumulated earnings" would be sufficient.

Too much emphasis has been placed upon the gathering of passenger mile statistics. Although it is an ideal measure of service consumption, the additional cost of collecting these statistics for bus transit operators and their inability to use these data for route planning, makes the requirement burdensome. Accurate reporting of total and revenue passengers, passenger revenue and base fare would be more helpful for transit performance research.

Information on ownership (private, municipality or special district) and operations control (direct or contract management) would also be helpful. Significant variance occurs in operating costs. These could result from managerial differences and ought to be investigated.

Inability to obtain significant results from Section 15 for operator wage data is disappointing. Much more attention should be given to accurate and complete reporting of wage data because the wage variable is one of the three variables essential for calculating cost models. These models are helpful when evaluating improvements in transit performance. And for this reason, it is essential that the exclusion of operators with fewer than 25 vehicles from reporting wage data be reconsidered.

TABLE 1. ESTIMATES OF SUPPLY EQUATIONS FOR BUS TRANSIT SUPPLY STUDIES

Dependent Variable	Log of Total Vehicle Miles Nelson	Log of Total Vehicle Miles Section 15	Total Vehicle Miles Veatch	Total Vehicle Miles Section 15
Log of Annual Revenue Passengers	0.727***	0.771***		
(S.E.)	(.095)	(0.0595)		
Log of Cost per Vehicle Mile	-0.601***	-0.984***		
(S.E.)	(.164	(0.1809)		
Log of Cost/Revenue Ratio	-0.065	-0.219		
(S.E.)	(.189)	(0.4605)		
Log of Urban Area	0.055	0.076		
(S.E.)	(.072)	(0.053)		
Log of Urban Population	0.248*	0.082		
(S.E.)	(.142)	(0.053)		
Total Passengers			1.24***	0.204***
(S.E.)			(0.0840)	(0.0114)
Private/Public Ownership			-230**	-175332.0
(S.E.)			(106.48)	(408768.7)
Urban area, Square root of			22.5***	27639.41
(S.E.)			(4.9020)	(23154.47)
Cost per Vehicle Mile			-950***	-212430200
(S.E.)			(342.96)	(226137700)
Federal Subsidy			50.9	0.354***
(S.E.)			(91.055)	(0.055)
	N=51 (1968) R^2=.982	N=79 (1979) R^2=.807	N=29 (1970) R^2=.389	N=94 (1979) R^2=.984

Key: *Significance at .10 level
**Significance at .05 level
***Significance at .01 level

TABLE 2. ESTIMATES OF DEMAND EQUATIONS FOR BUS TRANSIT

Study Dependent Variable	Annual Revenue Passengers Nelson	 Section 15	Annual Total Passengers Veatch	 Section 15
Log Autos Per Capita: S.E.	-.175 (.40)	-0.219 (.158)		
Average Fare (S.E.)	-3.06 (1.60)	-0.00000306*** (0.00000066)		
Miles per Capita (S.E.)	8.81*** (2.00)	-3.210*** (0.281)		
Log Population per City Highway Capacity	0.156 (.16)	N.A.		
Percent Family Income Less than $3,000 (1960) (S.E.): Section 15 Variable is Per Capita Income	-3.02*** (1.03)	-0.00215*** (0.000737)		
Percent Family Income Greater Than $10,000, Section 15 Variable is Per Capita Income Squared (S.E.)	-3.57* (1.97)	+0.0000000260*** (0.000000087)		
Percent Urban Pop. Younger than 18 (S.E.)	-5.95** (2.44)	-0.00423 (0.0315)		
Percent Urban Pop. Older than 65 (S.E.)	-8.17** (3.42)	-0.01269 (0.0294)		
Log Urban Population (S.E.)	1.10*** (.13)	1.063*** (0.0810)		
Log Urban Area (S.E.)	0.0208 (.11)	0.00166 (0.0640)		
Families with No Autos: Veatch used <u>number</u> of urban families; Section 15 is <u>percent</u> of urban families (S.E.)			0.0544*** (0.0120)	-13673.8 (72264.07)
Urban Population (S.E.)			-0.00188*** (0.00058)	-0.152 (0.169)
Urban Area (S.E.)			-0.0432 (0.0790)	-8382.96** (3931.02)
Total Vehicle Miles (S.E.)			0.613*** (0.0614)	3.606*** (0.057)
	N=51 (1968)	N=75 (1979)	N=29 (1970)	N=95 (1979)
	R^2=.976	R^2=.799	R^2=.968	R^2=.979

Key: *Significant at .10 level
**Significant at .05 level
***Significant at .01 level

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