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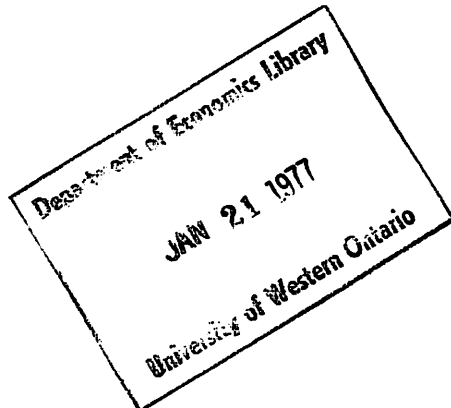
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Discussion Paper 015

THE DEMAND FOR URBAN BUS TRANSIT  
IN CANADA

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RESEARCH PROGRAM:  
IMPACT OF THE PUBLIC  
SECTOR ON LOCAL ECONOMIES



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I. Introduction

All levels of government in Canada have become increasingly involved in promoting urban public transit, and public ownership and subsidization are now the rule. Government involvement has increased in part in order to stem the decline in ridership and related financial problems facing transit companies and in part in response to growing public concern over urban, environmental, and energy issues.

If governments and transit authorities are to make rational urban transit policy decisions, they will need empirical evidence concerning the determinants of transit ridership. The purpose of this paper is to provide empirical estimates of a demand function for urban bus transit services in Canada. The study uses annual city-wide data for bus systems in 28 urban areas during the years 1962 to 1974 and estimates the demand function using two-stage least squares.

We begin in section two by specifying the demand function. In section three we present a simultaneous equation model of a transit system which incorporates this demand function. In sections four and five we discuss the estimation and the empirical results. In section six we compare our results with those of other studies of the demand for transit, and in section seven we summarize our findings.

## II. Specification of the Demand Function

We hypothesize that the quantity of bus services demanded per capita in an urban area depends upon the money and time costs of travel by bus and by private automobile, average income and other socio-economic characteristics of the population, and geographic characteristics of the urban area.

### A. Variables

#### 1. Quantity of Bus Services Per Capita

Because Canadian bus companies record data for number of passengers but not for lengths of passenger trips, the dependent variable in the demand function specified here is number of bus rides per capita (R/P) rather than number of bus passenger miles per capita. In arriving at a figure for rides per capita, population is measured for the area served by the bus system rather than for the urban area.

#### 2. Money and Time Costs of Travel by Bus

The money cost of travel by bus is measured by the lesser of the adult ticket and cash fares per ride (F).<sup>1</sup> Like all monetary variables in the study, fares are measured in real terms. Fares are adjusted to 1974 cents by using the national consumer price index because provincial and municipal CPI's are not available.

We hypothesize that the coefficient on fare in the demand equation is negative. We are also interested in testing the rule-of-thumb used in the transit industry that the fare-elasticity of demand is  $-.3$ .

One of the important time costs of travel by bus is the time spent walking to a bus stop, waiting for a bus, and transferring. In principle, walking and waiting time for buses could be measured by the annual number

of bus miles of service per square mile of area served (M/A). If an urban area has more bus miles of service per square mile of area, it typically has a higher density of routes and/or more frequent service.<sup>2</sup> Consequently, average walking and waiting time per ride are generally lower in an urban area with more bus miles per square mile of area. Unfortunately, the available data on area appear to be highly inaccurate as measures of area served. They generally measure the areas of political jurisdictions, which often include large undeveloped sections of the city. Consequently, in this study we use reported data on population served as a proxy for area served. The justification for this is that we expect that the developed area of the city which is served by the bus system is more closely related to population than to total area.

We hypothesize that the coefficient on bus miles per capita (M/P) is positive. It should be noted that use of population as a proxy for area introduces two problems because population is not proportional to area. First, if population is proportional to a power of area,  $P = \gamma A^{1/\delta}$  where  $\delta \neq 1$ , then use of P (rather than  $P^\delta$ ) as a proxy for A will bias the coefficient on the population variable in the demand equation. Second, if the relationship between population and area is stochastic, then use of P (or even  $P^\delta$  for that matter) as a proxy for A could bias the estimates of the coefficients of the other independent variables. For example, if urban areas with a higher population density systematically have a larger level of bus miles of service per capita, then use of a power of P as a proxy for A will lead to an upward bias in the estimated coefficient of the bus miles variable.<sup>3</sup>

Data on speed of buses are not available. However, average speed may vary among urban areas of different sizes because of differences in traffic congestion and use of express buses. Consequently, as a crude proxy for

speed, we include the population of the area served ( $P$ ) as an independent variable. However, for reasons which are discussed in the following sections, population may also serve as a proxy for a number of other determinants of the demand for bus services per capita. Furthermore, as we have indicated above, use of  $P$  (rather than  $P^\delta$ ) as a proxy for  $A$  in the bus miles variable will probably bias the coefficient on  $P$ . As a result, we have no hypothesis concerning the sign of the coefficient on population, and we cannot use that coefficient to test specific hypotheses about the effect of the speed of buses.

### 3. Money and Time Costs of Travel by Automobile

Four indexes of the costs of travel by automobile are included in the demand equation on the grounds that they measure the price of the major substitute for bus travel: two indexes of the costs of owning an automobile, an index of the money cost of operating an automobile, and an index of the speed of travel by automobile and the cost of parking an automobile.

The two indexes of the costs of owning an automobile measure depreciation and real interest costs. First, we use an index of the real purchase price of an automobile ( $X_1$ ) constructed from Statistics Canada and Canadian Red Book data. Second, we use an index of the interest cost of funds used to hold an automobile net of the capital gains on a non-depreciating automobile ( $X_2$ ). The latter index is constructed as the prime lending rate of commercial banks minus the percentage increase in the nominal purchase price of an automobile. We assume that depreciation is proportional to  $X_1$  while the real interest cost of holding an automobile is proportional to the product  $X_2X_1$ .

As an index of the cost of operating an automobile, we use the real

price of gasoline ( $X_3$ ).<sup>4</sup>

As a crude proxy for the speed of automobiles and for the real cost of parking an automobile, we use the population of the area served by the bus company (P).

We hypothesize that the coefficients of all these costs of owning and using an automobile are positive. However, for reasons which are discussed in other sections, we have no hypothesis concerning the sign of the population variable.

It should be added that we also considered an alternative specification of the demand function for bus rides per capita in which the stock of private automobiles per capita would be included as an explanatory variable. In this case, the two indexes of the costs of owning an automobile would be omitted from the demand function for bus rides, but an additional equation explaining automobile ownership per capita would be specified. This alternative approach is not pursued in this paper because our empirical work found no support for the hypothesis that the demand for bus rides depends on the stock of automobiles. Although somewhat surprising, Nelson (1972, 80) obtained the same result in a study using U.S. data.

#### 4. Income and Other Socio-Economic Variables

We hypothesize that the demand for bus rides depends on average income because other studies of urban travel behavior indicate that on average people with higher incomes (a) take more intraurban trips and (b) own more automobiles, put a higher value on time savings, and therefore are less likely to take a given trip by bus. Income is measured as average weekly wage and salary income per employed worker (Y).

The net effect of average income on bus rides per capita depends on whether the effect of income on total number of trips by all modes outweighs



the effect of income on mode of travel. Thus, we have no hypothesis concerning the sign of the coefficient of income. However, a survey of the literature on urban bus transit reveals that most researchers believe that the sign is negative, except perhaps among the poor.

We hypothesize that a number of other socio-economic characteristics of the population influence the demand for bus services. We include percentage of the population under 15 years old ( $S_1$ ) and percentage of the population 65 years old and over ( $S_2$ ). One expects that members of these age groups would (a) take fewer intraurban trips but (b) be more likely to take a given trip by bus, at least in the case of the young. Nelson (1972, 77) found that the coefficients on similar variables are negative, but we have no a priori hypotheses about these signs.

We also include percentage of the population born outside Canada ( $S_3$ ). Litt (1975) found that the coefficient on this variable is positive.

Finally, we include the female labour force participation rate ( $S_4$ ). Females account for 60 to 77 per cent of bus passengers in a sample of eight Canadian urban areas for which data are available [Shortreed (1974, 28)], and Ahsan (1976) found that other things equal females are more likely to travel by public transit than are males in Montreal. It is hypothesized that the coefficient on  $S_4$  is positive.

All four of these socio-economic variables are measured using census data for 1971 rather than data for the years of the actual observations.

##### 5. Geographic Variables

We hypothesize that the demand for bus trips per capita depends on the spatial structure, climate, and size of the urban area. Probably the most important feature of urban spatial structure is the percentage of employment

which is located in the central business district and therefore relatively accessible by bus. The female labour force participation rate may act as one proxy for location of employment, because urban areas with high female participation rates may have relatively large, centrally located office sectors. This is one reason for anticipating a positive coefficient on the female participation rate. We also include the percentage of dwelling units constructed before 1920 (B) as a measure of the age of the urban area. Employment may be more centralized in older urban areas, and consequently we hypothesize that the coefficient on B will be positive.

We hypothesize that the demand for bus trips depends on the severity of the winter and on precipitation.<sup>5</sup> We measure the severity of the winter by the number of days per year with temperature below freezing ( $W_1$ ). We also include the number of inches of rain per year ( $W_2$ ) and the number of inches of snow per year ( $W_3$ ). We have no hypotheses concerning the signs of these weather variables. In bad weather, some people might stay home or travel by car rather than travel by bus. However, some might travel by bus rather than by car while still others might travel by bus rather than walk or ride bicycles. All weather variables are measured by long-term averages.

There are at least four reasons that the size of the urban area may affect the number of bus trips demanded per capita. Two reasons have been discussed already. First, the real cost of parking may be higher in larger urban areas. Second, average speed of buses and automobiles may depend upon the size of the urban area. Third, the average trip may be longer in larger urban areas. Bus fares are charged per ride regardless of length while automobile operating costs are proportional to distance. Consequently, for a given fare level and gas price, the relative money cost of travel by

bus may be lower in larger urban areas. Finally, if the average trip is longer in larger urban areas, fewer trips by all modes might be taken.

As a measure of size, we use the population served by the bus system (P).<sup>6</sup> We have no hypothesis concerning the net effect of population on demand for bus rides per capita.

### B. Functional Form

The dependent variable and, with one exception, all independent variables in the demand equation are transformed into natural logarithmic form. Thus, we impose the assumption of constant elasticity of demand with respect to these independent variables. The one exception is the fare, which is used without transformation in order to make the fare-elasticity of demand depend on the level of fare, more or less in the way it would along a straight-line demand curve.<sup>7</sup>

Thus, we hypothesize:

$$(1) \quad \log\left(\frac{R}{P}\right) = \alpha_0 + \alpha_1 F + \alpha_2 \log\left(\frac{M}{P}\right) + \sum_{i=1}^3 \alpha_{i+2} \log X_i + \alpha_6 \log Y + \sum_{i=1}^4 \alpha_{i+6} \log S_i \\ + \alpha_{11} \log B + \alpha_{12} \log P + \sum_{i=1}^3 \alpha_{i+12} \log W_i + \epsilon_1$$

$$\alpha_1 < 0; \quad \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_9, \alpha_{10}, \alpha_{11} > 0; \quad \alpha_6, \alpha_7, \alpha_8, \alpha_{12}, \alpha_{13}, \alpha_{14}, \alpha_{15} \geq 0.$$

The fare-elasticity of demand is given by:

$$E_F = \alpha_1 F$$

and we wish to test the rule-of-thumb that  $E_F = -.3$  at the sample mean.

### III. Simultaneous Equation Model of a Transit System

Consideration of the process by which the number of bus trips per capita is determined quickly convinces one that at least two variables on the right-hand side of the demand equation -- fare and bus miles per capita -- are determined simultaneously with bus trips per capita. Consequently, the demand equation must be estimated using a simultaneous equations technique. We use two-stage least squares.

The simultaneous equation model which we use is similar to one introduced by Nelson (1972) and estimated by him using U.S. data. We suppose that the bus firm in a particular urban area is a monopolist which sets the fare per trip and the number of bus miles of service per square mile of area ( $M/A$ ) to maximize the number of bus trips taken per capita.<sup>8</sup> The bus firm takes as exogenously given the population and area served<sup>9</sup> as well as the other variables on the right-hand side of the demand equation. The firm operates subject to a constraint on its cost-revenue ratio imposed by government regulatory and subsidy policies. The cost per bus mile of service is a constant.<sup>10</sup>

Thus, the firm chooses  $F$  and  $M/A$  to maximize the number of bus trips demanded per capita:

$$(2) \quad R/P = f(F, M/A)$$

subject to the constraint:

$$(3) \quad CM/FR = K$$

where

$R$  = passenger rides by bus;

- P = population of area served;
- F = fare in cents per ride;
- M = bus miles of service;
- A = area served in square miles;
- C = cost in cents per bus mile of service;
- K = cost-revenue ratio.

A necessary condition for this maximum is:

$$(4) \quad 1 > E_{M/A} = -E_F > 0$$

where  $E_{M/A}$  and  $E_F$  are the elasticities of demand with respect to bus miles of service per square mile of area and the fare.

Suppose that the demand function is:

$$(2') \quad \log \frac{R}{P} = \alpha_0 + \alpha_1 F + \alpha_2 \log \left( \frac{M}{A} \right)$$

Solving the constrained maximization problem for F and M/A and taking logarithms, one derives the following equations describing the behavior of the bus firm:

$$(5) \quad \log F = \log (-\alpha_2 / \alpha_1)$$

$$(6) \quad \log (M/A) = \log (-\alpha_2 / \alpha_1) + \log K - \log C + \log (R/P) + \log P - \log A$$

For reasons we have discussed in section II, we use M/P rather than M/A in the empirical estimation. Solving equation (6) for  $\log (M/P)$ , we obtain:

$$(6') \quad \log \left( \frac{M}{P} \right) = \log \left( -\alpha_2 / \alpha_1 \right) + \log K - \log C + \log \left( \frac{R}{P} \right)$$

Further, we hypothesize that the cost-revenue ratio of the bus firm can be explained by ownership and control arrangements and government subsidy policies. In particular, we assume that the cost-revenue ratio depends on the following five variables:<sup>11</sup>

- (i)  $D_1$ : If the firm which operates the bus company also supplies electric power, it can (and typically does) subsidize its bus operations from profits earned on its electricity operations.  $D_1 = 1$  if the bus firm also supplies electricity and 0 otherwise.
- (ii)  $D_2$ : If the firm is publicly owned, we hypothesize that it will receive larger government subsidies.  $D_2 = 1$  if the bus firm is publicly owned and 0 if it is privately owned.
- (iii)  $D_3$ : If the bus system is not only publicly owned but operated as a municipal department directly under control of the city council, we hypothesize that it will receive more government subsidies than if it is operated by a commission which is at least nominally independent of city council.  $D_3 = 1$  if the bus system is operated as a municipal department and 0 if it is operated by an independent commission.
- (iv)  $D_4$ : If the provincial government subsidizes the bus company, it will operate with a higher cost-revenue ratio.  $D_4 = 1$  if the province gave a subsidy to the bus firm and 0 if it did not.

(v) T: Over time government subsidies have increased. T is a trend variable which takes a value of 101 in 1962, 102 in 1963, etc.

Thus, we hypothesize that:<sup>12</sup>

$$(7) \quad \log K = \beta_0 + \sum_{i=1}^4 \beta_i D_i + \beta_5 \log T + \epsilon_4$$

and

$$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5 > 0.$$

The full simultaneous equation model is as follows, with a stochastic error term added to each equation:

$$(1) \quad \log\left(\frac{R}{P}\right) = \alpha_0 + \alpha_1 F + \alpha_2 \log\left(\frac{M}{P}\right) + \sum_{i=1}^3 \alpha_{i+2} \log X_i + \alpha_6 \log Y + \sum_{i=1}^4 \alpha_{i+6} \log S_i \\ + \alpha_{11} \log B + \alpha_{12} \log P + \sum_{i=1}^3 \alpha_{i+12} \log W_i + \epsilon_1$$

$$(5') \quad \log F = \log(-\alpha_2/\alpha_1) + \epsilon_2$$

$$(6'') \quad \log\left(\frac{M}{P}\right) = \log(-\alpha_2/\alpha_1) + \log K - \log C + \log\left(\frac{R}{P}\right) + \epsilon_3$$

$$(7) \quad \log K = \beta_0 + \sum_{i=1}^4 \beta_i D_i + \beta_5 \log T + \epsilon_4$$

The error term in each equation is assumed to be normally distributed with zero mean and constant variance and to be independent both cross-sectionally and time-wise.<sup>13</sup> In addition, there is the constraint given by (3).

#### IV. Background to Estimation

In estimating the demand equation, we treat R/P, F, M/P, and K as endogenous. From constraint (3), one can determine that  $\epsilon_2 = \epsilon_3$  in equations (5') and (6'') above. However, because we do not have data on K or C, we are forced to ignore constraint (3).

We do not have data on the cost per bus mile, C, but we do have data on three components of cost. Hence, we use these three elements of cost rather than  $\log C$  as instruments in the estimation of the demand equation. The three elements of cost for which we have data are the log of the wage rate of bus drivers per hour ( $\log C_1$ ), the log of the price of diesel fuel per gallon to the bus firm [excluding the fuel tax in cases where the bus firm is exempt] ( $\log C_2$ ), and a dummy variable ( $C_3$ ) which takes a value of one if the bus firm pays municipal property taxes and a value of zero if it is exempt from municipal property taxes.<sup>14</sup>

In addition to the exogenous variables in equations (1), (6''), and (7), we use the log of the area served by the bus company ( $\log A$ ) as an instrument in the two-stage least squares estimation of the demand equation. Thus, the full list of instruments used is:  $\log X_1$ ,  $\log X_2$ ,  $\log X_3$ ,  $\log P$ ,  $\log Y$ ,  $\log S_1$ ,  $\log S_2$ ,  $\log S_3$ ,  $\log S_4$ ,  $\log B$ ,  $\log W_1$ ,  $\log W_2$ ,  $\log W_3$ ,  $\log C_1$ ,  $\log C_2$ ,  $C_3$ ,  $D_1$ ,  $D_2$ ,  $D_3$ ,  $D_4$ ,  $\log T$ ,  $\log A$ , and a constant.

The demand equation is identified because the number of zero restrictions exceeds the number of endogenous variables less one. In order to use data on ridership to estimate the demand function, we assume that there was no excess demand for bus services, i.e., buses were not too full to admit all people wishing to ride.



V. Empirical Results

The demand equation is estimated using 223 observations from 28 urban areas during the years 1962 to 1974.<sup>15</sup> These represent all the observations for the specified time period which meet the following criteria: (a) the urban transit system was a member of the Canadian Urban Transit Association; (b) the system operated only conventional motor and trolley buses, not streetcars, subways, or dial-a-ride buses; (c) the urban area had a school bus system which was operated separately from the public bus system; (d) the system did not sell passes to adult passengers; (e) the system was not on strike; (f) complete data for all variables for the particular urban area and year are available; and (g) at least two annual observations are available for the system.

The two-stage least squares (TSLS) estimates for the demand equation are presented in the Table. Ordinary least squares (OLS) estimates are also presented for those who are interested.

The TSLS estimate of the coefficient of fare is negative as expected, but it is significantly different from zero only at the 10 per cent level. The coefficient implies a point estimate of the fare elasticity of demand of  $-.38$  at the mean of the fare variable. This is very close to the rule-of-thumb used in the industry, and it is consistent with the prediction in equation (4) that  $0 > E_F > -1$ . This finding implies that the typical bus system could reduce its deficit by increasing its fare.

The TSLS estimate of the coefficient of bus miles of service per capita is positive as expected and significantly different from zero at the 5 per cent level. The TSLS estimate of the elasticity of demand with respect to bus miles of service per capita is  $1.12$ . This elasticity appears

TABLE  
Estimates of Equation (1)

Independent Variable		TOLS	OLS
C	Constant	-6.48†† (-1.81)	-5.94+ (-2.08)
F	Adult bus fare	-.015** (-1.32)	-.013* (-3.15)
$\log \frac{M}{P}$	Log of bus miles per capita	1.12* (13.75)	.89* (19.43)
$\log X_1$	Log of automobile purchase price	-.15 (-1.84)	-.10 (-1.31)
$\log X_2$	Log of net interest rate on funds used to hold an automobile	-.018 (-.78)	-.021 (-.95)
$\log X_3$	Log of gas price	.89* (2.91)	1.03* (3.77)
$\log Y$	Log of wage and salary income per worker	-.63+ (-2.37)	-.69+ (-4.08)
$\log S_1$	Log of percentage of population under 15	1.30+ (3.51)	1.01+ (3.01)
$\log S_2$	Log of percentage of population 65 and over	.083 (.41)	.13 (.76)
$\log S_3$	Log of percentage of population born outside Canada	.15* (3.38)	.16* (4.74)
$\log S_4$	Log of female labour force participation rate	.51* (1.97)	.52* (2.34)
$\log B$	Log of percentage of dwelling units constructed before 1920	0.068** (1.30)	0.066** (1.40)
$\log P$	Log of population	.11†† (1.78)	.17+ (5.65)
$\log W_1$	Log of number of days below freezing	.021 (.26)	.041 (.60)
$\log W_2$	Log of rainfall	.16+ (2.20)	.11+ (2.02)
$\log W_3$	Log of snowfall	-.029 (-.33)	-.041 (-.54)
	$R^2$	.86	.88
	F(15, 207)	86	100

Notes: t-statistics are in parentheses.

\*: significantly different from zero at 5 per cent level, one-tailed test.

†: significantly different from zero at 5 per cent level, two-tailed test.

\*\* : significantly different from zero at 10 per cent level, one-tailed test.

††: significantly different from zero at 10 per cent level, two-tailed test.

implausibly large as a general description of bus transit demand behavior. It should be recalled, however, that this elasticity is derived for the variable M/P rather than M/A, and for reasons discussed in section II.A.2 it appears likely that there is an upward bias in this estimate.<sup>16</sup>

There is no empirical support for the hypothesis that an increase in the costs of owning an automobile leads to an increase in the demand for bus services.<sup>17</sup> This is true of lagged values of the costs of owning an automobile as well, in regressions which are not presented in the Table.

The coefficient of the real price of gasoline is positive as expected and significantly different from zero at the 5 per cent level. The TSLS point estimate of the elasticity of demand for bus trips with respect to the price of gasoline is .89. Lagged values of the price of gas are not significant in regressions which are not presented in the Table.

In the average city in the sample, roughly 10 per cent of all trips by either bus or car are taken by bus [Frankena (1975, 8)]. Consequently, an elasticity of demand for bus trips with respect to the price of gasoline of .89 would imply that a 10 per cent increase in the price of gasoline would divert about one per cent of the people travelling by automobile over to buses.

However, the elasticity of .89 is implausibly large in absolute value compared to the fare-elasticity of -.38. First, one would expect that a \$.01 change in the fare per ride (F) would affect the number of bus rides demanded (R) by more than a \$.01 change in the gasoline cost (G) for an automobile trip the length of the average bus ride:

$$\left| \frac{\partial R}{\partial F} \right| > \left| \frac{\partial R}{\partial G} \right|$$

This follows unambiguously if we ignore income effects, assume that some

members of the population choose between travel by bus and travel by foot or non-travel activities, and recall that cars often have two or more occupants to share the cost of gasoline. Second, assuming that the average bus trip is under 5 miles long (as it certainly is in our sample) and that the cost of gasoline is \$.05 per mile, the gasoline cost for the average trip would be less than the bus fare (\$.25):  $F > G$ . Consequently, one would expect:

$$\left| \frac{\partial R}{\partial F} \right| \cdot \frac{F}{R} > \left| \frac{\partial R}{\partial G} \right| \cdot \frac{G}{R}$$

i.e., the absolute value of the elasticity of demand for bus rides with respect to the cost of gasoline should be less than the absolute value of the fare-elasticity.

The fact that the estimates of the fare-elasticity and the gas-price elasticity appear inconsistent with each other indicates that the absolute value of the fare-elasticity has been underestimated, or the absolute value of the gas-price elasticity has been overestimated, or both. A survey of the literature on urban travel demand behavior reveals that most other researchers, using a variety of types of data and estimating techniques, have arrived at estimates of fare-elasticities reasonably similar to ours and much lower than .89. Furthermore, the only other study of the cross-elasticity between the demand for public transit rides and the money cost of automobile travel found that this elasticity is not significantly different from zero [Domencich and Kraft (1970)]. On the other hand, in a study similar to our own but using U.S. data, Nelson (1972) estimated the fare-elasticity to be between -.67 and -.81.

The TSLS coefficient of average weekly wage and salary income is negative and significantly different from zero at the 5 per cent level.

The TSLS point estimate of the elasticity of demand with respect to wage and salary income is  $-.63$ .

Among the socio-economic variables, the coefficients of percentage of population under 15, percentage of population born outside Canada, and female labour force participation rate are positive and significantly different from zero at the 5 per cent level. The coefficient of percentage of population 65 and over is not significantly different from zero.

The coefficients of the two variables which were expected to serve as proxies for the spatial structure of employment are positive as hypothesized. As we have already reported, the coefficient of female labour force participation rate is significantly different from zero at the 5 per cent level. The coefficient of percentage of dwelling units constructed before 1970 is significantly different from zero at the 10 per cent level. These results provide indirect evidence that the demand for bus rides per capita is greater if a larger percentage of employment is located in the central business district.

The TSLS coefficient of the population variable is positive, but it is significantly different from zero only at the 10 per cent level in a two-tailed test. This is consistent with the hypothesis that, other things equal, the demand for bus rides per capita is greater if parking costs are higher or if the average trip is longer. However, in view of the very general nature of the population proxy and our suspicion that the estimate of its coefficient will be biased upwards, one cannot conclude very much from the coefficient of this variable.

Among the weather variables, the coefficient of average rainfall is positive and significantly different from zero at the 5 per cent level. However, neither average number of days below freezing nor average snowfall

appears to have a significant effect on demand for bus transit.

#### VI. Comparison to the Results of Other Studies

Eight previous studies have used city-wide data to estimate demand functions for public transit. Six of these studies [Boyd and Nelson (1975), Carstens and Csanyi (1968), Gaudry (1975), Litt (1975), Sohn (1975), Wabe and Coles (1975)] use single-equation models and estimating techniques, and consequently we will not review their results.<sup>18</sup> The remaining two studies [Nelson (1972), Veatch (1973)] use simultaneous equation models and two-stage least squares.

Veatch's results cannot be compared with ours because of major differences in the specifications of the models, but Nelson's model is similar to the one used here. Nelson estimated his model twice using cross-sectional data for 44 and 51 U.S. cities for 1960 and 1968 respectively. His point estimates for elasticity of demand with respect to fare are  $-.81$  and  $-.67$  respectively, which are a good deal larger than our estimate of  $-.38$ . His estimates for elasticity of demand with respect to miles of bus service per capita are  $.92$  and  $1.35$  respectively, compared to our estimate of  $1.12$ . His estimate for the elasticity of demand per capita with respect to population is  $.1$  in both cases, which is the same as our estimate.<sup>19</sup> His estimate for the elasticity of demand with respect to area is zero in both cases, while we imposed a zero coefficient on the area variable a priori. Nelson found that percentages of the population 18 or under and 65 or over both have negative coefficients, which are significantly different from zero in 1968 but not 1960. We found that the coefficients on similar variables are positive, although the latter is not significant. The results for the other variables included in the demand equation by Nelson and

ourselves cannot be compared because of differences in the specifications.

## VII. Summary

In summary, the empirical results are consistent with our hypotheses concerning the determinants of the demand for bus services, except that there is no evidence that the costs of owning an automobile affect this demand. The coefficient of the price of gasoline is larger in magnitude than we would expect. In cases where we have no a priori expectation concerning the direction of the effect, the evidence suggests that bus transit is an inferior good and that the demand for bus services per capita is greater if the population is larger, if a larger percentage of the population is under 15, and if average rainfall is greater. There is no evidence that the demand for bus services is influenced by the percentage of the population 65 and over, average winter temperature, or average snowfall.

FOOTNOTES

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<sup>1</sup>For a large majority of the observations in the sample, the fare did not depend upon the length of the trip. In a few urban areas, primarily in the early years covered by this study, a small additional charge was made for trips beyond the city limits, but such trips were a small percentage of the total.

<sup>2</sup>An urban area with more bus miles of service per square mile might also have service during more hours per year. Public transit systems in larger urban areas tend to offer service during more hours of the day and more days of the week [Shortreed (1974, 16)].

<sup>3</sup>As an example of the latter bias, suppose that two cities have the same population but that city I has half the area, twice the bus miles of service, and twice the total bus ridership found in city II, while all other things are equal. In this case, rides per capita and bus miles per capita would be twice as high in city I as in city II while bus miles per square mile of area would be four times higher in city I than in city II. One would estimate that the arc elasticity of demand for rides per capita



with respect to bus miles per square mile was .56 while one would estimate that the arc elasticity of demand for rides per capita with respect to bus miles per capita was unity. In this case, the unbaised estimate of the elasticity of demand with respect to bus miles of service (holding area and population constant) would be .56, not unity.

<sup>4</sup>Maintenance costs are not included because of lack of satisfactory data.

<sup>5</sup>An alternative hypothesis, which we did not test, would be that the demand for bus trips depends on the deviation of weather conditions from their long-term averages.

<sup>6</sup>For reasons which are discussed in section II.A.2, the bus miles variable has been misspecified as M/P rather than M/A. One effect of this is probably to bias the coefficient of P upward.

<sup>7</sup>I owe this feature of the specification to Nelson (1972, 23-24). We do not wish to assume a constant elasticity of demand with respect to fare as well as with respect to miles of bus service because, according to the condition in (4) below, the absolute values of these elasticities should be equal in equilibrium for a bus firm which maximizes rides per capita. However, if one uses the logarithm of the real fare as an independent variable, the fare elasticity at the sample mean and the other coefficients are virtually unaffected in our empirical estimation.

<sup>8</sup>This objective is plausible for publicly owned firms but probably not for privately owned ones. Of the 223 observations in the sample, 20 are

for privately owned firms. For reasons which are explained below in connection with equation (7), when the demand equation is estimated we include among the instruments a dummy variable which measures whether the firm is public or private. This variable may pick up not only the effects of different access to subsidies but also the effects of different objective functions.

<sup>9</sup>A case could be made for treating the population and area served as endogenous, since a bus firm may not serve the entire urban area in which it operates.

<sup>10</sup>The assumption that the cost per bus mile is constant is consistent with empirical cost studies by Lee and Steedman (1970) and Nelson (1972, Appendix A).

<sup>11</sup>A case could be made for treating  $D_2$ ,  $D_3$ , and  $D_4$  as endogenous.

<sup>12</sup>An alternative specification for equation (7) would drop the constant term and include a separate dummy variable for each of the twelve categories of firms implied by  $D_1$ ,  $D_2$ ,  $D_3$ , and  $D_4$ . This specification was not used because several of the resulting categories would include only one firm.

<sup>13</sup>Alternatively, because we are using pooled time-series and cross-sectional data, we could have assumed an error components model, possible with an autocorrelated between time-period error.

<sup>14</sup>A case could be made for treating  $\log C_1$ ,  $\log C_2$ , and  $C_3$  as endogenous.

<sup>15</sup>Except as noted here, all data were obtained from the Canadian Urban Transit Association. The following data were obtained from Statistics Canada publications: consumer price indexes for all items and automobile purchase from Catalogue 62-002, Tables 8 and 9; average weekly earnings from Catalogue 72-002, Table 17; climatic data from Canada Year Book (1960, 33-77); motor vehicle fuel tax rates from Canada Year Book; urban spatial structure and socio-economic variables other than population served and average weekly earnings from 1971 Census of Canada. In addition, unpublished data on the price of gasoline for urban areas were obtained from Statistics Canada. Regional automobile price differentials were obtained from Canadian Red Book (monthly).

<sup>16</sup>In principle, we could use equation (4) to derive an estimate of  $E_{M/A}$  or  $\alpha_2$  in equation (2'). However, we do not have enough confidence in our specification of the behavior of bus firms to do this. For example, bus firms may operate with both fares and bus miles of service below the levels which would maximize ridership as a result of constraints on fares imposed by municipal and provincial governments.

<sup>17</sup>The hypothesis concerning the real interest cost of holding an automobile is tested using  $\alpha_4$ . The hypothesis concerning depreciation is tested using  $(\alpha_3 - \alpha_4)$ .

<sup>18</sup>However, since our TSLS and OLS estimates are quite similar, the results of these other studies may not have been very different if they had used simultaneous equation models and estimating techniques.

<sup>19</sup>This coefficient has been adjusted to allow for differences in the specification of the dependent variable used by Nelson and ourselves.

REFERENCES

- Ahsan, S. M. (1976) "Choice of Urban Mode of Travel," Department of Economics, University of Western Ontario, London.
- Boyd, J. H., and G. R. Nelson (1975) "Demand for Urban Bus Transit: Two Studies of Fare and Service Elasticities," Paper P-983, Institute for Defense Analyses, Arlington.
- Canadian Red Book (monthly) Official Used Car Valuations, Toronto.
- Canadian Urban Transit Association (1974) 1973-4 Transit Fact Book, Toronto.
- Carstens, R. L., and L. H. Csanyi (1968) "A Model for Estimating Transit Usage in Cities in Iowa," Highway Research Record 213, pp. 42-49.
- Domencich, T., and G. Kraft (1970) Free Transit, Heath, Lexington, Mass.
- Frankena, M. (1975) "Urban Transportation in Canada," Department of Economics, University of Western Ontario, London.
- Gaudry, M. (1975) "An Aggregate Time-Series Analysis of Urban Transit Demand: The Montreal Case," Transportation Research 9, pp. 249-58.
- Lee, N., and I. Steedman (1970) "Economies of Scale in Bus Transport," Journal of Transport Economics and Policy 4, pp. 15-28.
- Litt, R. M. (1975) "A Cross-Sectional Study of the Demand for Urban Transit in Canada," Department of Economics, University of Western Ontario, London.
- Nelson, G. R. (1972) "An Econometric Model of Urban Bus Transit Operations," Paper P-863, Institute for Defense Analyses, Arlington.
- Shortreed, J. H., ed. (1974) "Urban Bus Transit: A Planning Guide," Department of Civil Engineering, University of Waterloo, Waterloo.

Sohn, C. M. (1975) "The Demand for Mass Transportation in New York City,"  
Ph.D. thesis, Department of Economics, State University of New York,  
Albany.

Statistics Canada (annual) Canada Year Book, Information Canada, Ottawa.

Statistics Canada (monthly) Employment, Earnings and Hours, Catalogue 72-002,  
Information Canada, Ottawa.

Statistics Canada (1973-1975) 1971 Census of Canada, Catalogue 92-715,  
92-720, 92-727, 93-702, 93-731, 93-737, 94-703, 95-701 through 95-759,  
Information Canada, Ottawa.

Statistics Canada (monthly) Prices and Price Indexes, Catalogue 62-002,  
Information Canada, Ottawa.

Veatch, J. F. (1973) "Cost and Demand for Urban Bus Transit," Ph.D. thesis,  
Department of Economics, University of Illinois, Urbana-Champaign.

Wabe, J. S., and O. B. Coles (1975) "The Peak and Off-Peak Demand for Bus  
Transport: A Cross-Sectional Analysis of British Municipal Operators,"  
Applied Economics 7, pp. 25-30.

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