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ESTIMATING THE DEMAND FOR MOTOR VEHICLE GASOLINE IN WESTERN CANADA

by

Robert D. Hale
B.A., Simon Fraser University, 1970

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ARTS in the Department of Economics

Robert D. Hale 1979

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Estimating the Demand for Motor Vehicle Gasoline in Western Canada

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ABSTRACT

The major objective of this paper is to estimate the effect of a change in the price of gasoline on its use in private automobiles; i.e. gasoline's own price elasticity.

Canada's energy problem is really an oil problem; how to conserve dwindling supplies and how to price remaining reserves. Although there have been studies done to estimate the effect of price increases in reducing gasoline consumption, disparate methods and data have been used, resulting in a wide range of elasticity estimates. This thesis compares the various models, both within the context of a theoretical formulation of the private demand for motor gasoline, and using a consistent set of data.

First, the theoretical basis of gasoline demand for private automobiles is discussed within the context of traditional microeconomic theory. A single-equation, reduced form model of the demand for gasoline is presented. Second, six econometric studies, each estimating a different model of the demand for gasoline, are summarized and compared. These models are also compared with the reduced form equation based on the theoretical model. Finally, the demand for motor gasoline in Western Canada is estimated using econometric techniques. A number of different equations, based on the different models and two different data bases, are estimated.
The models estimated fall into three major categories; a) the traditional model where gasoline is a linear or log-linear function of price, income and other independent variables, b) a variable-form model where price elasticity increases with price while income elasticity decreases with income, and c) a dynamic model where motor gasoline is separated into its fixed and flexible components.

The results, using data for the four Western Canadian provinces, were not completely unambiguous. The results of the dynamic models were more consistent than the traditional models, but more stringent assumptions were required in order to apply econometric techniques. The results of the variable form model were least satisfactory. Based on the evidence presented in this and other studies gasoline price elasticity is in the range of -0.20 to -0.25 in Western Canada. A 10% increase in the price of gasoline, therefore, results in a 2 to 2.5% decrease in motor gasoline consumption. Income elasticity is in the range of +0.9 i.e., a 10% increase in real personal disposable income results in a 9% increase in gasoline consumption. Finally, these results are used to estimate future private motor gasoline consumption.
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I. Introduction

This thesis is concerned with the demand for motor gasoline for use in private automobiles. The major objective is to estimate the own price elasticity of this demand, and to assess the implications of this elasticity on the demand for gasoline in the future, within the context of energy demand generally.

Since the winter of 1973-1974, much public attention has focused on energy. Energy - its price, its availability, its use as a political weapon and its effect on the environment - has increasingly been the object of discussion among economists, policy makers, scientists, environmentalists and the general public. Despite the attention given to these problems (or perhaps because of their variety and complex interrelationships) and the myriad of proposed solutions, the problems remain. In fact, during the spring of 1979 an energy 'crisis' similar in magnitude and origin to the one in 1973-1974 occurred.

The energy problems facing most of the world clearly affect Canada as well. Canada, of course, experiences each of the various energy issues in different degrees than other countries. The issues of greatest concern in Canada are not necessarily important elsewhere.

1 Although concerns with respect to the availability of energy were discussed prior to 1973, the winter of 1973-1974, concurrent with the oil embargo imposed by Arab members of OPEC, is generally considered the beginning of the energy crisis.
Similarly, there is less emphasis on some aspects of energy in Canada than in other countries.

Canada has substantial amounts of indigenous energy supplies and, compared to many countries, a relatively larger percentage of her energy consumption is produced internally. However, Canada is the largest per capita user of energy in the world. Her relatively large abundance of domestic energy sources do not shield her completely from the problems facing the rest of the world. And Canada's relative abundance of energy supplies is available for consumption only at a rapidly rising price.

Canada's main energy concern is oil. The dependence Canada places on imported oil imposes, in many minds, substantial security risks. It is avowed government intention to reduce this risk by some combination of three means: 1) increasing Canada's oil supplies and its oil transportation network in order to substitute Canadian oil for foreign oil, 2) displacing oil, whether foreign or domestic, with domestic sources of alternate energy (both conventional, such as natural gas or electricity, and unconventional such as solar power) and 3) reducing the demand, or at least the growth in demand, of energy, particularly oil products.2

2In the short term there is a fourth policy aimed at reducing the security risk of Canada's dependence on foreign oil - purchasing oil from more dependable, secure sources such as Mexico or Venezuela.
To an economist, accustomed to thinking in terms of traditional supply and demand curves and market clearing forces, the solution seems to be straightforward. Simply increase the price of energy to the level that will elicit enough new supplies to meet the quantity of energy demanded at that price level.

It is clear, however, that market forces have not been permitted to work for a variety of reasons. Moreover, there are negative externalities involved in the use of foreign crude oil that imply that market forces will not solve Canada's energy problems.

It is not, however, the prime purpose of this paper to discuss Canada's energy problems or to propose solutions. The objective here is to look at one part of the demand for energy, examine its sensitivity to price and discuss the efficacy of gasoline price increases in meeting the goal of reducing the growth in Canadian energy demand and therefore Canada's dependence on foreign oil.

In 1976, oil comprised 52% of Canada's consumption of total energy. 43% of the crude oil refined in Canada was imported in that year (34% in 1978). Motor gasoline accounted for 38% of all oil consumption in 1976 and 37% in 1978 making it the largest single component. Thus, in 1976, motor gasoline accounted for 20% of Canada's total energy
consumption. Next to natural gas, motor gasoline is the largest single component of total energy consumption. Certainly, therefore, policies designed to lessen the rate of growth in motor gasoline consumption in Canada would be beneficial in reducing energy demand generally, particularly since current technology is not sufficiently developed (or inexpensive) to permit the substitution of other energy forms for oil-based products consumed in automobiles.

During the period 1957 to 1973, the amount of gasoline sold at service stations in Western Canada grew at an average annual rate of 3.8%. During the same period, the real price of regular grade gasoline fell from approximately 43¢/gallon to 38¢/gallon (in 1961 dollars). From 1973 to 1978 the average annual rate of consumption of motor gasoline purchased at service stations in Western Canada declined from this historical rate to approximately 2.5%. During this latter period, the real price of regular grade gasoline rose roughly 6¢ per gallon. Although this 'correlation' is unscientific and there are obviously other factors influencing the growth rate of gasoline consumption, it does suggest that gasoline prices may be an influencing factor in determining the level and growth of gasoline demand.

Sources: Statistics Canada - 57-202 Detailed Energy Supply and Demand 1976
One of the primary purposes of this thesis is to quantify the impact price has on the consumption of motor gasoline used in private automobiles; i.e., to measure the own price elasticity of gasoline consumption. The price elasticity is measured within the context of an equation estimating the demand for motor gasoline.

Chapter II provides a theoretical discussion of gasoline demand within a traditional microeconomic framework. The derived nature of the demand for motor gasoline used in private automobiles is discussed. The factors influencing gasoline demand and their interrelationships are also discussed. Finally, a general reduced-form equation of the demand for gasoline is presented.

Chapter III discusses the results of previous studies on the demand for gasoline within the context of the theoretical approach of Chapter II. The various approaches to modeling the demand for gasoline are compared to the theoretical base in that chapter. The econometric results of the studies are summarized and compared.

One of the problems encountered in studying the demand for gasoline is the number of different models used. Comparison is made even more difficult because each study uses different data and different estimating techniques. One of the goals of Chapter IV is to compare the results of these models using a consistent set of data and one
estimating technique. Chapter IV also presents a discussion of some of the econometric problems encountered in estimating demand functions in general and the demand for gasoline in particular. Finally, the econometric results of various equations estimating the demand for gasoline in the four western Canadian provinces are summarized.

The final chapter (Chapter V) presents the conclusions relating to the demand for gasoline, in particular own price elasticity. The conclusion with respect to the 'best' model of gasoline demand and its components is also presented. In addition, Chapter V discusses the implications of these conclusions for reducing the demand for gasoline. A discussion of the efficacy of lowering the growth rate of motor gasoline consumption by price increases and by non-price conservation measures is made. Finally, Chapter V presents a forecast of the demand for gasoline used by private automobiles.
II. The Demand For Gasoline - A Theoretical Discussion

A. Introduction

According to traditional microeconomic theory, the demand function of any individual for a given commodity is derived from maximization of the individual's utility function subject to that individual's budget constraint. The solution to this maximizing problem is a demand function whose arguments include income (i.e., the budget), the price of the commodity, the prices of other commodities and tastes or preferences. The individual's tastes determine his preferences for a set of commodities and the ordering of this set of preferences gives rise to his utility function. The income (or wealth) of the individual determines the amount of money that can be spent on commodities. By dividing this budget by the prices of the commodities one can determine the amounts of each commodity (or combination of commodities) that can be purchased within the budget. Thus, given income, tastes and prices, the demand for a particular commodity is determined. The demand function signifies the changes that occur in the demand for the commodity, given a specified change in income, prices or tastes.

The theoretical framework for determining a demand function is, therefore, specified. Estimating the nature of the demand function and, more particularly, the coefficients of an individual demand function is, however, an empirical question. Although microeconomic
theory does provide some insight as to the direction of the change in
the demand for a commodity given the sign of the change in any of the
arguments (or independent variables) in the demand function, little
can be said, a priori, about the extent of the change.

If the good in question is 'normal', consumer demand theory postulates
that an increase in income will result, other things being equal, in
an increase in the demand for the commodity. In addition, a decrease
in the price of a commodity would, according to consumer demand theory,
result in an increase in the demand for that commodity. (A 'Giffen'
good is the one exception to this "law of demand".) The effect of a
change in the prices of other goods on the demand for the good in
question depends on whether or not the good is a complement or a
substitute. An increase in the price of a complement will result in
a decrease in the demand for a particular commodity while an increase
in the price of a substitute will result in an increase in the demand
for that commodity. Although this specification of the demand function
says nothing, a priori, about the effects of a change in tastes on
the demand for a commodity, an intuitive estimate of the direction of
the change on the demand for the commodity can generally be made.

The sign of the arguments, therefore, can generally be determined
either by reference to consumer theory or by an intuitive estimate of
the effect of a particular change in tastes.
The magnitude of the change in the demand for a commodity given a specified change in an independent variable - the elasticity\(^1\) - cannot be determined with reference to consumer demand theory; it is an empirical question.

The demand for a good is elastic if its elasticity is greater than one (in absolute value) and is inelastic if its elasticity is less than one (in absolute value). A change in the price of an elastic good results in a greater than proportionate change in the demand for the good. The opposite is true for an inelastic good. Thus the absolute value of the elasticity of the good in question is of importance to economists and policy makers.

Although the analyst does not have an a priori theory as to whether a good has an own price elasticity greater than or less than one, the characteristics of the good can provide intuitive suggestions. For example, demand for a good with many substitutes and which is a luxury can be expected to be relatively elastic whereas demand for a good with no substitutes and which is a necessity can be expected to be relatively inelastic.

\(^1\)Elasticity is the percentage change of the independent variable divided by the percentage change of the dependent variable. If gasoline demand is expressed as a function of price, \(G_D = f(P)\), its price elasticity is equal to \(\frac{d(G_D)}{dP} \cdot \frac{P}{G_D}\).
Similar a priori statements can be made about the income elasticity of a particular good. If a good has an income elasticity of less than one (i.e., a change in income has little effect on the demand for the commodity), the good can be considered a necessity since the amount consumed of the commodity is little affected by income. On the other hand, goods which are considered "luxuries" have an income elasticity greater than one since a change in income will cause a more than proportionate change in demand.

The sign of cross-price elasticities can be determined, a priori, by whether the good is a substitute or complement to the commodity under examination. The magnitude of cross-price elasticities can be roughly estimated a priori by whether or not the good is a weak or strong substitute or complement.

Very little can be said a priori about the functional form of the demand function for any commodity. Consumer theory requires that the price coefficient be negative throughout the range of the demand function (excepting a Giffen good); i.e., a negative first derivative. The second derivative of the price variable in a demand equation is generally considered to be less than or equal to zero following from the principle that the marginal rate of substitution on an indifference curve declines. Thus the functional form of a demand equation, at least with respect to price, can be limited to those with declining slope, either at a constant or decreasing rate.
throughout the range under consideration.

As noted, consumer theory suggests that the first derivative of the income coefficient be positive. There is nothing in consumer theory, however, to suggest the sign of the second derivative.

In general, therefore, some characteristics of the demand function of a particular commodity can be prespecified. In the final analysis, however, no matter how plausible these a priori estimates, they must be tested empirically.

Up to this point, only demand functions for individual consumers have been discussed. In general, it is market demand functions that are of interest. Market demand curves are derived by simply summing up individual demand curves horizontally. In the theoretical formulation, market demand curves have properties identical to individual demand curves. Depending on the functional form of the demand function, however, market demand functions can create some econometric problems.

The above discussion of commodity demand functions and their properties applies in general to all commodities. In addition, the analysis can be easily extended to services. Demand functions for accounting and transportation services, for example, have the same properties as demand functions for "commodities" such as sugar or clothes.
In this paper, the demand for gasoline is of interest. Although a gasoline demand function has much in common with demand functions for other commodities, there are two characteristics of gasoline demand that suggest complications in estimation. First, gasoline is not consumed directly. An individual does not eat or wear gasoline but uses it as a means to an end. The individual's demand for gasoline is derived from his demand for transportation services or, more particularly, from his demand for private transportation services.

A second characteristic of gasoline that differs from many other goods is its use in conjunction with a durable good. The demand functions for durable goods differ from those for non-durable goods since consumption of durables occurs over a much longer period of time.

Once a durable good has been purchased, the consumer's demand function is reduced to the demand for the services of that particular durable; e.g., the demand for private transportation given the possession of a particular automobile. The demand function for a durable includes, among the independent variables, the price of the durable plus the cost (price) of operating the durable. Other things equal, an increase in operating costs results in a decrease in the demand for the durable. Gasoline is an obvious part of the cost of operating an automobile.

---

2Although all commodities could be considered "a means to an end" e.g., food is used to provide calories, a characteristic of gasoline is that it is not consumed directly, but that it provides a service.
Once the durable has been purchased, its use (i.e., the demand for the services of the durable) is determined by changes in the costs of operation and in income. The durable's purchase price and other fixed costs such as insurance and license fees, no longer enter into the decision of how frequently to utilize the durable. Thus the demand for commodities used in the operation of the durable are "derived" from the decision to purchase the durable. The consumer can still alter its use in response to changes in the price of the commodity, but, in large measure, the use of the commodity has been determined by the decision to purchase the durable. A difficulty, therefore, in formulating the demand function for a commodity like gasoline is to separate the demand that is derived or determined by the decision to purchase an automobile, and the demand associated with its use.

The demand for gasoline is, therefore, often characterized as a 'derived' demand. Its demand is derived initially from the demand for transportation services and secondly from the demand for automobiles. A third element in the demand for gasoline is the demand for the use of an automobile given its purchase. A function explaining the demand for gasoline is, therefore, the reduced form of a system of three equations - the first determines the demand for transportation services; the second determines the purchase of automobiles, which provide part of these transportation services; the third equation determines the utilization rate of gasoline used in automobiles.

Thus, a single reduced-form equation expressing gasoline demand as a
function of prices, income and other variables implicitly assumes that the demand for transportation services and the demand for automobiles are also functions of prices, income and other variables.

This reduced form of the demand for gasoline permits the estimation of total elasticities; e.g., the effect of a price change on gasoline consumption after all adjustments in transportation services, automobile purchase and automobile use have been completed. The single reduced-form equation does not, however, provide elasticities at each stage of the adjustment process.
B. Theoretical Basis Of The Demand For Gasoline

First, we start with the individual i's demand for transportation services (TS) in period $t^3$. The demand for transportation (miles travelled), by individual $i$, is a function ($f_i$) of individual $i$'s real income ($Y_i$), the real price of transportation per mile ($P_T$) and a vector ($Z_i$) reflecting individual $i$'s tastes and preferences.

\[(II-1) \quad D_i(TS) = f_i (Y_i, P_T, Z_i)\]

$P_T$ is the real price of transportation services. It includes the prices of all modes of transportation and is, therefore, a weighted average price per mile of all disparate transportation alternatives. If $\alpha$ represents the weights assigned to public transportation, $P_T$ can be rewritten as $\alpha P_{PU} + (1 - \alpha) P_{PR}$ where $P_{PU}$ and $P_{PR}$ are the prices of public and private transportation respectively.

The vector of tastes and preferences ($Z_i$) includes such things as distance from place of work, the effect of weather on the individual's travelling decision, demographic characteristics and recreational pursuits.

$^3$A glossary of terms and symbols is presented in Appendix I.
Given the demand for transportation services, individual i must choose between public and private transportation modes. Although there are a variety of each of these types of services available, it is assumed here that only private automobiles satisfy the demand for private transportation services and all forms of public transportation services can be represented by a single unit called public transportation (PU).

The demand for an automobile (A) by individual i is represented by a function \( g_i \) of i's income, the real price of the automobile (including its operating costs) \( P_A \), the real price of public transportation \( P_{PU} \), a vector \( (Z_i') \) of tastes and preferences and the demand for transportation services \( f_i \).

\[
(II-2) \quad D_i(A) = g_i \left( Y_i, P_A, P_{PU}, f_i, Z_i' \right) \quad \text{for } D_i (T_S) > 0
\]
\[
D_i(A) = 0 \quad \text{for } D_i (TS) = 0
\]

Equation II-2 represents the demand for an automobile in period t given some level in the demand for transportation services in period t.

Since the automobile can satisfy the demand for transportation services over more than one period, \( D (TS) \) can be considered a representative period's demand for transportation. The automobile can, therefore, satisfy \( f_i \) for a number of periods. The other independent variables are, in effect, present values accounting for expected changes over the automobile's life.
The variable $P_A$ represents the price of the automobile. Since automobiles are the only form of private transportation considered here, $P_A = P_{PR}$. $P_A$ includes not only the real price of the automobile (new or used), but also the associated operating costs such as insurance, repairs and the cost of fuel. $P_A$ could then be divided into three components: $P_{AV}$ (the automobile's fixed costs), $P_{AR}$ (the variable costs of operation excluding fuel) and $P_G$ (the price of gasoline).

The $Z_i$ vector is, again, a vector representing tastes and preferences. The prime is used to differentiate tastes important in purchasing an automobile from those relevant to determining the total level of transportation services required. One element of $Z_i'$ would be the current ownership of an automobile. If, for example, individual $i$ already owned an automobile, both the decision to purchase another or a new one and the decision not to purchase any car would be represented by equation II-2.

If it is assumed, for simplicity, that functions $f$ and $g$ can be represented by multiplicative equations, II-1 and II-2 can be rewritten as follows:

$$D_{i}^{TS} = a_0 \cdot \gamma_i^{a_1} \cdot p_{PU}^{\alpha} a_2^{(1-\alpha)} a_2 \cdot Z_i^{a_3}$$  (II-3)
Substituting II-3 for \( f_i \) in equation II-4 and collecting terms yields:

\[
D_i^A = b_0. Y_i. P_{PU}^{b_2}. P_{AV}^{b_3}. P_{AR}^{b_3}. P_G^{b_3}.
\]

\[ Z_i^{b_4} \cdot f_i^{b_5} \]

Given the purchase of an automobile, the consumption of gasoline for private transportation depends on the extent of its use.

\[
N_1 = K_i. (P_G, P_{AR}, P_{PU}, Y_i, Z_i^{''})
\]

\( N \) represents the number of miles driven which is a function \((K)\) of the real price of gasoline, the real price of other operating costs, the real price of public transportation, real income, and a vector \( Z_i^{''} \) representing tastes and preferences unique to utilizing an automobile. Representing equation II-6 multiplicatively yields:
(II-7) \[ N = c_0 \cdot P_G^{c_1} \cdot P_{AR}^{c_2} \cdot P_{PU}^{c_3} \cdot Y_i^{c_4} \cdot Z_i^{c_5} \]

Gasoline consumption (GD) depends on miles driven \((N)\), the number of automobiles \((A)\) and the fuel efficiency of each automobile \((A^E)\), i.e.:

(II-8) \[ GD = \frac{A \cdot N}{A^E} \]

Identity II-8 states that gasoline consumption is (identically) equal to the number of miles driven per vehicle \((N)\), times the number of vehicles \((A)\), divided by fuel efficiency \((A^E)\) as measured in miles per gallon.

Substituting equation II-7 for \(N\) and equation II-5 for \(A\) into identity II-8 yields:

(II-9) \[ GD_i = \left[ b_5 a_0 \cdot P_G^{c_1} \cdot P_{AR}^{c_2} \cdot P_{PU}^{c_3} \cdot Y_i^{c_4} \right] \cdot \left[ b_0 (a_1 b_5 + b_1) \right] \cdot \left( \alpha a_2 b_5 + b_2 \right) \cdot \left[ 1 - \alpha \right] a_2 b_5 \cdot P_{PR} \cdot (b_3) \cdot P_{AR} \cdot (b_3) \cdot P_{AV} \cdot (b_3) \cdot P_G \cdot Z_i \cdot (b_4) \cdot Z_i \cdot (a_3 b_5) \cdot \left[ A^E_i \right] \]
Note that $A_i^E$ represents the fuel efficiency (measured in miles per gallon) of individual $i$'s stock of automobiles. Before collecting the terms of equation II-9, the variable $P_{PR}$ of equation II-5 can be re-expressed. $P_{PR}$ (the real price of private transportation) is assumed to be equivalent to the real price of automobile transportation $P_A$. As noted previously, $P_A$ can be divided into three components: the fixed costs of the automobile ($P_{AV}$), fuel costs ($P_G$) and operating costs other than fuel ($P_{AR}$). The weights of each of the components in the weighted average price of private transportation can be represented by $B_1$, $B_2$ and $1-B_1-B_2$. Thus, $P_{PR} = P_{AV}B_1 \cdot P_GB_2 \cdot P_{AR}(1-B_1-B_2)$. The $P_{AV}$ component of $P_{PR}$ in equation II-9 would be expressed as $P_{AV}B_1(1-\alpha)$. For simplicity let $B_1(1-\alpha)a_2b_5 = j_1$; similarly the exponents of $P_G$ and $P_{AR}$ in the term $P_{PR}$ would be substituted by $j_2$ and $j_3$ respectively.

The term $A_i^E$, representing the average fuel efficiency of the stock of automobiles, is not simply a technological term but is determined, at least over the long run, by consumer preferences. Consumers choose a particular type of vehicle on the basis of its characteristics such as weight, size, acceleration and style, as well as its price. Individual $i$ chooses a particular automobile with fuel efficiency $A_i^E$ based on the price of gasoline, the price of automobiles with this fuel efficiency and individual preferences for the type of automobile characteristics which influence fuel efficiency. An equation determining the fuel efficiency of $i$'s automobile can be expressed as a function of the
real price of gasoline \( P_G \), the real price of automobiles \( P_{AV} \), real operating costs other than gasoline \( P_{AR} \), real income \( Y_i \), and a vector \( Z_i \) representing preferences for automobile characteristics affecting fuel efficiency.

\[(II-10) \quad A_i^E = h_i (P_G, P_{AV}, Y_i, Z_i)\]

In multiplicative form equation II-10 can be re-expressed as:

\[(II-11) \quad A_i^E = d_0 \cdot Y_i^{(d1)} \cdot P_G^{(d2)} \cdot P_{AV}^{(d3)} \cdot P_{AR}^{(d4)} \cdot Z_i^{(d5)}\]

With these substitutions and the collection of terms, equation II-9 can be rewritten as:

\[(II-12) \quad G_D = \left[ \frac{c_0}{d_0} a_0 b_0 c_0 \cdot \frac{(a_1 b_5 + b_1 + c_4 - d_1)}{(a_2 b_5 + b_2 + c_3)} \cdot \frac{(a_3 b_5 + b_3 + c_2 - d_2)}{(a_4 b_5 + b_4 + c_1 - d_3)} \cdot \frac{(a_5 b_5 + b_5 + c_0 - d_0)}{(a_6 b_5 + b_6 + c_0 - d_0)} \right] \cdot P_{PU} \cdot \frac{(i_3 + b_3 + c_2 - d_4)}{(j_1 + b_3 - d_3)} \cdot P_{PAR} \cdot \frac{(i_2 + b_3 + c_1 - d_2)}{(j_1 + b_2 - d_1)} \cdot P_G \cdot \frac{(j_5)}{(Z_i^{(d1)} \cdot Z_i^{(d2)} \cdot Z_i^{(d3)} \cdot Z_i^{(d4)} \cdot Z_i^{(d5)})} \]
Equation II-12 is the reduced-form single equation representing the demand for gasoline. Although the equation is in a tedious and inconvenient form, it does highlight the complexity involved in reducing the various components of the demand for gasoline into a single equation. It also shows that expressing the demand for gasoline in a single equation implicitly subsumes a number of adjustments.

Equation II-12, then, is an expression of a gasoline demand function as the reduced form of four equations. The first equation (equation II-3) represents the demand for transportation services; the second equation (equation II-5) represents the demand for private transportation services in the form of automobiles; the third equation (equation II-6) represents the use of the automobile; and the fourth equation (equation II-10) represents automobile efficiency. Equation II-12 can be simplified into the following form:

\[(II-13) \quad G_D = e_0 \, Y_1^e_1 \cdot P_{PU}^{e_2} \cdot P_{AR}^{e_3} \cdot P_{AV}^{e_4} \cdot P_G^{e_5} \cdot Z_i^{e_6}.\]

This equation expresses the demand for gasoline as a function of the real price of gasoline, the real prices of substitutes and complements, real income and a variable measuring tastes and preferences. Equation II-13 is similar to equations representing more traditional goods and services; i.e., those that are consumed directly for their own use.
The distinguishing feature about the demand for gasoline function is that its coefficients represent a number of adjustments that occur before a change in one of the independent variables results in a change in the dependent variable.

An example of this characteristic is evident from the price of gasoline which appears in all four equations (and, of course, in the reduced form equation).

The price of gasoline affects the demand for transportation services, the demand for automobiles, the use of the automobile (miles driven) and automobile efficiency. If equation II-13 is estimated empirically, the coefficient \( e_5 \) would show the total effect of a price change on the demand for gasoline. A gasoline price change would affect the demand for transportation services, the demand for automobiles (both number and type) and the use of a previously purchased automobile. However the variable \( e_5 \) which equals \( j_2 + b_3 + c_1 - d_2 \) is simply the sum of the individual partial elasticities.

As equation II-13 is presently written, it shows the change in the demand for gasoline in period \( t \) when the price of gasoline changes during period \( t \). However, the nature of the components of the demand for gasoline is such that a change in the real price of gasoline will not necessarily have its total effect until a number of time periods have elapsed. This is primarily because durable goods have been
A solution to this problem is to introduce price expectations into equation II-13. Since this equation is simply a reduced form, however, it is necessary to re-formulate the prior equations.

Equation II-6 shows the effect of price on miles driven during the time period under examination. The appropriate price variable would be current prices. This equation, therefore, does not cause any particular problem with regard to time.

Equation II-4, on the other hand, does present complications. The decision to purchase an automobile is made at a certain point in time. But that decision then continues throughout a number of periods. The independent variables used to explain the decision to purchase an automobile should not, therefore, be current period prices and income, but prices and income anticipated to prevail throughout the period when the automobile will be used. To the extent that current and past variables, or rates of change in variables, are thought to be indicative of the future value of the variables, they would be included in equation II-4. Similarly, the equation representing the demand for transportation services generally should also include appropriate lagged variables.
Equation II-13 would, therefore, also include lagged variables. Since the decision to purchase an automobile, once made, determines to a large extent the consumption of gasoline in future periods, the variables explaining automobile demand in the period when the decision is made should be included in this equation. Thus equation II-13 could be re-formulated to account for this complication. Lagged variables for gasoline prices, incomes, and the price of automobiles would be entered into the equation.

Another means of responding to the same problem would be to separate gasoline demand into two components: one component showing the demand for miles driven given a particular automobile and gasoline price. The second component would show gasoline demand as fixed since it depends on the automobile. "Free" demand would be dependent on traditional variables of price and income, whereas fixed demand would depend on past decisions and could be represented by a portion of the past period's gasoline demand.

In summary, to estimate the demand for gasoline, two approaches could be taken. One would be to estimate each of the four equations that together explain gasoline demand. The second approach would be to simply estimate the reduced form of the equations; i.e., equation II-13. Although the first approach is theoretically more appealing, it presents enormous data problems. Therefore, a single equation reduced-form of the gasoline demand model is estimated.
III. Other Studies Of The Demand For Gasoline

A. Introduction

Within the context of the theoretical discussion in Chapter II, various econometric studies on the demand for gasoline by other analysts are discussed in this chapter.

As is evidenced by the complexity of the model discussed in the previous chapter, there are a wide variety of single-equation models that could be estimated. Each model could have some basis in the theory of the demand for gasoline without encompassing all facets of that demand. Since income and the own price of gasoline enter all four equations, the estimated coefficients of each variable could be given a wide interpretation. In addition, the analyst has a wide theoretical basis for choosing variables to be included in the \( Z_i \) vector.

A further important consideration in formulating a demand for gasoline model is the question of time. Since the theoretical discussion of a gasoline demand model recognized that all the adjustments to a gasoline price change would not necessarily occur instantaneously or even within the time period under consideration, various means of coping with adjustments over time have been considered. As a result, gasoline demand models can generally be considered as static or dynamic. Static models assume that all adjustments occur within a single time
period, whereas dynamic models assume that adjustments to changes in an independent variable occur over a number of time periods.

The models considered in this chapter provide examples of a number of problems associated with the theory of gasoline demand models. In addition, the models highlight the econometric problems common to model estimation in general and the estimation of gasoline demand models in particular.

B. Dewees, Hyndman and Waverman

In a paper in *Energy Policy*¹, Dewees, Hyndman, and Waverman (DHW) estimated five single-equation models of the demand for motor gasoline, using pooled cross-section time series data for Canadian provinces from 1956 to 1972. The basic gasoline demand function employed by DHW is:

\[
\text{GD}_t = f(P_G, Y_t, \text{URB}_t, \text{PAV}_t)
\]

The independent variables in equation III-1 have all been previously defined with the exception of URB which DHW define as the "percentage of the population which lives in urban centres with population of 10,000 or more". Although DHW suggest that $P_{AV}$ (the real price of automobiles) is important since it influences the owning of an automobile, they have defined $P_{AV}$ to be the new car price, whereas the theoretical discussion in Chapter 2 suggests that the purchase price of automobiles, whether new or used, should be included. DHW rationalize their definition of the variable by suggesting that a price increase in new cars will raise used car prices, so that new car prices can be considered a proxy for all automobile prices.

According to the previous theoretical discussion, the DHW model is mis-specified since it excludes the price of public transportation and automobile operating costs other than gasoline. The variable 'URB' which is used by DHW as a proxy for interprovincial differences in the characteristics of the gasoline using population would, however, include some aspects of the missing variables. To the extent that communities with population greater than 10,000 have more choice of public transportation services, the coefficient of URB would capture some of the components of $P_{PU}$. The exclusion of $P_{AR}$ would, however, over or under estimate the own price elasticity depending on whether

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2 Dewees, Hyndman and Waverman, p. 118.
the real costs of operating an automobile increased or decreased over the 1956 to 1972 period.

DHW employ the following log-linear static model:

\[
\text{logGD}_t = a_0 + a_1 \log P_G + a_2 \log Y_t + a_3 \log P_{AV_t} + a_4 \log \text{URB}_t
\]

DHW expect that \( a_1 \) will be negative, \( a_2 \) will be positive and \( a_3 \) will be negative. They also expect that "a greater degree of urbanization would mean a more compact set of origins and destinations and therefore a lower use of gasoline per capita"\(^3\). Thus \( a_4 \) is expected to be negative. Moreover, since the urbanization variable encompasses part of the price and availability of substitutes, \( a_4 \) will be even more negative; i.e., it will be biased downward.

Before describing the econometric results obtained by DHW in estimating equation III-2, some discussion of their independent variable is appropriate. DHW used annual net sales of highway gasoline by province in gallons per capita. This variable includes gasoline used on highways only, but for trucks and buses in addition to private automobiles. The theoretical discussion in the preceding chapter and in DHW, however, is concerned only with the use of gasoline for private automobiles. Although it is clear that this problem results

\(^3\)Dewees, Hyndman and Waverman, p. 118.
in error in the interpretation of the estimated coefficients, it is not clear what the direction of error is. It has been estimated "that trucks consume at least 20% of highway motor gasoline used"\(^4\). To determine whether the inclusion of this consumption over or underestimates the price elasticity of gasoline consumed by private automobiles, one would need to estimate the sensitivity of commercial truck owners to gasoline prices. If truck owners are less sensitive to gasoline price increases than automobile owners, including their highway consumption of gasoline would result in an underestimation of the own price elasticity of gasoline for automobile use. However, a study by Rasche, Ramsay and Allen\(^5\) (to be discussed later) estimates a higher price elasticity of the demand for gasoline by the commercial, (or trucking) sector than by the private (or automobile) sector. Thus, including the consumption of gasoline by the trucking population in the dependent variable would underestimate the price elasticity of the demand for gasoline by the private sector.

DHW run ordinary least squares (OLS) regressions on pooled cross-section, time series data for Canadian provinces over the period 1956 to 1972. For this static log-linear form, DHW present two sets of results.


The first allows a different constant term for each province but a single price coefficient for Canada as a whole. The second set of results allows a different price coefficient for each province. The following two equations present DHW's results for these two equations (t values in brackets).

(III-3) \[ \log GD = a_{NFLD} + a_{MAR} + \ldots + a_{BC} - .45 \log P_G + .83 \log Y \]
\[ (-3.4) \quad (8.0) \]
\[ - .136 \log URB - .66 \log P_{AV} \quad R^2 = .97 \]
\[ (-1.3) \quad (-5.0) \]

(III-4) \[ \log GD = a_0 - .56 \log P_G \quad (NFLD) - .43 \log P_G \quad (MAR) \]
\[ (-4.1) \quad (-3.1) \]
\[ - .45 \log P_G \quad (QUE) - .42 \log P_G \quad (ONT) - .46 \log P_G \quad (MAN) \]
\[ (-3.4) \quad (-3.3) \quad (-3.4) \]
\[ - .40 \log P_G \quad (SASK) - .40 \log P_G \quad (ALTA) - .45 \log P_G \quad (BC) \]
\[ (-2.9) \quad (-3.0) \quad (-3.4) \]
\[ + .82 \log Y - 0.13 \log URB - .67 \log P_{AV} \quad R^2 = .97 \]
\[ (7.8) \quad (-1.2) \quad (-5.1) \]
The results all show 'correct' signs and significant results except for the URB coefficient which has the 'correct' sign, but is not significant at the 95% level. There are two possible interpretations for this result. First, the consumption of gasoline may be relatively insensitive to the level of urbanization or to the price and availability of private transportation substitutes. A second interpretation of these results is that the differences among provinces with respect to urban mix are accounted for by the provincial intercepts.

Equations III-3 and III-4 suggest an own price elasticity of -.40 to -.46 for Canada and the provinces (only Newfoundland was outside this range, although not significantly different from the Canadian coefficient). Because equations III-3 and III-4 are static, it is assumed that all adjustments in gasoline consumption resulting from price changes occur in the period under study. This assumption underestimates own-price elasticity since some adjustments in gasoline consumption in response to price changes likely occur after one year.

The estimated income elasticity is significantly less than one, suggesting that gasoline is a necessity and that price increases are more burdensome on lower than higher income consumers. However the assumption of a static model in a period of rising incomes would result in an underestimation of income elasticities.
In an attempt to deal with the problem of dynamics, DHW re-estimated their static equation with a lag structure imposed on both gasoline prices and income. A four year distributed lag on price and income was imposed, with weights of 0.3 on the current and previous years, 0.25 on the third year and 0.15 on the fourth. The weights were not estimated but simply "imposed on the basis of DHW's understanding of the rate of utilization of automobiles and the composition of the fleet in terms of new and used cars".6

This distributed lag function is run, again with one equation having a single price coefficient and one with price coefficients for each province. DHW do not provide complete results for this model, but do present elasticity estimates as follows (with 't' values in brackets):

<table>
<thead>
<tr>
<th></th>
<th>CANADA</th>
<th>NFLD. TIMES</th>
<th>QUEBEC</th>
<th>ONT.</th>
<th>MAN.</th>
<th>SASK.</th>
<th>ALTA.</th>
<th>B.C.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own Price (PG)</td>
<td>-0.22</td>
<td>-0.37</td>
<td>-0.21</td>
<td>-0.19</td>
<td>-0.17</td>
<td>-0.20</td>
<td>-0.20</td>
<td>-0.20</td>
</tr>
<tr>
<td></td>
<td>(-1.5)</td>
<td>(-2.5)</td>
<td>(-1.4)</td>
<td>(-1.3)</td>
<td>(-1.2)</td>
<td>(-1.4)</td>
<td>(-1.3)</td>
<td>(-1.1)(-1.3)</td>
</tr>
<tr>
<td>Income (Y)</td>
<td>+0.91</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(7.4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>URB</td>
<td>-0.49</td>
<td></td>
<td>-0.47</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-4.5)</td>
<td></td>
<td>(-4.3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TV</td>
<td>-0.70</td>
<td></td>
<td>-0.70</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-5.1)</td>
<td></td>
<td>(-5.1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>0.98</td>
<td></td>
<td>0.98</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6Dewees, Hyndman and Waverman, p. 119.
There are a number of important differences between these results and those of equations III-3 and III-4. First, the increase in income elasticity supports the hypothesis that the static equation underestimated income elasticity.

Second, all the price coefficients (except Newfoundland's) are insignificant at the 95% confidence level. DHW do not present the results for the individual lag coefficients so it is not possible to determine which are significant and which are insignificant. The insignificance of the price coefficients suggests that the lag structure imposed on the model is inappropriate.

The price coefficients do, however, suggest that the long term price elasticity, estimated from a dynamic equation, is lower than the short term price elasticity estimated from a static equation. This result is implausible. Even if the initial impact of a price change is stronger than the longer term adjustments that are made in response to the change, long run elasticity cannot be less than short run elasticity. If consumers simply adjust their current driving habits in response to a price change and do not change their pattern of new car purchases or if expectations of future price changes differ from past price patterns, then the long run elasticity could be equal to the short run elasticity but not less.

7McGuire, F., (op. cit.) suggests that the DHW lag structure is inappropriate since truck utilization was not considered and since other evidence suggests that a four-year lag is too short.
Third, there still seems to be no significant difference between the price coefficients of each province and of Canada as a whole (with the exception of Newfoundland).

Although the coefficient of the $P_{AV}$ variable was virtually unchanged from the static to the distributed lag model, the coefficient of the URB variable increased (in absolute value) and became highly significant. It is not clear what has caused this change. To the extent that 'URB' includes the availability of public transportation alternatives to the automobile, its more pronounced significance may reflect a lag in the switch to public transportation as a result of gasoline price increases (or, in a period of relative gasoline price declines, a switch from public transportation to private transportation).

A third model (also dynamic) employed by DHW utilizes the concept of 'free demand'. Since the stock of motor vehicles is an important component of gasoline demand, gasoline consumption does not move 'freely' with changes in income and price. Only a certain proportion of current gasoline consumption (that proportion not determined by previous purchase of automobiles) "is free to adjust according to current prices and incomes"8. The problem here, however, is to determine what proportion of current gasoline consumption is "free" to adjust and what proportion is tied to previous purchases of

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8Dewees, Hyndman and Waverman, p. 119.
automobiles. The best solution to this problem would be, of course, to estimate the proportion using equations discussed in Chapter 2. DHW, however, simply made an assumption that "because of retirement from the fleet and decreased use with increasing age, current gasoline consumption by those cars remaining from the previous year's fleet will be only 80% of the previous year's consumption". Besides the arbitrariness of this assumption and the lack of any quantitative back-up, DHW also implicitly assume that owners of automobiles will not change their use of automobiles i.e., their gasoline consumption, when a change in prices or incomes occur. Certainly past purchases of automobiles to a large extent determine current gasoline consumption, but consumption is not completely fixed. Consumers do have some freedom to vary their driving habits and hence their gasoline consumption despite past automobile purchases.

Despite these criticisms, the "free" demand model does make an attempt to include a dynamic element in the demand for gasoline. Long term elasticities are estimated directly from the equation while short term elasticities, given DHW's assumption, are one-fifth the long term elasticities. DHW employ the following model:

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9 Dewees, Hyndman and Waverman, p. 119.

10 McGuire, op. cit, also criticizes the assumption that 20% of gasoline consumption is free to adjust to current prices and income, but for the reason that it is "out of line with the available data".
\[ (III-5) \quad \log GF_t = a_0 + a_1 \log PG_t + a_2 \log Y_t + a_3 \log PAV_t + a_4 \log URB_t \]

Where GF is free demand (quantity sold in the current year less 80% of the quantity sold in the previous year).

The following results are obtained:

<table>
<thead>
<tr>
<th>Country</th>
<th>CANADA</th>
<th>NFLD.</th>
<th>MARI-</th>
<th>QUE.</th>
<th>ONT.</th>
<th>MAN.</th>
<th>SASK.</th>
<th>ALTA.</th>
<th>B.C.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own Price</td>
<td>-0.26</td>
<td>-0.44</td>
<td>-0.27</td>
<td>-0.24</td>
<td>-0.20</td>
<td>-0.25</td>
<td>-0.25</td>
<td>-0.21</td>
<td>-0.24</td>
</tr>
<tr>
<td>Income</td>
<td>0.69</td>
<td></td>
<td>0.69</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(7.7)</td>
<td></td>
<td>(7.0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>URB</td>
<td>-0.46</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.44</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-4.4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(4.3)</td>
<td></td>
</tr>
<tr>
<td>PAV</td>
<td>-0.93</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.92</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-7.5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(-7.5)</td>
<td></td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.98</td>
<td></td>
<td>0.99</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

These results are similar to those obtained previously by DHW although the income elasticity is lower and the effect of a change in automobile prices on gasoline consumption is more pronounced. Long term price elasticities (excepting Newfoundland) are in the order of -0.25 while short term elasticities are -0.05.
In this 'imposed' model, DHW explicitly argue that short term price elasticities are less than long term price elasticities (one-fifth the size). This hypothesis, however, contradicts the results obtained by DHW in their model using a four year distributed lag. The theoretical discussion in Chapter II also argues that long term price elasticities are higher than short term elasticities because, in the long term, consumers can make more adjustments to their consumption in response to price changes.

DHW's two other equations are modeled after other studies. Their results will be discussed at the same time as the relevant study.

C. **Energy Mines and Resources**

Energy Mines and Resources (EMR)\(^\text{11}\) estimated, as part of their long term energy forecast, an equation for the quantity of motor gasoline for road transportation. Unfortunately their gasoline consumption statistics included consumption for off-highway as well as on-highway use. Moreover, gasoline consumption data included commercial use as

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well as private use of gasoline. For these two reasons, the EMR model is not strictly comparable to the model discussed in Chapter II unless it is assumed that off-road and commercial on-road consumption of gasoline are explained in the same way as private on-highway use of gasoline.

EMR's "preferred" log-linear equation is of the following form:

\[
\log_{\text{RMV}} GD_t = a_0 + a_1 \log Y_t + a_2 \log PG_t + a_3 \log \frac{C}{HH_t} + a_4 \log \frac{C}{RMV_t}
\]

Rather than gasoline demand per capita, the dependent variable in equation III-6 is gasoline demand per registered motor vehicle (excluding motorcycles). An equation using gasoline consumption per vehicle as an independent variable is more useful in explaining gasoline consumption given the number of automobiles i.e., the amount of driving done per vehicle, than total gasoline consumption. This model, therefore, likely underestimates price elasticities since it ignores gasoline consumption resulting from purchases of cars during the period.
A comparison of equation III-6 with equation II-13 indicates a number of differences. First, equation III-6 excludes a number of variables included in the theoretical formulation of equation II-13. Although the cars per household term (C/HH) could be considered a 'Z' variable in the sense that an individual's consumption per vehicle is affected by the number of vehicles owned, EMR presents no theoretical justification for the inclusion of the cars per registered motor vehicle variable (C/RMV). It is unlikely that an individual's decision to consume gasoline is affected by the proportion of automobiles in the total stock of motor vehicles. Of course, EMR require such a variable in order to correct for including commercial consumption of gasoline in their definition of the dependent variable. Moreover, the variable might reflect inter-provincial differences in gasoline consumption.

The automobiles per household variable recognizes "the potential limits of the number of driving tasks per family, as well as the different tasks which more than one car may be required to perform". EMR's hypothesis is that the amount of gasoline consumed per vehicle declines as the number of automobiles per family increases i.e., $a_3$ is negative.

The term "C/RMV" is intended to allow "for differing driving patterns and efficiencies between the car and truck populations". This

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variable compensates to some extent for the inclusion of commercial gasoline consumption in the dependent variable. EMR has no a priori expectation of the sign of $a_4$. "To the extent that cars get better mileage and drive fewer miles, a negative coefficient could be expected. On the other hand, because a significant proportion of trucks use diesel rather than gasoline, the relationship might be positive"\(^{14}\). Besides the obvious uncertainty associated with this hypothesis, allowing any result to justify inclusion of the variable, the hypothesis suffers from the added problem that each factor might offset the other. Thus $a_4$ might be insignificant although each factor may be important in explaining gasoline consumption per vehicle. The solution would be, of course, to separate the C/RMV variable into its two components: cars per registered motor vehicle using gasoline only, and a term for vehicles using diesel only. Alternatively, statistics on relative fuel efficiencies as between trucks and cars and on the proportion of trucks using diesel could be used to make an estimate of the sign of $a_4$.

EMR's results, based on data over the period 1958 to 1972 on a pooled, cross-section, time-series basis, are as follows (with 't' values in brackets).

\(^{14}\)Energy, Mines and Resources, p. 38.
(III-7) \[ \ln \left( \frac{\text{GD}}{\text{RMV}} \right) = 3.07 \text{ ALTA} + 2.94 \text{ QUE} + 2.87 \text{ ONT.} + 3.25 \text{ PRA} \]
\[ (6.90) \quad (5.94) \quad (5.63) \quad (5.79) \]
\[ + 2.79 \text{ B.C.} + .48 \ln Y - .28 \ln \text{PG} - .62 \ln \text{C/HH} \]
\[ (15.2) \quad (8.44) \quad (-2.56) \quad (-8.07) \]
\[ + 1.24 \ln \text{C/RMV} \quad \text{R}^2 = .922 \]
\[ (4.59) \]

These results indicate that all variables are significant. All coefficients represent long term elasticities.

Equations III-6 and III-7 are static equations, but since they do not reflect the effect of changes in vehicle ownership on total gasoline consumption, this is likely not a serious problem. It is more reasonable to assume that decisions to adjust gasoline consumption per automobile will be taken in the current period than will decisions to make changes in total gasoline consumption.

The EMR model, therefore, is of limited use in explaining total gasoline consumption. It is of more value in explaining gasoline consumption per vehicle derived from changing driving habits.
D. Ramsay, Rasche and Allen (RRA)

RRA presented a model separating the demand for gasoline into its private and commercial components\(^{15}\). Although most studies are concerned with only the demand for gasoline by private users, the RRA study is one of the few that make this division explicit.

Another innovation in the RRA model is that it includes an equation explaining the supply side of the gasoline market. A third difference between RRA and other studies is their specification of the form of the demand equation. RRA's model does not assume, as in the case of log-linear equations, that elasticities are constant. Rather RRA specify a form whereby "each elasticity is a function only of the relevant variable"\(^{16}\).

RRA's accepted form of their equation for the private demand for gasoline is as follows:

\[
\frac{G_{D}}{H_{Ht}} = a_0 \exp \left( a_1 p_{Gt} + a_2 p_{PUt} + a_3 t_{Pt} + a_4 y_{t}^{-1} \right)
\]

\(^{15}\) J. Ramsay, R. Rasche and B. Allen op cit.

\(^{16}\) Ramsay, Rasche, Allen, p. 502.
The only variable in equation III-8 not previously defined is \( t_p \) - the proportion of the population in the 16-24 year age group.

Equation III-8 ignores the prices of complements but does include a term to represent the price of substitutes. RRA's price of public transportation (\( P_{Py} \)) is a price index of "passenger trains, mainly commuter lines". This index does not include all public transportation alternatives, but it is useful in the sense that it includes substitutes for both inter and intra city travel.

The term \( t_p \), representing the "proportion of the population in the 16-24 age group, is included to reflect the life-cycle consumption effects of a significant shift in the age distribution of the population over the period of the study". \( t_p \) can be considered a "Z" term since each household (RRA's gasoline consuming unit) would be assumed to have the same proportion of 16-24 year olds as the population as a whole. RRA do not speculate a priori on the sign of the coefficient of the \( t_p \) variable and it would depend on the extent to which this age group consumes gasoline at a rate greater or less than the average population. RRA seem to be implying that the 16-24 age group affects gasoline consumption per household in a different way from other age groups. An alternative formulation would be to estimate the per capita gasoline consumption of this group separately from the other age groups.

The form of RRA's regression equation implies that price elasticity increases with increasing prices and that income elasticity decreases as income increases. Both of these assumptions appear reasonable. It should be noted that $a_4$ is expected to be negative since the inverse of income is the independent variable.

RRA use a two-stage least squares (2SLS) approach since they are estimating an over-identified model\textsuperscript{19}. U.S. national data to 1969 is used (the beginning point is not stated).

The results of their private demand for gasoline equation are as follows:

\[(III-9) \quad (GD_{HH}) = 2.047 \exp (-.222 PG + .117 P_{PU} - 4.084 tp \\
\quad \quad \quad (-1.82) \quad (1.49) \quad (-4.74) \\
\quad - 1.078 Y^{-1} \\
\quad (-11.75)\]

At the 1969 levels of prices and incomes, these results give a long term own price elasticity of -.70, an income elasticity of 1.15 and a train travel elasticity of -.38. Since 1969 the real values of both price and income have risen so that, according to RRA, income elasticity has fallen and price elasticity has risen.

\textsuperscript{19}Ramsay, Rasche and Allen, p. 503.
Although not of particular relevance in this paper, the corresponding elasticities for the commercial demand for motor gasoline are -2.8 for own price, 2.6 for the price of diesel fuel and 1.24 for income. These results suggest that including some commercial demand for gasoline in the equation will overestimate the own price elasticity of the private demand for gasoline.

The RRA model is static in the sense that gasoline market equilibrium is assumed to be achieved within one year. RRA, however, perform a test to determine "the adequacy of the static model against an alternative dynamic formulation". Their method is to compare their model with a dynamic model and test for specification error. Although the test leads RRA to conclude that there is little evidence against a static model, the test assumes that the dynamic model tested is correctly specified. The RRA conclusion that the static model is appropriate should be limited to the statement that the majority of adjustments in gasoline consumption occur within one year.

DHW also estimate a static form similar to RRA. Their comparable equation (with variables defined as previously) is:

20 Ramsay, Rasche and Allen, p. 505.
\[
(III-10) \quad \log \left( \frac{GD}{POP_t} \right) = a_0 + a_1 PG_t + a_2 Y_t^{-1} + a_3 URS_t + a_4 PAV_t
\]

DHW's results, using OLS for pooled, cross-section time series data are as follows:

<table>
<thead>
<tr>
<th></th>
<th>CANADA</th>
<th>NFLD.</th>
<th>MAR.</th>
<th>QUE.</th>
<th>DNT.</th>
<th>MAN.</th>
<th>SASK.</th>
<th>ALTA.</th>
<th>B.C.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own Price</td>
<td>-.011</td>
<td>-.018</td>
<td>-.009</td>
<td>-.013</td>
<td>-.009</td>
<td>-.013</td>
<td>-.005</td>
<td>-.007</td>
<td>-.012</td>
</tr>
<tr>
<td></td>
<td>(-3.6)</td>
<td>(-4.3)</td>
<td>(-2.4)</td>
<td>(-4.1)</td>
<td>(-3.2)</td>
<td>(-3.7)</td>
<td>(-1.3)</td>
<td>(-2.0)</td>
<td>( -3.6)</td>
</tr>
<tr>
<td>Income (I/Y)</td>
<td>-.92</td>
<td></td>
<td>-.90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-8.6)</td>
<td></td>
<td>(-8.0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>URB</td>
<td>.05</td>
<td></td>
<td>.15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(.03)</td>
<td></td>
<td>(0.60)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAV</td>
<td>-.009</td>
<td></td>
<td>.009</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-6.9)</td>
<td></td>
<td>(7.1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(R^2)</td>
<td>.97</td>
<td></td>
<td>.97</td>
<td></td>
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</tbody>
</table>

\(^{21}\)DHW's summary of results, p. 121, show a coefficient of opposite sign to the equation with one price coefficient for all of Canada.
The elasticities at the 1972 levels of the variables are:

<table>
<thead>
<tr>
<th></th>
<th>CANADA</th>
<th>NFLD</th>
<th>MAR.</th>
<th>QUE.</th>
<th>ONT.</th>
<th>MAN.</th>
<th>SASK</th>
<th>ALTA</th>
<th>B.C.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own Price</td>
<td>-.44</td>
<td>-.83</td>
<td>-.36</td>
<td>-.48</td>
<td>-.36</td>
<td>-.47</td>
<td>-.21</td>
<td>-.26</td>
<td>-.44</td>
</tr>
<tr>
<td>Income</td>
<td>.37</td>
<td></td>
<td>.36</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>URB</td>
<td>.03</td>
<td></td>
<td>.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAV</td>
<td>.67</td>
<td></td>
<td>.67</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In general, the own-price elasticities of the RRA functional form of the DHW model are greater (in absolute value) than the "free demand" model and the distributed lag model and similar to DHW's static model. Since 1972, the real price of gasoline has increased so that price elasticities based on the RRA form have increased.

Income elasticities are significantly lower than other models presented by DHW following from the RRA assumption that income elasticity decreases as real income increases. This result is imposed rather than estimated.

The elasticity of the PAV variable is similar to the results of the previous DHW models, but the URB coefficients have now become insignificant (although they have the same sign as DHW postulated).
E. Houthakker, Verleger and Sheehan (HVS)

The HVS model\textsuperscript{22} is typical of the flow-adjustment model where "the stock of energy-using capital is assumed to be fixed over the short run, and the utilization of it is assumed to be a function of normal economic influences\textsuperscript{23}. HVS assume individuals have a 'desired demand' for gasoline that is a function of income and price. A simple adjustment process describes the movement from actual consumption to the desired level of consumption:

\begin{equation}
\frac{Q_{it}}{Q_{i,t-1}} = (Q_{it}^{*}/Q_{i,t-1})^{\theta}
\end{equation}

where $Q_{it}^{*}$ is desired demand by individual $i$ in period $t$ and $0 < \theta \leq 1$. Thus, for HVS the estimating equation becomes:

\begin{equation}
\log \frac{GD_{t}}{POP} = \theta \log a_{0} + \theta a_{1} \log PG_{t} + \theta a_{2} \log Y_{t}
\end{equation}

\begin{equation}
+ (1-\theta) \log \frac{GD_{t-1}}{POP}
\end{equation}

The coefficients $\theta a_{1}$ and $\theta a_{2}$ are the short term elasticities while $a_{1}$ and $a_{2}$ are the long term elasticities which are larger (in absolute value) than the short term ones.

\textsuperscript{22}H.S. Houthakker, Philip K. Verleger, Jr., Dennis P. Sheehan "Dynamic Demand Analyses for Gasoline and Residential Electricity" \textit{American Journal of Agricultural Economics} - May 1974.

\textsuperscript{23}Houthakker, Verleger and Sheehan, p. 413.
The HVS model is only an approximation to the dynamic model which should include the stock of energy-using capital explicitly. In addition, the model does not stipulate the length of the adjustment process. Finally the HVS model excludes the prices of both substitutes and complements which also affect the desired level of demand.

HVS tried a number of estimating techniques but settled on the error component (or variance component) technique for a cross-section time-series of quarterly U.S. data from 1961 to 1971 for 48 states. The fitted equation that HVS obtain is: ('t' values in brackets).

\[
(\text{III-13}) \log \frac{GD_t}{POP} = 0.593 - 0.075 \log P_G + 0.303 \log Y_t + 0.696 \log (\frac{GD_{t-1}}{POP})
\]

\[
(18.5) (-5.8) (17.8) (36.6)
\]

The short term own price elasticity is -.075 (short term is 3 months since HVS use quarterly data). Income elasticity is .303 in the short term. Over the long term price and income elasticities are estimated at -.24 and .98 respectively.

DHW also estimate an equation similar to the HVS model:

\[
(\text{III-14}) \log \frac{GD_t}{POP} = a_0 + a_1 \log P_G + a_2 \log Y_t + a_3 \log \frac{GD_{t-1}}{POP}
\]
The results for the estimated equation are unsatisfactory; all price coefficients are insignificant and have the wrong sign. The short and long term income elasticities are .24 and 1.7 respectively. (For DHW, the short term is one year.)

F. The National Energy Board (NEB)

As part of their forecasting responsibilities, the NEB has constructed a model for forecasting gasoline demand by passenger automobiles. The NEB model consists of five parts which, when combined, fit into the following standard equation:

\[ (III-15) \quad GD = \frac{A \times M/A}{A_E} \]

Where A is the number of passenger automobiles, M/A is miles travelled per automobile and \( A_E \) is efficiency of automobiles measured in miles per gallon.

This model has the advantage that it separates the individual components that determine the demand for gasoline, in turn permitting the model to be more applicable for determining policy. It is not, however, possible to determine total elasticities from the NEB model.

---

In summary, the model first estimates sales of new passenger cars. Second, new car sales are divided into large and small categories. Third, new sales of large and small size cars are added to the estimated stock at the beginning of the year. Fourth, the miles travelled for each category of automobile are estimated. The final step is to estimate the miles travelled in urban and non-urban areas. The automobile fuel economies for urban and non-urban travel are determined exogenously.

1) New Car Sales

The NEB's formulation of new car sales is as follows:

\[
(III-16) \quad \frac{NA}{POP_t} = f \left( \frac{PAV_t}{Y_t}, S_t, U_t, PG_t, \frac{A_{t-1}}{POP_{t-1}} \right)
\]

Equation III-16 specifies that new car sales per capita (NA/POP) are a function of the real price of new cars (PAV) divided by real per capita disposable income (Y), a supply constraint (S - representing man-days lost in strikes), the unemployment rate (U), the real price of gasoline (PG) and the lagged stock of cars per capita (A/POP)_{t-1}. 
There are three problems associated with equation III-16. First it excludes the price of substitutes. The exclusion of a variable representing the price and availability of public transportation is compounded by the fact that the NEB also excludes the price of used cars from their new car sales equation. This variable is a more perfect substitute than a public transportation variable and should be included in any equation attempting to estimate new car sales.

A second problem is that the definition of the own price variable should include operating costs as well as purchase price. The NEB's model does separate one component of operating costs (the price of gasoline) but ignores others.

The third problem is the inclusion of the lagged stock of automobiles. The NEB does not specify the theoretical reason for its inclusion but it could be considered a 'Z' variable assuming that an individual's decision to purchase a new car depends in part on previous ownership; i.e., replacement demand.

The NEB's results obtained from a linear equation using OLS techniques on data for seven Canadian regions over the period 1966 to 1975 follow:
Estimated in the NEB's equation, but excluded from equation III-17, are intercepts for each region and two dummy variables to accommodate for "some erratic observations for the Atlantic Provinces and Saskatchewan, for years 1969 - 1970 and 1969 - 1971, respectively".25

The NEB calculates an own price elasticity from the above equation of -.163 (assuming PG at the historical mean). The elasticity of new car purchase with respect to gasoline prices is estimated at -.49 - implying that a 10% increase (fall) in real gasoline prices decreases (increases) new car sales by 5%.

The elasticity of -.49 is based on the means of the variables; as the real price of gasoline increases the elasticity will also increase (in absolute value). The implication of this elasticity is that individuals faced with rising gasoline prices either purchase used cars (affecting

\[
(III-17) \quad \frac{NA}{POP} = -0.00413 \frac{PAV}{Y} - 0.000938 U - 275 \times 10^{-9} S - 0.000422 PG \\
\quad (-1.75) \quad (-3.10) \quad (-5.73) \quad (-2.10)
\]

\[+ 0.0799 \frac{A_{t-1}}{POP_{t-1}} \quad R^2 = 0.908
\]

\[(5.45)\]

25 National Energy Board, p. 4.
scrappage rates), utilize public transportation (which may utilize gasoline in another form), keep their present automobile or forego transportation services. The fact that automobiles purchasers are more responsive to gasoline price changes than to automobile price changes seems surprising. It implies that purchasers of new cars are insensitive to its price (i.e., that the 'newness' of the automobile is more important than its price), but that new car purchasers are not insensitive to gasoline prices.

The NEB does not state the income elasticity resulting from equation III-17.

2) Large and Small New Car Sales:

After estimating new car sales, the market share of large and small cars is estimated using an equation relating the market share of large automobiles to the unemployment rate (U), the proportion of females in the labour force \( \frac{F}{LF} \), the ratio of the real price of small cars to large cars \( \frac{PSA}{PLA} \), the ratio of the weighted average fuel economies of small and large cars \( \frac{AES}{AEL} \), real gasoline prices (PG) and the market share of large cars in the previous period \( \frac{LA}{NA}_{t-1} \).
The NEB postulates that all coefficients are negative except the ratio of the real price of small cars to large cars (PSA/PLA). These expectations seem reasonable, a priori, if one accepts the proposition that females and males have different demand functions for their choice of large or small cars, although it would be more useful to test this proposition directly.

The NEB gives no reason for excluding income from the equation estimating market shares of automobiles. The unemployment rate may serve as a proxy for general incomes, but it is reasonable to suppose that an individual's choice of a small or large car depends at least partly on household income. The NEB also gives no reason for including the lagged dependent variable. There may be some possibility that there is habit formation in the purchase of large automobiles, but the NEB presents no evidence to support it.

Again the NEB estimated a linear equation for seven Canadian regions over the 1966 to 1975 period. Their results are shown in the following equation (excluding provincial intercepts).
\[
\begin{align*}
(III-18) \quad \frac{LA}{NA} &= -0.0108 U -0.429 \frac{F}{LF} + 0.460 \frac{p_{SA}}{p_{LA}} - 0.000826 \frac{AES}{AE_L} \times PG \\
&\quad + 0.285 \frac{LA}{NA_{t-1}} \\
&\quad (-3.35) (-1.00) \quad (3.96) \quad (-.77) \\
&\quad R^2 = .966 \\
&\quad (3.28)
\end{align*}
\]

Although all coefficients have the hypothesized sign, the coefficients of the proportion of females in the labour force and the ratio of fuel economies are insignificant at the 95% level. Because of the way in which the price of gasoline is incorporated in equation III-18, its coefficient is also insignificant.

The explanation given for including gasoline price in a multiplicative form with the ratio of fuel economies is that "attempts to include it separately were unsuccessful"\textsuperscript{26}. The implication of this form is that "the higher is the gasoline price, the higher is the percentage reduction in the market share of large models in response to a given percentage improvement in the fuel economy of small models relative to large sizes"\textsuperscript{27}. Although this is a reasonable hypothesis, it is one that should be tested rather than imposed on the model.

\textsuperscript{26}National Energy Board, p. 8.

\textsuperscript{27}National Energy Board, p. 8.
The NEB also indicate that with the exclusion of the variable, "proportion of females in the labour force", the coefficient of relative fuel economies and gasoline prices becomes even less significant (although the sign remains negative). If insignificant coefficients are eliminated, the NEB's equation explaining the market share of large cars is reduced to a function of only the unemployment rate, the ratio of large and small car prices and last period's market share of large automobiles. The NEB's results do not support the hypothesis that real gasoline prices, the proportion of females in the labour force and the ratio of fuel economies explain changes in the market shares of large automobiles no matter how theoretically appealing their inclusion is. There are three possible explanations for these results. First these variables may not, in fact, influence the market share of large automobiles. A second possibility is that the formulation of the market share equation is incorrect. A third explanation is that weighted average fuel economies are not exogenous variables. They are determined by, rather than determine, the sales of large and small automobiles.

Despite the inadequacies of the NEB's results, the conclusions regarding elasticities are of interest. Following the analysis of HVS, equation III-18 gives both short and long term elasticities. Short term elasticities are calculated directly from the coefficients, while long term elasticities are calculated by dividing the short term elasticities by one minus the coefficient of the lagged variable. (The short-run is
considered one year.) The following table gives short and long run elasticities (calculated at the mean) for each of the important variables.

<table>
<thead>
<tr>
<th></th>
<th>SHORT RUN</th>
<th>LONG RUN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unemployment</td>
<td>-.10</td>
<td>-.14</td>
</tr>
<tr>
<td>Proportion of females in the labour force</td>
<td>-.25</td>
<td>-.35</td>
</tr>
<tr>
<td>Relative prices</td>
<td>.60</td>
<td>.84</td>
</tr>
<tr>
<td>Gasoline price</td>
<td>-.10</td>
<td>-.14</td>
</tr>
</tbody>
</table>

The results indicate that a gasoline price change has little effect on the market shares of small and large automobiles. However, the linear form of equation III-18 implies that as real gasoline price rises its elasticity will increase. The combined results of equation III-17 and III-18 indicate that a 10% increase in gasoline prices reduces new car purchases by 5% and reduces the market share of new large automobiles by 1.4%.

The effect of these results on gasoline consumption is unclear. A lowering of the market share of new large automobiles reduces gasoline consumption by the difference in fuel economies between large and small cars (assuming that the number of miles driven is the same for each class of automobile). It is less clear what the effect of lowering total new car sales has on gasoline consumption since would-be purchasers of new cars have other alternatives, some of which utilize...
gasoline.

3) **Scrappage Rates**

After estimating new car sales and the market shares of new large and small automobiles, the NEB model estimates scrappage rates (one minus survival rates) to determine the stock of automobiles at the beginning of the year. New car sales (which are assumed to have a 0% scrappage rate in the first year) were then added to this estimated stock to arrive at the total automobile stock. The same scrappage (survival) rates were assumed to apply to both small and large automobiles. The NEB was unable (mainly due to data limitations) to estimate an equation using economic variables such as income, prices and fuel economies to explain scrappage rates. After some experimentation, scrappage and survival rates were estimated based on an American study relating the probability of survival of a vehicle to the mean life and age of the vehicle. Again, no economic variables were included in this equation.

4) **Miles Travelled**

In Chapter II, it was hypothesized that miles travelled, given the possession of an automobile, would be a function of income, the variable costs of operating a vehicle (in particular the price of gasoline), the price of public transportation and variables (relating to tastes and
preferences) unique to utilizing an automobile such as type of work, social activity, etc. The NEB, however, based its estimate of annual mileage per automobile on an unpublished Environment Canada survey relating mileage travelled only to the age of the automobile. One equation was estimated for each of four size categories and summed to obtain equations for large and small sized cars. The $R^2$ for the equations ranged from .57 to .80; no t-values were given.

This formulation assumes, naively, that the use of the automobile depends only upon the age of the car and that other factors have no influence. Again, data limitations are the main reason for not estimating a more sophisticated equation.

5) **Fuel Economies**

Here again, the NEB's model did not include an econometric relationship for fuel economies. The NEB simply used Environment Canada survey results. These results showed different fuel economies for urban and non-urban travel. The NEB, therefore, made an estimate of the proportion of urban and non-urban miles travelled. Weighted average fuel economies were then derived for both small and large automobiles. Although data limitations make estimating a more theoretically appealing equation difficult, failure to correlate estimates of fuel economies with economic variables makes forecasts of efficiencies relatively arbitrary.
The NEB's model of gasoline demand is used for forecasting purposes. Any comments on the model should center on its success or failure as a forecasting tool. The model does not lend itself to theoretical analysis - total income and price elasticities are unavailable. The most serious criticism of the NEB model is its failure to relate miles travelled per automobile to income and the price of gasoline. Even in equations where the price of gasoline is used as an explanatory variable, it is unclear as to the effect of a price change on gasoline consumption.

G. Burright and Enns (B-E)

In a study prepared under the auspices of the Rand Corporation, B.K. Burright and J.H. Enns attempt to estimate a complete model of the demand for motor gasoline²⁸.

The B-E study dichotomizes the analysis into its short and long term components. In the short term, automobile ownership is assumed fixed - gasoline consumption can be varied only by changing driving habits.

or by driving fewer miles. In the long-run, changes in gasoline prices manifest themselves in changes in automobile ownership which, in turn, affect gasoline consumption.

1) **Short-run Analysis**

"The short-run is defined as the period in which the size and fuel efficiency characteristics of the automobile stock do not change". In this short-run analysis, B-E estimated equations that provide an estimate not only of the total elasticity of a price change with respect to gasoline consumption, but also the elasticity of a price change with respect to gasoline consumption holding automobile efficiency (miles per gallon) constant. This elasticity measures the decrease in automobile use as a result of a gasoline price increase (what B-E call the "scale" effect) as opposed to changes in driving habits which result in changes in automobile efficiency.

The other component of the total price elasticity estimated by B-E is the elasticity of fuel consumption with respect to automobile efficiency (holding prices constant) multiplied by the elasticity of automobile efficiency with respect to gasoline price changes. This "substitution" effect measures the changes in driving habits which manifest themselves into changes in automobile efficiency. The changes in driving habits consist (according to B-E) of substituting time for fuel (when gasoline

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29 Burright and Enns, p. 3.
prices increase) by slowing highway speeds, for example. B-E hypothesize that these changes in driving habits result in improvements in the miles per gallon efficiency of automobiles.

B-E's basic short-run model is that gasoline consumption is a function of the real price of gasoline (PG), real non-wage income per capita (Y), the real wage rate (W), time available (T) and the real value of vehicle services (PA).

\[
(III-19) \quad GD_t = F(PG_t, Y_t, W_t, T_t, PA_t)
\]

The wage rate is included in the model as a measure of the time spent in substituting more efficient (but time consuming) driving habits for gasoline.

In their short-run analysis, B-E estimated this model using two different sets of data. One set was pooled-time series data of U.S. States from 1955 to 1970. The other was national (U.S.) time series data for 1954 to 1972.

Using the first set of data, B-E estimated a number of different equations and employed different econometric techniques. The results of their two most preferred cases are as follows (both using generalized least squares and log-linear forms).
Before discussing the results, a number of clarifications are required. Equations III-20 and III-21 differ from B-E's basic short-run model (equation III-19) in a number of ways. First, B-E were unable to obtain a consistent measure of the wage rate and used personal disposable income as a proxy for wage and non-wage income. Vehicle registrations per capita (A/POP) were used as a proxy for the value of vehicle services.

Based on their theoretical formulation, B-E's dependent variables should have been fuel used by automobiles. The dependent variable used, however, was motor fuels to operate vehicles on highways. To compensate for differences among states with differing composition of motor vehicles, the percent of vehicles registered as trucks or buses (PT) was used.
B-E constructed their own series of average automobile efficiency by state \((A_E)\) based on unpublished survey results.

Equation III-20 shows the total own-price elasticity is \(-.25\). This price elasticity measures the total change in fuel consumption when gasoline prices change and includes adjustments in both vehicle miles driven and automobile efficiency.

The price coefficient in equation III-21 represents the partial price elasticity obtained when automobile efficiency (or driving habits) remain unchanged. To obtain total price elasticity, the partial elasticity of fuel consumption to automobile efficiency \((-0.78)\) times the elasticity of efficiency with respect to fuel prices must be added to the partial price elasticity (holding \(A_E\) constant) of \(-.22\). B-E estimate another equation to obtain the effects of changes in automobile efficiency resulting from changes in prices.

\[
\text{log } A_E = 2.2 + 0.058 \text{ log } PG - 0.001 \text{ log } Y/POP - 0.06 \text{ log } PT
\]

\[
(21.2) (11.2) \quad (-3.8) \quad (-1.9)
\]

\(R^2 = 0.30\)
The results of this equation suggest that a 10% increase in the price of gasoline results in a .58% increase in automobile efficiency. Equation III-22 is, however, marred by the low fit, suggesting that even though the sign and t-value of the price variable are adequate, there are other variables which need to be included.

In any event, total price elasticity can be calculated by adding the partial price elasticity of -.22 to -.78 times .058 yielding -.265, which is very similar to the results in equation III-20. This conclusion suggests that a 10% increase in the price of fuel yields a (short-run) gasoline decrease of 2.6%, consisting of two components: a reduction in miles driven of 2.2% (or 85% of 2.6) and an increase in automobile efficiency (resulting from changing driving habits) of 0.4% (or 15% of 2.6).

The B-E estimates of short term (one year) income elasticity (0.18) is low compared to previously discussed studies. However, the authors suggest that since per capita vehicle registration is highly correlated with per capita income, "the income variable has partially captured the effects of vehicle ownership on fuel use"30.

There are a few qualifications necessary to the B-E results. First, their dependent variable contains other fuels besides gasoline. To the extent possible, some gasoline consumers faced with a gasoline price increase will substitute diesel fuel for gasoline. The gasoline price elasticity therefore, may be slightly underestimated. This error is probably small since diesel and gasoline prices move together closely and because, in the short-run, consumers have little flexibility to switch from one fuel to another.

A second qualification is with respect to fuel efficiency. B-E attribute all the increases in fuel efficiency to changes in driving habits over the short term (one year). In fact as gasoline prices increase, there will be increasing purchases of more fuel-efficient cars. Some of these purchases would occur within the year period.

Again, the B-E equation estimating the change in fuel efficiency resulting from fuel price changes (equation III-22) must be qualified due to its low fit.

Using the other set of data (national time series) B-E reported the results of 33 equations, utilizing different definitions and combinations of the variables set out in the basic short-run model (equation III-19).
Basically, B-E estimated one set of equations to estimate total elasticities excluding automobile efficiency (comparable to equation III-20). A second set of equations explains automobile efficiency (comparable to equation III-22). Finally, a set of equations comparable to equation III-21 was estimated. B-E do not state which of each set of equations is preferred. However, from various comments they make, three equations can be considered typical of their results.

Before reporting the results of these three equations, the following general comments can be made. First, fuel consumption and number of vehicle registrations was expressed in terms of driving age population in addition to households and total population since driving age population accounted for changes in age composition over the time period under study. Moreover, B-E found that the change in age composition had an effect on gasoline consumption. In fact, they obtained a higher price elasticity normalizing over driving-age population than over households or total population.

The time variable of equation III-19 was dropped since B-E hypothesized that the available time for household activity and work was constant over the period and would not account for changes in fuel consumption. Automobile stock (A) was substituted for the value of automobile services due to lack of data. Although wage rate data were available, non-wage income was not and was deleted.
B-E did not obtain satisfactory results for the equation including wage rates. In one form of their model, (the one discussed here) they used the ratio of fuel price to the wage rate (PG/W), restricting the effect of a change in the average wage rate to the same value but opposite sign of the effect of a change in gasoline prices\(^3\). Two additional variables were added: the unemployment rate (U) to account for the fact that "the average wage rates do not fully reflect the value Americans place on their time"\(^2\), and a dummy variable (D) to account for the introduction of emission and safety standards in 1968.

The following equation gives B-E's results, excluding automobile efficiency; i.e., the price elasticity is a total one.

\[
\log \frac{GD_t}{DP_{OP}} = 6.013 - 0.423 \log \frac{PG_t}{W} + 0.656 \log A + 0.047 D
\]

\[
(30.23) (-2.79) (3.71) (3.09)
\]

\[R^2 = 0.990\]

These results suggest a much higher price elasticity than equation III-20. It should be noted that the dependent variable in equation

\(^{31}\)Burright and Enns, p. 33.

\(^{32}\)Burright and Enns, p. 34.
III-23, unlike equation III-19, is for gasoline use only and excludes other fuel used. Furthermore the vehicle variable is now simply automobiles rather than all types of vehicles. The results in this equation suggest that the underestimating of price elasticity expected from equation III-20 is significant.

B-E's estimate of the fuel efficiency equation (comparable to equation III-22) is:

\[(III-24) \quad A_E = 2.701 + 0.088 \frac{PG}{W} + 0.012 U - 0.019 D \quad R^2 = .945\]

\[(172.31) (5.816) (1.029) (-3.845)\]

Equation III-24 suggests a slightly higher effect on fuel efficiency from gasoline price changes than equation III-22. The coefficient of the dummy variable suggests that the introduction of safety and emission standards has reduced average fuel efficiency.

Finally, the results of equation III-23 and III-24 are used by B-E to derive separate estimates of the elasticities with respect to gasoline price and fuel efficiency.
Equation III-25 implies the following conclusions: 1) The partial elasticity of a gasoline price change on gasoline consumption in the short term (holding efficiency constant) is -0.367 i.e., a 10% increase in gasoline prices results in a 3.67% decrease in gasoline consumption due only to a reduction in miles travelled. 2) The partial elasticity of a change in fuel efficiency (holding prices constant) is -0.056 (0.088 x -0.633) i.e., a 10% increase in gasoline prices results in a 0.56% decrease in fuel consumption due to changes in driving habits which lead to improvements in fuel efficiency. 3) These results suggest that 88% of the reduction in gasoline use due to a gasoline price increase is as a result of reduced vehicle miles driven while approximately 12% is due to changes in driving habits.

2) **Long-Run Analysis**

Over the long-term an individual's gasoline demand is adjusted by changes in automobile ownership. The purpose of B-E's long-run analysis is to determine the effects of a gasoline price change on automobile ownership and the resultant change in gasoline consumption.
In their analysis B-E estimate two demand equations and one supply equation.

(III-26) \[ NA = N (P_{NA}, P_{UA}, Y, D) \]

(III-27) \[ UA = U (P_{NA}, P_{UA}, P_G, Y, D) \]

(III-28) \[ P_{UA} = P_{UA} (A_{t-1}, P_{NA}, P_G, Y, D) \]

NA is new car purchases; UA is used car purchases; \( P_{NA} \) and \( P_{UA} \) are the real prices of new and used cars respectively; \( Y \) is real income (B-E use permanent income); and \( D \) is a dummy variable representing strikes in the automobile and steel industries.

B-E estimate and give the results of 40 equations used to estimate these three. Before discussing the results, a number of comments are necessary: First, automobile ownership is normalized over total households or driving age population. The results using each of these bases are different because the proportion of the population that is of driving age varied over the study period.
Although B-E intended to include the price of gasoline in equation III-26, they "were unable to get a good relationship between new car sales and gasoline price when used car price was also in the equation". However, the price of used cars (PU_A) which is in part determined by gasoline prices is an argument of equation III-26. Thus the influence of changes in gasoline prices on new car sales is derived from used car prices.

Because the variables in the three equations are not all independent, specifically the used car price is endogenous, B-E used two-stage least squares (2SLS) as well as OLS.

Finally, B-E used two measures of gasoline price. One was the traditional price per gallon. The second was gasoline price expressed in units per mile (gasoline price divided by average auto fuel efficiency).

The following table summarizes derived elasticities from the various equations estimated by B-E.34

---

33 Burright and Enns, p. 60.
34 Burright and Enns, Table 15, p. 69.
<table>
<thead>
<tr>
<th>NORMALIZATION</th>
<th>ESTIMATION TECHNIQUE</th>
<th>GASOLINE PRICE</th>
<th>$/gal</th>
<th>$/mile</th>
<th>$/gal</th>
<th>$/mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driving age pop.</td>
<td>OLS</td>
<td>$/gal</td>
<td>-0.54</td>
<td>0.23</td>
<td>0.93</td>
<td>-0.70</td>
</tr>
<tr>
<td>Driving age pop.</td>
<td>2SLS</td>
<td>$/gal</td>
<td>-0.26</td>
<td>0.09</td>
<td>0.86</td>
<td>-0.86</td>
</tr>
<tr>
<td>Driving age pop.</td>
<td>2SLS</td>
<td>$/mile</td>
<td>-0.40</td>
<td>0.11</td>
<td>1.10</td>
<td>-0.97</td>
</tr>
<tr>
<td>Total households</td>
<td>OLS</td>
<td>$/gal</td>
<td>-0.34</td>
<td>0.09</td>
<td>1.34</td>
<td>-0.56</td>
</tr>
<tr>
<td>Total households</td>
<td>2SLS</td>
<td>$/gal</td>
<td>-0.24</td>
<td>0.07</td>
<td>0.95</td>
<td>-0.67</td>
</tr>
<tr>
<td>Total households</td>
<td>2SLS</td>
<td>$/mile</td>
<td>-0.28</td>
<td>0.06</td>
<td>1.08</td>
<td>-0.72</td>
</tr>
</tbody>
</table>

These results indicate that a 10% increase in the price of gasoline will result in a 5.6 to 9.7% reduction in new car sales and a reduction of between 2.4 and 5.4% in total automobile ownership.

B-E's long-run equations do not differentiate among different size classes of automobiles. Thus, it is implicitly assumed that a given percentage reduction in automobile purchases causes an equal percentage reduction in gasoline use.

3) **Total Elasticities**

Finally, B-E combine their short and long-run analyses to derive total elasticities of gasoline consumption with respect to gasoline prices. Again, B-E present a number of results. The total elasticities are separated into three components, two pertaining to the short-run and one to the long-run.
Total elasticities range between -0.50 and -0.68. Of this total, long-run changes in automobile ownership account for roughly 35%. In the short-run, which accounts for the remaining 65%, the elasticity of gasoline use with respect to miles driven ranges from -.25 to -.37 or 50% of the total elasticity. Changes in driving habits account for the remaining 15% of the total change in automobile consumption due to gasoline price changes.

H. Summary Of Results

There are two problems which make a summary of the results of these various studies difficult. First, the disparate models, estimating techniques, and definitions make comparisons almost meaningless. Second, most analysts present a wide variety of results without any order of preference so that a summary becomes unwieldy.

Notwithstanding these difficulties, a summary can provide some indication of the range of results. Table III-1 presents a summary of the studies discussed above.

The results seem to fall into two groups. One group estimates short-run price elasticities less than -.10 with corresponding long-run price elasticities in the range of -.25. The second group indicates short-run price elasticities around -.40, (higher than some long-run estimates) with long-run estimates as high as -.70.
Income elasticities also vary significantly among analysts, ranging from .48 to 1.15 in the long-run.

In addition to the wide range of elasticity estimates, the studies discussed in this chapter provide no consensus as to the form and content of gasoline demand equations. Moreover, because the studies use different data and estimating techniques, it is impossible to conclude, in a statistical sense, which model provides the most reasonable approximation to the determination of gasoline demand. All of the models discussed here have some basis in the theory discussed in Chapter II (although none are complete) and the results obtained in regression estimates lend some support to the analysts' particular formulation. These results, however, depend to a large extent on the data and estimating techniques used. A valid comparison of models can be made only if estimating techniques and data are held constant. The following chapter undertakes this task.
Table III-1

Summary Of Results

Elasticities Of Gasoline Demand Equations

<table>
<thead>
<tr>
<th>STUDY</th>
<th>SHORT-RUN</th>
<th></th>
<th>LONG-RUN</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PRICE</td>
<td>INCOME</td>
<td>PRICE</td>
<td>INCOME</td>
</tr>
<tr>
<td>Dewees, Hyndman &amp; Waverman</td>
<td>n/a</td>
<td>n/a</td>
<td>-.40 to</td>
<td>0.82</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-.46</td>
<td></td>
</tr>
<tr>
<td>Static</td>
<td>-.05</td>
<td>.14</td>
<td>-.21 to</td>
<td>.36 - .69</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-.48</td>
<td></td>
</tr>
<tr>
<td>Dynamic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy, Mines and Resources</td>
<td>n/a</td>
<td>n/a</td>
<td>-.28</td>
<td>.48</td>
</tr>
<tr>
<td>Ramsay, Rasche and Allen</td>
<td>n/a</td>
<td>n/a</td>
<td>-.70</td>
<td>1.15</td>
</tr>
<tr>
<td>Houthakker, Verleger and Sheehan</td>
<td>-.075</td>
<td>.303</td>
<td>-.24</td>
<td>.98</td>
</tr>
<tr>
<td>Burright and Enns</td>
<td>-.32</td>
<td>-.43</td>
<td>.50 - .68</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>n/a</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
IV. The Demand For Gasoline In Western Canada

This chapter presents the results obtained by estimating a single equation reduced-form model of the demand for gasoline in western Canada. The results in this chapter are based on models similar to those reported in Chapter III.

Beside presenting the results of the equations for the demand for gasoline, this chapter contains a discussion of the econometric techniques used and problems encountered in other studies of the demand for gasoline. In addition, the data used in developing the econometric relationships are discussed.

A. Econometric Considerations

The studies described in the previous chapter used a variety of econometric techniques to resolve the many statistical problems encountered in estimating demand functions generally and the demand for gasoline in particular. The major econometric problems are 1) misspecification, 2) autocorrelation, 3) the use of lagged dependent variables, 4) the use of pooled time-series and cross-section data and 5) identification.
1) **Misspecification**

Misspecification occurs in three ways. First, the model is misspecified if it does not conform strictly to the theoretical properties attributed to the model. This type of misspecification occurs when theory suggests that certain variables should be included in certain ways but data limitations, for example, preclude their inclusion.

Misspecification also occurs when the form of the equation is incorrect. For example, the form may be specified in the model in a linear fashion but the relationship between the dependent and independent variables may, in fact, be non-linear.

Finally, an equation can be misspecified when the data used are defined differently from the theoretical interpretation of the model. This type of misspecification is common in studies estimating the demand for gasoline. The theoretical formulation of many gasoline demand models is related to private automobile use. Data on gasoline consumption by private automobiles only are not available and total gasoline consumption (including use by trucks) is often used as the dependent variable but is "explained" by variables which, theoretically, are meant to explain gasoline consumption by private automobiles only. This problem is of consequence if one expects a significantly different relationship between commercial and private demand functions or if the data used cannot be considered proxies for the desired data.
Misspecification can be a serious problem particularly in interpretation of the econometric results. Results obtained from estimating misspecified equations can be attributed erroneously to the correctly specified model when in fact the results "explain" a different model.

Generally, the best solution is to estimate an equation conforming as closely as possible to the theoretical model. Differences from the theoretical model and the bias resulting from these differences should be clearly stated. Where data limitations are serious, proxies that are clearly indicative of the desired data should be used.

The most common form of misspecification is that of omitted variables. If variables which are theoretically important in estimating demand are omitted from the estimating equation, some of the effect of the omitted variables may be added to the included variables (when the omitted variable is correlated with the included variable) resulting in bias in estimates.
2) Autocorrelation

When the omitted variable(s) are autocorrelated, then one of the fundamental assumptions of ordinary least squares is violated. There are three main consequences of this violation\(^1\). a) although unbiased estimators are obtained, the sampling variance may be large, b) the ordinary least squares formula underestimates the sampling variance of the regression coefficients (i.e., with positive autocorrelation, t-values are overestimated) and c) predictors with large sampling variances are obtained.

The Durbin-Watson (DW) test is used to detect the presence of autocorrelation. If the DW statistic is greater than a specified upper limit then the hypothesis of no positive autocorrelation cannot be rejected.

The presence of autocorrelation is relatively easy to detect and econometricians generally correct for its presence before reporting their results. Omitted variables may remain a problem, however, even if the omitted variables do not result in autocorrelation of the error term.

3) **Lagged Dependent Variables**

The Durbin-Watson test for autocorrelation is, however, "not applicable ... when lagged Y values appear among the explanatory variables"\(^2\). Thus, other tests of autocorrelation resulting from omitting variables in stock-adjustment models of the form used by HVS should be used.

Even if it is assumed, in a model with a lagged dependent variable, that the error terms are serially uncorrelated, they are correlated with at least one of the explanatory variables (the lagged variable), thus violating a fundamental O.L.S. assumption. Johnston\(^3\) indicates that in this circumstance, least squares is still the best estimating technique but gives biased results in small samples.

To adjust for this problem, Houthakker, Verleger and Sheehan used the error components technique\(^4\). They found that the error components technique gave similar results to the OLS technique when a different intercept was estimated for each state. OLS techniques with a common intercept for all states gave unsatisfactory results. In particular, the coefficient of the lagged dependent variable was biased towards one.

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\(^2\)Johnston, p. 252.

\(^3\)Johnston, p. 306-307.

\(^4\)Houthakker, Verleger and Sheehan, p. 414.
4) Pooling of Time-Series and Cross-Sectional Data

When state or provincial data over a time period are used in regression analysis, the error terms are not all independent (as assumed in ordinary least squares). In this case the error term is composed of a provincial effect and a random effect. The random effect is assumed to be independently distributed with zero mean, and there is assumed to be no relationship among the individual province effects. Both these assumptions conform to the assumptions necessary for ordinary least squares. However, serial dependence is expected for a given province over time, thus violating an important OLS assumption.

All the studies referred to in the previous chapter used pooled data but only B-E explicitly adjusted for serial dependence within states. The other studies did, however, implicitly adjust by using dummy variables or explicit state variables which account for inter-province (or state) differences.

The arbitrary nature of geographic boundaries, however, suggests there are at least some similarities among provinces.
B-E use generalized least squares to account for and measure the inter-state differences. This method first estimates the inter-state differences by using the deviations from an individual constant term for each state.

Second, coefficient estimates are then based on the transformed observations.

Balestra and Nerlove, who first considered this problem, indicate that pooled cross-section, time series data present difficulties only when a lagged endogenous variable is used\(^6\). Otherwise, appropriate state dummies can be used. However, "the presence of lagged endogenous variables may make it difficult to separate the individual effects from the effect induced by the lagged variable"\(^7\). Despite the problems encountered with pooled data, the assumptions necessary for the application of the generalized least squares technique are stringent and the procedure is used infrequently. Moreover even when used, the results of generalized least squares estimating techniques are not very different from the results obtained from OLS.


\(^7\)Balestra and Nerlove, p. 592.
5) **Identification**

The problem of identification is encountered in every econometric study attempting to estimate a demand function. Observed data on consumption over time are actually intersections of demand and supply. Thus, it is not clear whether regressing this intersection of demand and supply on price and other economic variables will result in the estimation of a demand or supply curve or some combination of the two.

The most common practise among econometricians concerned with estimating the demand for motor gasoline is to ignore identification. There are two rationales for this procedure: a) the supply side is exceedingly complex and econometric techniques are not capable of handling it, b) the assumption is made that the supply of gasoline is infinitely elastic at the prevailing price.

The latter assumption is the preferable rationale and deserves some elaboration. The assumption of a perfectly elastic supply curve means that fuel prices are exogenous and that gasoline supplies will be available to meet demand at these exogenous prices. The implication of this assumption must be examined to determine if it is reasonable.

---

First, the assumption of a perfectly elastic supply function implies that gasoline prices are not determined by an intersection of the supply and demand curves. How then are they determined? Wilson\(^9\) argues that the prices of finished oil products are administered with little basis on cost. Thus, demand adjusts to the administered price determined within the oil industry.

Second, if the supply of gasoline is perfectly elastic, higher gasoline taxes would be fully reflected in higher consumer prices. "If the supply is limited or contains some inelasticities, part of the burden or incidence of the gasoline tax will be borne by gasoline suppliers rather than consumers and hence the tax would not be fully reflected in higher pump prices."\(^{10}\) In Canada, casual observation suggests that not all the increases in taxes and other costs have been reflected in higher wholesale and retail prices.\(^{11}\) This phenomenon is likely to be temporary, however, as refiners and marketers adjust to the significant

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\(^{11}\) In the period since 1974, increases in taxes and crude oil prices have been offset to some extent by decreases in marketing margins and, to a lesser extent, by decreases in refining margins. Prior to 1974, however, taxes and other exogenous cost increases were reflected, on a one-to-one basis, in higher retail prices.
excess capacity in refineries and service stations. Increased government regulation over gasoline prices in the past few years without shortages also suggests that gasoline supply adjusts to meet demand at any price level.

Finally, the lack of shortages or supply restrictions in evidence over the study period, at least in Canada, also supports the assumption that the supply of gasoline is elastic and that prices can be assumed to be exogenous to the model under examination.

Shortages in gasoline have occurred in the United States during 1974 and again in 1979, suggesting that the assumption of supply elasticity is less valid in the U.S. than in Canada. However, these shortages in the U.S. have resulted in the main from exogenous (non-market determined) shortages in crude oil supplies that came with little or no warning. Moreover, market forces (i.e., price increases), have not been successful in eliciting increased supplies, at least in the short-run.

B. Data

Pooled cross-section and time series data for the four western provinces were used to estimate demand equations for private gasoline demand. In general, two sets of data were used with, in some cases, additional subsets where data availability dictated.
The first set of data included quarterly observations for the period 1973 I to 1978 II. Thus, 22 observations for each province or 88 observations in total were used. Data used in some of the studies discussed in Chapter III, however, were available only for the period 1973 I to 1977 I. In these cases there were 17 observations for each province or 68 observations in total.

Although this data set reflects only 4 years of historical observation it has the advantage of increased reliability with respect to gasoline prices. The price data used here were from the Department of Energy, Mines and Resources and provided the retail price of regular gasoline at all service stations in the major urban centres of each province. The data therefore do not suffer from the small size disadvantage of the Statistics Canada sample used to develop the consumer price index. A further advantage of the EMR series is that more recent data points are available.

The second set of data was an annual series for each province for the period 1957 to 1976. Thus, 80 observations were available.

Personal disposable income by province is not available by quarters so that in the quarterly time series, labour income was substituted. Personal disposable income was used in the annual data.
A problem not often discussed in the literature is the definition of the dependent variable. Most of the studies discussed in the previous chapter, as in this one, are concerned with private demand for gasoline. The studies often, however, use total gasoline consumption as the dependent variable. Because there is reason to believe that the commercial and residential markets for gasoline are quite different, the commercial or trucking demand should be estimated separately from the residential or private demand. The dependent variable used in this study is sales of gasoline through retail pump outlets. Although not all commercial sales are excluded, gasoline sales directly to industry, farms and government, whether on highway or off, are excluded.

All price and income data have been deflated by the relevant regional consumer price indices. The use of regional price indices to deflate prices and incomes causes a problem, however, when the data are pooled. These price indices, set at 1971 equal 100, measure price changes within each city. They cannot be used to compare the absolute level of prices among provinces, only the rate at which prices change.

When data are pooled, however, it is implicitly assumed that prices and income are comparable among provinces, i.e., that the 1971 level of the prices of goods included in the consumer price index 'basket' is the same in each province. Although it is unlikely that prices differed greatly among the four Western Canadian provinces in 1971, it is equally unlikely that they were the same. Pooling the data in a single regression equation would result in bias.
A solution to this problem is to include provincial intercept dummies which would adjust, at least in part, for differences in base year price levels. The advantage of regional price indices is that they measure, in each region, price changes which can be related to changes in the region's gasoline consumption. When these indices are used with pooled data, however, provincial intercept dummies should also be included to account for base year price differences among provinces.

The definitions of other independent variables are discussed when relevant.

C. Results

The model discussed in Chapter II suggests that there is a theoretical basis for a wide variety of reduced form equations. Indeed, the various models discussed in Chapter III display a wide variation in their theoretical approaches. Beside variations based on theory, the models differ widely due to econometric problems and their solutions and to data limitations. It is not surprising, therefore, that there are a myriad of alternative formulations of gasoline demand models, each with at least some theoretical justification. It is also not surprising that the range of estimated price and income elasticities is wide.
Before discussing the results of the various possibilities, it is useful to discuss solutions to some of the econometric problems discussed above. This discussion permits the elimination of many alternatives. Where alternatives cannot be eliminated on the basis of theory or evidence from other researchers, econometric results provide the justification for choosing among the many different approaches.

When pooled cross-section, time-series data are used (as is the case here), there is likely to be auto-correlation in the error term. When lagged dependent variables are not included, OLS can still be used, provided differences among regions are explicitly taken into account. Even when lagged dependent variables are included, OLS results are similar to results obtained when using more stringent techniques. The obvious conclusion is that, at a minimum, only results with different intercepts among provinces should be reported.

Demand theory provides no clear decision as to whether the form of the demand function should be linear, log-linear or non-linear. Generally the form that gives the "best" fit to the equations is retained. The results obtained in this study had a slightly higher, unadjusted, "goodness of fit" using the log-linear rather than the linear form.
The log-linear form has the added advantage that elasticities can be obtained directly from the estimated equation. A disadvantage is that elasticities are not permitted to vary with changes in the independent variables. Generally, the results using the log-linear form will be given. In order to compare the results obtained here with the results obtained by RRA, however, their form will be used in the appropriate model.

Gasoline demand exhibits large seasonal variation within a year. Thus all equations run with the quarterly data include seasonal dummies.

The $t$-values are in brackets in all regression equations.

1) **Static Models**

As discussed in Chapter II, the derived nature of the demand for gasoline suggests that adjustments in gasoline demand resulting from changes in the dependent variables occur over both the short and long term. There are short term adjustments drivers make to an increase in gasoline prices such as driving fewer miles and there are long term adjustments, such as buying a smaller car. The static model implicitly assumes that both these types of adjustments occur within the time period under consideration. The elasticities using this model are, therefore, long term elasticities.
a) Simple Model

The demand for a commodity is, at a minimum, a function of real income and real own price i.e., \( \frac{GD_t}{POP} = f\left(\frac{PG_t}{POP}, \frac{Y_t}{POP}\right) \). This model is estimated to provide a basis of comparison with more rigorous models.

i) Quarterly Data:

\[
\text{(IV-1)} \quad \log \frac{GD}{POP} = 3.449 - 0.133 \log \frac{PG}{POP} + 0.811 \log \frac{Y}{POP} + D(\text{QtRS}) + D(\text{PROV}) \quad R^2 = 0.936
\]

\( (29.665) (-1.426) (13.366) \)

Equation IV-1 states that the long term own price elasticity is -0.133 while the long term income elasticity is 0.81. Since it is unlikely that adjustments occur within a 3 month period, these elasticities likely underestimate the response of gasoline consumption to price and income.
ii) **Annual Data**:

(IV-2) \[
\log \frac{\text{GD}}{\text{POP}} = 0.799 \log (\text{B.C.}) + 0.850 \log (\text{ALTA}) + 0.864 \log (\text{SASK}) \\
(1.917) \quad (2.053) \quad (2.039)
\]

\[+ 0.775 \log (\text{MAN}) - 0.240 \log PG + 0.954 \log \frac{Y}{\text{POP}} \quad R^2 = 0.893
\]

\[(1.862) \quad (-.924) \quad (22.555)\]

Equation IV-2, using annual data, assumes that all adjustments occur within one year - a more reasonable adjustment period. The elasticities are slightly higher than those in the equation using quarterly data (although the price coefficient is only significant at the 60% level).

There is evidence of autocorrelation in this regression equation. An analysis of the residuals suggests that the problem is due to serial correlation within each province's data. This hypothesis is confirmed when the twenty years of annual data were run for each province individually. Serial correlation is evident in all provinces, but particularly in Manitoba.

The results of the two simple models suggest that they, particularly the annual series, suffer from omitted variables.
b) DHW Static Model

DHW use the following log-linear static model

$$(IV-3) \quad \log \left( \frac{GD_{POP}}{\text{pt}} \right) = a_1 + a_2 \log P_G_t + a_3 \log \left( \frac{Y_{POP}}{\text{pt}} \right) + a_4 \log URB_t + a_5 \log PAV_t$$

$URB =$ degree of urbanization (percentage of population living in urban centres with population of 10,000 or more)

$PAV =$ real price index of new automobile purchases.

Other variables are as previously defined.

DHW predict $a_2$ and $a_5$ to be negative and $a_3$ and $a_4$ to be positive (DHW's results are shown in equations III-3 and III-4 of Chapter III.)
i) Quarterly Data

It was not possible to obtain quarterly data on the degree of urbanization. The equation used to compare with the DHW model, therefore, excludes an "urbanization" variable.

\[ \text{IV-4} \quad \log \frac{GD}{POP} = 3.453 - 0.194 \log PG + 0.815 \log \frac{Y}{POP} + 0.012 \log PAV \]
\[ (29.827 \ (-1.071) \quad (13.480) \quad (1.315) ) \]
\[ + D (QTR) + D (PROV) \quad R^2 = .938 \]

Equation IV-4 gives results very similar to equation IV-1. The addition of the automobile price variable (as a proxy for the costs of owning an automobile) does not markedly change the results. In fact, the sign of the new automobile price coefficient is the opposite of its hypothesized sign.

The price elasticity resulting from equation IV-4 is slightly less than half the value determined by DHW (equation III-3), supporting the hypothesis that using quarterly data does not account for all the adjustments in gasoline demand caused by a change in gasoline price.

On the other hand, the income elasticities are very similar, suggesting gasoline consumption adjusts relatively more quickly to changes in income or that changes in income are more gradual.
ii) **Annual Data**

An analogous equation to the DHW model was run using annual data, and including data on the degree of urbanization in each province. The percentage of the provincial population living in urban centres of over 10,000 people was available from Statistics Canada for census years and was interpolated for intervening years. **Two definitions of the PAV variable were used.** One was the deflated price of new cars while the other was the deflated price index of all car sales. The results shown here are those with all car prices included.  

\[(IV-5) \quad \log GD = 3.543 \text{(B.C.)} + 3.615 \text{(A)} + 3.652 \text{(S)} + 3.536 \text{(M)}
\]

\[
(2.825) \quad (2.851) \quad (2.906) \quad (2.798)
\]

\[+ .114 \log (PG) + .844 \log Y - 1.020 \log PAV + .142 \log URB
\]

\[.482 \quad (15.061) \quad (-3.022) \quad (1.437)\]

\[R^2 = .921\]

\[\text{\textsuperscript{12}DHW used the deflated price of new cars, but only as a proxy for all car prices. (see DHW, p. 118).}\]
The result using the DHW model is marred by the incorrect sign of the price coefficient. Since the coefficients are insignificant, equation IV-5 suggests that price is not a significant determinant of the consumption of gasoline, at least in the static, one-year model. The income coefficient remains around 0.84. The URB and the PAV coefficients have the sign hypothesized by DHW and are significant.

A comparative summary of the results obtained here with those of DHW is included in Table V-1, page 124.

i) **Quarterly Data**

An equation similar to the EMR model (equation III-6) was estimated as follows:

\[
\text{(IV-6)} \quad \log \frac{GD_{RMV}}{Y/POP} = 3.486 - .252 \log PG + 0.798 \log Y/POP \\
(3.340) (-1.984) (6.468)
\]

\[
- 1.357 \log C/HH + 1.360 \log C/RMV + D (Q_{tRS}) + D (PROV) \\
(-5.404) (5.336)
\]

\[ R^2 = .925 \]
The results of equation IV-6 are generally satisfactory. The signs are as hypothesized by EMR and all coefficients (including those of the seasonal and provincial dummies) are significant. The price elasticity is similar to the one estimated by EMR. The income elasticity (again around 0.8) is significantly higher. The coefficients of both the cars per household and cars per registered motor vehicle variables are higher (in absolute value) than EMR's.

The results of equation IV-6 suffer, however, from two problems. First there are 68 data points for four provinces by quarters. Thus, there are only four years of data for each province. The second problem is that there is strong evidence of positive multi-collinearity between the cars per household and the cars/registered motor vehicle variables. Dropping the cars/registered motor vehicle results in an increased price elasticity but a decreased income elasticity.

ii) Annual Data

Running the EMR equation on annual data provided generally unsatisfactory results. The $R^2$ was only .64; the price coefficient was positive; the income elasticity was low (0.30) but significant; the automobile/household variable was insignificant; the percentage of automobiles in total registered vehicles was positive and significant; and finally, there was evidence of serial correlation.
Burright-Enns Short-Run Models

In the B-E analysis, the short-run is defined as the period during which the motor vehicle stock is fixed. Thus all adjustments in gasoline consumption that accompany price and/or income changes are due to different driving habits or to a change in miles driven. B-E used annual data suggesting that short-run adjustments occur within a one-year period.

Using quarterly data, equations were run similar to equations III-20 and III-23.

\[
(IV-7) \log_{POP} GD = 2.661 - 0.172 \log PG + 0.941 \log_{POP} (Y) \\
(3.380) (-1.374) (7.175)
\]

\[
- 0.182 \log_{POP} (A/POP) - 0.563 \log PT + D (PROV) + D (QtrS) \\
(-0.946) (-0.165)
\]

\[R^2 = .945\]
\[(\text{IV-8}) \quad \log \frac{GD}{POP} = 1.390 - 0.398 \log \frac{PG}{M} + 0.764 \log \frac{A}{POP} + D (\text{QTRS}) \]
\[(3.714) (-2.866) (7.304) \]
\[+ D (\text{PROV}) \quad R^2 = .903\]

The results of equation IV-7 differ from those of equation III-20. Although the price and income coefficients are significant and similar to results obtained from other equations in this chapter, B-E's income coefficient of .18 is significantly lower than in equation IV-7. In addition, the coefficient of the proportion of trucks among registered vehicles (PT) is insignificant, and the coefficient of the variable associated with the current period's automobile stock has the opposite sign from B-E's hypothesis.

Equation IV-8 is much closer to the results shown in equation III-23. All coefficients have the "correct" sign and are significant. Moreover, the income/wage elasticity is not significantly different from the one obtained by B-E. Similarly, the coefficient of the automobile stock variable in equation IV-8 is very close to B-E's estimate.

These results indicate that there is a strong correlation between income and automobile stock. Each variable can be substituted for the other. Including both in the same equation gives ambiguous results.
ii) Annual Data

The annual series did not give satisfactory results. The price coefficients were positive. The income variable, although its coefficient was significant, was highly correlated with the automobile per capita variable.

e) Ramsay, Rasche and Allan

As discussed in Chapter III, the RRA model is of interest for a number of reasons: (1) private and commercial demand for gasoline have been explicitly separated; (2) a separate supply equation has been estimated; (3) a price substitute variable has been included; and (4) the form of the equation permits price elasticity to rise as prices rise and income elasticity to fall as incomes rise. Their model of private demand for gasoline is summarized in equation III-8, and their results are shown in equation III-9.

i) Quarterly Data

Using quarterly data, an equation similar to the RRA model was run. Gasoline demand per household was used as the independent variable since it was used by RRA. RRA used a deflated price index of train travel as their "price of substitute" variable. Here the deflated price index of public transportation for the major city in each
province was used as the price of substitutes.

\[ \text{IV-9} \quad \log \left( \frac{\text{GD}}{\text{HH}} \right) = 3.437 + 0.239 \text{PG} + 0.0522 \text{PS} - 0.312 \left( \frac{Y}{\text{POP}} \right)^{-1} \]

\[ (23.369)(2.275) \quad (0.483) \quad (-12.996) \]

\[ + D \text{ (QtRS)} + D \text{ (PROV)} \quad R^2 = .987 \]

In equation IV-9, the price coefficient has the wrong sign. Although the "price of substitutes" coefficient is of the correct sign, it is insignificant. The income coefficient is much smaller than that estimated by RRA.

Before discussing the results using annual data, the results of this model are compared with those of a similar model estimated by DHW. The results of the DHW analysis are shown following equation III-10. Using a similar model but with data from the four western provinces by quarter, the following results were obtained.

\[ \text{IV-10} \quad \log \left( \frac{\text{GD}}{\text{POP}} \right) = 2.130 - 0.130 \text{PG} - 0.002 \left( \frac{Y}{\text{POP}} \right)^{-1} + 0.036 \text{PA} \]

\[ (38.591) (-1.642) (-14.480) \quad (1.572) \]

\[ + D \text{ (QtRS)} + D \text{ (PROV)} \quad R^2 = .944 \]
The elasticities derived from these equations (using the mean values) are: -0.069 for own price, 0.310 for income and 0.296 for the price of automobiles.

The price elasticity is lower than that obtained by DHW. This low price elasticity likely follows from using quarterly rather than annual data. The income elasticity is close to the DHW estimates.

ii) Annual Data

No data are available on the price of substitutes for the period prior to 1973. Thus the following equation is of similar form to the RRA model, but the price of substitute variable is excluded.

\[(IV-11) \log \left( \frac{GD}{\text{POP}} \right) = 1.082 (\text{B.C.}) + 1.137 (\text{ALTA}) + 1.153 (\text{SASK}) \]

\[
(9.237) \quad (9.912) \quad (9.211)
\]

\[
1.060 (\text{MAN}) + .0008 \text{ PG} - .802 \left( \frac{Y}{\text{POP}} \right)^{-1} \quad R^2 = .876
\]

\[
(9.085) \quad (0.266) \quad (-20.711)
\]
The price coefficient in equation IV-11 is insignificant. The \( R^2 \) value is low indicating that more explanatory variables are required. Moreover the results in equation IV-2 using the more traditional log-linear equation are "better" than those of equation IV-11.

Finally, an equation using the form chosen by RRA but the variables used by DHW, is run with annual data.

\[
(IV-12) \log \left( \frac{GD}{POP} \right) = 1.183 \text{ (B.C.)} + 1.205 \text{ (ALTA)} + 1.174 \text{ (SASK)} \\
+ 1.113 \text{ (MAN)} + .004 \text{ PG} - 0.182 \left( \frac{Y}{POP} \right) + 0.0004 \text{ URB} \\
(13.088) \quad (13.315) \quad (13.457) \\
+ (13.509) \quad (1.982) \quad (-3.022) \quad (0.846) \\
- 0.626 \text{ PA} \quad \text{ R}^2 = .957 \\
(-9.151)
\]

The inclusion of the URB and automobile price variables have significantly increased the "goodness of fit" of the equation. However, the gasoline price variable has the 'wrong' sign. The PA variable has almost the same value as obtained by DHW. The URB coefficient is insignificant although of the same sign as hypothesized by DHW.
f) Summary Of Static Models

The static model is based on the assumption that all adjustments to gasoline consumption occur within the time period under consideration. Although this assumption likely conflicts with the true nature of adjustments in gasoline consumption, many analysts use it and it is a useful starting point.

Although casual observation and theory regarding gasoline use suggests that data used to measure adjustments in gasoline consumption should be for relatively long periods, the results in this section indicate that the "best" results occur using the quarterly data series. This conclusion likely results because price increases were more pronounced in the period for which quarterly data have been collected and the price data were more representative of actual changes.

Using quarterly data, all forms of the models with the exception of the RRA model, gave satisfactory results. The 'simple' model where gasoline demand is related only to price and income performed almost as well as models with more variables.

13 "Best" in this context means a combination of goodness of fit, coefficients whose signs are as hypothesized, significance in the coefficients and little evidence of econometric problems.
Own-price elasticities ranged from -.13 to -.25 with the median around -.18. These results fall within the wide range of estimates found by other analysts (summarized on page 78). Although the assumptions of the static model imply that these are long-run elasticities, it is more likely that these elasticities relate to the short term, signifying the adjustments that occur over one quarter.

A comparison of the results of the models with quarterly and annual data supports the hypothesis that using quarterly data underestimates elasticities.

With the exception of the equations using the RRA form, income elasticities were on the order of 0.8 using quarterly data. In equations using annual data, income elasticities were slightly higher at between 0.85 and 0.95. Again, these elasticities are of the same order as found in other studies.

The inclusion of other variables, such as the price of substitutes, the price of automobiles (as a proxy for complements), an urbanization variable, the stock of automobiles and the percentage of automobiles among all registered motor vehicles did not yield unambiguous results.

The price of automobiles coefficient was significant and of the correct sign (negative) only when annual data were used. Using the DHW form, the elasticity of gasoline consumption with respect to automobile
prices was 1.02 (slightly higher than the DHW results). Using the RRA form, this elasticity was between 0.3 and 0.5 (lower than the DHW results).

The percentage of provincial population living in urban centres of greater than 10,000 was not highly significant but did seem to account for much of the inter provincial differences in per capita gasoline consumption. In equations where the urbanization variable was included, there was little difference between the provincial intercepts.

In the one equation where a "price of substitutes" variable (index of public transportation) was included, the coefficient was insignificant. It seems reasonable to conclude, therefore, that the price of public transportation is not an important variable in explaining gasoline consumption.

The percentage of private automobiles among all registered motor vehicles was significant in one equation (the EMR model) but of the wrong sign in another (the B-E model). The stock of automobiles was insignificant in one equation but very significant in another.
The theory and the results both indicate that price and income are important in determining gasoline consumption. The results (and the theory) are more ambiguous with respect to other variables.

2) Dynamic Models

Dynamic models of the demand for motor gasoline recognize the derived nature of motor gasoline and the relatively long period of time that it takes to make all adjustments in gasoline consumption when there is a change in gasoline prices and/or other independent variables. Gasoline consumers cannot immediately adjust their investment in goods that consume gasoline. A period of adjustment long enough to accommodate short term adjustments such as changes in miles driven and changes in driving habits, as well as changes in automobile stock, is required.

Dynamic models attempt to separate the long term from the short term effects of changes in independent variables.

a) DHW "Free" Demand Model

Equation III-5 shows the DHW free demand model where the dependent variable is defined as the quantity of gasoline sold (per capita) in the current year less 80% of the quantity sold in the previous year.
This formulation implies that short term elasticities are one-fifth the size of long term elasticities. The results obtained by DHW are shown on page 37.

i) **Quarterly Data**

The equations run on quarterly data are similar to those of DHW with the exception of the "urbanization" variable for which there are no comparable data available at the quarterly level.

\[
(IV-13) \quad \log \frac{CDP}{POP} = 1.193 \text{ (B.C.)} + 1.229 \text{ (A)} + 1.213 \text{ (S)} + 1.105 \text{ (M)} \\
(2.271) \quad (2.307) \quad (2.096) \quad (2.017)
\]

\[-0.811 \log PG + 0.067 \log Y + 0.060 \log PA + D \text{ (QtRS)}
\]

\[-1.655 \quad (0.233) \quad (1.430)\]

\[R^2 = 0.358\]

Equation IV-13 has a very low $R^2$, suggesting that "free" gasoline demand is random, incorrectly defined or that there are other variables that explain it better than income and prices. The price coefficient, however, is significant. The long and short term own price elasticities, at -.811 and -.162 respectively, are significantly higher than the results obtained by DHW.
While the price coefficient is significant, the income coefficient is insignificant. These results suggest that free demand (i.e., demand untied to previous automobile purchases) is related more to price than to income. It is likely that income is more closely related to automobile purchases in the long term while in the short term, adjustments in gasoline consumption are price related.

The main problem with this equation, however, is likely the definition of 'free' demand. DHW define rather than estimate it. For the data set under study here, it appears that this definition is inappropriate.

b) Berndt and Watkins

In a study estimating natural gas demand, Berndt and Watkins (BW) utilized a more sophisticated approach to the concept of free demand. Their approach can be applied easily to a model of the demand for gasoline.

Following the analysis of BW, gasoline consumption in period t is defined to be the product of a utilization rate \( u_t \) and a stock

---

variable ($S_t$). The stock variable (automobiles in this case) is composed of investment ($I_t$) plus the proportion of last period's stock that has not been replaced; i.e., $S_t = I_t + (1-r)S_{t-1}$ where $r$ is the depreciation rate. **Substituting this expression into the definition of gasoline consumption yields the following equation:**

$$ (IV-14) \quad G_t = u_t I_t + u_t (1-r) S_{t-1} $$

This equation consists of two parts which together explain gasoline consumption. The first expression on the right hand side of equation IV-14 is 'flexible' demand which is defined to depend on price, income and demographic variables. The flexible demand is, in turn, composed of an investment component (e.g., a decision to purchase a new car) and a utilization component (e.g., miles driven).

The second expression on the right hand side of equation IV-14 is 'captive' demand - period t-1's stock that is not replaced in period t.

Although BW do not stop at this point, it is of interest to estimate an equation similar to equation IV-14. If flexible demand is defined as a function of real income and gasoline prices, then equation IV-14 can be rewritten as:
GD = a_0 + a_1 PG + a_2 Y + a_3 S_{t-1} where a_3 = u_0 \ (1-r)

i) Annual Data

Using annual data the following results were obtained. (The stock variable used was registered passenger automobiles by province).

\(\text{(IV-16)} \ \log \left( \frac{GD}{\text{POP}} \right)_t = 0.575 \ (\text{B.C.}) + 0.653 \ (A) + 0.648 \ (S)\)

\(\begin{align*}
(2.138) & \quad (2.443) & \quad (2.369) \\
+ 0.595 \ (M) + 0.357 \log PG_t + 0.276 \log \left( \frac{Y}{\text{POP}} \right)_t \\
(2.219) & \quad (2.015) & \quad (3.860) \\
+ 1.062 \log (\text{C/POP})_{t-1} & \quad R^2 = .956 \\
(10.279)
\end{align*}\)

The significant feature of equation IV-16 is that the price coefficient is positive. Since it is theoretically implausible that gasoline consumption per capita would change in the same direction as a change in price of gasoline, equation IV-16 more likely reflects insignificance with respect to changes. When equation IV-16 was run without

\(15\) The correlation of the price variable with the dependent variable was negative but low. \((-0.2103)\)
the lagged stock variable, the price coefficient was negative. In addition there is evidence that the stock variable and income are highly correlated.

ii) Quarterly Data

Data on vehicle registrations are unavailable by quarters. To obtain estimates in order to run the model on quarterly data, annual motor vehicle registrations were interpolated. The following results were obtained.

\[
(IV-17) \quad \log \left( \frac{GD_{POP}}{POP} \right)_t = 1.915 - .224 \log P_G_t + 0.833 \log \left( \frac{Y}{POP} \right)_t
\]

\[
(13.538) \quad (-2.001) \quad (12.629)
\]

\[
+ .003 \log \frac{CARS_{POP}(t-4)}{POP} + D(QtRS) + D(PROV) \quad R^2 = .944
\]

\[
(0.144)
\]

(Note that \( t-4 \) refers to the same quarter one year earlier.)

Although the price coefficient is negative and significant (and of comparable magnitude to other estimates), the coefficient of the stock variable is insignificant. This is perhaps due to errors in the variable arising out of the method of interpolating registered passenger cars by quarter.
B-W continue their model formulation by assuming that the utilization rate is constant between periods. With this assumption, equation IV-14 can be re-expressed as follows:

\[(IV-18) \quad GD_t = u_t I_t + (1-r) GD_{t-1}\]

As before, the first part of the right hand side of equation IV-18 is assumed to be flexible demand while the second part is captive demand. If flexible demand is assumed to be dependent on income and prices, equation IV-18 can be re-expressed as:

\[(IV-19) \quad GD_t = a_0 + a_1 P_t + a_2 Y_t + a_3 GD_{t-1}\]

Where \(a_3 = 1-r\).

This formulation is of less relevance to the demand for gasoline since it does not permit changes in the utilization rate between periods. As discussed in Chapter II, gasoline consumers have a number of adjustments from which to choose if gasoline prices change.

Precluding possible adjustments limits the value of the model.\(^{16}\)

\(^{16}\) There may be reasons why this assumption is less critical in the case of residential home heating, although even here, the natural gas user has the option of changing his utilization rate (by, for example, lowering the thermostat) in response to a price increase.
Equation IV-19 is of identical form to the models estimated by HVS. However, HVS has a different interpretation of their model; $a_3$ is interpreted by HVS as $1-\theta$ where $0 \leq \theta \leq 1$ is the speed with which actual demand reaches desired demand.

i) **Quarterly Data**

\[
(IV-20) \quad \log \left( \frac{GD}{POP} \right)_t = 2.257 - 0.154 \log PG_t + 0.501 \log \left( \frac{Y}{POP} \right)_t \\
\quad (5.848) (-1.742) (4.471)
\]

\[+ 0.303 \log \left( \frac{GD}{POP} \right)_{t-4} + D(QtRS) + D(PROV) \quad R^2 = .944 \]

(3.223)

These results, following the BW interpretation, suggest an implausibly high level of the yearly depreciation rate (.697). Based on the HVS interpretation, on the other hand, the short term price elasticity is -.154 while the long term elasticity is -.221. The short term income elasticity is 0.501 while the long term elasticity is .719. These results are all in line with results obtained in other studies and are comparable to other results reported in this chapter.
ii) Annual Data

\[(IV-21) \log \left( \frac{GD}{POP} \right)_t = 0.429 \text{ (B.C.)} + 0.439 \text{ (A)} + .453 \text{ (S)} + .432 \text{ (M)}
\]

\[
= (2.787) (2.863) (2.890) (2.815)
\]

\[- 0.225 \log PG_t + 0.210 \log \left( \frac{Y}{POP} \right)_t + 0.825 \log GD_{t-1}
\]

\[
= (-2.355) (5.582) (21.799)
\]

\[R^2 = .986\]

If the coefficient of the lagged dependent variable is defined as one minus the depreciation rate (following the analysis of Berndt and Watkins), the depreciation rate is roughly .174, similar to that assumed by DHW.

Following the HVS interpretation of this model, short term price elasticity is -.225 while the long term price elasticity is -1.29 (much higher than the results of other studies). Short and long term income elasticity are 0.21 and 1.21 respectively.
The HVS stock adjustment model performed much better. However, the results were markedly different depending on whether annual or quarterly data were used. Using quarterly data the short term price elasticity was -.154 while the long term price elasticity was -.221. With the annual data, both the short and long term elasticities (at -.225 and -1.29 respectively) were significantly higher, supporting the hypothesis that using quarterly data results in underestimating price elasticities.

Income elasticities, however, did not show similar consistency. The short term income elasticity was lower using annual data while the long term income elasticity was lower when quarterly data was used.

Although, theoretically, the static models present long term elasticities, the assumption that all adjustments occur within a 3 month period is unrealistic. The models using quarterly data actually measure only those changes that occur over a 3 month period and should be considered, therefore, short term elasticities.

The results of these models and their permutations are disparate enough that it is difficult to reach a firm conclusion as to price and income elasticities. Short term price elasticities, from -.154 to -.225, fell within the same range as the estimates based on static models. The long term price elasticity estimates were, however, quite different ranging from -.221 to -1.29.
D) **Summary Of The Results Of Dynamic Models**

Three versions of the dynamic model of the demand for gasoline were estimated: the DHW "free" demand model, the Berndt-Watkins stock approach and the HVS stock adjustment model.

The DHW "free" demand model performed poorly. Although there is justification for estimating an equation assuming the dependent variable is non-captive, logic and the econometric results suggest that the proportion of gasoline demand that is free (i.e., is not tied to past purchases of automobiles) should be estimated, not assumed.

The Berndt-Watkins approach relates current gasoline consumption to a free component plus a component which is tied to past levels of automobiles. However, the results of the equation based on this model were unsatisfactory. Using annual data, the price coefficient had the incorrect sign and the coefficient of the stock variable was implausibly high. Using quarterly data the price and income coefficient were significant (suggesting short term elasticities of -0.224 and 0.833 respectively), but the coefficient of the stock variable was insignificant.
V. Conclusions And Implications

The main purpose of this chapter is to draw conclusions as to 1) the most appropriate model of motor gasoline consumption; 2) own-price elasticity of gasoline for use in private automobiles; and 3) income elasticity. A secondary purpose is to consider the implications of these conclusions on future motor gasoline consumption and on the comparative efficacy of price increases and non-price conservation factors in reducing the growth in consumption.

A. Gasoline Demand Models

The gasoline demand models discussed in the previous chapters fall into three main categories: a) the traditional demand model where gasoline demand is assumed to be a linear or log-linear function of income, price and other variables considered to be relevant; b) the 'RRA' model which differs from the traditional model in form only; and c) the dynamic model which separates gasoline demand into its fixed and flexible components.
Reduced form equations based on various models were estimated. None of the models was a complete formulation of the theoretical model discussed in Chapter II, although all had some theoretical base. At best all the models were approximations to the 'true' model. It is not surprising, therefore, that they showed a great deal of variation. Although income and price coefficients were generally significant and of the 'correct' sign, there was a wide disparity among the models as to the significance of other variables. In addition, when one model "worked well" with one set of data, often it failed using the other set.

Table V-1 compares, in tabular form, the main results obtained from the studies discussed in Chapter III with the results obtained using data for the Western Canadian provinces.

The DHW 'free' demand model performed least satisfactorily using data on the four Western Canadian provinces. The fit was extremely low (0.36) and the price and income elasticities were markedly different from those obtained using other models. The problem likely lies in DHW's rather arbitrary definition of 'free' demand; i.e., demand that is not tied to previous automobile purchases. Captive and free demand should be estimated, not assumed. In any event, the results for this model suggest that DHW's definition is incorrect, at least for the data used in this paper.
The RRA model, where own price elasticity increases with increases in real prices and income elasticity decreases with real income increases, also performed unsatisfactorily on data for the four Western Canadian provinces. The fit was poor in all equations and, more importantly, the own price coefficients were positive in all but one equation. In both RRA's own results and DHW's results using the RRA form, the own price elasticity was much higher, in absolute value, than in other equations.

Variations on the traditional model gave inconsistent results. Using quarterly data, these models all resulted in price coefficients with the 'correct' sign, with own price elasticity ranging from -0.133 to -0.398, averaging -0.219. Of the five variations, the t-values associated with the gasoline price variable was significant at the 95% level in only two. The t-values (in absolute value) in the other three were all between one and two. Income elasticities were around 0.8 for all but one of the five equations. Using Western Canadian data, the EMR and BE models both resulted in own price elasticity estimates similar to the results in the original studies, whereas other models produced results quite different from the ones shown in the original studies. EMR, however, estimated an income elasticity significantly below the one obtained using Western Canadian data.
TABLE V-1
Comparison Of Elasticities Of Demand For Gasoline Models

<table>
<thead>
<tr>
<th>Model</th>
<th>Original Study Result</th>
<th>DHW Results</th>
<th>Chapter IV Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Own Price</td>
<td>Income</td>
<td>Own Price</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple Model(^3)</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>DHW Static Model(^4)</td>
<td>-0.45</td>
<td>0.83</td>
<td>na</td>
</tr>
<tr>
<td>DHW Distributed Lag(^5)</td>
<td>-0.22(^1)</td>
<td>0.91</td>
<td>na</td>
</tr>
<tr>
<td>DHW 'free' Demand(^6)</td>
<td>-0.26</td>
<td>0.69</td>
<td>na</td>
</tr>
<tr>
<td>EMR Model(^7)</td>
<td>-0.28</td>
<td>0.48</td>
<td>na</td>
</tr>
<tr>
<td>RRA Model(^8)</td>
<td>-0.70(^1)</td>
<td>1.15</td>
<td>-0.44</td>
</tr>
<tr>
<td>HVS(^9) - long term</td>
<td>-0.24</td>
<td>0.98</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>-0.075</td>
<td>0.303</td>
<td>2</td>
</tr>
<tr>
<td>B-E(^10) - short run</td>
<td>-0.25</td>
<td>0.18</td>
<td>na</td>
</tr>
<tr>
<td></td>
<td>11 - short run</td>
<td>-0.423</td>
<td>na</td>
</tr>
<tr>
<td>BW(^12) stock model</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>
Footnote for Table V-1 on page 124.

na - not applicable or not available
1 - not significant at 5% confidence interval
2 - incorrect sign
3 - equations IV-1 and IV-2
4 - equations III-3, IV-4 and IV-5
5 - see page 33
6 - see page 37 and equation IV-13, these are long term elasticities; short term are one-fifth long term ones
7 - equations III-7 and IV-6
8 - equations III-9, III-10, IV-9 and IV-11
9 - equations III-13, III-14, IV-20 and IV-21
10 - equations III-20 and IV-7
11 - equations III-23 and IV-8
12 - equations IV-16 and IV-7
The series of annual data gave much less conclusive results. None
of the price coefficients were negative. The fit was generally poor.
One possible interpretation of these results is that during much of
the 1957 to 1973 period, gasoline consumers were relatively insensitive
to price and price changes were not pronounced. In the post 1973
period, however, price changes were more significant.

The stock adjustment model developed by HVS produced more consistent
results. For both quarterly and annual data, coefficients were of
the hypothesized sign, although the price coefficients were not always
significant at the 95% level. This dynamic model, however, has more
potential econometric problems than the traditional models since a
lagged dependent variable is combined with pooled data.

No unanimous conclusion can be reached. The dynamic version of a
gasoline demand model is theoretically more appealing than traditional
models since long term adjustments are included. The traditional
model, however, has fewer econometric problems.

More work is necessary to estimate a model with a more complete
theoretical foundation than the ones discussed here. Multi-equation
models explaining motor vehicle demand as well as gasoline consumption
should be estimated in order that the dynamic nature of gasoline
demand can be explicitly considered.
B. Elasticities

Despite the wide variation in model results, income coefficients were highly significant. Moreover, income elasticities were, with few exceptions, all in a relatively narrow range. Short term income elasticities at approximately 0.80 were generally invariant to model and data choice. Long term income elasticities were on the order of 0.95.

The studies summarized in Chapter III reached similar conclusions with respect to long term elasticities, only RRA estimated an income elasticity greater than 1.0. In addition, EMR's estimate of long term elasticity, at 0.48, fell outside the 0.8 to 1.0 range.

In those studies where short term elasticities were calculated (such as HVS and BE), the results were much lower than estimated in Chapter IV.

Of the various equations estimated in Chapter IV, only a few of the coefficients of the gasoline price variable were significant at the 95% level. The 't' values were, however, generally above 1.0. Short term price elasticities were in the order of -0.20 - roughly midway between the estimates made in other studies - regardless of the model or data used (whether annual or quarterly).
Long term price elasticities at -0.25, were only slightly higher. However, these elasticities varied significantly depending on the model and data set chosen.

In summary, the available evidence suggests that the income elasticity of gasoline consumed in private automobiles is around 0.8 in the short term and 0.95 over the long term. This income elasticity of less than one suggests that gasoline demand is more a necessity than a luxury, and that price increases are only slightly regressive in that lower income groups are more affected than upper income groups by increases in gasoline prices.

With respect to gasoline price elasticity, the evidence suggests a value in the -0.20 and -0.25 range over the short and long term respectively.

C. Implications

Estimates of gasoline price elasticity made in this and other studies differ widely depending on the model used, the econometric techniques employed, the data, the region under examination and the time frame considered. Nevertheless, there is unanimity on at least one essential point - all the studies summarized in Chapter III and the results obtained in Chapter IV agree that the demand for gasoline consumed in private automobiles is price inelastic; i.e., the own
price elasticity of demand is less than one.

This conclusion does not imply that gasoline consumers are price insensitive. Clearly, at any price elasticity greater than zero, there is some response from gasoline consumers to a gasoline price increase. The low level of this response, however, suggests to some\(^1\) that price increases will not reduce consumption sufficiently to alleviate the energy (or oil) problems facing Canada today. Moreover, these price increases would, the argument continues, add to inflation and worsen income distribution without significantly affecting gasoline consumption.

It is further argued that gasoline consumption (and energy consumption generally) could be reduced more effectively through non-market policies. Various private actions and government policies which would result in lower gasoline consumption have been advocated. These actions include imploring gasoline consumers to drive less frequently or to maintain their automobiles in good working order, highway speed limit restrictions and taxes on large, energy intensive automobiles.

\(^1\)See, for example, _Oilweek_, April 10, 1978, p. 3.
In a general sense, all actions taken by individuals to reduce their per unit consumption of energy, whether in response to price increases or to government initiatives, can be considered conservation measures. The term "conservation", however, is often associated only with non-price actions to reduce energy consumption.

In economics, non-price-induced conservation actions are evidence of market failure. In a perfectly competitive economy, where prices can freely adjust, all markets will clear. In such circumstances there would be no gasoline or energy shortages and no need to resort to non-market means of reducing gasoline consumption. As costs of oil production and prices increase, consumers will adjust their consumption to levels that will elicit adequate supplies to maintain market equilibrium. Conservation would be practised, but it would be price induced conservation. If price elasticity is low, demand may change only moderately, but prices would increase rapidly enough to ensure that new, more costly supplies become available.

The economy in general and the energy market in particular is, however, not perfectly competitive. For example, the major oil producing exporting countries (OPEC) have formed a cartel for the purpose of maintaining the price of their crude oil exports at levels in excess of the marginal cost of production. At the same time, the OPEC cartel maintains production at levels lower than the levels
which would prevail with perfect competition; i.e., the cartel operates as a monopolist.

The presence of a large cartel does not, however, suggest that market forces cannot clear markets at reduced, albeit artificially, levels. The presence of the OPEC cartel implies the world is not Pareto optimal but monopolies and oligopolies are common in other markets as well. Produce marketing boards, for example, act on behalf of farm producers to maintain stable prices which, at least part of the time, result in higher prices and lesser output than if 'free' market forces prevailed. In produce or chicken markets, however, non-price induced conservation measures are not advocated. Even with an oil cartel, an economist would expect markets to clear without the need to resort to non-market means of reducing demand.

There are three reasons to believe that the gasoline market will not clear without non-price induced conservation. The most obvious reason is that the market has not been permitted to work. Both the Canadian and American governments maintain the price of crude oil and therefore its derivatives, at levels below the "world" or OPEC price. The price of Canadian crude oil is sold in domestic markets below its opportunity cost. Consumers are, therefore, not given the proper price signals.
Even if market forces were permitted to work, timing creates a problem. There is a long lead time in developing new sources of Canadian oil (from, for example, tar sands or heavy oil deposits) and an even longer lead time in developing new energy sources such as nuclear or solar energy. Thus, market forces could not be relied upon to develop alternatives to foreign crude oil except over the long term.

A third reason for expecting that market forces are not adequate to achieve a Pareto optimum is a "security of supply externality". Dependence on foreign sources of oil exposes countries to the risk of oil supply disruptions. This risk should theoretically result in a discount off the price of insecure foreign sources. The cartel, of course, does not permit this. An alternative would be a premium on more secure (e.g., domestic) sources. However, domestic governments prevent this. One solution is to maintain demand at "artificially" low levels, that is, at levels lower than would prevail at the current price in order to reduce dependency on insecure energy sources. In this way, the costs of supply disruptions are lessened and consumers, as a whole, pay the costs when shortages occur.

The combination of these three factors reduces the efficiency of market forces to automatically adjust supply and demand of gasoline, particularly in the short term. It is the first factor — where governments refuse to permit market forces to operate — that is most important. It is Canadian government intention to reduce
gasoline consumption, but not at the expense of adding to inflation or
deteriorating the current distribution of income. Therefore, the
Canadian government uses a combination of price increases with a
variety of other fiscal and moral suasion policies to reduce consumption.

There are a number of difficulties associated with comparing the
efficacy of price and non-price conservation measures. Nevertheless,
a comparison serves a useful purpose in determining whether the costs
associated with promoting non-price induced conservation factors are
worth the benefits derived from reduced consumption and the lessened
impact on inflation and income distribution.

It is difficult to incorporate non-price induced conservation measures
into an econometric study. Tax increases on certain classes of
automobiles can be incorporated if the study is able to distinguish
the prices of various automobile sizes. An advertising campaign to
reduce consumption through moral suasion can be introduced by an
appropriate dummy variable. The problem, however, with these and
other methods is that it is difficult to separate completely the
price from the non-price reasons for a reduction in consumption.
A partial analysis would forecast gasoline consumption if prices had been free to rise to world levels and assess the impact this price rise would have on income distribution and inflation. The costs associated with this level of gasoline reduction can be compared, at least qualitatively, with the costs associated with non-price conservation measures.

In the second quarter of 1978 gasoline sales by retail outlets in the four western provinces was 470 million gallons at a weighted average retail price of 85¢/gallon or 53.4¢ per gallon in 1973 dollars. At that time, the crude oil price in Canada was $12.75 per barrel at the wellhead, and roughly $13.60 at Toronto/Montreal. The landed price of foreign crude oil was approximately $16.30 per barrel - a difference of $2.70 per barrel. Assuming a gasoline price increase of 3.0¢ per gallon\(^2\) for every $1.00 per barrel increase, a $2.70 per barrel increase in the price of crude oil results in a gasoline price increase of 8.1¢ per gallon or 5.1¢ in real terms (9.6% increase). A price elasticity of -.25 implies a reduction in gasoline consumption of 2.4% with a 9.6% increase in retail gasoline prices. Thus, if Canadian crude oil prices and therefore gasoline prices were increased to equivalent world prices, Western Canadian gasoline consumption would have been 2.4% (11 million gallons) lower in the second quarter of 1978.

\(^2\)Source: B.C. Energy Commission.
There are, however, two additional costs associated with this reduction in gasoline consumption. One is the effect on inflation, the other is the effect on income distribution.

a) Inflation

A crude oil price increase affects more than the price of gasoline. All petroleum product prices are increased as are the costs of other products which use petroleum products as an input. The direct effect on the consumer price index of a 62.5% increase in crude oil prices has been estimated to be roughly 0.29% in the first year. Including both indirect and direct effects, the increase in the CPI from a 62.5% increase in oil prices has been estimated at between 2.26% and 3.5%.

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Studies undertaken by the Ministry of Energy, Mines and Resources estimate that a $1.00 per barrel increase in Canadian crude oil prices increases the CPI by 0.5 to 0.7 points\textsuperscript{5,6}.

A $2.70 per barrel increase in crude oil prices (roughly 20%) therefore would result in roughly a 1.5% increase in the Canadian consumer price index. If gasoline prices increased without an increase in the price of crude oil, for example, by imposition of an excise tax, the CPI would increase by less than if all petroleum product prices increased.

b) Distribution of Income

An assessment of the impact of gasoline price increases on income distribution can be determined from an analysis of the income elasticity associated with gasoline price increases. Income elasticities calculated in this and other papers are generally slightly below unity, implying that higher prices are regressive but not significantly so.

\textsuperscript{5} Ministry of Energy, Mines and Resources, private communication.

\textsuperscript{6} An October 19, 1979 article in the Toronto Globe and Mail provided the following results from a survey inquiring as to the increase in the Consumer Price Index from a $1.00 increase in the price of crude oil:

- Conference Board of Canada: 0.5 - 1.0%
- National Commission on Inflation: 1.0%
- The New Democratic Party: 0.7
- Government of Ontario: 0.4
If gasoline price increases derive as a result of crude price increases, significant inflationary pressures could result. Although income distribution is relatively unaffected by gasoline price increases, price increases on other petroleum products could affect income distribution. The implication of these rather tentative conclusions is that gasoline price increases not resulting from crude oil increases but of a magnitude sufficient to reach world energy price levels could reduce gasoline consumption with an adverse inflationary effect but little income distribution effects.

This reduction in gasoline consumption of 11 million gallons (2.4%) is associated with a real price increase of 5.1¢ per gallon in 1973 dollars (9.6%) or a total increase in consumer expenditures of $23,400,000 in the second quarter of 1978. In addition, the Consumer Price Index would rise by 1.5%.

To compare this result with the effect of non-price-induced conservation measures would require knowledge of the costs associated with a conservation program that results in a reduction in gasoline demand roughly equivalent to 11 million gallons. Unfortunately, the cost of such a program is not available. Moreover, as noted above, it is difficult to measure precisely the effect of a non-price conservation measure on motor gasoline consumption.
D. Future Gasoline Consumption

Finally, the results in previous chapters can be used to forecast gasoline consumption in Western Canada, given assumptions as to future real price and income increases. The procedure used here to forecast gasoline consumption is simply to forecast the percentage increase in real prices and per capita income and, on the basis of a gasoline price elasticity of -.25 and an income elasticity of 0.90, to estimate the percentage change in gasoline consumption per capita. Given a population forecast, the total gasoline sales from service stations can be estimated.

This procedure must be considered a partial analysis since it ignores other independent variables that have some impact on gasoline consumption. There is, however, no conclusive evidence as to which independent variable (or variables) is important and what the degree of that importance is. Thus, these other independent variables are not considered. The results likely, however, provide a reasonable order-of-magnitude forecast.
In 1978, gasoline sales at service stations in Western Canada were 2,153 million gallons\(^7\). Population in 1978 was 6,458,000\(^8\). Thus, per capita gasoline consumption was 333 gallons.

The real price of crude oil in 1978 dollars has been forecast to increase by $5.00 per barrel by 1985 and $6.00 per barrel by 1990\(^9\). Assuming no real increases in refining and marketing margins and a 3.0¢ per gallon increase in gasoline prices per $1.00 per barrel increase in crude oil prices, the real price of gasoline will increase 15¢ per gallon by 1985 and 18¢ per gallon by 1990, or 18 and 21% over the 1978 price of 85¢ per gallon.

Combining this assumption with the assumption that per capita income increases at 1.8% per annum\(^10\) results in a per capita consumption of 349 gallons in 1985 and 377 in 1990. Using a Statistics Canada forecast of population, total gasoline sales at service stations in Western Canada will be 2,511 million gallons in 1985 and 2,894 million gallons in 1990.

\(^7\)Source: Statistics Canada catalogue No. 45-004, Refined Petroleum Products, Ottawa, December, 1978, p. 11. The figures shown for the four western provinces are multiplied by 80% to arrive at sales at service stations.

\(^8\)Source: Statistics Canada catalogue no. 11-003.


\(^10\)National Energy Board, Canadian Oil Supply and Requirements, Department of Supply and Services, Ottawa, 1978, p. 84.
Appendix I

Glossary Of Terms And Symbols

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>TS</td>
<td>transportation services (measured in miles travelled)</td>
</tr>
<tr>
<td>t</td>
<td>time period</td>
</tr>
<tr>
<td>$f_i$</td>
<td>individual $i$'s demand function for transportation services</td>
</tr>
<tr>
<td>$Y_i$</td>
<td>personal disposable income deflated by the consumer price index i.e., real income</td>
</tr>
<tr>
<td>$P_T$</td>
<td>weighted average &quot;price&quot; of all types of transportation services per mile travelled deflated by the consumer price index</td>
</tr>
<tr>
<td>$\bar{P}$</td>
<td>price index of all goods e.g., the consumer price index</td>
</tr>
<tr>
<td>PU</td>
<td>public transportation services</td>
</tr>
<tr>
<td>PR</td>
<td>private transportation services (assumed to be private automobiles)</td>
</tr>
<tr>
<td>$P_{PU}$</td>
<td>the price of public transportation services deflated by the consumer price index</td>
</tr>
<tr>
<td>$P_{PR}$</td>
<td>weighted average &quot;price&quot; of private transportation services deflated by the consumer price index i.e., all costs (measured per mile travelled) associated with driving an automobile</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>weight of public transportation services in the weighted average price of transportation services</td>
</tr>
<tr>
<td>A</td>
<td>private automobiles</td>
</tr>
<tr>
<td>$g_i$</td>
<td>individual $i$'s demand function for private automobiles</td>
</tr>
</tbody>
</table>
PA - price (cost) of owning and operating an automobile
deflated by the consumer price index (assumed to beequivalent to \( P_{PR} \))

\( Z \) - vector of tastes and preferences relating to the demandfor transportation services

\( Z' \) - vector of tastes and preferences unique to the demandfor private automobiles

\( Z'' \) - vector of tastes and preferences unique to the demandfor the use of private automobiles

\( Z''' \) - vector of tastes and preferences for automobilecharacteristics affecting average fuel efficiency

\( P_{AR} \) - the operating costs (excluding fuel) of automobile usei.e., the variable costs of operation, deflated by theconsumer price index

\( N_i \) - number of automobile miles per vehicle driven byindividual \( i \)

\( P_{AV} \) - the purchase price of an automobile (proxy for all fixedcosts associated with automobile ownership) deflated bythe consumer price index

\( A_E \) - average fuel efficiency of each automobile (measured inmiles per gallon)

GD - gasoline demand

\( B_1, B_2 \) - weights of private transportation costs assigned to fixedcosts and gasoline costs respectively
### Chapters III and IV

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>URB</td>
<td>percentage of provincial population living in urban centres with population of 10,000 or more</td>
</tr>
<tr>
<td>GF</td>
<td>&quot;free&quot; demand for gasoline - the quantity of gasoline sold in the current period less 80% of the quantity sold in the previous period</td>
</tr>
<tr>
<td>POP</td>
<td>population</td>
</tr>
<tr>
<td>HH</td>
<td>number of households</td>
</tr>
<tr>
<td>RMV</td>
<td>registered motor vehicles (excluding motorcycles)</td>
</tr>
<tr>
<td>C</td>
<td>number of registered private automobiles</td>
</tr>
<tr>
<td>tp</td>
<td>proportion of the population in the 16-24 year age group</td>
</tr>
<tr>
<td>M</td>
<td>miles travelled</td>
</tr>
<tr>
<td>S</td>
<td>automobile supply constraint (man-days lost in strikes in the automobile industry)</td>
</tr>
<tr>
<td>U</td>
<td>unemployment rate</td>
</tr>
<tr>
<td>NA</td>
<td>new car sales</td>
</tr>
<tr>
<td>F/LF</td>
<td>proportion of females in the labour force</td>
</tr>
<tr>
<td>AES</td>
<td>ratio of the weighted average fuel economies of small and large cars</td>
</tr>
<tr>
<td>AEL</td>
<td></td>
</tr>
<tr>
<td>PSA</td>
<td>the ratio of the real price of small cars to large cars</td>
</tr>
<tr>
<td>PLA</td>
<td></td>
</tr>
<tr>
<td>LA/NA</td>
<td>market share of new large automobiles</td>
</tr>
<tr>
<td>W</td>
<td>wage rate</td>
</tr>
<tr>
<td>T</td>
<td>time available for work and leisure</td>
</tr>
</tbody>
</table>
PT - percentage of vehicles registered as trucks or buses
DPOP - driving age population
UA - used car sales
PNA - price of new cars deflated by the consumer price index
D(QTRS) - dummy variables representing seasonality $D_1 = 1$ in first quarter, zero in other three; $D_2 = 1$ in second quarter, zero in other three; $D_3 = 1$ in third quarter, zero in other three; $D_4 = 1$ in fourth quarter, zero in other three
D(PROV) - dummy variables representing the four western provinces
$D(BC) = 1$ for British Columbia, zero for other provinces;
$D(A) = 1$ for Alberta, zero for other provinces;
$D(S) = 1$ for Saskatchewan, zero for other provinces;
$D(M) = 1$ for Manitoba, zero for other provinces.
Bi bliography


Canada. Statistics Canada
- Canadian Statistical Review - 11-003
- Consumer Price and Price Index - 62-010
- Consumer Price Index - 62-001
- Consumer Price Index for Regional Cities - 62-009
- Earnings and Hours of Wages: manufacturing - 72-204
- Employment, Earning and Hours - 72-002
- Energy Statistics Service Bulletin - 57-002
- Estimates of Labour Income - 72-005
Canada. Statistics Canada
- Industry Price Index - 62-011
- New Motor Vehicle Sales - 63-007
- New Vehicle Sales: annual statistics - 63-208
- Price and Price Indexes - 62-002
- Refined Petroleum Products - 45-004
- Refined Petroleum Products: consumption of petroleum products - 45-208
- Road Motor Vehicles: fuel sales - 53-218
- Road Motor Vehicles: registration - 45-208
- System of National Accounts: national income and expense accounts - 13-210
- Quarterly Estimates of Population for Canada and Provinces - 91-001
- Population by Sex and Age, 1921-1971 - 91-512


