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A MODEL FOR PASSENGER CAR GASOLINE DEMAND IN CANADA*

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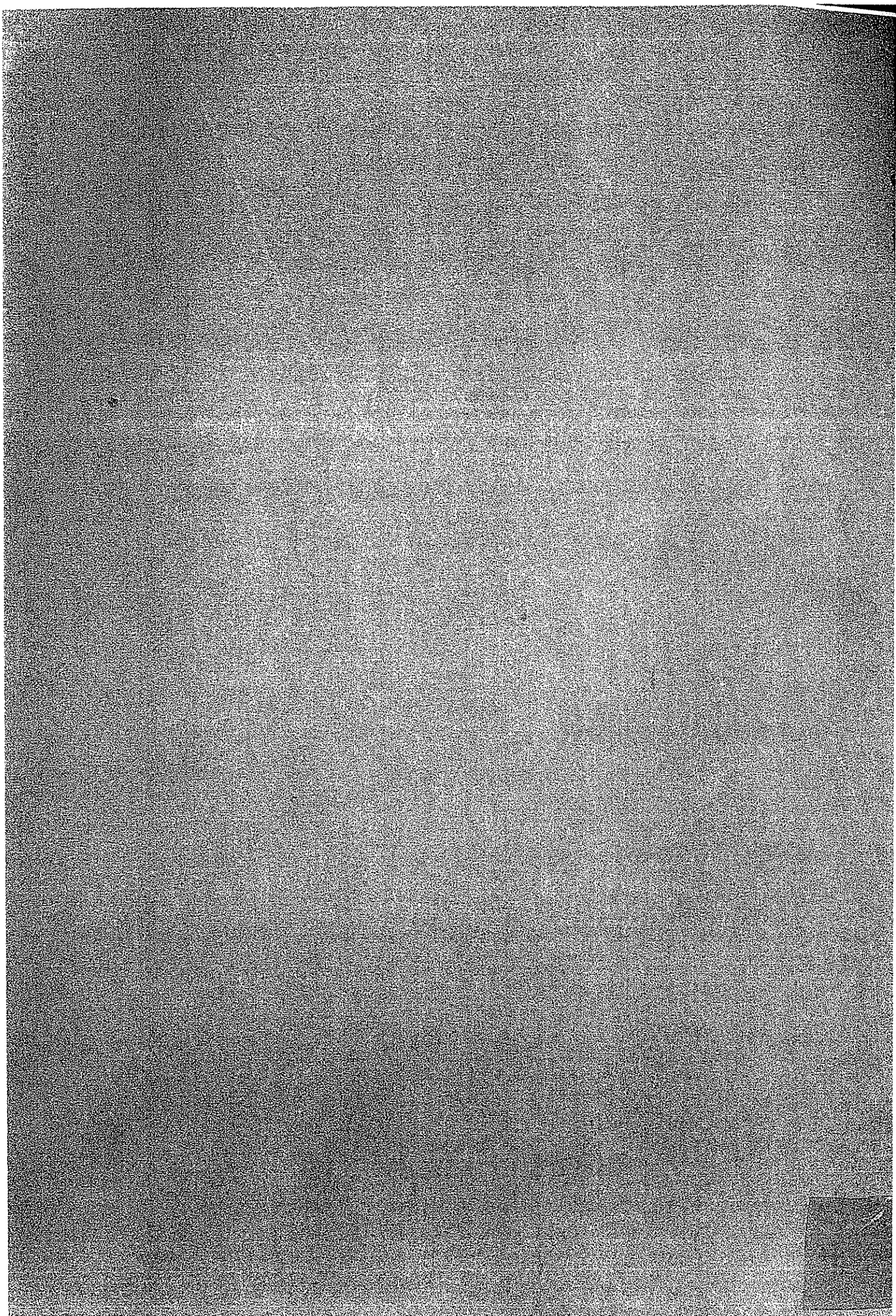## Discussion Paper Series

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ABSTRACT

A model for motor gasoline demand in Canada is developed by household. The model identifies and separates effects of several responses by the household to a change in gasoline prices such as driving fewer miles, purchasing fewer cars, and buying more fuel efficient cars. It also estimates the manufacturers' response of improving the technology of new automobiles. The size and the composition of the fleet according to the interior volume of four classes of automobiles rather than their natural weight is used.

The estimated coefficients suggest that most of the adjustment after a gasoline price increase comes from miles driven in the short run and from miles per gallon, hence fuel efficiency improvements in the long run.

The model gave the total short run (one year) price elasticity of gasoline consumption between 0.312 - 0.313.

One of the more interesting results is that approximately 10 percent of the household response to a price change in the first year was due to a change in the composition of the fleet to a more fuel efficient vehicle. Approximately 75 percent was due to driving fewer miles while the remaining 15 percent was attributed to a change in the size of the fleet.

The intermediate run (five year) price elasticities range from 0.689 to 0.709 and the long run price elasticities (ten year) range from 0.975 to 1.059.

A Model For Passenger Car Gasoline Demand In Canada

Mohamed Nagy Eltony

I. The Introduction

There have been major changes in the world energy situation in recent years. Since 1981 crude oil prices have declined dramatically, plunging from U.S. $ 26 per barrel in 1985 to below $10 per barrel in April 1986. The massive real oil price increases which occurred between 1973 and 1980 caused sufficiently large reductions in world oil demand and increases in oil supply so that the 1981 price of $ 34 per barrel could not be sustained. However, the crisis in the Gulf has caused the price to reach U.S. $ 40 per barrel in October 1990.

In terms of primary energy consumption, Canada's energy needs are met by oil, natural gas, coal, and electricity. Oil is the largest energy source consumed in Canada and motor gasoline is the most important oil product. Also, since the rapidly changing oil prices have been most noticeable to consumers in the gasoline market, an understanding of the automotive market demand for gasoline is very important. Therefore a study of passenger-car gasoline demand is crucial to comprehending the effects of the recent changes in the world energy market and their impact on consumer behaviour and the setting of the energy policy in Canada.

Very few attempts to measure the price responsiveness of gasoline consumption in the transportation sector have been made; Dewees, Hydman and Waverman (1975), NAV (1976), Pindyck-Heide (1979), Shalaby and Waghmare(1980), Dahl (1982), Gallini (1983) and Berkowitz, Gallini, Miller and Wolfe (1990).

In this paper a model for passenger car gasoline demand in Canada was developed and estimated. The model is capable of identifying several responses by consumers to changes in gasoline prices such as driving fewer miles, purchasing fewer automobiles, buying more fuel efficient cars, and the automobile manufacturers' response by altering the technology of new automobiles produced in the future. The model was simulated to determine future demand as well as to forecast future gasoline demand under different hypotheses.

The next three sections of this paper give a discussion of the model, the data, and the estimation results respectively. The conclusions are given in the final section of the paper.

II. The Model

The model presented in this study is of the investment-utilization type. The basic identity for aggregate gasoline demand, AG, in the model is given by

(1) $\quad AG = MS \cdot S \cdot 1/e$

where MS = miles driven per car (vehicle miles)

$\quad$ S = total automobiles in the fleet

$\quad$ e = average fuel economy of the fleet

This model has its theoretical basis in the household production literature, i.e., Baker (1960), Lancaster (1966), Pollack and Wachter (1975).

A. The Gasoline per Car Equation

A well-defined preference ordering over commodities, vehicle miles, Ms, all other commodities, X, time spent driving, T1, and time spent in leisure, T2, conditional on automobile ownership, is assumed to exist for the household. The bundle of characteristics describing the vehicle which produces vehicle miles is assumed to enter the utility function and is given by the vector C = (C1,...,Cn).

The utility function is:

(2) $\quad U = U(MS, X, T1, T2; C)$

A production function describes the relationship between the output of miles from a particular automobile, and the inputs of gasoline, GS, and time, T1, conditional on the automobile's characteristics. That is:

(3) $\quad MS = f(GS, T1; C)$

Following the convention of earlier models, the
production function in equation (3) could be re-defined as
(4) MS = GS . E(T1)
Where GS = gasoline input per automobile and E(T1) is the
fuel economy of the vehicle as a function of time spent
driving the MS miles. The budget constraint faced by the
household is given by:
(5) Pg . GS + Ps(C) + Px . X + W(T1 + T2) $\leq$ V + W$\dot{T}$
Where

> Pg   = price of gasoline per gallon
>
> Ps(C) = rental cost of the automobile services
>
> Px   = price of all other goods--the consumer price index
>
> W   = wage rate per unit of time
>
> V   = non-labour income
>
> $\dot{T}$ = available hours per period where $\dot{T}$ = T1 + T2

The relationships in (2), (4) and (5) are sufficient to
produce the household's decision of whether or not to
purchase a vehicle, the type of vehicle, the number of miles
to be driven, and finally, gasoline consumption.

It is assumed that the household has already made its
decisions regarding the allocation of available income
between saving and current expenditure. Then the household
is assumed to make its decisions in the following order. At
the beginning of each year the household reassesses its stock
of holdings of automobiles. Conditional on car ownership and
accounting for the type of car (used or new, large or small,

power...etc.), the household chooses the utility-maximizing number of miles to drive the automobile. Then the household chooses the type of car which maximizes utility given the usage factor of the automobile or the expected number of miles.

The first step in solving the problem is to find the commodity price of miles. This is obtained from equation (8) by the following equation:

(6) $Pm = Pg / E(T1)$

which gives the gasoline cost per mile. The second step is to derive the commodity demand function as follows:

(7)   Maximize $U(MS, X, T1, T2, C)$

        $MS, X, T1, T2; C$

    subject to the budget constraint

    $Pm \cdot MS + Ps(C) + Px \cdot X + W(T1 + T2) < V + WT$ [1]

The solution value of each of the amounts consumed of MS, X, T1, T2 depends, of course, upon the values of the exogenous variables Pm, Px, Ps, W, and V. Hence, the optimum amount consumed of each commodity can be expressed as a function of all prices and income, i.e.:

(8) $MS = g(Pm, Ps(C), Px, W, V; C)$

The gasoline costs per mile depend upon the fuel economy characteristic of the car. That is, cost per mile is the per gallon price of gasoline divided by the fuel economy of the automobile. The other characteristics of the automobile are assumed not to be important determinants of the number of

miles demanded and therefore the C variable can be removed from equation (8). Also, all prices can be expressed relative to the price of other goods, Px, and by homogeneity of degree zero the relationship in equation (8) is preserved. Then, the relationship in equation (8) can be re-written as follows:

(9)   MS   =   g(Pm, Ps(C), W, V)

Moreover, in the previous gasoline demand studies, household disposable income, YH, has been substituted for the wage rate and the non-labour income because data on these variables are not available. Further, the wage rate represents the opportunity cost of not working for those households earning W. But the opportunity cost of unemployed household is not observable, and therefore the unemployment rate, UN, could be used to proxy this effect [2].

By changing the notation of Pm = Pg/E(T1) to Pm = Pg/e (where e = E(T1) = fuel efficiency) and re-writing equation (9), the following relationship for miles per car is obtained.

(10)   MS   =   g(Pg/e, Ps, YH, UN)

In order to obtain gasoline demand per car, the production function in (4) can be re-expressed as:

GS   =   MS   .   1/e

Then, by substitution of equation (10) the relationship yields:

(11)   GS   =   g(Pg/e, Ps, YH, UN) . 1/e

which gives the gasoline consumed per automobile. Previous studies have experimented with a number of demographic variables. The current study includes the following demographic variables: the percentage of population living in metropolitan areas (RU), the percentage of population of driving age (16-65) (POP), and the number of automobiles per household (AH) from survey data.

Then, the log-linear relationship for equation (11) can be written as:

(12) Ln GS = Ai + B1 Ln Pg/e + B2 Ln Ps + B3 Ln YH + B4 Ln UN
              + B5 Ln RU + B6 Ln POP + B7 Ln AH + B8 Ln e

The average costs of owning, operating and maintaining an automobile, Ps, net of gasoline costs, are not available. In the presence of this data deficiency, one of two approaches have been suggested by previous studies. The first is to proxy the average cost of vehicle services by the stock of cars, as in Dahl (1982). The second is to simply enter the rental cost of the automobile services into the Px vector--the consumer price index, as in Gallini (1983). In this case, the rental cost of the automobile services is assumed to affect the miles driven only through its influence on total expenditure. The second approach is adopted for the gasoline equation and the rental cost variable is not explicitly included in the estimated equation.

B. Stock of Cars Per Household Equation

Previous studies have used the lagged values of the stock of cars, along with the cost of gasoline per mile and the average price of new cars, as explanatory variables for the stock holding decision. However, since strikes in the automobile industry may delay the purchase of a new vehicle, a variable which represents the man-days lost in the automobile industry due to strikes, ST, is included. Also, an income per household variable, YH, the unemployment rate, UN, the percentage of population in the driving age, POP, the percentage of population living in urban areas, RU, and the prime interest rate in Canada, ca.r, are all tested.

The basic equation for estimating the car holdings per household is given as:

$$(13) \quad (S/H) = g(\ Pn, \ Pg/e, \ (S/H)_{t-1}, \ YH, \ UN, \ ST, \ POP)$$

The log-linear functional form will be:

$$(14) \quad Ln \ (S/H) = Ci + D1 \ Ln \ Pn + D2 \ Ln \ Pg/e + D3 \ Ln \ YH + D4 \ Ln \ (S/H)_{t-1} + D5 \ Ln \ UN + D6 \ Ln \ ST + D7 \ Ln \ POP$$

C. The New Automobile Sales Per Household Equation

In this part, the possibility of households choosing the new car option is discussed. The basic relationship is given by:

$$(15) \quad (NR/H) = f(\ Pn, \ Pg/e, \ YH, \ UN, \ (S/H)_{t-1}, \ ST)$$

Where NR/H = new car sales divided by the number of households in each province.

Assuming a log-linear functional form, equation (19) gives the following relation:

(16) $Ln\ (NR/H) = E_i + F_1\ Ln\ Pg/e + F_2\ Ln\ Pn + F_3\ Ln\ YH$

$+ F_4\ Ln\ UN + F_5\ Ln\ ST + F_6\ Ln\ (S/H)_{t-1}$

D. The New Car Fuel Efficiency Equation

The fuel economy of new cars in the model is defined by the sales weighted average as follows :

(17) $EN = \sum_{j=1}^{4} ENj\ .\ Nj/NR$

Where:

ENj : Technical fuel economy for the j-th size class of automobiles [3].

Nj/NR : Ratio of cars j sold to total new sales in Canada.

The relationship in the equation above identifies the two determinants of a change in the fuel economy; first the change in the technology of the automobiles and the change in the distribution of new cars sales by size. The first change is determined by the manufacturers and is the subject of this paper.   The second is the result of households preference and is discussed in Chapter VIII of Eltony (1990).

A comparison of the fuel economy of different classes of automobiles by their size rather than their weight has been suggested by both the U.S. Environment Protection Agency (1984) and the Society of Automotive Engineers (1985). Both argued that the consumers are probably more interested in the size and utility of a vehicle rather than its weight. The

EPA developed a vehicle size classification based on the interior volume of the automobile and this classification method can be utilized to compare the fuel economy of vehicles within the same size classes.

One of the significant improvements of the current model is its detailed treatment of fuel economy of the fleet of automobiles. In particular the fuel economy of new cars is classified by the EPA's proposed interior volume classes. In the current model, four different categories were established based on the interior volume of new cars. Table 1 below gives a description of these classes.

Table 1

The Interior Volume Classes of New Cars

Type*	FT^3	M^3
1. Sub-Compact	< 85 - 100	< 2.41 -2.84
2. Compact	100 - 110	2.83 - 3.11
3. Mid-Size	110 - 120	3.11 - 3.40
4. Large	> 120	> 3.40

* Units are in Cubic Feet & Cubic Metres.

One of the advantages of using the above classification is the ability to relate the fuel efficiency of a new automobile to its size and utility. The recent use of new ultra-light materials in the manufacturing of automobiles has made it possible to build a vehicle with more, or at least the same, interior space but with less weight and thus more

fuel efficient engine. The above classes capture these technological advances rather well.

The new automobile fuel efficiency equation in the model follows the same approach adapted by the NAV (1976) and Gallini (1983) models. In particular, because of the relatively small Canadian market, automobile manufacturers are primarily concerned with economic conditions in the United States, especially the gasoline prices.

Automobile manufacturers are assumed to make decisions on the design of four interior volume classes of new cars several years prior to the commercialization of the model. The fuel economy chosen for the future model is that level which maximizes the present value of revenues less costs. The manufacturers believe that consumers' demand for fuel efficiency in year t depends upon the price of gasoline that year subject to a particular size car. That is to say, the manufacturers are assumed to hold static expectations for the real price of gasoline; that is future gasoline prices are expected to be very close to current values. Therefore, different lag structures were tried for the U.S. gasoline prices. A polynomial distributed lag [4] has been found to be the most successful.

Furthermore, in order to capture the costs of designing a more fuel efficient automobile in the interior volume class j, dummy variables for the size classes Z_j j=1,...,4 are imposed. In 1975 fuel efficiency standards were passed in

the U.S. which set sales-weighted fuel economy levels for 1978-1990. Failure to meet these standards meant a monetary penalty [5]. To capture the response by producers to these standards, several dummy variables were tested.

The new car fuel efficiency equation in the log-linear functional form is given as :

(18) $Ln\ EN_j = K1\ Z_j + K2\ DST + K3,i\ Ln\ Pg_{t-i}$

Where :

    Z_j : Dummy variable for each j-th interior volume class.

    DST : dummy variable for fuel efficiency standards 1975-1985.

    Pg_{t-i} : U.S. gasoline prices lagged i time periods.

At this point two important identities that relate the new car registration and the technical fuel efficiency of these new cars on one hand and the stock of cars of automobiles in the fleet and the fuel economy on the other, should be introduced.

The fuel economy of the fleet, E, is defined as the harmonic mean of the new car fuel economy, EN, and the fuel economy of the last year's stock, UC.

(19) $E = EN\ .\ NR/S\ +\ E_{t-1}.\ UC/S$

The proportions of new cars, NR/S, and used cars, UC/S, can be determined from the following relationship:

(20) $S = NR + UC$

which simply states that the addition of used cars, UC,

and New cars, NR, is equal to the current stock of automobiles in the fleet. In equation (14) the stock of cars in the fleet was specified while in equation (16) the new car sales was specified. Therefore, the proportions of new car sales and used cars, over the fleet, can be determined by the following equation:

(21) NR/S = NR/(NR + UC)   and

UC/S = UC/(NR + UC) = 1 - (NR/S)

By substituting the resulting estimates for NR and S from the previous equations into the above relation, we obtain the required proportions for determining the value of E in equation (19). However, before doing that, the consumer choice of new car type, Nj/NR, is modelled and estimated in the following sub-section.

E. Sales Ratio Of New Automobiles

Following the previous discussion, there are four classes of new automobiles to choose from; namely, Sub-Compact, Compact, Mid-size, and Large.

Because there are four alternatives available, of which one is chosen by the consumer, the decision can best be modelled in a framework similar to the multinomial quantitive choice model [6]. In this type of model, the household is assumed to choose among several alternatives and the decision depends upon characteristics of the household and of the alternatives. The objective of the model is to provide a prediction of the probability that a household with

particular characteristics will choose one type of car over another.

Let the ratio of the probability of choosing alternative z to the probability of choosing alternative x by household i be Piz/Pix. Let Ki denote a bundle of characteristics of the household and Li represent characteristics of the alternative.

Then, the model of new car choice can be described by the following equation:

(22) $Piz/Pix = e^{Az + Bz\ Ki + C\ Lz} / e^{Ax + Bx\ Ki + C\ Lx}$

Taking the logarithems of both sides of the above equation yields

(23) $Ln\ (Piz/Pix) = (Az - Ax) + (Bz - Bx)\ Ki + C\ (Lz - Lx)$
$$for\ z = 2,\ 3,\ 4$$

Data on the basis of household choice of the type of new automobile is not readily available; however, the probabilities can be substituted by the relative frequencies of the households with attribute bundle Ki choosing alternative Z. Then substituting the relative frequencies for the probabilities and suppressing the household subscript yields the following equation:

(24) $Ln\ (Nz/Nx) = (Az - Ax) + (Bz - Bx)\ K + C\ (Lz - Lx)$
$$for\ z = 2,\ 3,\ 4$$

In order to be able to estimate the equations in a manner similar to logit [7] estimation, the coefficient on the automobile variable, x, should be constrained to be equal across the equations [8].

In the estimation of the equations the household disposable income, the regional unemployment rate, the number of man-days lost due to strikes in the automotive industry and the percentage of driving age population are the characteristics of the household, Ki.

The difference in the car prices, (Pnz - Pnx), and in the gasoline cost per mile, Pg (1/enz -1/enx) are the characteristics of the new automobile type, Li. The equation (24) can be re-stated as follows:

(25) $\text{Ln } (Nz/Nx) = A + B \text{ YH} + C \text{ UN} + D \text{ ST} + E \text{ POP}$

$$+ F (Pnz - Pnx) + G \text{ Pg}(1/enz - 1/enx)$$

for z = 2, 3, 4

Where :

$A = (Az - Ax)$
$B = (Bz - Bx)$
$C = (Cz - Cx)$
$D = (Dz - Dx)$
$E = (Ez - Ex)$

III. The Data:

Pooled time-series and cross-section data on the Canadian provinces from 1969-1988 were used. All prices and income are expressed relative to the consumer price index (1981 = 100). Statistics Canada published reports provided the data on stock of cars, regional unemployment rates, net gasoline sales [9], price of gasoline at the pump in several major Canadian cities, and the consumer price index in major cities. The household income was obtained from Statistics Canada's Household Expenditure Survey. The number of automobiles per household was obtained from the Household Facilities and Equipment Survey. The average fuel efficiency data were obtained from the Household Fuel Consumption Survey, conducted by Statistics Canada since 1978. The earlier fuel efficiency series were gathered from the Canadian Automobile Survey, the Economic and Technical Review Report, published by Environment Canada. The data on the percentage of population living in urban areas, and the percentage of population of driving age were obtained from several issues of Canada's Year Book.

The price of new cars from four categories, classified by the interior volume of the vehicle are weighted averages of the prices of the four largest sellers in Canada for that year. The source of these prices was the Canadian Golden Book of Used Car Prices 1968-1989.

The prime interest rate in Canada was obtained from different issues of the Statistics Canada Year Book. Stock of cars was obtained from Statistics Canada's Catalogue 53-219 and the number of households in each province was obtained from Statistics Canada's Household Facilities and Equipment Survey catalogue 64-202.

The new car registration data was obtained from Statistics Canada's catalogue 63-007. Sales of all models of automobiles in Canada were made available to this study by R. L. Polk & Co. (Toronto). The sales data were used to construct the sales ratios for fuel categories of automobiles classified by their interior volume. The fuel economies for these four classes of automobiles are published annually in the Gas Mileage Guide, the Environmental Protection Agency by the U.S. Department of Energy. The fuel economies data and the sales ratios for the different classes were used to create the sales-weighted average fuel economy for new cars (ENj) as defined in Equation (17) above.

Several issues of the United States Statistical Abstract 1968-1988 were used as the source for the information on gasoline retail prices and for the consumer price index in the U.S.

IV. The Estimation Results

A variance components model [10], which allows separate provincial intercepts, is assumed using pooled time series, cross-sectional data. The estimation procedure employed for most of the equations in the model is Ordinary Least Square (OLS) with auto-correlation correction where necessary.

Estimation of Gasoline Per Car

Table 2 below gives the best results amongst numerous trials for equation (12). The signs of the estimated coefficient on income, unemployment rate, price of gasoline per mile, fuel efficiency of the fleet and the number of vehicles per household are consistent with economic theory in the three equations. Furthermore, the price of gasoline per mile, the fuel economy of the fleet, the household disposable income, the unemployment rate and the number of vehicles per household are all significantly different from zero at the 99 percent level in the third equation.

The intercept terms account for the differences among provinces which can not be quantified, i.e., the availability of public transportation systems, degree of urbanization etc., are captured by the separate intercepts. All of the intercept terms yield a high T-statistic.

The short-run gasoline price elasticities per car, holding the fuel economy constant is in the range of -.19 to -.22. The results give a short-run income elasticity in the range of 0.15 to 0.25.

Table 2

The Gasoline per car Results

	NFLD	PEI	NS	NB	QUE	ONT	MAN	SASK	ALTA	BC
1. Ln GS	9.1182	9.0669	9.1153	9.1505	9.0448	9.0612	8.9524	9.0044	9.1136	8.9193
	(6.831)	(7.187)	(6.837)	(6.945)	(6.435)	(6.393)	(6.424)	(6.657)	(6.556)	(6.411)
2. Ln GS	8.3529	8.4045	8.3567	8.4008	8.1934	8.2059	8.1282	8.2361	8.2889	8.0858
	(8.717)	(8.753)	(8.663)	(8.405)	(8.484)	(8.428)	(8.347)	(8.445)	(8.564)	(8.371)
3. Ln GS	7.2006	7.2234	7.1705	7.2336	7.0088	7.0179	6.9269	7.0283	7.1069	6.9064
	(10.61)	(10.86)	(10.75)	(10.90)	(10.44)	(10.26)	(10.26)	(10.44)	(10.44)	(10.23)

	Ln YH	Ln Pg/e	Ln E	Ln UN	Ln AH	Ln POP	Ln RU				
1. Ln GS	.2493	-.1928	-.6091	-.0348	-.4581	-.5625	-.2387	R-Square = .908	D.W. = 2.1279	S.E.R = .0489	F = 116.01
	(2.6788)	(-3.591)	(-5.897)	(-1.513)	(-7.382)	(-1.659)	(-1.930)				
2. Ln GS	.2136	-.1881	-.6061	-.0411	-.4615	-.5205	----	R-Square = .9081	D.W. = 2.1187	S.E.R = .0498	F = 123.32
	(2.402)	(-3.49)	(-5.896)	(-1.859)	(-7.494)	(-1.542)	----				
3. Ln GS	.1466	-.2095	-.7470	-.0495	-.4714	----	----	R-Square = .9074	D.W. = 2.0927	S.E.R = .0500	F = 130.36
	(2.045)	(-3.971)	(-11.319)	(-2.298)	(-7.599)	----	----				

* T-statistics are in parentheses

Estimation of Stock Of Automobiles Per Household

The coefficient for the cost of gasoline per mile has a negative sign as a reflection of the fact that gasoline and automobiles are complementary goods. It has been argued by Dahl (1986) that the gasoline cost per gallon, rather than per miles, is a more appropriate regressor for the stock of automobiles equation. Researchers have reported that the price of gasoline and the price of new cars tend to be correlated. This is because other characteristics of the automobile which are related with fuel efficiency, e.g. power and size, are not accounted for. Thus, the estimated coefficient on price of gasoline per mile may actually be explaining the effect of a change in the power or size of an automobile which in return will be reflected in the price of new cars and create a problem of colinearity between the two prices.

After extensive experimentation with this equation, a number of satisfactory results were obtained. Because of the problem of colinearity between the price of gasoline and the price of new cars, none of the specifications tried produced statistically significant coefficients for both prices in the same equation. The best results for equation (14) are reported in Table 3 below. The estimation procedure employed is the Ordinary Least Square (OLS). Two Stages Least Square (TSLS), Generalized Least Square (GLS), Autoregressive and Zellner methods were all tried.

Table 3

The Stock of Automobiles per Household Results

	NFLD	PEI	NS	NB	QUE	ONT	MAN	SASK	ALTA	BC
1. Ln S	.2073 (.2381)	.3284 (.3754)	.2638 (.3019)	.2814 (.3216)	.2256 (.2570)	.2508 (.2844)	.2828 (.3215)	.2475 (.2812)	.3143 (.3547)	.2920 (.3310)
2. Ln S	-.0759 (-.086)	.0381 (.0428)	-.0296 (-.033)	-.0090 (-.010)	-.0698 (-.078)	-.0471 (-.052)	-.0113 (-.013)	-.0434 (-.048)	.0205 (.0227)	-.0074 (-.008)
3. Ln S	.6474 (.6520)	.8887 (.8943)	.7896 (.7933)	.8307 (.8352)	.7032 (.7035)	.7603 (.7565)	.8166 (.8152)	.7690 (.7679)	.8681 (.8615)	.8433 (.8403)

	Ln YH	Ln Pg t-1	Ln Pn	Ln S t-1	Ln POP	Ln CA.R				
1. Ln S	.1402 (2.1061)	-.1206 (-3.029)	-.0297 (-1.402)	.4955 (7.789)	.3906 (1.825)	---- ----	R-Square = .8125	S.E.R = .0555	D.W. = 2.0670	F = 62.59
2. Ln S	.1544 (2.307)	-.1185 (2.986)	-.0053 (-.696)	.5012 (7.898)	.4951 (2.2173)	-.0303 (-1.573)	R-Square = .8140	S.E.R = .0553	D.W. = 2.0693	F = 59.05
3. Ln S	.3825 (4.317)	-.1241 (-2.341)	-.0995 (-.9976)	---- ----	.6179 (2.0907)	-.0327 (-1.4000)	R-Square = .7993	S.E.R = .056	D.W. = 2.0303	F = 53.56

* T-statistics are in parentheses

The price of gasoline per gallon was found empirically
to be more appropriate for the stock of automobiles equation.
However, the best results were obtained when the price of
gasoline per gallon, lagged one time period, was included in
the regression equation. This may indicate that, regarding
the stock-holding decision, the household forms a static
expectation of gasoline prices.

The strikes in the automobile industry variable was
found to be insignificant for the stock of cars equation and
has been removed. The unemployment rate and the percentage
of population living in urban areas have been dropped from
the equation on the grounds that they displayed a wrong sign
or were found to be consistently insignificant.

Regarding the new car price, one possible reason why it
did not behave well in the stock equation is that the new car
price is not the flow cost of the services, the latter
depending on the financing of the automobile, and
approximately the real interest rate times the price of the
car, plus maintenance costs. If the real interest rate were
relatively constant and maintenance costs were a constant
proportion of the automobile price over the estimation
period, then the price of cars represents a good proxy for
the desired variable.

The prime interest rate in Canada was included in an
alternative specification. Its estimated coefficient has the
right sign and it was found to be statistically significant.

However, the price of new cars remained insignificant.

Moreover, in the results, the gasoline price elasticities of the stock of cars per household were found to be small. It should be noted that these are short run elasticity since in the long run, the household could switch to smaller more fuel efficient cars or current owners could use their more fuel efficient cars more extensively. The results suggest that in the short run, the response to gasoline price changes is not expected to be large.

Estimation of New Automobile Sales

The coefficient of the new car prices variable has a negative sign, as an increase in own-price should reduce purchases. Income per household has a positive sign, since automobiles are considered normal goods. Shalaby and Waghmar's model (1980) used the ratio of automobile price to disposable income in their new car sales equation. They argued that the implication of using the ratio variable is that the elasticity of demand for new car sales with respect to car price varies inversely with income. This specification was also tried but it was difficult to interpret the size of the coefficient.

Moreover, Westin (1975) suggested that lagged transitory income and unemployment should be included in the list of regressors explaining new car sales. As the permanent income hypothesis indicates, the timing of transitory income gains is more effective than permanent income in determining the

timing of new car purchases. In Westin's model, the
coefficient on current transitory income was assumed to be
the negative value of the coefficient on lagged transitory
income, holding permanent income constant. To account for
this effect in the new car sales equation, the household
disposable income lagged one time period was included. The
expected sign on lagged income is negative since an increase
in income one year prior to the year in which a household
planned to purchase a new automobile may have provided the
flexibility to purchase the vehicle early, thus decreasing
purchases in the current period. The coefficients on current
and lagged income are not expected to be equal in absolute
value since household income is a composite of permanent and
transitory income. The results of this alternative
specification of the new car sales equation are given in
Table 4 below. However, the specification in equation (16)
was chosen since it gave more reasonable results.

The coefficient for the unemployment rate (UN) has
a negative sign since at lower levels of unemployment, new
car sales are expected to increase. The unemployment rate
variable has been included as a cyclical indicator of
economic conditions. It provides information about the phase
of the business cycle and the expected income which would not
be provided by the inclusion of only the disposable income
variable.

Table 4

The New Automobile Sales Results

	NFLD	PEI	NS	NB	QUE	ONT	MAN	SASK	ALTA	BC
1. Ln NR	7.8894 (4.329)	7.7907 (4.284)	7.8021 (4.286)	7.8878 (4.335)	7.8721 (4.305)	7.6989 (4.162)	7.4788 (4.065)	7.3571 (3.993)	7.5888 (4.086)	7.4933 (4.068)
2. Ln NR	7.7800 (4.393)	7.6951 (4.361)	7.7090 (4.366)	7.7978 (4.418)	7.7782 (4.386)	7.6092 (4.240)	7.3908 (4.139)	7.2571 (4.061)	7.5280 (4.181)	7.4104 (4.151)
3. Ln NR	9.1844 (5.020)	9.0915 (4.973)	9.1086 (4.983)	9.1870 (5.029)	9.1873 (5.003)	9.0497 (4.866)	8.8192 (4.769)	8.6999 (4.697)	8.9443 (4.790)	8.8262 (4.769)

	Ln YH	Ln Pg/e	Ln Pn	Ln UN	Ln ST	Ln Pg/e t-1	Ln Y t-1			
1. Ln NR	.3453 (2.9921)	---- ----	-.7179 (-4.985)	-.2956 (-6.975)	-.00395 (-2.451)	-.2726 (-3.002)	---- ----	R-Square = .7655	S.E.R = .1054	D.W. = 2.0342 F = 41.19
2. Ln NR	.3678 (2.996)	-.1902 (-1.731)	-.7154 (-4.557)	-.2764 (-6.452)	-.00365 (-2.102)	---- ----	---- ----	R-Square = .7459	S.E.R = .109	D.W. = 2.0402 F = 39.76
3. Ln NR	.7676 (4.433)	---- ----	-.7549 (-5.3437)	-.2462 (-5.527)	-.00468 (-2.975)	-.2591 (-2.941)	-.5266 (-3.119)	R-Square = .7765	S.E.R = .1029	D.W. = 2.0254 F = 41.25

* T-statistics are in parentheses

The variable man-days lost due to strikes in the automobile industry (ST) represents a supply constraint on the availability of new cars and the coefficient for this variable has a negative sign. Some researchers have argued that the coefficient of this variable should be zero since any problems with the availability of domestic cars could be made up by an increase in imports. This is certainly plausible. However, if imported cars are not a perfect substitute for domestic ones, then the argument is weak. The new car sales could be regarded partly as the net addition to the stock and partly as replacements for scrapped vehicles, the number of which depend on the stock of cars. Therefore, the stock of cars per household lagged one time period (S/H) has been included as a determinant of new car sales. The coefficient for this variable has a negative sign since the higher the number of vehicles available to the household during the past period, the less likely that the household will purchase a new car in the current period.

Estimation of New Car Fuel Efficiency

As expected, the higher the interior volume class, the lower the fuel economy of the new car. The fuel efficiency standard restrictions caused the fuel efficiency of new cars to improve.

A polynomial distributed lag of degree 1 is imposed on the gasoline price with zero restriction on the coefficient of the current period price. On the basis of both R-square

and Minimum Standard Error criteria, the optimum lag length is 4. This indicates that design changes are made 1 to 4 years prior to the year of marketing the final product. There is evidence from the industry in support of this finding. According to the international Business Week [11] Magazine, several automobile manufacturers spend about 3 to 4 years in designing a new model before the commercialization year.

Table 5

The New Cars Technical Fuel Efficiency Equation

	Z1	Z2	Z3	Z4	
LEN	4.0061	3.9380	3.7232	3.5491	
	(29.763)	(29.583)	(27.969)	(26.662)	

LEN	DST	Pt-1	Pt-2	Pt-3	Pt-4
	0.082372	0.20138	0.19829	0.19519	0.19209
	(2.0329)	(3.0178)	(5.3147)	(7.9252)	(4.1945)

$$R^2 = 0.9991 \qquad S.E.R = 0.0091 \qquad F = 9621.9$$

The coefficients of the gasoline price are of almost the same size, indicating that the design of the new model can be altered up to the last year before the marketing which contradicts Gallini's results. Further, the gasoline price elasticity of new car fuel efficiency is about 0.8 percent over the four years designing period.

The results for the dummy variables for size classes illustrate that the larger the interior volume of the automobile the lower the fuel economy. Also, the dummy variable for the fuel economy standards indicates a positive effect on the fuel efficiency of new cars of all classes.

Estimation of Sales Ratio Of New Automobiles

Three equations with cross restrictions on the estimates of the new car price variable (Pnz - Pnx) and gasoline cost per mile variable (Pgz - Pgx) are estimated simultaneously. The three equations were estimated for the sales in categories 2, 3 and 4 relative to the sales in category 1.

The estimation results for the new car sales ratios are given in Table 6 below. However, the larger the difference between the price of new cars in category 1, the smallest size, and that of the other categories, the smaller is the ratio of small to larger car sales. This is clearly indicated by the negative sign for the price of new cars variables. The same argument holds for the cost of gasoline per mile across different new cars categories. As the gasoline cost increases, the sales of smaller cars are more frequent than sales of larger ones. The results also demonstrated that both variables of car prices and gasoline cost are significantly different from zero at the 99 percent level.

Moreover, as the household disposable income rises, the number of cars sold in categories 2, 3, and 4 relative to sales in category 1 rises, which is evidenced by the positive sign for the household income variable in all three equations. The results illustrate that it is more common for households to be moving to the larger, more expensive new cars than to be buying a car for the first time. A rise in the unemployment rate induces households to move down the size spectrum, decreasing the ratio of car sales in each category relative to the smallest automobiles.

Furthermore, man-days spent on strike in the Canadian automobile industry appears to have a negative effect on the sales in categories 2, 3, and 4 relative to category 1. This result is intuitively appealing since a large proportion of the automobiles in the smallest category are imported, and thus, would not be subject to domestic strikes.

Another interesting result are the coefficients for the driving age population, POP. The results illustrate that this variable has a negative effect on the sales in category 2, 3, and 4 relative to sales in category 1. This finding is also intuitively appealing because new drivers who had not owned a car before are more likely to enter the market at the lower cost categories, e.g., category 1 and 2.

Finally, all the household characteristics variables are statistically significant at the 95 percent level.

Table 6
Sales Ratios for the New Cars

Categories	2	3	4
Pg/e	-11.738 (-8.105)	-11.738 (-5.272)	-11.738 (-5.996)
Pn	$-.1073 * 10^{-3}$ (-4.684)	$-.1073 * 10^{-3}$ (-3.047)	$-.1073 * 10^{-3}$ (-3.465)
YH	$.56133 * 10^{-4}$ (5.728)	$.6720 * 10^{-4}$ (4.496)	$.19093 * 10^{-4}$ (1.876)
UN	.0428 (3.582)	.0668 (3.629)	-.0443 (-2.676)
ST	$-.14345 * 10^{-6}$ (-3.109)	$-.99303 * 10^{-7}$ (-2.409)	$-.41328 * 10^{-7}$ (-1.656)
POP	-.08312 (-6.671)	-.20643 (-10.613)	-.1797 (-10.634)
NFLD	3.6621 (6.333)	11.482 (11.98)	12.327 (14.101)
PEI	4.3113 (6.324)	12.873 (11.624)	13.257 (13.335)
NS	4.3874 (6.261)	13.040 (11.469)	13.163 (12.903)
NB	4.2971 (6.399)	12.837 (11.737)	13.465 (13.686)
QUE	4.4644 (6.292)	13.224 (11.482)	13.553 (13.086)
ONT	4.4766 (6.189)	13.423 (11.452)	13.703 (12.935)
MAN	4.4798 (6.128)	13.568 (11.493)	13.775 (12.98)
SASK	4.4935 (6.175)	13.426 (11.444)	13.899 (13.184)
ALTA	4.1269 (5.926)	12.710 (11.256)	13.316 (12.993)
BC	4.2509 (6.033)	12.585 (10.973)	12.926 (12.442)

Price Elasticity Estimates

A major objective of developing the model was to
determine the transportation sector's potential for
conserving gasoline. One widely used economic indicator of
conservation potential is the elasticity of demand for
gasoline with respect to the price of gasoline. By
simulating the model over the desired time horizon, 1989-
2000, the price elasticities were detemined. A base case was
specified in which real household income, the unemployment
rate, the real price of new cars, the interest rate, and the
real price of gasoline per gallon in Canada and United States
are assumed to equal the 1988 values and remain constant
for the rest of the time horizon.

In an alternative solution of the model, the disturbed
solution, only the real prices of gasoline in Canada and the
U.S. are assumed to increase by 10 percent. The two
dynamically controlled solutions of the model were obtained
and the dynamic price elasticity at time t was calculated by
applying the following formula :

$$(26) \qquad Ep = \frac{(AG_t^b - AG_t^\alpha)}{\left(\dfrac{AG_t^b + AG_t^\alpha}{2} \right)} \Bigg/ 0.1$$

Where AG_t^b = aggregate gasoline consumption under the base case at time t.

AG_t^α = aggregate gasoline consumption under the alternative scenario at time t.

The price elasticity as defined above includes all direct and indirect effects on gasoline consumption due to a 10 percent change in the price of gasoline per gallon. The increase in the price of gasoline has a direct effect on the number of miles driven per car, the average fuel economy of the fleet, new car sales, and on the stock of cars. All these effects are captured in the price elasticity estimates. Table 7 below gives the short-run (one-year) price elasticity and the longer-run price elasticity estimates for 2 to 10 years for the ten provinces and Canada.

Because the intercept term is the only parameter that is allowed to vary across provinces, there is little variation in the price elasticities across provinces. However, the estimated price elasticities in Table 7 are relatively larger than some of reported in previous studies.

The short-run (one year) elasticities appear larger than expected. Recall that from Table 2 the direct response to an increase in the price of gasoline, holding the stock of cars and the fuel economy of the fleet constant, ranges from -0.1881 to -0.2095. When the changes in the fuel economy of the vehicles on the road and the fleet size through new car sales and the scrapping of used cars are included, -0.1 is added to the price elasticity. This is significantly higher than Gallini's result of -0.06 and indicates that at least 25 percent of the decrease in gasoline consumption in the first

Table 7

Dynamic Price Elasticities of Gasoline Demand

	NFLD	PEI	NS	NB	QUE	ONT	MAN	SASK	ALTA	BC	Canada
1	0.3116	0.3122	0.3121	0.3125	0.3116	0.3119	0.3118	0.3119	0.3121	0.3120	0.3120
2	0.4666	0.4672	0.4672	0.4677	0.4683	0.4685	0.4662	0.4661	0.4660	0.4691	0.4673
3	0.5328	0.5386	0.5345	0.5369	0.5347	0.5349	0.5399	0.5381	0.5412	0.5380	0.5370
4	0.5967	0.5973	0.5972	0.5976	0.5979	0.6006	0.5978	0.5976	0.5977	0.6003	0.5981
5	0.6895	0.7018	0.6920	0.6972	0.6922	0.6933	0.7055	0.7024	0.7092	0.7014	0.6984
6	0.8001	0.8181	0.8019	0.8109	0.8032	0.8043	0.8246	0.8206	0.8315	0.8168	0.8132
7	0.8748	0.8999	0.8770	0.8904	0.8784	0.8803	0.9092	0.9044	0.9202	0.8977	0.8935
8	0.9246	0.9562	0.9266	0.9444	0.9294	0.9307	0.9677	0.9625	0.9836	0.9528	0.9478
9	0.9564	0.9934	0.9576	0.9802	0.9628	0.9625	1.0075	1.0020	1.0281	0.9889	0.9839
10	0.9749	1.0168	0.9754	1.0022	0.9814	0.9811	1.0332	1.0269	1.0587	1.0220	1.0073
11	0.9842	1.0296	0.9834	1.0157	0.9904	0.9896	1.0482	1.0414	1.0789	1.0312	1.0192
12	0.9868	1.0350	0.9846	1.0204	0.9923	0.9915	1.0556	1.0486	1.0915	1.0328	1.0239

year is due to changes in the average fuel economy of the
fleet, new car sales, and the stock of cars. The rest is due
to changes in driving habits.

The adjustment to the price increase appears to be
rapid, which is indicated by the rise in the price elasticity
within the first four to six years after a price shock.
Furthermore, ten years after the 10 percent increase in the
gasoline price, the reduction in consumption settles to
approximately 10 percent of the consumption level under no
price increase.

V. Conclusions

The model presented in this study is one of the few econometric studies that has attempted to model the gasoline demand exclusively for Canada. The attempt was made to improve upon the existing models through careful description of the underlying decision making process that faces the household, making the household rather than the individual the focus of the model and significantly extending the time series beyond the scope of existing studies.

In the model, the household which already owns a car can react immediately to a price increase by driving fewer miles (e.g. leisure miles). The household which is planning to buy a new car can either postpone their vehicle purchases or choose a more fuel efficient new car. Finally, the household which owns an aged car can scrap their automobile in response to a higher gasoline price.

In the long run, the size and composition of the fleet according to the interior volume of the vehicles can continue to change and necessary miles may fall as households move closer to work. Also, in the long run, car manufacturers can modify the technology of the new cars according to their expectations regarding the future levels of gasoline prices and consumers' demand for more fuel efficient cars.

Among the most significant contributions of the model to the current literature is the use of the household expenditure survey data which have been published by

Statistics Canada. These data have led to the inclusion of such variables as number of persons in the household who can drive, percentage of household living in urban areas, number of cars per household and the household income.

The detailed treatment of the fuel efficiency of the new cars where the automobiles were categorized according to their interior volume rather than their natural weight is significant improvement over the previous models.

The results of estimating the model provided revealing information about elasticity of gasoline demand in Canada. The short run dynamic own price elasticity of gasoline demand ranged between 0.311 to 0.313 in absolute value across the provinces. Close to 75 percent of the household response to price change in the first year was due to driving fewer miles. While these results are in line with Gallini (1983) and the Rand Corporation Study findings (1975), they exhibit a unique feature. That is, at least 10 percent of the first year response is due to an alteration in the composition of the fleet to more fuel efficient vehicles, a response that accounted for only 4 percent in Gallini's study. The remaining 15 percent is attributed to the change in the size of the fleet, which is very much the same result as Gallini's. The intermediate run (five years) price elasticities range from .689 to .709 and the long term elasticities (ten years) range from 0.975 to 1.059. Moreover, the dynamic elasticities imply that the adjustment

seems to take place very rapidly during the first four years. These results suggest that while no one disputes that gasoline demand is inelastic in the short run, the belief that it is also inelastic in the long run is unsupported.

The short run household income elasticity is about 0.31. The intermediate run income elasticity is around 0.67 and the long run is about 0.91. That long run household income elasticity is greater than the short run which is in line with most of the previous findings.

There are two policy instruments that have been used with regard to gasoline consumption, namely fuel efficiency standards for new vehicles and gasoline taxes. The fuel efficiency standards are set by the E.P.A. in the U.S.A., but since all car companies in Canada are subsidiaries of the U.S. based parent firms, these standards are effective in Canada too. The present model could be used to assess the influence of these fuel efficiency standards. Under the base and the alternative cases discussed in Eltony (1990), most of these standards are met. The results also indicate that in many cases the households were able to keep their favourite car size because the manufacturers instituted significant improvements.

These findings point to the importance of improving fuel efficiency as an effective means of reducing household gasoline consumption. They also show that the detailed treatment of the fuel efficiency of the fleet was justified.

As an explanatory variable, the fuel efficiency variable was found to possess the right sign and to be highly significant in all equations. This reinforces the earlier conclusion that fuel efficiency improvements have significant impact on energy conservation.

The empirical evidence from the model has indicated that the 1986 oil price collapse has not substantially affected the incentive for conservation in gasoline demand in Canada since the reduction on gasoline prices was not sustained and because the high rate of return on fuel efficiency investment meant that it remains cost effective.

Notes

1. From equation (4) GS = MS/E(T1)   by substituting this
    value in equation (5) in the first term yields
    Pg * MS/E(T1) or Pm * MS.

2. Shalaby and Waghmare (1980) in their model, and Gallini
    study (1983), both used the same approach to this
    problem.

3. The technical fuel economy of automobiles is the fuel
    economy under test driving conditions. A reliable source
    for this information is provided by the Environment
    protection Agency's publications for all models of new
    cars.

4. Econometrics, by G. S. Maddala. McGraw-Hill, 1977.
    Chapter 16, Distributed-Lag Models

5. The fuel economy standards set in the United States were:

Year	U.S. Fuel Economy Standard
1978	18 mpg
1979	19 mpg
1980	20 mpg
1981	22 mpg
1982	24 mpg
1983	26 mpg
1984	27 mpg
1985 and after	27.5 mpg

    The penalty for not achieving the standard is $5.oo per
    vehicle for each 1/10 of a mile per gallon below the

mandated level. However, due to the failure of the 1985 - 1987 model year cars in achieving these standards, the E.P.A. has modified the standards for 1987, 1988, 1989 and 1990 to 26, 26, 26.5, 27.5 mpg respectively.

6. McFadden, D. " Conditional Logit Analysis of Quantitative Choice Behaviour" in Zarembka, Frontiers in Econometrics, New York: Academic Press - 1973.

7. Amemiya, T., " Qualitative Response Models: A Survey. " Journal of Economic Literature, December 1981, P. 1483 -1536.

8. To explain this point further, consider the following set of equations:

(i) $Ln (N2/N1) = (A2 - A1) + (B2 - B1) K + C21 (L2 - L1)$

(ii) $Ln (N3/N1) = (A3 - A1) + (B3 - B1) K + C31 (L3 - L1)$

(iii) $Ln (N4/N1) = (A4 - A1) + (B4 - B1) K = C41 (L4 - L1)$

From (i) & (ii), Ln (N2/N3) can be found. That is

(iv) $Ln (N2/N3) = (A2 - A1) + (B2 - B1) K + C21 (L2 - L1)$
$$- (A3 - A1) - (B3 - B1) K - C31 (L3 - L1)$$

If $C31 = C21 = C$ then

(v) $Ln (N2/N3) = (A2 - A3) + (B2 - B3) K + C (L2 - L3)$

The same argument holds for Ln (N2/N4) from (i) & (iii) and all other possible combinations.

9. For example, the taxable gasoline which is primarily sold to the drivers of cars, buses and trucks at the gas pump.

10. Pindyck and Rubinfeld, Econometric Models and Economic Forecasts, 1976 by McGraw-Hill. P. 203 - 206.

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