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RESEARCH PROGRAM: IMPACT OF THE PUBLIC SECTOR ON LOCAL ECONOMIES

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1. Introduction

The objectives of this study are to assess the economic factors which affect the stock demand for automobiles in Canada and to illustrate the sensitivity of the stock demand to the variables which enter into its determination. The determination of the stock of automobiles is thought to be important because the provision of transportation infrastructure for automobile travel and of mass transit facilities must depend in part on the number of automobiles held by the public. At a time when the relative prices of various forms of energy are changing rather dramatically, it would appear to be useful to be able to assess the importance of these changes on the demand for automobiles. The existing literature which bears on these questions is relatively sparse.[1] Our results suggest that the stock demand for automobiles is much more sensitive to changes in the relative price of gasoline than to other prices and incomes. Section 2 develops the specification of the equation to be estimated; section 3 deals with the problems of estimation and shows the results; section 4 concludes the paper with a discussion of the relevant elasticities.

2. Specification

We postulate that a consumer has a finite time period $t = 0,\ldots,\tau$ over which the potential benefits and costs of automobile ownership are calculated. Non-ownership is assumed to involve only one alternate mode, mass transit, for which a fee of PT is charged per trip. If the consumer purchases an automobile, we assume that he takes N^a trips per year as compared with N^b

trips per year on mass transit if he does not. One part of the benefit of purchase will therefore be the savings in transit fare costs.[2]

The gross benefit of automobile purchase will also be related to the time savings from trips by automobile as opposed to trips by mass transit and the comfort, flexibility, and convenience of automobile travel. This benefit is expressed as an increasing function of income because studies on the value of travel time have shown that, as income increases, commuters value their travel time at an increasing proportion of their wage rate; these studies have also shown that the total number of intraurban trips taken varies positively with income. The travel benefits from automobile purchase are expressed as $B(Y_t)$, the average benefit per trip of travelling by automobile as opposed to by mass transit.

We assume that the individual chooses between an automobile purchase at price PA_0 and investment in an asset which earns interest at rate r_t. With purchase, the individual is returned the discounted value of the depreciated automobile at the end of the period, $PA_0(1-\delta)^\tau/(1+r_\tau)^\tau$. With non-purchase, he receives $r_t PA_0$ in interest per period and the discounted value of the full amount PA_0 at the end of the period which is $PA_0/(1+r_\tau)^\tau$. The financial cost of the purchase is therefore

$$PA_0 \left(\frac{1-(1-\delta)^\tau}{(1+r_\tau)^\tau} + \sum_{t=o}^{\tau-1} r_t/(1+r_t)^t \right)$$

The first term in parentheses is a factor representing the cost of depreciation and the second term represents the opportunity cost of ownership as compared to investment in a financial asset.

A further cost of automobile ownership and use is the cost of gasoline and maintenance. We assume that the quantities of gasoline and maintenance consumed per time period vary in proportion to the number of trips in that period, by factors k^g and k^m respectively. These quantities have unit prices PG_t and PM_t associated with them respectively. Operating costs per time period therefore equal

$$N_t(k^g\ PG_t + k^m\ PM_t)$$

The consumer purchases an automobile if the present discounted value of the stream of benefits less costs of the purchase is greater than zero, which is expressed by

$$\sum_{t=o}^{\tau-1} \frac{N_t^a(B(Y_t) - k^g\ PG_t - k^m\ PM_t) + N_t^b\ PT_t - r_t\ PA_o}{(1+r_t)^t} - PA_o \left(\frac{1-(1-\delta)^\tau}{(1+r_\tau)^\tau} \right) > 0$$

From this expression, the net benefits and hence the probability of ownership vary positively with income and the price of mass transit, and negatively with the price of gasoline, the price of maintenance, the price of automobiles, and the interest rate.[3] This describes the economic factors affecting the demand for automobiles and allows us to specify the desired stock of automobiles as a function of the expected values of the independent variables, or

(1) $$K_t^D = f(Y_t^e, PA_t^e, PG_t^e, PM_t^e, PT_t^e, R_t^e) + \varepsilon_{1t}$$

In the above, the stock of automobiles K is defined to be the total stock of automobiles divided by the number of persons between 15 and 65 years of age, which is an approximation to the car-driving population. Income Y is defined to be real per capita disposable income, PA is an index of the purchase price of automobiles divided by the consumer price index, PG is an index of the price of gasoline deflated by the consumer price index, PM is an index of maintenance costs also deflated by the consumer price index, PT is an index of the cost of the alternate mode deflated by the consumer price index, and R is the real rate of interest which is defined as the nominal rate minus the rate of change in consumer prices. The superscript e denotes the expected value of the variable. The error term ε_{1t} is assumed to be distributed normally with zero mean and variance σ_1^2.

Because the expected values are not directly observable, we assume that consumers adapt their expectations in the current period on the basis of the difference between the current value of the variable and the value which was expected to prevail in the previous period. More precisely, we postulate that

$$(2) \qquad X_t^e - X_{t-1}^e = (1 - \gamma)(X_t - X_{t-1}^e)$$

where X^e is the expected value of the independent variable and $0 \leq \gamma < 1$. This may be rewritten as

$$(3) \qquad X_t^e = (1 - \gamma) X_t + \gamma X_{t-1}^e$$

which implies that the current expected value is a simple weighted average of the actual current value and the previous expected value where the weights sum to one. The formulation also implies that the current expected value is a geometric distributed lag of the current and past actual values, that is,

$$(4) \qquad X_t^e = (1 - \gamma)(X_t + \gamma X_{t-1} + \gamma^2 X_{t-2} + \ldots) .$$

The desired stock may not be fully realized in the current period. We therefore postulate that the actual increment in the stock will be a fixed proportion λ of the difference between the desired stock and the existing stock in the previous period, with a stochastic error term. Formally,

$$(5) \qquad K_t - K_{t-1} = \lambda (K_t^D - K_{t-1}) + \varepsilon_{2t}$$

where $0 < \lambda \leq 1$ and the error term ε_{2t} is distributed normally with zero mean and variance σ_2^2. Substituting equation (1) for K_t^D, we have

$$(6) \qquad K_t = \lambda f(Y^e, PA^e, PG^e, PM_t^e, PT_t^e, R_t^e) + (1-\lambda)K_{t-1} + \lambda\varepsilon_{1t} + \varepsilon_{2t} .$$

Assuming the demand function is linear and using the expression for the expected value of each of the independent variables shown in equation (4) above allows us to write

$$
\begin{aligned}
(7) \qquad K_t = \; & \alpha_o\lambda + \alpha_1\lambda(1-\gamma)(Y_t + \gamma Y_{t-1} + \gamma^2 Y_{t-2} + \ldots) \\
& \pm \alpha_2\lambda(1-\gamma)(PA_t + \gamma PA_{t-1} + \gamma^2 PA_{t-2} + \ldots) \\
& + \alpha_3\lambda(1-\gamma)(PG_t + \gamma PG_{t-1} + \gamma^2 PG_{t-2} + \ldots) \\
& + \alpha_4\lambda(1-\gamma)(PM_t + \gamma PM_{t-1} + \gamma^2 PM_{t-2} + \ldots) \\
& + \alpha_5\lambda(1-\gamma)(PT_t + \gamma PT_{t-1} + \gamma^2 PT_{t-2} + \ldots) \\
& + \alpha_6\lambda(1-\gamma)(R_t + \gamma R_{t-1} + \gamma^2 R_{t-2} + \ldots) \\
& + (1-\lambda) K_{t-1} + \lambda\varepsilon_{1t} + \varepsilon_{2t} .
\end{aligned}
$$

In (7), $\alpha_o, \alpha_1, \ldots, \alpha_6$ are the parameters in the demand function for the desired stock, which is assumed to be linear.

Applying the Koyck transformation and rearranging terms permits simplification to

$$(8)\qquad K_t = \alpha_o\lambda(1-\gamma) + \alpha_1\lambda(1-\gamma)Y_t + \alpha_2\lambda(1-\gamma)PA_t + \alpha_3\lambda(1-\gamma)PG_t + \alpha_4\lambda(1-\gamma)PM_t + \alpha_5\lambda(1-\gamma)PT_t + \alpha_6\lambda(1-\gamma)R_t + (1-\lambda+\gamma)K_{t-1} - (1-\lambda)\gamma\, K_{t-2} + \eta_t$$

where $\eta_t = \lambda\varepsilon_{1t} + \varepsilon_{2t} - \gamma(\lambda\varepsilon_{1t-1} + \varepsilon_{2t-1})$.

3. Estimation

Equation (8) presents two estimation problems. First, ordinary least squares estimates of the coefficients would be inconsistent, because of the presence of the lagged dependent variables on the right hand side. Second, because of the constraints on λ and γ, the coefficient on K_{t-1} must fall in the range $0 \leq (1-\lambda+\gamma) < 2$, and the coefficient on K_{t-2} must fall in the range $0 \leq (1-\lambda)\gamma < 1$. The constraint problem may be dealt with by first writing

$$(9)\qquad K_t - (1-\lambda+\gamma)K_{t-1} + (1-\lambda)\gamma K_{t-2} + \gamma(\lambda\varepsilon_{1t-1} + \varepsilon_{2t-1}) = \alpha_o\lambda(1-\gamma) + \alpha_1\lambda(1-\gamma)Y_t + \alpha_2\lambda(1-\gamma)PA_t + \alpha_3\lambda(1-\gamma)PG_t + \alpha_4\lambda(1-\gamma)PM_t + \alpha_5\lambda(1-\gamma)PT_t + \alpha_6\lambda(1-\gamma)R_t + \lambda\varepsilon_{1t} + \varepsilon_{2t}.$$

We next define transformed variables as follows:

$$K_t^* = K_t - (1-\lambda+\gamma)K_{t-1} + (1-\lambda)\gamma K_{t-2}$$

$$CON = \lambda(1-\gamma)$$

$$Y_t^* = \lambda(1-\gamma)Y_t$$

$$PA_t^* = \lambda(1-\gamma)PA_t\ , \quad \text{etc.}$$

We select the ordinary least squares estimates of the following equation, for the combination of λ and γ which minimizes the sum of squared residuals:

$$K_t^* = \alpha_0\, CON + \alpha_1\, Y_t^* + \alpha_2\, PA_t^* + \alpha_3\, PG_t^* + \alpha_4\, PM_t^* + \alpha_5\, PT_t^* + \alpha_6\, R_t^*.$$

All pairs of λ and γ were first tested for $0 < \lambda \leq 1$ and $0 \leq \gamma < 1$, by increments of .1. Two pairs of λ and γ minimized the sum of squared residuals in this trial: ($\lambda = .3, \gamma = 0$) and ($\lambda = 1, \gamma = .7$). The second trial attempted combinations of λ and γ for $.2 \leq \lambda \leq .4$ and $.6 \leq \gamma \leq .8$, by increments of .02. The resulting pairs of values which produce equal minimum values of the sum of squared residuals are ($\lambda = .28, \gamma = 0$) and ($\lambda = 1, \gamma = .72$).

The generation of two minima for the sum of squared residuals is expected, because equation (8) is overidentified in λ and γ.[4] Note that either pair of values for λ and γ generate the same numerical values for $\lambda(1-\gamma)$, $(1-\lambda+\gamma)$, and $(1-\lambda)\gamma$. The last term $(1-\lambda)\gamma$ is zero in both cases. The economic sense of the problem of overidentification is that we have postulated a structural relationship between a desired quantity and some expected quantities, neither of which can be observed. The specification also assumes a particular form of the relationship between expected and observed quantities of the independent variables and a particular form of the relationship of the desired stock to the actual. Because we have only one equation in observed magnitudes, we cannot expect the estimation to yield information about the expected and desired relationships separately; rather, the estimates produce information only on the net effect of the two processes.

The results of the estimation for either pair of λ and γ are identical. In the estimated equation shown as A in Table 1, all of the variables have the hypothesized signs but income and the price of maintenance are not significant at any reasonable level when the tests for significance are made on each of these variables independently of the significance of the other variables. The real rate of interest was insignificant in this equation; all the results in Table 1 accordingly use R defined as the nominal rate of interest. The explanatory power of the model is very high (R^2 = .98) and there is no evidence of serially correlated residuals.

The consistency problem may be dealt with by assuming in equation (8) alternatively the extreme values for λ and γ, $\lambda = 1$ and $\gamma = 0$ respectively. In either case, the coefficient $(1-\lambda)\gamma$ on K_{t-2} is zero and the coefficient $(1-\lambda+\gamma)$ on K_{t-1} is between zero and unity. Consistent estimates of the parameters may be obtained by the instrumental variables technique. Each of the independent variables is an instrument for itself and the lagged value of any one of the independent variables may serve as an instrument for K_{t-1}.

The results using PA_{t-1} as an instrument for K_{t-1} are shown as equation B in Table 1. All of the variables have the hypothesized signs and the coefficient on the lagged stock falls within the specified range. The lowest significance levels are for income and the price of automobiles. The explanatory power of the model is very high (R^2 = .999) and the whole equation is highly significant, as shown by the value of the F-statistic.

The same equation was estimated directly using ordinary least squares. This equation is shown as C in Table 1. Again, the variables have the hypothesized signs, with higher t-values associated with the respective coefficients. Note also that the coefficient $(1-\lambda+\gamma)$ on K_{t-1} in equation C is .727 which is close to the value of .72 generated in the iterative procedure used for the first equation in Table 1. A consistent estimate of this coefficient is .630 (in equation B), which implies that ($\lambda = .37$, $\gamma = 0$) or ($\lambda = 1$, $\gamma = .63$).

Table 1

Empirical Results

Eqn.	Dep. Var.	CON	Y_t^*	PA_t^*	PG_t^*	PM_t^*	PT_t^*	R_t^*		R^2	D.W.	N	F D.F.	F
A	K_t^*	1.0309 (3.237)	.04156 (.884)	-.001744 (-1.651)	-.004428 (-5.579)	-.001344 (-.923)	.003614 (3.958)	-.03355 (-4.273)		.982	2.47	23	6,16	141.48
		Constant	Y_t	PA_t	PG_t	PM_t	PT_t	R_t	K_{t-1}					
B	K_t	.4150 (1.479)	.01119 (.647)	-.0006718 (-1.174)	-.001854 (-1.439)	-.0005961 (-1.294)	.001357 (1.202)	-.01147 (-1.721)	.6301 (2.591)	.999	2.50	22	7,14	1367.20
C	K_t	.3098 (2.508)	.01521 (1.110)	-.0004801 (-1.446)	-.001350 (-2.887)	-.0005585 (-1.304)	.0009194 (2.128)	-.008979 (-3.038)	.7272 (9.468)	.999	2.78	22	7,14	1523.52

(t-values in parentheses)

4. Conclusions

Steady-state or long run elasticities at sample means may be derived directly from the coefficients in equation A in Table 1, and indirectly from the coefficients in equations B and C in Table 1. In the latter case, we assume that $K_t = K_{t-1} = K_{t-2}$ and transform the estimated coefficients following equation (8) in section 2. Note that either pair of λ or γ generates the same structural elasticities, because the value of $\lambda(1-\gamma)$ is the same for either pair. Because the variables do not simultaneously take on their mean values at any one point in the sample period, and because we are interested in the effects of the exogenous variables at recent values, we show in Table 2 long run elasticities calculated at the end of the sample period (1972).

The outstanding feature of the results in Table 2 is that the absolute values of the price of gasoline and price of transit elasticities are both about double the absolute values of the other four elasticities, with the price of gasoline elasticity being slightly higher in absolute value than the price of transit elasticity. The other elasticities range from .2 to .3 in absolute value whereas the price of gasoline and price of transit elasticities range from .6 to .9 in absolute value. The evidence from this study is therefore that the total stock of automobiles held in Canada reacts quite strongly to changes in the price of gasoline energy. The purpose of this study is not to trace out the implications of this responsiveness for the allocation of resources (in particular, between public and private transportation facilities), but the established relationship between the stock, the price of gasoline, and the other variables would be relevant in assessing the long-run demands for the different types of infrastructure as well as the demands for the consumption of gasoline.

Table 2

Long Run Elasticities at Sample End Point

Independent Variable	Equation		
	A	B	C
Y	.207	.166	.305
PA	-.287	-.328	-.318
PG	-.720	-.895	-.884
PM	-.226	-.297	-.378
PT	.592	.660	.607
R	-.312	-.317	-.336

APPENDIX I

Sources of Data

K: stock of automobiles. This variable is defined as the total stock of automobiles divided by the number of people between the ages of 15 and 64 inclusive. The total stock of automobiles is total passenger car registrations (including taxis) given in the Canada Year Book, 1942 to 1974. The population aged 15 to 64 inclusive was taken from Vital Statistics, 1973.

Y: real per capita disposable income. Income is defined to be total current dollar disposable income (CANSIM Matrix No. 000557.1) divided by the total population (CANSIM Matrix No. 000060.1) and deflated by the consumer price index (CANSIM Matrix No. 000429.1), adjusted to be unity in the base year (1971).

PA: purchase price of new automobiles. This price is defined to be the automobile purchase price index (CANSIM Matrix No. 000429.1.4.1.1), deflated by the consumer price index.

PG: price of gasoline. This price is defined to be the price of gasoline index (CANSIM Matrix No. 000429.1.4.1.2.1), deflated by the consumer price index.

PM: price of maintenance. The price of maintenance series was generated from Statistics Canada price data. Prior to 1961, CANSIM data include a price of private transportation index, PO' (Matrix No. 00429.1.4.1). In general,

$$PO' = a_o PA' + a_1 PG' + \sum_{i=2}^{m} a_i PX_i' , \quad \sum_{i=o}^{m} a_i = 1$$

where PA' is the nominal purchase price index for new automobiles, PG' is the nominal price index for gasoline, and PX_i' $(i = 2,3,\ldots,m)$ are the nominal price indices for such costs as tires, batteries, insurance, and registration fees. In order to generate PM', the nominal price of maintenance series, it is necessary to subtract the contributions of purchase and gasoline prices and then normalize the series so that PM' and PO' have the same base year. Thus,

$$PM' = \frac{PO' - a_0 PA' - a_1 PG'}{1 - a_0 - a_1}$$

From 1961 on, CANSIM lists a new price of automobile operation and maintenance index, POM' (Matrix No. 000429.1.4.1.2), which includes gasoline prices as well as a number of other costs (some of which had not been included previously, such as parking), but not purchase price. Here

$$POM' = b_1 PG' + \sum_{i=2}^{n} b_i PY_i' , \qquad \sum_{i=1}^{n} b_i = 1$$

In this case,

$$PM' = \frac{POM' - b_1 PG'}{1 - b_1}$$

In addition to the existence of two different PM' indices (pre- and post-1961), the weights (a_i and b_i) do not remain constant over the complete sub-periods. To generate a consistent series for PM' we weighted the components using, arbitrarily, alternatively the 1967 and 1973 weights, as specified by Statistics Canada, Retail Prices and Living Costs Service Bulletin, Catalogue 62-005, Volume 3, No. 3, 1974. The series using the 1967 weights revealed a discontinuity between 1960 and 1961. For this reason, and because the index using the 1973 weights performed better in the regressions, the results shown in the text use the 1973-weighted series (deflated by the consumer price index).

PT: price of local transportation. The index has two components -- the price of mass transit and the price of taxis. The source is CANSIM (Matrix No. 000429.1.4.2.1). This series is also deflated by the consumer price index.

R: interest rate. We experimented alternatively with the average end-of-month chartered bank prime business loan rate (CANSIM Matrix No. 002560.20) and the Canada Savings Bond first coupon rate (CANSIM Matrix No. 002560.4). To express these rates in real terms, we simply subtracted the rate of change in the consumer price index.

FOOTNOTES

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[1]Cragg and Uhler (1970) review the studies on the demand for automobiles published to 1970 and present empirical results of a model using U.S. survey data, but there are no published studies of the direct determinants of the total stock demand for automobiles using Canadian data. Blomqvist and Haessel (1976) investigate the determinants of the stock demand for automobiles in different age and size categories. Wilton (1972) presents a simultaneous equation model of the automobile industry which includes a behavioral equation for the dollar value of retail sales of automobiles. The Bank of Canada RDX2 econometric model contains a behavioral equation for consumer expenditure on motor vehicles and parts and a definitional equation for the constant dollar value of the stock of motor vehicles held by consumers (Bank of Canada, 1976, pp. 83 and 86). Similarly, CANDIDE 1.2M at the Economic Council of Canada uses behavioral equations to determine various types of expenditures on automobiles, in constant dollars. Also, an estimated definitional equation determines total passenger car registrations (CANDIDE Project, 1976, block 2, equations 28, 29, 31, 32, and 60). Finally,

there is one published study (Gaudry, 1975) on the choice of mode in a Canadian city, Montreal; Frankena (1975) discusses other studies and related issues in Canadian urban areas; and Frankena (1976) presents a small simultaneous equation model of the determinants of urban bus travel using cross-section data for twenty-eight Canadian cities.

[2]We are implicitly assuming that the prices of different modes of interurban and rural travel do not affect the demand for automobiles, although our formulation conceptually allows these relative prices to affect the choice of mode for any given rural or interurban trip. This specification is based on two observations: (1) much interurban travel is simply not practical by automobile (long distance and intercontinental) and (2) automobile is the only practical mode for most rural travel.

[3]The above approach was suggested by an equation in Fairhurst (1975, p. 193). The formulation of the model which follows in this section draws on the discussion of adaptive expectation and stock adjustment models in Kmenta (1971, pp. 473-487). Also, Kmenta (1971, pp. 479-480) suggests the method of instrumental variables used in section 3 of this paper.

[4]Note that we may form a quadratic in γ or λ from the coefficients on K_{t-1} and K_{t-2} but the solution of this quadratic necessarily gives complex roots, because of the restrictions on γ and λ.

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