

AN INVENTORY OF SELECTED
MATHEMATICAL MODELS RELATING
TO THE MOTOR VEHICLE
TRANSPORTATION SYSTEM AND
ASSOCIATED LITERATURE

SECOND SUPPLEMENT

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1.0 INTRODUCTION

This volume continues an inventory of selected mathematical models (econometric, accounting, physical, etc.) relating to the motor vehicle transportation system, and of literature related to the subject matter or objectives of the models. This is a supplement to two earlier volumes^{1,2} that contain descriptions of 142 models and abstracts of 116 associated documents. This volume contains descriptions of 60 models added to the inventory, and a revised report on three of those from the earlier volumes. There are also 56 abstracts of 83 associated documents added to the collection.

Each model predicts some variable(s) related to the motor vehicle transportation system as functions of policy-related variables. Most models have the potential for use in public policy analyses. Other models have been included because they have either advanced the development of models pertaining to the motor vehicle transportation system or they pertain to the public policies that may be analyzed by using models. The associated literature that is summarized contains data that may be used in running or building models, describes uses of models, or reports on evaluations of models.

The inventory is a product of a project entitled "Analytical Study of Mathematical Models of the Motor Vehicle System," sponsored by the Motor Vehicle Manufacturers Association (MVMA) and conducted by the Policy Analysis Division of the Highway Safety Research Institute (HSRI) at The University of Michigan.

The work for this volume was done during the period September 1980 through May 1981. The project is a continuing one, and it is planned to periodically publish additional supplements to the inventory.

1.1 Organization of This Volume

The purpose of this volume is twofold: (1) to present succinctly and in a structured way useful information about policy-oriented models of the

¹Richardson, B.C.; Segel, L.D.; Barnett, W.S.; Joscelyn, K.B., An inventory of selected mathematical models relating to the motor vehicle transportation system and associated literature, Ann Arbor, Michigan: UMI Research Press, an imprint of University Microfilms International, 1979.

²Richardson, B.C.; Segel, L.D.; Joscelyn, K.B., An inventory of selected mathematical models relating to the motor vehicle transportation system and associated literature--First Supplement, Ann Arbor, Michigan: UMI Research Press, an imprint of University Microfilms International, 1980.

motor vehicle transportation system, and (2) to present abstracts of related model literature. Section 1.0 describes how the information contained in the report is organized and presented, and how it was collected. Section 2.0 contains the detailed "long-form" reports on individual models collected through April 1981. Section 3.0 contains less-detailed "short-form" abstracts on the model-related documents. Section 4.0 is a set of indexes that may be used to locate particular models or documents according to six different categories: personal authors, organizational authors, sponsors, keywords, model names, and report titles. This section indexes reports and abstracts contained in both this supplement and the previous volumes.

1.2 Project Background and Objectives

The staff of the Highway Safety Research Institute in 1976 began an effort whose general objective has been to examine and describe mathematical models that have the potential to be used in formulating policy related to the motor vehicle transportation system. The specific objectives have been to:

- 1) find, collect, and describe existing mathematical models of the motor vehicle transportation system,
- 2) find, collect, and describe associated model literature,
- 3) provide the capability for exercising selected models via computer,
- 4) analyze selected models, and
- 5) investigate the use of models in policy formulation.

This volume reports on the progress made during the period September 1980 through May 1981 on the first two of these objectives. In accordance with the other objectives of the project, several other reports have been prepared. Four of these are: a report on the analysis of the Wharton Econometric Forecasting Associates' Automobile Demand Model³, a report on the use of that model in federal policy studies⁴, a report on the limitations on the use of mathematical models

³Golomb, D.H.; Luckey, M.M.; Saalberg, J.H.; Richardson, B.C.; Joscelyn, K.B., An analysis of the Wharton EFA automobile demand model, Ann Arbor, Michigan: UMI Research Press, an imprint of University Microfilms International, 1979.

⁴Saalberg, J.H.; Richardson, B.C.; Joscelyn, K.B., Federal policy applications of the Wharton EFA automobile demand model, Ann Arbor, Michigan: UMI Research Press, an imprint of University Microfilms International, 1979.

in transportation policy analysis⁵, and an overview of national-level energy models with transportation sectors⁶. A report on an analysis of the Faucett Automobile Sector Forecasting Model is forthcoming⁷.

1.3 Technical Approach

Literature for this inventory was found and collected in four ways: searching library catalogs, searching computerized literature data bases, reviewing references cited in other reports, and personally contacting model authors, sponsors, and other knowledgeable people in the field.

Models and related documents were considered appropriate for the inventory if a check of titles and abstracts indicated that they were related to the motor vehicle transportation system and (1) were judged to be usable in policy analyses, or (2) advanced the development of models.

The term "model" has been broadly used in this inventory. Any system of equations that is intended to represent a process or a system, such as the motor vehicle market, may be called a model. Taking this into account, the inventory includes models that consist merely of single-equation econometric regression specifications as well as sophisticated programs with large data bases that have been developed specifically for policy analyses. The complex models are included here because they have the potential for being used in research and policy-making, especially by the federal government. The simple models have been included because they are representative of research that has advanced economic theory as it applies to automobile demand, fuel or energy consumption, market share, vehicle miles traveled, or other aspects of the motor vehicle transportation system.

In general, the project staff concentrated their efforts on identifying models and documents written after 1970. In this supplement, however, an effort was made to collect the models that are frequently cited as being important in the historical development of motor vehicle price and

⁵Richardson, B.C.; Joscelyn, K.B.; Saalberg, J.H., Limitations on the use of mathematical models in transportation policy analysis, Ann Arbor, Michigan: UMI Research Press, an imprint of University Microfilms International, 1979.

⁶Richardson, B.C.; Barnett, W.S.; Dahl, C.A.; Roberts, D.C.; Joscelyn, K.B., An overview of selected national-level energy/transportation mathematical models, Ann Arbor, Michigan: UMI Research Press, an imprint of University Microfilms International, 1980.

⁷Richardson, B.C.; Barnett, W.S.; Musgrave, G.L.; Roberts, D.C.; Sanghvi, P.B.; Segel, L.D.; Joscelyn, K.B., An analysis of the Jack Faucett Associates Automobile Sector Forecasting Model, Ann Arbor, Michigan: UMI Research Press, an imprint of University Microfilms International, in press, 1981.

demand modeling theory. The models included are generally of national rather than local applicability. Models developed outside of the United States are included if the possibility exists of applying them in the U.S. or if certain aspects of them might be useful in building U.S. models.

The following model reports are revised versions of reports that appeared in earlier editions: 76-025, 78-263, and 78-297.

Each of the models and documents has been assigned one or more keywords that describe their subject matter. The keywords are listed in the table below.

KEYWORDS

Accidents	Market Share
Air Pollution/Air Quality	Modal Split
Automobile Demand	Model Assessment
Automobile Design	National Economic Impact
Automobile Supply	Noise Pollution
Data	Pricing
Emissions	Scrappage
Energy Consumption	Trucks
Fleet Size	Vehicle Manufacturing Resource Utilization
Fuel Consumption	Vehicle Miles Traveled
Fuel Economy	Vehicle Operating Performance
Fuel Price	Vehicle User Costs/Vehicle Operating Costs
Industrial Financial Performance	Weight

Every effort was made to be as comprehensive as possible, but the authors recognize that any effort of this nature is bound to be incomplete and somewhat outdated at the time of publication. They would, therefore, appreciate receiving any information the reader may have pertaining to new models of the type reported here, updates or corrections to the summaries of models included in this inventory, or references to related literature.

1.4 Format of Information Reported

The inventory reports in section 2.0 and abstracts in section 3.0 follow standard formats, with similar information about each model or document summarized under a consistent outline of categorical headings. It has not been possible to provide information for every category for every model and document. This is because the required information was either unavailable or inappropriate for the subject model or report. The level of detail for each report is dependent on the level of detail contained in the published documentation from which the information for the inventory was extracted.

1.4.1 General Information

The following categories of information are contained in both the ("long-form") inventory reports and in the ("short-form") abstracts.

Accession Number: Each model or document is assigned a five-digit accession number. The first two digits represent the year in which the report was written and the last three the order in which the reports were received by HSRI project staff. It is the last three digits by which the reports are ordered in this volume. For example, 74-005 follows 75-004.

If there are a small number of distinct submodels within a model, each submodel is further designated by appending a letter (i.e., A, B, C, etc.) to the five-digit accession number. A separate inventory form is included for each submodel to facilitate more complete and accurate reporting.

The accession numbers of the non-model document abstracts in section 3.0 are prefixed by "S-" (a symbol referring to "supporting" material). This distinguishes model descriptions from descriptions of documents that are not on models as such.

Although the reports are ordered consecutively, there are gaps in the sequence of accession numbers. These gaps occur because some documents proved to be duplicates or irrelevant during the in-depth review process that occurs prior to final inclusion in the inventory. These documents were deleted from the inventory, but only after the accession numbers had been assigned.

Sponsor: Included in this item are the name and address of the organization which sponsored the study or the construction of the model. If there was more than one sponsoring organization, each of these is included.

Organization Author: This designation includes the name and address of the organizational author or authors of the model or study. On the long-form reports in Section 2.0, this information will be found under the "AUTHOR" heading. On the short-form abstracts in Section 3.0 this information appears under the "PERFORMING ORGANIZATION" heading. The

"AUTHOR" heading on the long-form reports also includes the names of personal authors.

Keywords: These refer to the basic subject matter of the study or the outputs that the model was built to produce. Every report is categorized according to one or more of the keywords listed in Table 1.

Reference: The sources for the information presented are cited. These citations generally follow this format: personal authors' names, report or paper title, organizational author or publication data, report number, date, and National Technical Information Service (NTIS) number, if there is one.

1.4.2 Detailed Information on Models

The following categories of information are found only on the "long-form" inventory reports of Section 2.0:

Model Name: The model name refers to the commonly recognized name of the model if it has one. Otherwise, the name of the report in which the model is presented is listed.

Summary: The first paragraph of each report is a summary statement about each model, including its name, author, date, sponsor, purpose, and, if documented, its use in policy analysis.

Objective of Model: The objective of the model is the purpose for which the model was built. This often includes the relationships which are analyzed in the model.

Relationship to Other Models: If the model is a submodel of a larger system, this is explained here. Inputs from or outputs to other models are discussed.

Historical Background: Relevant history pertaining to the model is summarized, including the reasons for its development, models which preceded it and constituted developmental antecedents, and other work by its authors.

Assumptions: Basic assumptions made in the construction of the model, including primarily those reported by model authors, are indicated. These may include assumed relationships among variables and substitutability of variables, as well as other imposed conditions.

Validation: This includes any information relating to the forecasting behavior and dynamic properties of the model that has been reported by model authors or others. Forecasting behavior refers to comparing actual values with predictions of the model. Dynamic properties refer to the time paths of changes in the endogenous variables of the model in response to a change in one or more of the exogenous variables of the model. When no model validation has been done, but the authors report results from their research with the model, that information is described.

Limitations and Benefits: Limitations may include the fact that a model is out of date, that the relative importance of variables has changed over time, or other problems reported by the model authors. Benefits might include a successful, innovative approach to a particular analytic problem, or special abilities of the model. Generally the limitations and benefits listed are those reported by the model authors.

Structure: This heading describes the analytical logic and flow of the submodels, equations, and output of the model. The form of key or representative equations may be presented.

Model Construction: This section discusses, for econometric models, the sources of the historical data used to estimate the equations. For other types of models the theory, academic field, or branch of science upon which the model is based is presented.

Data Used In Running Model: The input data, parameters, or options that the user must specify to run the model are listed.

Computer Requirements: When available, information is provided pertaining to the computer requirements or specifications of the model, including hardware, running time, programming language, etc.

1.4.3 Information on Supporting Literature

The following items will be found only on the "short-form" abstracts of section 3.0:

Concerning Model: The names and accession numbers of models with which the abstracted document is concerned are listed. This is appropriate if the document reports on the use, validation, or assessment of a specific model reported in Section 2.0 of this report.

Abstract: This paragraph summarizes the contents of the document.

1.4.4 Indexes

In the fourth section of this volume, all of the models and documents are indexed. There are six separate indexes in which personal authors, organizational authors, sponsors, keywords, model names, and report titles are all listed alphabetically, followed by the accession numbers.

In the case of joint authorship or sponsorship each author or sponsor is listed separately. Not all documents or models have both personal and organizational authors and sponsors, and therefore not all of them appear on each list.

Most models and documents have more than one keyword, so they appear under several keywords in the index.

To save the user the trouble of having to search through two sets of indexes, the models from Section 2.0 and the associated literature from

Section 3.0 are included in each of the indexes. Once an accession number is acquired from the indexes, the user may find either a model inventory report in Section 2.0 (for accession numbers without the "S-" prefix) or an abstract in Section 3.0 (for accession numbers preceded by "S-"). Within each section the reports or abstracts are in accession number order (by the last three digits), and the accession numbers appear in the upper outside corner of each page.

The indexes are cumulative, in that they list models and documents contained in both this supplement, in the original (1979) report, and in the first (1980) supplement. Accession numbers followed by (79) or (80) refer to abstracts or reports that are to be found in an earlier volume of the Inventory.

2.0 MODEL INVENTORY REPORTS

CRA HEDONIC MARKET SHARE MODEL

The CRA Hedonic Market Share Model, also referred to as the CRA Hedonic Demand Model, was originally developed at Charles River Associates, Inc. (CRA) in 1976. Improvements and extensions to the model have been sponsored by CRA, the U.S. Department of Labor (DOL), the Electric Power Research Institute--Energy Analysis and Environment Division (EPRI), and the U.S. Department of Transportation (DOT). The model estimates the impact of changes in vehicle attributes on the market shares of the particular vehicles that are offered by manufacturers.

SPONSOR

U.S. Department of Labor
Bureau of International Labor Affairs
Washington, D.C.

Electric Power Research Institute
Palo Alto, Calif.

U.S. Department of Transportation
National Highway Traffic Safety Administration
Washington, D.C.

AUTHOR

N. Scott Cardell, J. Hayden Boyd, Robert E. Mellman, Fred C. Dunbar
Charles River Associates, Inc.
200 Clarendon Street
Boston, Mass. 02116

KEYWORDS

Market share, automobile demand

OBJECTIVE OF MODEL

The objective of the model is to estimate the impact of changes in vehicle attributes (such as price, fuel economy, or frequency of repair) or in manufacturer product offerings (such as the types or models of vehicles) on the market shares of those product offerings.

RELATIONSHIP TO OTHER MODELS

There is no relationship to other models.

HISTORICAL BACKGROUND

The hedonic model was originally developed by N. Scott Cardell for the purpose of estimating the effects of tariff changes on imported automobile sales. Under the sponsorship of EPRI, CRA refined the model and tested its algorithms on the market for electricity-using goods. This indicated its potential applicability to commodities other than motor vehicles. Under DOL sponsorship, a 1974 model year automotive database was developed and used to assess the economic effects of potential changes in U.S. tariffs and the imposition of quotas by the U.S. on the importation of foreign cars. Under DOT sponsorship, a new version of the computer program for the model was developed and data bases for model year 1977 and 1978 automobiles were compiled. These were used to study the impact of changes in vehicle attributes, particularly fuel economy, on the market share and competitive situation in the U.S. automobile industry. DOT also sponsored a study of the societal impacts of automobile downsizing, which was based on the original version of the model program and on the 1977 data base.

ASSUMPTIONS

The model assumes that individual car and light-truck product offerings by manufacturers can be treated as bundles of identifiable and measurable characteristics or attributes that are relevant to purchases by consumers of particular makes and models of automobiles. In their purchase decisions, consumers are assumed to maximize their utility, subject to their individual preferences for vehicle attributes and for the vehicle offerings produced by the manufacturers. The estimation technique assumes that individual consumers vary in their demand for a particular automobile characteristic, including prices, because of differences in their incomes, use patterns, and personal tastes. The model also assumes that the size of the total market is fixed, that the utility function is linear, and that consumers' tastes are stable as prices change.

VALIDATION

The predictions derived from the model have not been validated by comparison with actual historical experience. The model authors noted that the results were similar to estimates from time-series regressions included in the studies by CRA (1977) and by Toder, Cardell, and Burton (1978), and to the predictions derived by questionnaire techniques in a study that was done by Market Facts, Inc. Cardell and Dunbar (1980) noted that the taste distribution parameter estimates were relatively consistent over both the 1974 and 1977 data bases.

LIMITATIONS AND BENEFITS

For the share predictions to be reasonable, the set of automobile models included for consideration must cover nearly the entire market.

In order to predict new-car sales, estimates of the total price elasticity of new-car demand must be obtained from other sources.

STRUCTURE

The model estimates the distribution (mean and standard deviation) of consumers' tastes for each of up to ten out of over fifty possible attributes of vehicles. Given the actual market shares of each of the set of vehicle models offered by the manufacturers, a measurement of each attribute for each vehicle model, and a random probability of the importance that each of up to 1000 consumers attaches to each of the attributes, the computer program estimates the distribution parameters. The estimates of the distributions of consumer tastes may then be used to predict the market share distribution that might result if there were a change in prices or in the measurements of the set of attributes for some or all of the vehicles.

The model begins with the assumption:

$$U_{ij} = U(C_j, P_j, \alpha_i)$$

where:

U_{ij} = the utility of individual consumer i from the purchase of model j

C_j = a vector of attributes of model j

P_j = the price of model j

α_i = a set of parameters that maps C_j and P_j into U_{ij}

The utility function is assumed to be linear, so that the α 's represent the marginal rates of substitution between the attributes and the price. Then α is viewed as a vector of random variables, allowing the generation of a probability distribution for the choice among automobile models. A simple functional form for the probability distribution of the α 's is assumed. The model seeks to find the distribution of consumers' utility functions that most closely reproduces the market shares actually observed for the individual models of vehicles. Either logit or hedonic estimation-technique algorithms may be used to determine the distributions. Algorithms are provided that use the taste distribution parameter estimates to simulate the market's response to changes in the attributes of the vehicles offered. The various applications of the model have involved using these algorithms on alternative data bases. The different versions of the model (i.e., different parameter estimates) occurred when the various research teams selected different vehicle attributes for their particular studies. Thus, the structure of this model differs from most others in that the algorithms are used to build the specific version through the estimation of the parameters as well as to simulate alternative scenarios.

Toder, Cardell, and Burton (1978) and CRA (1977) used vehicle price, volume, passenger area, weight, turning circle, and miles per gallon as their attributes. Cardell and Dunbar (1980) used price, fuel consumption, acceleration, frequency of repair, luxury (a construction based on Consumer Reports noise and ride ratings), and passenger space. Boyd and Mellman (1980) reported the results of three alternative specifications, but their analysis was primarily based on the specification that contained price, fuel consumption, acceleration, frequency of repair, style (a construction based on exterior dimensions), and noise ratings.

MODEL CONSTRUCTION

This model was constructed on cross-section data for vehicle prices, characteristics, and new-car sales. The model has been applied to automobile data bases for model years 1974 (106 makes and models of vehicles), 1977 (153 vehicles), and 1978 (162 vehicles).

DATA USED IN RUNNING MODEL

To use the model for predictions, a relatively detailed vehicle data base is required. The data base would include new product offerings, vehicle attributes (e.g., prices, acceleration, frequency of repair), and projected policies (e.g., tariff levels, vehicle taxes).

REFERENCES

Boyd, J.H.; Mellman, R.E., Impact of automotive fuel economy standards on competition in the automotive industry, U.S. Department of Transportation, Report no. DOT-HS-805-528, July 1980.

Impact of trade policies on the U.S. automobile market, Charles River Associates, prepared for Bureau of International Labor Affairs, U.S. Department of Labor, CRA Report No. 219, October 1976.

Methodology for determining the demand for new electricity-using goods, Electric Power Research Institute, Report no. EA-593, December 1977.

Boyd, J.H., Market effects of CAFE-induced changes in automotive attributes--A hedonic demand analysis, presented at First Annual Automotive Fuel Economy Research Conference. Charles River Associates, Inc., November 1979.

Boyd, J.H.; Mellman, R.E., Effect of fuel economy standards on the U.S. automotive market: An hedonic demand analysis, Transportation Research, 14A:367-378, 1980.

Cardell, N.S.; Dunbar, F.C., Measuring the societal impacts of automobile downsizing, Transportation Research, 14A:423-434, 1980.

Toder, E.J.; Cardell, N.S., Effects of trade barriers on the U.S. automobile market, in The Impact of International Trade and Investment on Employment, ed. Dewald, W.G., pp. 33-63, including Comments by H.M. Kramer and J.E. Triplett, a Reply by the authors, and a Rejoinder by Triplett. U.S. Department of Labor, 1978.

Toder, E.J.; Cardell, N.S.; Burton, E., Trade policy and the U.S. automobile industry, New York: Praeger Publishers, 1978.

COMPUTER REQUIREMENTS

The computer program for the model consists primarily of an algorithm for the numerical evaluation of probability integrals using the Monte-Carlo method. Programs are also provided for calculating the market share changes under the different scenarios, for producing results reports, and for managing the data bases. The earlier version of the program was written in PDP-11 machine code and FORTRAN and required several hand calculations at various points in the maximum-likelihood and Monte-Carlo procedures. The 1980 version of the program was written in IBM-compatible FORTRAN and does not require hand calculations. The 1980 version is relatively expensive to use, requiring about 500 seconds of CPU time to determine the taste-parameter estimates. The earlier version of the program is more efficient and less expensive to use.

INTEREST RATES AND THE DEMAND FOR CONSUMER DURABLE GOODS

This model illustrating the effects of interest rates on the demand for automobiles and other consumer durable goods was developed in 1967 at the Federal Reserve Bank of New York. Its results show that interest rates have an effect on demand that is significant and independent.

AUTHOR

Michael J. Hamburger
Federal Reserve Bank of New York
New York, N.Y.

KEYWORDS

Automobile demand

OBJECTIVE OF MODEL

The model shows how monetary variables, such as interest rates, have an effect on the demand for consumer durable goods, such as automobiles. The objective of the study was to cast doubt on the widely accepted notion that consumers do not respond to changes in interest rates and to show that interest rates have a more direct effect than other monetary policy. A new approach was used in modeling automobile demand.

RELATIONSHIP TO OTHER MODELS

There is no interaction with other models.

ASSUMPTIONS

Desired aggregate stock of a physical asset is assumed to be a function of aggregate income, yields on financial assets and liabilities, and the price of the asset. There is a stock adjustment relationship wherein consumers make an adjustment towards equating their actual and desired asset balances during any time period. The independent variables may have different lags to allow the adjustment to begin at different periods. Depreciation is some percentage of existing stock and of current purchases, but is not necessarily fixed. The depreciation on existing stock and the lags on the variables are not known beforehand.

LIMITATIONS AND BENEFITS

The rate of depreciation on current purchases is explicitly recognized, but is generally ignored in other studies. Weighted differences of the explanatory variables as opposed to the levels of the

variables tends to reduce the amount of multicollinearity which might otherwise be present.

STRUCTURE

The model author's assumptions and transformations result in the following general equation:

$$X_t = a + b [Y_{t^*} - (1 - e_2) Y_{t^*-1}] + c [r_{t^*} - (1 - e_2) r_{t^*-1}] \\ + d [P_{t^*} - (1 - e_2) P_{t^*-1}] + (1 - T) X_{t-1} + v_t$$

where:

X = personal consumption expenditures on automobiles and parts, seasonally adjusted at annual rates

Y = disposable personal income, seasonally adjusted

e_2 = annual rate of depreciation of the existing asset stock

r = Moody's Aaa rate on long-term corporate bonds, per cent

P = relative price of automobiles, either the implicit price deflator for personal consumption expenditures on autos and parts divided by the deflator for all consumption expenditures, or the new car component of the consumer price index deflated by index value for all items

T = stock adjustment reaction coefficient

v = residual term

t^* = the varying lags associated with each independent variable

The model and several alternative specifications were estimated, for automobiles and parts and also for other consumer durable goods. These are compared with the results of other studies.

Income is shown to have a longer lag, supporting the view that consumers spend more time planning their automobile expenditures than their smaller ones. Estimated lags of the interest rate may serve as indicators of the reaction times of suppliers of consumer credit to changes in open market rates.

An estimation of the model with different data and variable specifications did not produce significantly different results. The model author concludes that the hypothesis is correct that aggregate consumer durable purchases are influenced by both the prices of goods and the costs of financing them. A number of different money supply variables were added to alternative model specifications. The results seem to show that interest rates do not serve as proxies for the monetary supply variables; they have their own effect. The addition of

residential construction expenditures as a variable also does not significantly change the automobile equation.

MODEL CONSTRUCTION

Since the rate of depreciation on existing stock and the lags on the explanatory variables are not known beforehand, an iterative estimation procedure had to be employed. If residuals are normally and independently distributed, maximum likelihood estimates of the coefficients could be identified. This was done by computing the weighted differences of the exogenous variables for each of a number of values of the depreciation rate and the lags associated with the independent variables. Then the least squares regression was computed, for each of these values, of X_t on the weighted differences of the independent variables and X_{t-1} . The maximum R^2 with respect to the depreciation rate and the lags was then found. The associated coefficients were the maximum likelihood estimates. Quarterly observations are used to estimate the model, from the period 1953-64.

REFERENCE

Hamburger, M.J., Interest rates and the demand for consumer durable goods, American Economic Review 57:1113-1153, December 1967.

DISAGGREGATE MODEL OF AUTO-TYPE CHOICE

This disaggregate model of auto-type choice that determines the probability of household choices for types of cars was developed at Cambridge Systematics, Inc./West and the University of California at Irvine in 1977 and was published in 1979. It was sponsored by the U.S. Department of Energy. The model was used to predict the market shares of potential future non-gasoline-powered cars.

SPONSOR

U.S. Department of Energy
Washington, D.C.

AUTHOR

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KEYWORDS

Market share

OBJECTIVE OF MODEL

This disaggregate model is meant to show the decision of a household in choosing what type of car will be bought from those available. The model estimates the probability that a household will choose to buy a new auto within one of ten classes of auto types.

RELATIONSHIP TO OTHER MODELS

This is not related to other models. This is a different model from that of Manski and Sherman at Cambridge Systematics (East) (78-297), or from modal split models by Train.

ASSUMPTIONS

The probability of choosing some type of car is assumed to depend on three types of explanatory variables: household characteristics, car characteristics, and environment; or more specifically: income, family size, number of cars owned, miles driven, ratio of car cost to income, ratio of seats to people in the family, ratio of gas price to fuel economy, and weight or performance of car times household age or education. Some hypotheses confirmed by the results are that a rise in income increases the probability of choosing an expensive class of car, as does an increase in fuel economy or the the number of seats; households with many autos tend to buy smaller cars; high income people care less about cost; large families are less likely to buy sport cars; households who do more driving choose large autos; those with less education like big cars and vice versa; young people are more influenced by car performance; and all households value operating cost similarly.

VALIDATION

A study was done to examine several specific types of non-gasoline-powered automobiles, estimating what the market shares of these vehicles would be in the years 2000 and 2025, if the vehicles were available in any quantity, if consumer's valuations of auto characteristics remained the same over time, if no major changes occurred in regulations or taxes, and if gas and electricity real prices do not rise over time. Characteristics of the vehicles were designed for a project at Lawrence Livermore Laboratories; these were medium and small gas autos, diesel, nickel-zinc battery, high-temperature battery-powered, hybrid, aluminum-air cell-powered electric, and hydrogen-burning vehicles. Household-characteristic data were obtained from the 1969 Nationwide Personal Transportation Study and the Survey Research Center, and were extrapolated into the future. Assumptions were made concerning the procedure by which a household chooses a second or third car, given their current holdings. The resulting "base case" forecasts of market shares for these vehicles were determined from the probabilities predicted by the model. They were compared with electric vehicle forecasts made by Mathtech (77-217) and SRI International (based on the Crow and Ratchford model 77-574). Problems with this model found to have a bearing on the study are the means for specifying the limited range of battery-powered vehicles; the extent to which a household's choices for a first, second, and third car are made simultaneously; and the dynamic effects of owning and buying new or used cars.

LIMITATIONS AND BENEFITS

Previous econometric models of auto-type choice have used aggregate data with only price and fuel economy as explanatory auto characteristics. Automobile characteristics do not vary substantially over time or across regions, resulting in large coefficient standard errors. A disaggregate econometric approach, as used in this model, would avoid the problems of lack of sufficient variation and large correlations among the auto characteristics.

The model assumes that the ratio of the probabilities of choosing any two alternatives is independent of the availability or attributes of other alternatives. This is called the independence from irrelevant alternatives (IIA) property. The model may violate the IIA assumption, but the authors believe that the estimation procedures and empirical testing prevent this. Because a stratified sampling procedure was used, some theoretical work lead the authors to warn that the estimated coefficients should be viewed with caution. Also there is some question as to how much information an explanatory variable contains about the effect of the attribute rather than the effect of the decisionmaker's tastes as captured by his socioeconomic characteristics, when most of the auto attributes do not vary over the population.

STRUCTURE

All the makes and models of cars were classified into ten classes, each of which was homogeneous in size and price: subcompact, sports car, two classes of subcompact, two compact classes, intermediate, two standard classes, and luxury.

This multinomial logit (MNL) model estimates the probability of choosing a new auto in class i :

$$P_i = e^{B z(x_i, s)} / \sum_{j=1}^{10} e^{B z(x_j, s)}$$

where:

P_i = probability of choosing a new auto in class i

$B z(x_i, s)$ = "representative" utility of auto class i

B = vector of coefficients

z = vector-valued function of x_i and s

x_i = vector of attributes of autos of class i

s = vector of attributes of the household

The independent variables, the elements of $z(x_i, s)$, are: initial auto cost divided by household income, auto operating cost per mile, weighted seats, dummy for whether the household owns more than two autos, dummy for whether the household earns more than 25,000 dollars a year, number of persons in household, vehicle miles traveled per month by the household, auto weight times age of respondent, auto weight times education of respondent, auto performance times age of respondent, and dummy variables for nine of the car classes. The model has 24 coefficients that are applied selectively to each of the ten alternative classes.

MODEL CONSTRUCTION

Data for estimation of the model came from a stratified random sample of 541 new car buyers, collected during the summer of 1976 by Arthur D. Little, Inc. in seven cities. Information on the various physical characteristics for each type of car was taken from the 1976 Automotive News Market Data Book. Price data for each car included sticker price, destination charges for each city, and taxes for each city, as obtained from auto manufacturers and government sources.

REFERENCES

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Lave, C.A.; Train, K., Progress report no. 2: Description of auto-choice model, preliminary and confidential, University of California, December 1976.

Train, K., Potential market for non-gasoline-powered automobiles, Transportation Research 14A:405-414, 1980.

Behrin, E.; Anderson, C.J.; Bomelburg, H.; Farahat, M.; Forsberg, H.C.; Hudson, C.L.; Kullman, B.C.; O'Connell, L.G.; Strickland, G.; Walsh, W.J., Energy storage systems for automobile propulsion: 1978 study, two volumes, Lawrence Livermore Laboratory, Report no. UCRL-52553, December 15, 1978.

ECONOMETRIC MODEL OF CONSUMER DEMAND FOR NEW AND REPLACEMENT AUTOMOBILES

An econometric model of demand for automobiles was developed in 1976 at Data Resources, Inc. (DRI). Automobile usage, scrappage, and demand for stock are explicitly modeled, while new car sales are determined from them.

AUTHOR

Philip K. Verleger, Jr., and James Osten
Data Resources, Inc.

KEYWORDS

Automobile demand, fleet size, scrappage, vehicle miles traveled, fuel consumption

OBJECTIVE OF MODEL

This econometric model of automobile demand describes the relationships between automobile usage, the demand for the stock of automobiles, and the manner in which autos decay. It simulates the consumer demand for auto stocks, usage, and scrappage. New car sales result from growth in demand for stock and scrappage. Gasoline consumption is also calculated.

RELATIONSHIP TO OTHER MODELS

There is no interaction with other models.

HISTORICAL BACKGROUND

Previous studies used consumption function models in which the emphasis was on new car sales as a function of real income, household assets, population, stock market performance, and the stock of autos. Those earlier models, by including the stock of autos and measures of consumer sentiment to explain auto demand, are said to be inappropriate for policy analysis except in the very short run. In those models autos are demanded for themselves instead of for the services they provide; sales are determined by economic conditions rather than as a result of increases in demand for capital or its scrappage; and scrappage occurs at a fixed rate instead of responding to major fluctuations. This DRI model explicitly considers the demand for stock rather than the demand for investment, and scrappage is based on auto usage rather than age.

Mr. Osten subsequently moved to Data Resources of Canada in Toronto. Some of the work on this model was integrated into other modeling services of DRI.

VALIDATION

Three historical simulations were done over the 1970-1975 period, to analyze the model's predictive accuracy, the impact of pollution devices, and the effect of the increase in oil prices. Considering that new car sales are not explicitly modeled, the average annual error of 2.1% is considered good. Simulations over the 1976-85 period were done using exogenous inputs developed by Data Resources, Inc. for the Federal Energy Administration's National Energy Outlook for 1976. These forecasts were intended to analyze the potential size of the auto market in the absence of any major changes, the impact of the fuel economy standards, increased auto service lives, and the effects of a gasoline tax.

LIMITATIONS AND BENEFITS

The model authors believe that this model is better for forecasting the long term than the short term. Relationships involving feedback effects from the auto sector to the economy have been ignored. Analysis of demand for autos by size has been excluded.

STRUCTURE

Three variables are modeled: miles driven, stock of cars, and scrappage. New car sales are a residual. The specifications are:

$$\ln(S_{j,t}/S_{j,t-1}) = \alpha_j - \frac{.635}{(3.108)} [\ln(M_t/M_{t-1})] - \frac{.420}{(7.598)} [\ln(CM_{j,t})] \\ + \frac{.010}{(4.619)} [\ln(RU)] - \frac{.022}{(4.139)} (\text{LEMON})$$

$$\bar{R}^2 = .6675 \quad \text{SEE} = .0815$$

where t-statistics are in parentheses, and

$S_{j,t}$ = percentage of the model year j surviving in year t

α_j = intercept for cars of model year j

M_t = demand for miles of travel per person in year t

$CM_{j,t}$ = cumulative miles driven by cars of model year j

RU = unemployment rate

LEMON = factor to account for 1957-58 "lemon effect" of higher than average scrappage rates

$$\ln(M) = \frac{.351}{(1.227)} + \frac{.672}{(3.377)} [\ln(K)] + \frac{.464}{(3.453)} [\ln(Y)] - \frac{.187}{(1.650)} [\ln(C)]$$

$$\bar{R}^2 = .97 \quad DW = .61$$

where:

M = miles driven per capita usage of autos

K = consumer holders of autos

Y = real personal disposable income

C = variable operating cost for an average auto, including cost per mile of gas, maintenance, tires, etc.

$$\begin{aligned} \ln(K) = & \frac{-5.602}{(5.073)} - \frac{.132}{(3.012)} [\ln(C)] + \frac{.818}{(5.152)} [\ln(D)] + \frac{.408}{(7.091)} [\ln(YP)] \\ & + \frac{.062}{(1.274)} [\ln(M_t/M_{t-1})] \end{aligned}$$

$$\bar{R}^2 = .995 \quad DW = .241$$

where:

K = per capita demand for holdings of stock

C = the cost of automobile stock, including depreciation, first year operating cost, and the interest cost of carrying a new car

D = number of drivers per capita

YP = permanent income

M_t = miles driven per capita

$$\ln(G) = \frac{6.3765}{(171.157)} + \frac{.813616}{(60.396)} \left[\ln\left(\frac{M N}{\sum_i w_i g_i K_i}\right) \right]$$

$$\bar{R}^2 = .9875 \quad DW = 1.6594$$

where:

G = gasoline usage

M N = total miles driven

$w_i g_i K_i$ = relative gasoline consumption of an auto of vintage i

w_i = normalizes auto usage since older cars tend to be driven fewer miles than newer ones

g_i = average gallons per mile of vintage i

K_i = stock of vintage i

A regression equation is needed for gas consumption because not all gasoline is consumed by autos. A complete set of elasticities are presented in the model report. The simulation model includes two simultaneous equations and fifteen recursive retirement equations. It is estimated and simulated at a quarterly frequency. Scrappage is explained for autos from age two to fifteen and older. Simulations are dynamic.

MODEL CONSTRUCTION

Yearly estimates of cumulative miles driven by model year were constructed from data supplied by the U.S. Department of Transportation, Census of Transportation and Highway Statistics. The price of used cars is based on Bureau of Labor Statistics data. Other data used in construction of the model was from R.L. Polk.

REFERENCE

Verleger, P.K., Jr.; Osten, J., Econometric model of consumer demand for new and replacement automobiles, Data Resources, Inc., March 26, 1976.

ORNL HIGHWAY GASOLINE DEMAND MODEL

The Oak Ridge National Laboratory Highway Gasoline Demand Model is a midterm (5-15 years forecast horizon) model developed in 1978-80 for the Energy Information Administration Office of Applied Analysis to be used in conjunction with the Midterm Energy Forecasting System (MEFS) (S-79-418). The model is a forecasting tool designed for use in evaluating policies and trends affecting regional economics, demographics, spatial structure, fuel price levels, and technological changes in light-duty highway vehicles.

The Oak Ridge National Laboratory (ORNL) Highway Gasoline Demand Model (HGDM) is referred to by several names. These include the ORNL State-Level Transportation Energy Demand Model and the ORNL State-Level Gasoline Demand Model.

SPONSOR

U.S. Department of Energy
Energy Information Administration
Assistant Administrator for Applied Analysis
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AUTHOR

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Oak Ridge, Tenn. 37830

KEYWORDS

Fuel consumption, automobile demand, fleet size, fuel economy, market share, scrappage, vehicle miles traveled

OBJECTIVE OF MODEL

The model is a forecasting tool designed for use in evaluating policies targeted to alter the fuel efficiency and composition of the vehicle stock, including those policies directly affecting gasoline prices. Vehicle purchase and ownership for six classes of cars and light trucks are modeled along with fuel demand. Model output includes new-vehicle sales, fleet (stock) composition by class and state, fuel efficiency of the fleet by state, vehicle miles traveled, and gasoline demand. These variables are forecast at the state, DOE regional, and national levels.

Demand forecasts are a function of exogenous demographic and economic variables. Geographic and other regionally varying factors also affect

vehicle and fuel demand. The model combines econometric relationships with engineering relationships to deal with changes in vehicle technology. The model has the capability to simulate the impact of market penetration of various motor vehicle technologies. The fuel and engine types currently included are leaded and unleaded gasoline, diesel, Stirling, Brayton (turbine) engines, and electrics. These engine types are likely to change as future technologies and market influences become more apparent. Presently, the impact of the market penetration of electric vehicles can be simulated by the model but the fuel consumption of those vehicles is not forecast.

The model forecasts the fuel consumption of only light-duty vehicles. The fuel consumption of heavy-duty trucks is not included in the model. (The model authors do alert the potential user to possible problems caused by the assumption concerning heavy trucks.)

RELATIONSHIP TO OTHER MODELS

This model may potentially be used as the transportation sector submodel of the Midterm Energy Forecasting System (MEFS) (S-78-419), which is used by the Energy Information Administration of the Department of Energy.

HISTORICAL BACKGROUND

The model documentation includes an extensive review of previous fuel consumption and automobile demand models.

ASSUMPTIONS

The model is based on household production theory, which represents the consumer as constrained by technology as well as by a budget, and seeks to separate the effects of household production technology from those of preferences on consumer behavior. Thus, the model explicitly considers the impacts of transportation technology on energy use, as well as more traditional economic factors such as price and income. The long-run focus of the model is on changes in the stock of vehicles that alter fuel economy, and thus gasoline demand. In the short run, the aggregate stock of vehicles is fixed, but the model attempts to allow for consumer substitution among inputs in producing travel.

STRUCTURE

The model, as originally designed, can be decomposed into five major submodels: (1) used-vehicle fleet supply and demand, (2) new-vehicle supply and demand, (3) vehicle fleet mix, (4) fleet fuel efficiency, and (5) gasoline demand. In operation, the model is to proceed sequentially from submodel 1 to submodel 5 for each year, with a recursive feedback from submodel (3) to submodel (1). Thus, the fleet composition of the previous year influences used-vehicle demand in the current year, which

in turn influences current-year new-vehicle demand. Each of these five submodels is discussed below.

Output is produced for 1977 to 1995. Printed output can include the exogenous input data (to facilitate identifications and comparison of model runs), various intermediate calculations, and forecast variables. The forecast variables are presented at the state, federal region, and national levels of aggregation (all are by class and engine type). Those variables are: unit new-vehicle sales, fleet composition, miles per gallon, vehicle miles traveled, and fuel consumption.

HGDM Submodel: Motor Vehicle Demand Model

HGDM is based on a hypothesis that new vehicles are not simply additions to the stock, but are considered to be distinct, superior goods that are close substitutes for used cars. Different types of vehicles are also assumed to be distinct commodities whose demand should be estimated separately. Thus, rather than having a new-vehicle shares equation and a set of market share equations, the model authors developed a set of demand equations, one for each vehicle class.

Six vehicle classes were defined. Five are automobile classes whose characteristics are defined through a cluster analysis technique, based on the class distinctions of eight variables: (1) wheelbase, (2) curbweight, (3) engine displacement, (4) a roominess index, (5) number of passengers, (6) manufacturer's list price, (7) price divided by number of passengers, and (8) ratio of horsepower to curbweight. The six vehicle classes may be generally described as:

- Class 1: high performance, luxury sports cars;
- Class 2: large luxury cars;
- Class 3: small economy cars;
- Class 4: medium-sized economy cars;
- Class 5: large economy cars; and
- Class 6: light trucks under 10,000 pounds GVW.

Using a variance components estimation technique, demand equations were estimated for each of the six vehicle classes as a function of the following variables: own price, other vehicle prices, fuel cost, fuel efficiency, income, household size, age (18-44), percent SMSA, population, and unemployment. The equations for the six classes are presented in the table below. Implicit in the structure of this model is that new-vehicle supply is assumed to be perfectly elastic at the exogenously set price.

The Motor Vehicle Demand Model also contains equations that estimate used-vehicle prices by class as a function of new-vehicle prices. Used-vehicle prices are used in the Fleetmix Model to project changes in the fleet composition.

VARIANCE COMPONENTS ESTIMATES OF NEW-VEHICLE CLASS-DEMAND
EQUATIONS USING TRANSFORMED DEPENDENT VARIABLE TECHNIQUE
(standard errors in parentheses)

Class	Intercept	Own-Price	Cross-Price	Gasoline	Income	Household Size	Age 18-44	Percent SMSA	Population Density	Unemployment	Residual Variance (D.F.)
1	-5.523 (3.554)	-0.7 *	0.182 (0.381)	0.346 (0.195)	1.431 (0.195)	-1.450 (0.456)		0.237 (0.071)	0.050 (0.029)	-0.105 (0.045)	0.135 (542)
2	3.754 (2.375)	-2.5 *	1.449 (0.261)	-0.092 (0.167)	0.809 (0.135)		-1.878 (0.198)	0.090 (0.046)		-0.089 (0.033)	0.072 (543)
3	5.587 (2.057) Year 67	-0.9 *	0.463 (0.188) Year 68	0.271 (0.148) Year 70	0.338 (0.153) Year 71	-0.927 (0.435)	1.957 (0.243)	0.137 (0.053)		-0.191 (0.034)	0.085 (537)
	-1.334 (0.078)	-1.113 (0.077)	-0.881 (0.073)	-0.461 (0.065)	-0.201 (0.062)						
4	2.770 (2.017) Year 77	-0.4 *	0.366 (0.202)	-0.072 (0.140)	0.062 (0.111)	0.892 (0.264)			0.056 (0.013)	-0.157 (0.026)	0.061 (542)
		0.317 (0.192)									
5	0.004 (2.498) Year 77	-2.5 *	2.160 (0.254)	-0.126 (0.162)	0.440 (0.142)	2.169 (0.380)	-1.864 (0.236)			-0.236 (0.234)	0.059 (542)
		-0.483 (0.155)									
6	1.193 (2.249)	-1.1 *	1.057 (0.247)	0.002 (0.190)	0.345 (0.137)	-1.349 (0.353)	0.626 (0.224)	-0.130 (0.047)	-0.265 (0.019)	-0.243 (0.032)	0.051 (541)

* The value of the own-price coefficient was fixed outside of the regression analysis, so its standard errors are unknown. Source of table: Greene, Rose, and Chen 1980.

HGDM Submodel: Fleetmix Model

The Fleetmix Model represents the used-car market through the use of the Scrappage and Migration Estimator, and Class and Vintage Accounting Model. The former forecasts scrappage and migration rates by state, vehicle class, and vintage. The latter uses the forecasts to track the fleet composition over time.

The rate of vehicle scrappage is forecast by means of a probabilistic model that has scrappage rates as a function of vehicle age and used-car price. Individual equations were estimated for each state. Separate scrappage equations are included for the primarily domestic vehicle classes 2, 4, 5, and 6. Classes 1 and 3 are generally imported vehicles, and equations could not be estimated because of the data limitations. The specification of the Scrappage and Migration Estimator considers the interstate migration of certain vintages (1-4 years old) as well as state differences in vehicle lifetimes. The equations were estimated by means of a nonlinear least-squares technique.

HGDM Submodel: Vehicle Efficiency Model

HGDM maintains the fleet composition, by state, by 6 vehicle classes, 6 technology (engine) types, and 18 vehicle age groups (vintages). This submodel contains the engineering relationships necessary to develop fleet-weighted, harmonic-mean fleet fuel efficiencies at various levels of aggregation. The HGDM formulation incorporates three simplifying assumptions: (1) all vehicles of a particular vintage are driven the same number of miles annually; (2) the declining use of vehicles with age is constant across vehicle classes; and (3) the vehicle use/age relationship is independent of where the vehicle is driven.

State-level vehicle fuel economies (by class, engine type, and vintage) are determined by the calculation of national average on-the-road fuel economies and the subsequent modification by state-level "correction factors." The national average on-the-road fuel economies are modified EPA-measured fuel economies. State correction factors account for variations in operating conditions, including ambient temperature, trip lengths, and urban/rural driving split.

HGDM Submodel: Gasoline Demand Model

The Gasoline Demand Model estimates household gasoline demand at the state level. The double-log equation was estimated using a variance-components form of the generalized-least-squares technique:

$$\begin{aligned}
\text{GSALES} = & -0.1396 (\text{PRICE}) + 0.3564 (\text{HHINC}) \\
& - 0.04722 (\text{YPOP}) + 0.03991 (\text{SMCARS}) \\
& + 0.1556 (\text{LGCARS}) + 0.03025 (\text{LTRUCKS}) \\
& - 0.04918 (\text{URBAN}) - 0.04982 (\text{POPDEN}) \\
& - 0.7705 (\text{MPG}) + 0.5715 (\text{MAINCST}) \\
& + (\text{STATE INTERCEPT TERM})
\end{aligned}$$

where:

GSALES = gasoline demand divided by number of households

PRICE = [(gas price) + (% no lead) x (leaded and unleaded price differential)]/(cost of living index)

HHINC = household income

YPOP = population under 18 divided by population

SMCARS = stocks of class 1 and 3 (small cars) vehicles per household

LGCARS = stocks of class 2, 4, and 5 (large) vehicles per household

LTRUCKS = stocks of class 6 vehicles (light trucks) per household

URBAN = population in SMSAs divided by population

POPEN = population divided by area of the state

MPG = miles per gallon

MAINCST = maintenance cost (in 1967 dollars) divided by a cost of living index

STATE INTERCEPT TERM = scales result to particular state

State values for some of the variables and state intercept terms produce the state-level estimates of gasoline demand per household. These values can then be combined with household population estimates to produce aggregate gasoline demand.

HGDM Submodel: Fuels and Technology Assumptions Model

This submodel disaggregates the forecast light-duty vehicle "gasoline" demand into state-level fuel demand by vehicle class and engine type, using the state-level gasoline demand forecast from the Gasoline Demand Model, the on-the-road fuel efficiencies (state-level fleet, vehicle class and engine type) from the Vehicle Efficiency Model, and a measure of relative usage of vehicles by class and technology

(engine) type. The relative-usage measure is determined by user-specified assumptions concerning usage of vehicles of a particular technology. Model users must also input assumptions concerning the market penetration of particular technologies into vehicles of each class.

From this information, the model calculates fuel demand and VMT by vehicle class and engine type for state, regional, and national levels of aggregation. Vehicle miles traveled is determined from fuel demand rather than the reverse, as is characteristic of most other models.

DATA USED IN RUNNING MODEL

Because the model forecasts at the state level, a forecast run from 1977 to 2000 requires approximately 14,000 individual data items.

The scenario-defining exogenous data are those likely to be modified by the model user. The variables of this type are generally the economic and demographic data as well as the technical data related to fuel efficiencies. Model users can create a working data base from their own data or by modifying an existing data base. Users can select data from four different data bases provided by the model authors.

The "other" exogenous data base contains those data that are not likely to be changed by the model user. These are generally the model's coefficients and constants as well as the historical data required for the initial forecast year. The values in this data base can be modified, but the process is not part of the model's program.

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COMPUTER REQUIREMENTS

An interactive program facilitates the manipulation of input data for policy analysis. Values of variables can be changed for a specific state and year, or for a time interval, or for all states. As a safeguard, the demand model program checks the input data for gross errors before execution.

The model reports provide complete documentation on the program use and structure and on the data base. The program was written in FORTRAN

to run interactively on the PDP-10 system at Oak Ridge. It was later modified for the EIA TSO and IBM systems.

LINE AND AREA SOURCE EMISSIONS FROM MOTOR VEHICLES

A methodology for determining the line- and area-source emissions from motor vehicles was developed in 1976 at Washington University for the Environmental Protection Agency. Four models, or computer programs, are employed in the methodology: the Automobile Exhaust Emissions Modal Analysis Model (described more fully under 74-219), a network link selection program (NETSEN II), a line-source emissions calculating program (ECOMP), and an area-source emissions program (ASEP). This summary describes the interaction and use of all four.

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KEYWORDS

Air pollution/air quality

OBJECTIVE OF MODEL

The methodology, or system of models and programs, is used to determine the emissions from mobile sources (motor vehicles), given vehicle emission rate factors and the description of a roadway network or region and its traffic characteristics. The amounts of carbon monoxide (CO), oxides of nitrogen (NO_x), hydrocarbon (HC), sulfur dioxide (SO₂), and particulates emitted may be estimated for any specified hour of the day or day of the week. Varying levels of detail are possible, depending on the availability of data and the level of spatial refinement sought by the user.

RELATIONSHIP TO OTHER MODELS

The Automobile Exhaust Emission Modal Analysis Model (74-219) is used to provide emissions rate factors. The Network Sensitivity program (NETSEN II) selects the links in a roadway network that have the relevant characteristics and level of refinement. The ECOMP program estimates the emissions from all types of vehicles on arterial and freeway line-sources, using emission factors from the modal analysis model and given the roadway links selected by NETSEN II). The Area

Source Emissions Program (ASEP) computes estimates of emissions from the mobile source component of non-line or grid square area sources.

HISTORICAL BACKGROUND

The first version of the network program, NETSEN, was designed to work in conjunction with the emissions estimation model SAPOLLUT. NETSEN II was expanded and revised to work with the modal analysis model.

VALIDATION

The methodology was applied to the Regional Air Pollution Study of the St. Louis air quality control region.

STRUCTURE

The modal analysis model uses the speed and time characteristics of groups of vehicles to calculate emissions-rate factors. To allow it to work for the entire network, analogies of speed profiles had to be constructed for roadways for which no collected speed-profile data exist. Every line-source segment in the entire network was cross-classified by three relevant and available indicators of traffic flow quality: volume, volume/capacity, and class of roadway. Twenty-nine base segments were found, for which two speed profiles were selected, for peak and off-peak conditions. These were run through the modal analysis model, and the emissions rates were adjusted for ambient temperature and cold-start operation.

The roadway characteristics that can be used to select links by the network program include traffic volume, topography (cut, fill, street canyon, rolling), capacity alterations (interchanges, lane reductions, bottlenecks), sensitive land uses (commercial, industrial, recreation, hospital, college, airport, multi-family), activity centers (CBD, fringe, residential, rural), progressive movement (pre-timed, interconnected signals, one-way), channelization, functional classification (freeway, principal or minor arterial, collector, local), link distance, peak speed difference, truck and bus volumes, and volume/capacity ratio.

The ECOMP program outputs an hourly summary of the emissions totals for the five pollutants from each line source. Line-source emissions for each grid may also be totalled. For example, if looking at freeways with average daily traffic volumes of 60,000 to 80,000 vehicles and volume-to-capacity ratios of .60 to .90, 57 line sources are found by NETSEN II, representing 49.2 kilometers of roadway and 3,469,987 vehicle kilometers of travel (VKT). ECOMP computes an estimate of the emissions produced between 4 and 6 p.m. of 271.8 kilograms of HC, 4397.1 of CO, 367.9 of NO_x, 14.8 of SO₂, and 36.0 of particulates. In 24 hours on an average weekday the entire St. Louis region is estimated to produce 1,547,482.10 kilograms of carbon monoxide.

For finding the emissions from the non-line or area sources, defined by grid square areas of the region, a work-trip generation approach was used. Number of trips times mean trip length resulted in VKT for the local and collector routes, which was assumed to be related to the known VKT for the arterial routes in the area. Emissions factors were then applied to the VKT for each area.

MODEL CONSTRUCTION

The St. Louis air quality control region and regional highway network were used in devising the methodology. Vehicle operation is characterized by data from the Federal Highway Administration Vehicle Operating Survey, the Transportation Systems Center Traffic Analyzer Survey, and the General Motors Proving Grounds CHASE Car Program. The roadway inventory was compiled from data from the East-West Gateway Coordinating Council, Missouri State Highway Department, Illinois Department of Transportation, St. Louis street department, and county governments.

DATA USED IN RUNNING MODEL

The inputs to the modal analysis model are representative second-by-second speed profiles on the defined line sources, the number of automobiles assignable to the particular speed profiles, their age distribution by model year, the relative altitude at which they are operated, and emission-rate coefficients that are specific to speed profiles. The inputs to the network model are the attributes for which the model is to test the line sources, and the descriptions of each line source in the roadway network. The inputs to the ECOMP program are the descriptions of the line sources selected by the network model, the emission rates computed by the modal analysis model, the emission factors for trucks (supplied by the EPA), the percentage of trucks, and the hours of the day for which emissions are desired.

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COMPUTER REQUIREMENTS

The software system for the methodology is written in FORTRAN and operates on the IBM 360/65 computer at Washington University. The documentation provides program listings, explanations, input data specifications, and examples.

HEDONIC MODELS OF AUTOMOBILE PRICES

The Hedonic Models of Automobile Prices were developed in 1972 under the sponsorship of the National Science Foundation while the authors were at Tohoku University and Harvard University. The objective of the models is to test various hypotheses about the prices of automobiles. The impact of the make (or brand) effects on automobile prices and depreciation are considered. The models extend the hedonic approach by considering both the physical and performance attributes of automobiles.

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KEYWORDS

Pricing, scrappage, automobile demand

OBJECTIVE OF MODEL

The objective of these models is to test hypotheses about the pricing of automobiles and to use the estimated equations to produce quality-adjusted (hedonic) price indexes. The models focus on the role of makes or brands in the determination of an automobile's price. Both the physical characteristics and the performance variables of various model cars are used in the models.

RELATIONSHIP TO OTHER MODELS

This model has no direct relationship to any other model.

HISTORICAL BACKGROUND

The study and models reported here were part of a longer unpublished manuscript by M. Ohta and Z. Griliches, "Makes and Depreciation in the U.S. Passenger Car Market: An Application of the Hedonic Hypothesis to

the Construction of Price Indexes and the Study of Market Structure," Cambridge, Mass., 1972.

ASSUMPTIONS

Using single-equation models that are variations of the model presented below, the authors tested a number of hypotheses about the automobile market. These included:

- 1) the constancy of the implicit prices of the physical characteristics over time (not rejected for the period 1961-71)
- 2) the relative-imputed prices of the physical characteristics are the same across producers (not rejected)
- 3) the equality of imputed prices of physical characteristics across age and the equality of the depreciation patterns across physical characteristics (not rejected for two years tested 1965 and 1971)
- 4) no difference in the imputed prices of characteristics in the new and used car markets (generally not rejected)
- 5) the equality of make-effects (or brand) of the cars in the used and new car markets (not rejected)
- 6) the constancy of depreciation patterns across makes (rejected)
- 7) depreciation is geometric (declining balance or exponential) for cars (rejected, but authors note it's "not too bad an assumption on the average")
- 8) the coefficients of physical characteristics are all zero in the regression containing performance variables (generally rejected)
- 9) the coefficients of the performance variables are all zero in the regression containing physical characteristics (rejected)
- 10) test of the "two-stage hypotheses" (see Structure section) (authors note that it seems to be "not too poor" an assumption)

VALIDATION

The authors compare their regression results to those of other researchers and find that the results are similar. Hedonic price indexes are developed and compared with those developed by another researcher and the Consumer Price Index and Wholesale Price Index produced by the federal government. The comparison showed mixed results about how indexes differed in price change estimates.

LIMITATIONS AND BENEFITS

The major benefits of these models is the extensive testing of various hypotheses about the impact of the different makes on price and depreciation, and about the use of physical characteristics as opposed to performance variables.

STRUCTURE

The basic relationship has price as a function of the characteristics of the cars. Unlike other researchers, the authors explore the usefulness of both the physical and performance aspects of a car. In general, physical characteristics enter the cost function but do not affect the consumer's utility function. Under the "two-stage hypothesis," the physical characteristics of a car produce its performance variables which enter the consumer's utility function. Some physical characteristics are also performance variables. Examples of physical characteristics are horsepower, weight, and length; examples of performance variables are acceleration, handling, fuel economy, and luxury.

The typical regression model used in the empirical sections of the study is:

$$P_{kits} = \text{Const} \times M_i \times \bar{P}_t \times D_s \times e^{(\sum_j A_{tj} X_{kivj})}$$

where:

P_{kits} = price of a model k of make i and age s at time t

M_i = effect of make i (the effect of make 1 is set at 1)

\bar{P}_t = pure (hedonic) price index at time t

D_s = effect of age s (depreciation)

A_{tj} = parameter reflecting the imputed price of physical characteristic j at time t

X_{kivj} = the level of the physical characteristic j embodied in model k of make i and vintage v ($v = t - s$)

A semilogarithmic form was chosen for the basic regression models as it provided a good fit to the data.

The physical characteristics used in the regression were shipping weight, overall length, maximum brake horsepower, and dummy variables for body type and number of cylinders. The performance variables considered include: handling, steering, engine, engine power, automatic transmission, ride, accommodation, probable trade-in value, probable dollar depreciation, frequency of repair record of past models, acceleration, top speed, fuel economy, and braking.

MODEL CONSTRUCTION

The sample used in the estimation of the models' coefficients were sedans and hardtops of the major U.S. domestic producer: American Motors, Chrysler, Ford, and General Motors. Data on the 1955 to 1971 model automobiles were obtained from Ward's Automotive Yearbook, National Automobile Dealers Association Used Car Guide (Central Edition), Automotive News Almanac, Automotive Industries, and Consumer Reports.

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A.T. KEARNEY/WHARTON/NHTSA AUTOMOBILE DEMAND MODEL

A.T. Kearney, Inc. completed a study in 1979 for the National Highway Traffic Safety Administration (NHTSA) on the impact of the 1980-85 automotive fuel economy standards on competition in the automotive industry. The Wharton EFA Automobile Demand Model (77-046) was extended to analyze the profitability of the domestic manufacturers. This summary describes the extensions.

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KEYWORDS

Fuel economy, industrial financial performance, automobile demand, market share

OBJECTIVE OF MODEL

The model was used to analyze the impact of the 1981-85 fuel economy standards on competition between the automotive manufacturers. These effects were looked at: the impacts on market shares, in total and by size-class; the impacts on the long-run profitability of the Big Four domestic automakers; the viability of strategies to induce shifts in demand mix and to reduce import penetration; and impacts of measures such as a gasoline tax or a "gas-guzzler" tax.

The modeling effort is part of a study that also analyzed competition in engineering, design, and product attributes.

RELATIONSHIP TO OTHER MODELS

The model is an expansion of the Wharton EFA Automobile Demand Model (77-046), sponsored by the Transportation Systems Center (TSC). Shares of new car sales are broken down into shares by manufacturer in addition to shares by size class. Equations for profitability of the manufacturers are added. Revised inputs to the model are: projections of automobile technology characteristics by size class; incremental maintenance costs and savings by size class; and incremental fixed and variable manufacturing costs of improved technology.

HISTORICAL BACKGROUND

The model was also extended and applied for an analysis of environmental regulations done for the U.S. Environmental Protection Agency.

ASSUMPTIONS

Three methods are made available to manufacturers in the simulations to achieve compliance with the fuel economy standards: technological improvements, including downsizing, material substitution, improved lubrication, and power plant and transmission improvements; performance degradation; and shifting production mix towards smaller, more efficient cars.

VALIDATION

Simulations were run under several scenarios and combinations: a baseline with technology frozen at 1980 level; technology improvements through 1985, with and without diesels; phased reduction in subcompact car prices and increases in larger car prices; reduction in import shares; drastic reductions in Chrysler's shares of size-classes; tax on larger cars; and gasoline taxes. These demonstrated that for relatively small variations in price, strategies to influence product mix are attractive, but their application has limited scope. Sensitivity tests were also done on the results and assumptions.

LIMITATIONS AND BENEFITS

Predictions of the analysis are subjected to the constraints of an econometric model of automobile demand, and acknowledge a relationship between projected financial results of individual firms and their choice of strategies in product planning and marketing under competitive industry equilibrium. A limitation of the model is that significant variation in individual firm shares within size-classes is not permitted; size-class market shares for each firm are fixed at predetermined levels roughly equal to those of 1978.

STRUCTURE

The profitability equation is as follows: It was estimated for each of the Big Four manufacturers.

$$\pi = \sum \alpha_i (s_i) + \beta (\sum s_i m_i) + c(x) + u$$

where:

π = operating margin for each domestic automaker, defined as pretax operating profits from sales

α_j = estimated coefficient

s_i = dollar sales share of size class i

β = estimated coefficient

m_i = market share in size-class i , including imports

x = total unit sales (in all size-classes) relative to trend, or capacity utilization

c = estimated coefficient

u = residual term

Estimated coefficients show that the Big Three domestic automakers profit more from sales of larger cars, while American Motors appears to profit more from its emphasis on small cars.

Potential changes in retail prices of automobiles attributable to the incremental costs of meeting the fuel economy standards are calculated as follows:

$$\Delta RP = 1.25 (GR \times CI + \Delta VC)$$

where:

ΔRP = change in retail price

GR = gross rate of return on investment, including taxes and amortization, assumed to be 27%

CI = extraordinary capital expenditures per car

ΔVC = change in variable manufacturing cost per unit

When the standards are imposed, after-tax profits are reduced from baseline profits, shown above:

$$P = \pi - r [K(x)] - f(y) - t [\max(T - x - y, 0)]$$

where:

P = after-tax profits for a manufacturer, with standards

π = baseline profits without standards

r = real after-tax cost of capital, including depreciation

$K(x)$ = total capital investment associated with technological improvement in average mpg, x

$f(y)$ = loss in after-tax profits associated with mix shifts that improve average mpg by amount y

t = civil penalty per mpg shortfall

T = mandated level of mpg improvement

x = mpg improvement that a manufacturer achieves through investment in technology

y = mpg improvement via shifts in product mix

MODEL CONSTRUCTION

The profitability equation was estimated using generalized least squares, for annual data from 1947 to 1976. Data sources were the Wharton EFA data base and Moody's Investment Manual (for gross operating margins).

DATA USED IN RUNNING MODEL

Automobile technology characteristics, foreign automobile fuel economy projections, discounted incremental maintenance costs, and incremental fixed and variable manufacturing costs used in simulations were derived from NHTSA's fuel economy standard rulemaking support efforts. The baseline demographic, economic, and auto-characteristic input data were the same as those provided by Wharton EFA for their auto demand model.

REFERENCE

Impact of automotive fuel economy standards on competition in the automotive industry, two volumes, U.S. Department of Transportation, Report nos. DOT-HS-805244,5, April 1979.

COMPUTER REQUIREMENTS

The model is implemented in TROLL, an econometric and statistical package, at the Massachusetts Institute of Technology. This version of the model was shown to produce virtually identical results to those of the Wharton model implemented at TSC.

HOUSEHOLD CHOICE AMONG MOTOR VEHICLES

An empirical analysis of household choice among motor vehicles was done in 1978 at Cambridge Systematics, Inc. and was published in 1980. The model was built as part of two larger projects, sponsored by the National Highway Traffic Safety Administration and the National Science Foundation, on consumer behavior towards fuel-efficient vehicles, and an assessment of national use, choice, and future preference toward the auto and other transportation modes, respectively. It was also used in studying the feasibility of electric cars.

SPONSOR

U.S. Department of Transportation
National Highway Traffic Safety Administration
Technology Assessment Division
Washington, D.C. 20590

National Science Foundation
Scientific, Technological, and International Affairs
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KEYWORDS

Automobile demand, market share

OBJECTIVE OF MODEL

This econometric model explains the make, model, and vintage composition of individual household motor vehicle holdings, conditional on the number of vehicles owned. It is a recursive forecasting model that may provide estimates of holdings of new and used cars annually for the years 1977 through 1985.

RELATIONSHIP TO OTHER MODELS

This is not related to other models. It is a different model from that built by Lave and Train at Cambridge Systematics, Inc./West (77-055).

HISTORICAL BACKGROUND

Until recently, the dominant theme in the literature has been the estimation, usually from national time series data, of models of aggregate motor vehicle demand. The last few years have seen a growing interest in the application of discrete choice models. The authors believe that this model constitutes the first serious effort to explain the composition of individual household vehicle holdings.

The model was built at Cambridge Systematics, Inc. Manski is also in the Department of Economics at Hebrew University. Sherman subsequently moved to the Transportation Economics Center of Booz, Allen and Hamilton, Inc.

The Survey Research Center at the University of Michigan and Westat, Inc. of Rockville, Maryland were subcontractors on the survey done for the study.

ASSUMPTIONS

The important features of the approach are as follows. Each year a household is assumed to evaluate its current vehicle holdings and determine if any changes should be made. The choice set available includes all makes, models, and vintages, each characterized as a distinct bundle of attributes. A household's decisions are assumed to depend on the previous year's decisions and the transactions costs of entering the market. The composition of holdings conditional on the number of vehicles owned is modeled prior to modeling the extent of holdings as a choice among zero vehicles, the most preferred single vehicle alternative, the most preferred pair, etc. Distinct models were developed for single- and multiple-vehicle households. By iteratively applying the model to predict the sequence of holdings decisions made by households across successive decision points, the timing of market transactions and composition of holdings at points in time may be forecast.

LIMITATIONS AND BENEFITS

The data used did not identify the engine type, transmission, and amenity options that differentiate cars with a single make/model/vintage designation. The way this data problem was resolved was to characterize each make/model/vintage of vehicle by the highest-selling type of characteristics.

The model explains household vehicle holdings separately for households with one and two vehicles, but it does not explain why households own varying numbers of vehicles.

STRUCTURE

The characteristics of vehicles considered by households include: passenger carrying--seating space, weight, ride quality, amenities; load carrying--volume, luggage space, configuration, limits; performance--acceleration, braking distance, noise level, maneuvering (turning distance), reliability (scrappage probability); cost--price, depreciation schedule, fuel costs, repairs, search and transactions cost; and class and style--vintage, body shape, color, image. How a household evaluates these depends on how it intends to use a vehicle or vehicles and on the household attributes. To capture the enhanced transportation availability and specialization that two vehicles can provide, the model specifies the utility of any vehicle pair to depend on the characteristics of each vehicle separately and on those of a fictitious composite vehicle combining the best of both real vehicles.

The parameters explaining vehicle choice in single-vehicle households were estimated by maximizing a pseudo-likelihood function of the observed choices made by 430 households which held one vehicle, as if each household faced a choice set composed of its chosen alternative plus 25 alternatives chosen at random from the 600 vehicle types actually available. At decision point m , a household t selects that alternative j from the choice set C_{tm} that maximizes the utility:

$$U_{tjm} = (Z_{tjm})^a + b (X_{tjm}) + E_{tjm}$$

where:

U_{tjm} = utility of choice

Z_{tjm} = vector of functions of observed exogenous vehicle and household attributes

X_{tjm} = transaction/search cost dummy variable

E_{tjm} = Weibull disturbance distributed independently and identically across decisionmakers, alternatives, and decision points

(a,b) = parameter vector to be estimated

Estimation results for the single- and multiple-vehicle households are showed in the model reports. Results showed that there is a correlation between age of a household and preference for vehicle weight; seating and luggage space are of greater consequence to larger families; acceleration is not as important as would be thought; other performance parameters are of little concern to consumers; there is a correlation between education and concern for operating costs; and transactions costs favor maintaining existing holdings.

The two-vehicle choice model was estimated on a sample of 445 households. The results are shown in the report.

The effect of the number of seats in addition to the driver's seat on two-vehicle-household utility is:

$$U_S = \frac{-.268}{(-1.51)} \left(\frac{S_{ti} + S_{tj}}{2} \right) - \frac{.0722}{(-1.63)} (S_{ti}^2 + S_{tj}^2) + \left[\frac{.120}{(1.52)} \right. \\ \left. + \frac{.0293}{(3.50)} (d_t) \right] [\max(S_{ti}, S_{tj})]$$

where t-statistics are in parentheses, and

U_S = utility attributed to the number of seats excluding the driver's seat

(i,j) = a vehicle pair

t = a household

S = the number of seats excluding the driver's seat

d_t = dummy variable indicating households with four or more members

The effect of cost per mile of two vehicles on a household's utility is:

$$U_C = \frac{-.346}{(-1.35)} \left(\frac{C_i + C_j}{2} \right) + \frac{.145}{(1.27)} [\min(C_i, C_j)]$$

where:

U_C = utility attributed to vehicle cost per mile

(i,j) = a vehicle pair

C = cost per mile of the vehicle

MODEL CONSTRUCTION

The household data source for this model was The University of Michigan Survey Research Center's (SRC) winter 1976 survey of 1,063 households drawn from its rotating consumer panel. This edition of the SRC survey obtained from each household typical socioeconomic and demographic data plus information regarding up to three vehicles currently held by the household. In addition to the SRC data, a file of vehicle characteristics for some 2,000 vintage vehicles was developed from the Automotive News Almanac and the Consumer Union Reports. Used-car prices were obtained from the Red Book. The model documentation describes the data collection and the methods for synthesizing missing data. The model programs could be used to develop estimates from another data base with the same variables.

REFERENCES

Manski, C.F.; Sherman, L.; Ginn, J.R., Empirical analysis of household choice among motor vehicles, draft, Cambridge Systematics, Inc., Nov. 1978.

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Sherman, L.; Manski, C.F., Analysis of the effects of gasoline prices and vehicle design attributes on consumer choice of vehicle type, Cambridge Systematics, Inc., 1979.

Assessment of national use, choice and future preference toward the automobile and other modes of transportation, three volumes (vol. I has two parts) and executive summary, National Technical Information Service, National Science Foundation, Report nos. NSF/PRA-7716108/1,2,3,4,4, June 1, 1979, February 1980. NTIS nos. PB80-204 175,183,191,209,217.

Sherman, L.; Manski, C.F.; Ginn, J.R., Consumer behavior towards fuel efficient vehicles, three volumes, U.S. Department of Transportation, Report nos. DOT-HS-805-339,340,341, February 1980.

Berkovec, J.A.; Ginn, J.R., Consumer behavior towards fuel efficient vehicles: Volume IV: Operating instructions and program documentation for the CS vehicle choice simulation model, U.S. Department of Transportation, Report no. DOT-HS-805 741, September 1980, released February 1981.

Manski, C.F.; Sherman, L., Empirical analysis of household choice among motor vehicles, Transportation Research, 14A:349-366, 1980.

Manski, C.F.; Sherman, L., Forecasting the fuel efficiency of household motor vehicle holdings, Cambridge Systematics, Inc., August 1979.

Manski, C.F.; Sherman, L., Forecasting equilibrium motor vehicle holdings by means of disaggregate models, Transportation Research Record 764, pp. 96-103, 1980.

Sherman, L., Implications of current household vehicle ownership and use patterns on the feasibility of electric cars, Transportation, 9:209-227, 1980.

COMPUTER REQUIREMENTS

Documentation is provided for the computer programs for estimating and simulating the model, and for the data bases. The programs are written in FORTRAN and assembler for an IBM computer system.

HIERARCHICAL DECISION-PROCESS MODEL FOR FORECASTING AUTOMOBILE TYPE-CHOICE

This forecasting model employing a hierarchical decision process was developed at the University of California at Irvine in 1979. Its purpose is to model the decisionmaking process of buying a new car.

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KEYWORDS

Automobile demand

OBJECTIVE OF MODEL

The objective of this model is to inductively predict the type of car purchased by a household, given certain characteristics of the household members' age and number, and of previous cars purchased.

RELATIONSHIP TO OTHER MODELS

There is no relationship to other models.

HISTORICAL BACKGROUND

This model is a pilot study tested on a relatively small sample of car buyers. Further research is underway to validate the model on a new sample. In future research, the model will be tested on a larger representative sample, using a much shorter interview.

ASSUMPTIONS

The price that one is willing to pay for a new car is assumed to be a function of the amount paid for the car being replaced, the largest other car owned by the household, and a car previously owned or regularly driven before the car being replaced by the new car.

VALIDATION

The model correctly represents the choices of 42 of the 45 car buyers interviewed.

LIMITATIONS AND BENEFITS

Given the small sample size, the model should be considered descriptive of the data from which it was constructed, but it probably would not do as well in predicting the choices of a new sample. The authors also note that the interviews were done during the summer of 1978 when real gasoline prices were lower than in 1960. With the recent rapid increase in real gasoline price, the current impact of fuel economy on car choice may be somewhat understated.

STRUCTURE

The model maps the decisionmaking process of a person in the market for a new car in the form of a flow chart with each successive step asking a yes/no question. The direction taken in the flow chart toward a final decision depends on the answer to each question.

There are four sections in the model; the first part models the effects of family composition on the purchase decision; the second part, called the multi-car decision subroutine, models the effects of the vehicles already owned. The third part, called the cost category formula, places the buyer's choice inside of a certain price range; and the fourth part incorporates foreign or domestic preference, importance of fuel economy, and buyer age into the decision model.

The first two stages determine whether the car purchased will be in one of four transportation requirement categories: (1) car for a large family, (2) car for a small family, (3) single person car, and (4) family car for limited use. The cost category formula works independently of the first two sections to predict what price the buyer will be prepared to spend on a new car. In a one-car household, the formula predicts that buyers will spend in real terms as much on a new car as they did for the car they are replacing. If there is no car being replaced, the predicted price of the new car is 60% of the price of the last car owned or previously driven, in real terms.

In a multi-car household, if the replaced car was purchased new, then the following equation holds:

$$CC = \text{COST}_{RC} + (\text{COST}_{PC} - \text{COST}_{RC})/2;$$

where:

CC = calculated cost of new car which is to be purchased

RC = replaced car (i.e., car which is being traded in or sold)

PC = largest other car presently in the household

This basic equation is altered depending on the age of the replaced car, the sum of the ages of the buyer's children, and if the replaced car was purchased used.

On the basis of these predictions, the buyer's choice is predicted to lie within one of the four following price ranges: (1) 3 to 5 thousand dollars, (2) 5 to 7 thousand dollars, (3) 7 to 9 thousand dollars, and (4) over nine thousand dollars.

The last step makes the finest subdivision of choice, breaking the selection down into a small group of specified makes and models. A different flow chart selection procedure is made for the 16 combinations of the four transportation requirement categories and the four price ranges.

MODEL CONSTRUCTION

The methodology employed is the hierarchical decisionmaking process modeling technique, developed by mathematical anthropologists.

A list of new-car registrations from Orange County, California communities within twenty minutes driving time from the University of California at Irvine was randomly sampled. The car buyers were interviewed for one to two hours in two parts. In the first part, buyers were asked about the cars they seriously considered, the showrooms they visited, and the reasons for their final choice. In the second part, buyers were asked why they preferred their final choice to other specific cars on the market.

REFERENCE

Murtaugh, M.; Gladwin, H., Hierarchical decision-process model for forecasting automobile type-choice, Transportation Research, 14A:337-348, 1980.

CANADIAN AUTOMOTIVE MANUFACTURING INDUSTRY

This econometric model of the Canadian automotive manufacturing industry was developed at Massachusetts Institute of Technology and Queen's University and was published in 1972. Its objective is to econometrically model the Canadian motor vehicle manufacturing industry and to assess the effects on Canada of an agreement allowing free trade in motor vehicles between the United States and Canada.

AUTHOR

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KEYWORDS

Industrial financial performance, automobile demand, automobile supply, pricing, national economic impact

OBJECTIVE OF MODEL

The objective of the model is to simulate the demand, supply, prices, wages, costs, profit, and investment of the Canadian motor vehicle industry for the period of 1948 through 1964.

The model also is used to examine the effects of the 1965 Automobile Agreement by running the model with actual data for the period 1965-68 and comparing the simulation results to them. The free trade agreement's beneficial effect on Canada's auto industry may potentially provide a useful example for altering current relations between the U.S. industry and other countries.

RELATIONSHIP TO OTHER MODELS

There is no relationship to other models.

HISTORICAL BACKGROUND

Professor Wilton moved from the Massachusetts Institute of Technology to Queen's University while working on this model.

ASSUMPTIONS

Automobile demand is assumed to follow a stock adjustment process. The technique developed by Chow (S-57-413) is used.

VALIDATION

Approximately two-thirds of all the parameter estimates are significant at the 5 per cent level. The model is shown to replicate historical data very well. The effect of the free trade agreement on changes in the market structure was analyzed by comparing the predictions of the model, estimated with pre-agreement data, with post-agreement experience.

LIMITATIONS AND BENEFITS

The model, though satisfactorily explaining U.S. imports, proved to be largely unsuccessful in attempting to explain other imports. Thus, non-U.S. imports to Canada are classified as exogenous to the model. The model's wage bargaining equation is unique.

STRUCTURE

Demand and price indexes for motor vehicles are split into two components: automobiles and commercial vehicles.

To translate retail demand into domestic production the following mechanism is employed.

$$TSH = RSA + RSTR - COMMIS - EMT - USMT + XSH$$

where:

TSH = total shipments by the motor vehicle industry

RSA = retail sales of automobiles, millions of Canadian dollars
(endogenously determined by the demand segment of the model)

RSTR = retail sales of commercial vehicles (endogenously determined by
the demand segment of the model)

COMMIS = endogenously determined dealer mark-up or retail value-added,
millions of Canadian dollars

EMT = non-U.S. imports of motor vehicles, exogenous

USMT = endogenously determined imports of motor vehicles from the U.S.

XSH = total export shipments by the Canadian motor vehicle industry,
exogenous

All variables are in millions of Canadian dollars.

Profits of the motor vehicle industry are determined residually by the following equation. Incomplete data, the dominance of exogenous factors, and measurement errors account for the existence of a residual expenditure category.

$$\text{PROFIT} = \text{DSH} + \text{XSH} - \text{MATR} - \text{WB} - \text{CCA} - \text{RESID}$$

where:

PROFIT = total corporate profits from Canadian manufacturing of motor vehicles

DSH = endogenously determined total shipments to the domestic market

MATR = material inputs, endogenously determined

WB = wage bill, endogenously determined

CCA = capital consumption allowance, endogenously determined

RESID = residual of unclassified expenditures in the automotive industry, exogenous

The equations simulating the wholesale and retail automobile price indexes, and the equation of the per cent change in the negotiated base wage rate in the industry are presented as examples of the econometric equations used in this model and to illustrate its interconnectedness and simultaneity.

A modified form of the base wage rate equation output is input to the wholesale price index equation. The wholesale price index is used in turn in the equation used to determine the retail price index.

The base wage rate equation employs industry profit as an independent variable, but the dependent variable is a component in the industry wage bill, which is a factor in determining industry profit.

In the following wage equation, eight rounds of wage bargaining sessions from 1948 to 1964 are modeled. Dummy variables are used to represent the periods when the union bargained for wage parity with the average hourly durable goods earnings and with earnings from General Motors in the United States.

$$\frac{\Delta \text{NEGAV}}{\text{NEGAV}} = -24.05 + 0.3555 \left(\frac{\Delta \text{CPI}}{\text{CPI}} \right) + 53.25 \left(\frac{\text{PROFIT}}{\text{TSH}} \right) + 20.91 (\text{DUMUS})$$

(7.83) (0.1714) (10.89) (6.52)

$$\times \left(\frac{\text{USW}}{\text{NEGAV}} \right)_{t-1} + 26.57 (\text{DUMCAN}) \times \left(\frac{\text{CANW}}{\text{NEGAV}} \right)_{t-1}$$

(8.40)

where standard errors are in parentheses, and

NEGAV = base wage rate as negotiated in collective bargaining sessions

CPI = Canadian consumer price index, 1949 = 100.0, exogenous

DUMUS = dummy variable for wage parity era, one in 1959-64, zero elsewhere

USW = base wage rate at General Motors in the United States,
exogenous

DUMCAN = dummy variable for the pre-wage-parity era, one in 1948-58,
zero elsewhere

CANW = average hourly earnings in Canadian durable goods manufacturing
industries, exogenous

$$\text{WPT} = -1.197 + 6.271 \left(\frac{\text{NEGAV}}{\text{PRODT}} \right) + 1.137 (\text{WPTUS}) + 0.3952 (\text{USCUR})$$

(0.228) (2.332) (0.034) (0.0928)

$$\text{SEE} = 0.01286 \quad R^2 = 0.99 \quad \text{DW} = 1.66$$

where standard errors are in parentheses, and

WPT = wholesale price index of motor vehicles, 1957 = 1.0

PRODT = real output per hour per worker, defined exogenously

WPTUS = exogenous wholesale price index of motor vehicles in the United
States, 1957 = 1.0

USCUR = Canadian dollars per United States dollars, exogenous

$$\text{RPA} = -0.2053 + 0.9927 (\text{WPT}) + 1.037 (\text{TOTTAX})$$

(0.0812) (0.0622) (0.122)

$$\text{SEE} = 0.01745 \quad R^2 = 0.96 \quad \text{DW} = 1.96$$

where standard errors are in parentheses, and

RPA = retail price index of automobiles, 1957 = 1.0

TOTTAX = total rate of federal sales and excise tax on motor vehicles

MODEL CONSTRUCTION

This multi-equation econometric model is estimated by using principal components with the two-stage least squares method. The data used to estimate the model are from the years 1948 to 1964.

DATA USED IN RUNNING MODEL

Twenty-three Canadian macroeconomic and motor vehicle industry statistics are exogenously input to the model.

REFERENCE

Wilton, D.A., Econometric model of the Canadian automotive manufacturing industry and the 1965 automotive agreement, Canadian Journal of Economics, 5(2):157-181, May 1972.

MULTI-VARIABLE MODELS OF CAR OWNERSHIP

Three multi-variable models of car ownership were developed at P.G. Pak-Poy and Associates Pty. Ltd. in Australia and published in 1979. This work was sponsored by the National Capital Development Commission in Canberra, and the Director-General of Transport and the Commissioner on Highways of South Australia. The purpose of the models is to predict car ownership, to be used as input into surface transport planning.

AUTHOR

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KEYWORDS

Automobile demand

OBJECTIVE OF MODEL

The objective of these three models is to estimate car ownership by households in an urban area, using various household characteristics and public transport factors. The models are based on Australian data, but the method could be applied to data from U.S. metropolitan areas.

RELATIONSHIP TO OTHER MODELS

There is no relationship to other models.

ASSUMPTIONS

One model bases the income variable only on incomes above 3000 dollars. It was assumed a priori that this variable reflected income over which the household had reasonable discretion in expenditure.

VALIDATION

Forty-nine out of seventy coefficients in the model were significant at a 95% confidence level. By using income over 3000 dollars as the income variable and including part-time workers as an explanatory variable, prediction accuracy was increased slightly for families with one car or more, but it was not changed for families owning zero cars.

LIMITATIONS AND BENEFITS

These models have the potential for absurd application by projecting more cars than household members. Except to the extent that such behavior is shown in the data, the model in application must be restrained by decision rules to prevent these absurdities, according to the author.

The model author concluded that adequate car ownership models can be developed on the basis of relatively small data sets, and that additional socioeconomic variables explain car ownership much better than only income.

STRUCTURE

The dependent variable for all three models is the probability of a household choosing between two different levels of auto ownership. There are separate equations for each car ownership-level choice: car ownership/non-ownership among households, one-car/multi-car ownership among car-owning households, and two-car/three-or-more-car ownership among multi-car-owning households. The basic model form is:

$$P = \frac{e^u}{1 + e^u}$$

where:

P = the probability of choosing the higher level of automobile ownership

u = an indirect relative utility function

The three models differ in the specification of the linear utility function.

Model 1:

$$u = a + b (\text{INC}) + c (\text{MEMBERS}) + d (\text{FTWORK})$$

where:

INC = household income in units of 1000 dollars per year

MEMBERS = number of household members

FTWORK = number of household members with full-time jobs

Model 2:

$$u = a + b (\text{INC3000}) + c (\text{MEMBERS}) + d (\text{FTWORK}) + e (\text{PTWORK})$$

where:

INC3000 = household income in units of 1000 dollars minus 3000 dollars
(zero if negative)

PTWORK = number of household members with part-time jobs

Model 3:

The third model includes measures of bus route accessibility and additional data concerning the head of the household.

$$u = a + b (\text{INC}) + c (\text{MEMBERS}) + d (\text{FTWORK}) + e (\text{SEX}) + f (\text{JOB}) \\ + g (\text{BWALK1}) + h (\text{BWALK2}) + i (\text{BUSES}) + j (\text{FLEXTIME})$$

where:

SEX = sex of head of household (0 = male, 1 = female)

JOB = occupation of head of household (1 = worker, 0 = other)

BWALK1 = access time from home to bus stop

BWALK2 = access time from home to most regular destination of head of household

BUSES = number of bus journeys needed to make the most regular journey of the head of household

FLEXTIME = head of household's flexitime status at work (1 = yes, 0 = no)

MODEL CONSTRUCTION

The probability of choice (P) is not directly observed and only the actual choice is made available as the dependent variable. The model uses a maximum-likelihood estimation technique to ensure that the dependent variable P can only take on the values 0 and 1.

The first and third models presented above use data from a random sample of 2253 households interviewed in Canberra, Australia in 1975. The first and second models presented above use data from a random sample of 4440 households interviewed in Adelaide, Australia in 1977.

REFERENCE

Hutchinson, M.J., Multi-variable models of car ownership, Traffic Engineering and Control, pp. 399-403, August/September 1979.

AUTOMOBILE FLEET FUEL EFFICIENCY FORECASTING

This model for forecasting the fuel efficiency of the automobile fleet was developed at Purdue University in 1979. It projects the average fuel efficiency of a fleet in a future year based on a vehicle survival procedure and the relative usage of autos by age. The study was conducted through the support of the Joint Highway Research Project of Purdue University and the Indiana State Highway Commission.

SPONSOR

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Indiana State Highway Commission
Joint Highway Research Project
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AUTHOR

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KEYWORDS

Fuel economy, scrappage, vehicle miles traveled

OBJECTIVE OF MODEL

The model projects the average fuel efficiency of the fleet of vehicles in existence in future years, considering impacts of prevailing economic conditions, governmental policy decisions regarding new vehicle fuel efficiency standards, and auto usage characteristics. The basic approach is to (1) determine the number of autos in use by model year, (2) estimate auto fuel efficiencies by model year, and (3) establish relative automobile usage by model year.

RELATIONSHIP TO OTHER MODELS

The Data Resources Incorporated TRENDLONG and PESSIMLONG macroeconomic models provide input values for new car sales and automobile ownership.

HISTORICAL BACKGROUND

This model was developed as part of a computer simulation model used to project statewide highway financing and system performance. Projection of auto fuel efficiency was necessary to estimate future highway fuel consumption, revenues derived from fuel taxes, and other factors affecting highway transportation system performance. The developer, Mannering, subsequently moved to the Massachusetts Institute of Technology.

ASSUMPTIONS

Scrappage rates of older automobiles change more in response to shifts in economic conditions than do rates for newer autos, since more older cars are marginally economic. Autos 12 years or older tend to have stable survival rates. New automobiles are used more than older ones; i.e., they are driven more miles in a given time period.

VALIDATION

The procedure for determining historical automobile survival rate changes was found to compare favorably with actual rates.

STRUCTURE

The extent of automobile ownership in a year is equal to the autos owned last year, plus new car sales, minus scrappage. New car sales and auto ownership are input to the model. Scrappage is projected within the model, by forecasting survival rates. Future survival rate distributions are indirectly approximated by estimating annual changes in each cohort survival rate. These changes are related to the number of "select" marginally economic automobiles in each age group or cohort.

$$CP = \frac{ACSA - (\sum_{i=1}^n SURV[-1] \times CPOP[-1])}{\sum_{i=1}^n CPOP - \sum_{i=1}^n (SURV[-1] \times CPOP[-1])}$$

where:

CP = the cohort probability of a "select" marginally economic automobile being retired or retained in that cohort during a given year

ACSA = actual number of surviving autos in the cohort

SURV[-1] = preceding year's survival rate

CPOP[-1] = cohort population of preceding year

CPOP = present cohort population

n = total number of cohorts

Results of this historical probabilities equation are used to create the following regression equation:

$$Y = 0.02684 + 0.000127 (X)^3$$

(4.93) (15.69)

$$F = 246.26 \quad R^2 = 0.965$$

where t-values are in parentheses, and

Y = the approximate probability of a "select" marginally economic auto being retired or retained in cohort of age X

X = the age of the cohort in years

This equation is uniformly adjusted by 9 percent to assure that the summation of cohort probabilities equals one.

The number of "select" marginally economic automobiles in any future year is a function of the projected auto ownership and new car sales in the year, and the cohort survival rate and population in the preceding year. These "select" autos are assigned to or subtracted from specific cohorts in the year, using a random number generator and the probabilities described above (Y).

New automobile fuel efficiencies by model year are input to the model.

The automobile usage by age equation is:

$$W = 1.8535 - 0.4813 [\ln(Z + 1)]$$

(20.38) (-10.039)

$$F = 100.796 \quad R^2 = 0.92$$

where t-values are in parentheses, and

W = weighted usage by automobile age

Z = age of auto in years (e.g., Z=1 for cars 1-2 years, Z=2 for cars 2-3 years, etc).

Overall fleet fuel efficiency in any year is the sum of the fuel efficiencies for each cohort, each of which is a function of the average new car efficiency, the cohort population in the year, the total auto population, and the relative usage of the cohort.

MODEL CONSTRUCTION

Data for the historical automobile survival model came from the Motor Vehicle Manufacturers Association's 1978 Motor Vehicle Facts and Figures. Data for the relative usage of automobiles by age equation came from the Census Bureau's Nationwide Personal Transportation Study 1969-70.

DATA USED IN RUNNING MODEL

Necessary inputs to the model are new car fuel efficiencies by model year, and new car sales and total auto ownership by year.

REFERENCE

Mannering, F.L.; Sinha, K.C., Forecasting automobile fleet fuel efficiency, Traffic Quarterly, vol. 33, no. 4, pp. 637-648, October 1979.

AUTOMOBILE INDUSTRY RESPONSE TO GOVERNMENT RULE-MAKING

This model of the corporate strategies of the automotive manufacturers has been under development since late 1978 by The Futures Group for the National Highway Traffic Safety Administration (NHTSA) as a part of a study to examine the likely strategic actions of automobile manufacturers as a result of legislation and regulation designed to improve automobile fuel efficiency. The model's output on total automobile demand was used in this study. The model is described in the fourth volume of this study, cited below. Its purpose is to improve upon a previous model and to obtain information on automotive manufacturers to assist in rulemaking by NHTSA.

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KEYWORDS

Vehicle manufacturing resource utilization, industrial financial performance, automobile demand, market share, pricing, model assessment, fuel economy, automobile supply

OBJECTIVE OF MODEL

The objective of this model is to analyze and forecast the behavior of the four major U.S. automobile manufacturers under various government regulations and economic conditions to assist NHTSA in its rulemaking. Outputs used in this task are total sales, market shares by size and manufacturers, vehicle characteristics, corporate financial characteristics, and corporate manufacturer capacities and employment.

HISTORICAL BACKGROUND

NHTSA requested in late 1977 that The Futures Group choose and modify a model on the automotive manufacturers to obtain results for rulemaking as a part of an original proposal awarded in October 1977 on the manufacturer's response to fuel efficiency standards. The model chosen to be modified was the Automobile Industry Response to Government Regulations Model (77-035), by Pugh-Roberts Associates.

VALIDATION

In its present form, according to the author, the model is producing total sales that reproduce history rather well. However, the author states that virtually all of the financial output is incorrect, or misleading at best.

LIMITATIONS AND BENEFITS

The ability of the model to replicate historical fluctuations in total sales of automobiles suggested to the author that the previous model (77-035) was viable and could satisfactorily meet its objectives with modification. Some flaws discovered have not been corrected in the present version and need attention.

Recommended changes include incorporating financial data of the entire automotive corporation, rather than just the passenger car sector, because decisions are simulated on only a subset of the total product line and financial picture of each company. An important deficiency only partially corrected is the item that accounts for the demand for passenger automobiles that has been satisfied increasingly by light trucks. Further work is needed also in the areas of car size definition and market share modeling structure.

STRUCTURE

The model is a computer simulation model using thousands of variables. The basic structure of the model is essentially the same as the previous model. There are three sectors of the model: the consumer sector, the industry sector, and the regulatory sector. The consumer sector simulates car purchase and driving patterns in response to automobiles that are available. This supply is determined in the industry sector and influenced by corporate financial situations, management goals, and the regulatory sector.

The industry sector is composed basically of two functions: decisionmaking and accounting. The accounting function generates the information on which decisions such as supply are based. Decisions are determined by continually assessing how a company's situation compares with various corporate goals. How well its corporation does in meeting its goals determines management concerns. These management concerns affect all blocks within the industry sector: production, capacity, prices, and product features.

In the consumer sector, demand for new cars is calculated in three stages: total demand, demand by size, and demand by size and manufacturer. Total demand is dependent upon population and transportation costs relative to disposable income. Total demand is disaggregated into demand by size of car as a function of relative transportation costs among size classes. Size-class demand is disaggregated into demand of a car model by a specific manufacturer as a function of relative "attractiveness." Price, availability, fuel

efficiency, and performance among manufacturers jointly determine the attractiveness of an offering. Within a size class, buyers shift toward the manufacturers with the more attractive offerings relative to the industry average.

The regulatory sector includes the regulatory requirements imposed on the manufacturers, both historical and projected. The historical and forecasted values of these data have profound effects on the outputs of the model.

The present model differs from the previous model in three general areas: documentation, new data sources, and new independent variables and other small structural changes.

The documentation was improved by generating detailed flowcharts. Incorrect historical data on various demographic and economic parameters were changed. New variables added to the model include the unemployment rate, the foreign exchange rate, the Consumer Confidence Index, and annual passenger car registrations. New areas in which changes in the model structure were made include production costs; light-duty truck, van, and four-wheel drive demand; and regulation effects.

MODEL CONSTRUCTION

The model is constructed with 1970 cross-sectional data of socioeconomic conditions and with automobile industry finances and production.

DATA USED IN RUNNING MODEL

The historical input data needed are in three categories: socioeconomic conditions, regulatory environment, and industry characteristics. Socioeconomic factors include auto price elasticity and time required for consumers to accept new car sizes. Fuel economy, emissions, and safety standards can be input to represent the regulatory environment. Goals and concerns of management are included as a part of industry characteristics.

Input assumptions of inflation, gas price, and government regulation are replaced by variables. Inflation can be input as a constant percent cent growth. Gas price can be input as a constant percent growth as well, or as a function of the inflation rate. A gas-guzzler tax lever-selection variable and an add-on gas tax to start in year "x", increasing for 10 years, are available.

REFERENCE

Becker, Harold S., Corporate strategies of automotive manufacturers, four volumes, U.S. Department of Transportation, Report nos. DOT-HS-804-914,915,916,917, November 1978.

SHORT-TERM INTEGRATED FORECASTING SYSTEM (STIFS)

The Short Term Integrated Forecasting System was developed in 1979 by the Logistics Management Institute (LMI) and the Short Term Analysis Division of the Energy Information Administration (EIA). It is the primary tool used by EIA to produce monthly forecasts of energy consumption, and for the short-term analysis presented in EIA's annual reports to Congress. It can be used to simulate the resulting shortages or surpluses in the national energy supply, given a variety of scenarios. A quarterly-published document, the EIA's Short Term Energy Outlook is based on STIFS calculations. (EIA performs midterm analyses with the Midterm Energy Forecasting System (MEFS) (78-419), and long-term analyses with the Long-term Energy Analysis Program (LEAP) (77-286)).

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KEYWORDS

Energy consumption, fuel consumption

OBJECTIVE OF MODEL

STIFS is an energy data balancing system, or an inventory and accounting system, that monitors reported energy stocks and flows from primary production through conversion to usable form. It is intended to produce automated monthly forecasts of energy supply and demand balances and stock changes over the short term (such as 12-18 months). National production, supply, demand stocks, and surplus or shortages are simulated for motor gasoline, distillate fuel oil, residual fuel oil, jet fuel, natural gas, coal, coke, nuclear power, hydro and geothermal

power, and electricity. The energy types forecast correspond to those of the EIA's Monthly Energy Review.

RELATIONSHIP TO OTHER MODELS

STIFS is used to support the EIA's Energy Emergency Management Information System (EEMIS).

HISTORICAL BACKGROUND

The impetus for the development of STIFS came from the April 1977 National Energy Plan and the 1979 fuel shortage crisis. Early models were fuel-specific and could not account for interfuel substitution. The phase I or preliminary version is described here. Further development will make the system partly regionalized, will include improved supply and demand forecasting models, and will include a series of contingency planning models and an extension of the data base.

LMI no longer has responsibility for STIFS.

The gasoline demand model of STIFS, developed at EIA for their August 1980 report, replaced earlier short-term models.

ASSUMPTIONS

Unlike the EIA's Midterm Energy Forecasting System (MEFS) (78-419), which assumes that there will be a market equilibrium in the longer run, STIFS follows the seasonal characteristics of supply and demand, and evaluates the potential for short-term supply shortages or surpluses. It is assumed that demand patterns are stable and the regulatory and tax environment is static in the short term.

The demand for gasoline is assumed to be a reflection of household and business demand for travel, the mode of travel selected, and the efficiency of fuel use. These are also termed the utilization effect, the scale effect, and the technology effect. This involves simplifications, but in the short run the effects of these deficiencies upon the accuracy are minimized because the stock of vehicles and its composition are highly rigid.

The assumptions underlying the impact of price on utilization are that the adjustment process is described by a geometric progression in which the cumulative impact of a price change increases at a decreasing rate over time; the adjustment takes place within one year following a price change; and the price effect has a slow but cumulatively larger impact due to habit, information delays, time required for carpool formation, time required to search for alternatives, and the switch to diesel fuel.

VALIDATION

Validation of forecasting procedures is to be an integral part of the system. Forecast error can be decomposed into historical benchmark data revisions, exogenous forecast error caused by unrealized values of scenario-specific exogenous variables, supply forecast error, demand forecast error, network parameter error, and pure network model forecast error. The August 1980 Short-Term Energy Outlook presents a comparison of actual and predicted values for the motor gasoline model.

LIMITATIONS AND BENEFITS

All analysis is at the national level; the phase I version of STIFS does not address regional energy shortages. Variables are expressed in standard units, with conversions made from one unit of measurement to another when needed: thousand barrels daily, thousand cubic feet, British thermal units, or metric units. Specialized scenarios that could be forecast include: maximum level of petroleum imports, coal strike, harsh or mild winter, nuclear power outages, conservation policies, and cutoff of oil imports. Crises and alternative measures for mitigating them could be simulated.

STRUCTURE

The components of the system are: a historical data base, containing elements within the national energy network back to June 1977; a historical "closing" computation routine that balances energy supplies and demands through double-entry accounting; a forecasting system to simulate supply and demand responses to various scenarios; and a forecast closing routine to balance the forecast energy accounts. The national energy sector is represented by a reference network, consisting of nodes (stocks of fuels), and arcs (flows), through which energy flows from supply to conversion to demand. Subnetworks are provided for oil and refining, natural gas, electric utility, and coal. Variable types within the network represent production, stocks, imports or exports, conversion inputs and outputs, total supplies, final demands, losses, and discrepancies.

Some forecasting is done by fuel-specific econometric models that are external to STIFS. Simple predictive algorithms using various trend techniques are used to extend some variables in the data base. Each variable is forecasted individually, using a technique most appropriate to that variable. Eventually the system may provide for the formulation and solution of certain optimization problems within the context of the network, using techniques such as linear programming.

The Gasoline Demand Model portion of STIFS is as follows.

Automobile Trend Demand

$$\begin{aligned} \text{AUSE} = & \exp(\text{CONSTANT} - 0.11 [\ln(\text{RPMG}/\text{EFF})] + 0.11 \\ & \times 0.50^{12} [\ln(\text{RPMG}/\text{EFF})_{-12}] + 0.79 [\ln(\text{YD72})] \\ & - 0.79 \times 0.50 [\ln(\text{YD72})_{-1}] + 0.50 [\ln(\text{AUSE})_{-1}]) \end{aligned}$$

where:

AUSE = auto use, number of miles driven per automobile

RPMG/EFF = real cost per mile = real price of gasoline divided by the average efficiency of the auto stock

YD72 = real disposable income

-12, -1 = twelve and one month lags

$$\text{AUTO} = \text{AUSE} \times \text{KCARS} / (365 \times 42 \times \text{EFF})$$

where:

AUTO = monthly trend of automobile gasoline demand

KCARS = stock of cars

42 = gallons of gas per barrel

Non-Automobile Trend Demand

$$\text{OUSE} = \exp(\text{CONSTANT} - 0.10 [\ln(\text{RPMG}/\text{EFF}_{-12})] + 0.79 [\ln(\text{YD72})])$$

where:

OUSE = non-automobile use

$$\text{OTHER} = \text{OUSE} \times [(1 + \% \text{ KCARS}) / (365 \times 42 \times [1 + \% \text{ EFF}])]]$$

where:

OTHER = non-automobile gasoline demand

% = percent change

Total Demand

$$\text{XDMG} = \text{SEASONAL FACTOR} \times (\text{AUTO} + \text{OTHER})$$

where:

XDMG = total gasoline product supplied

MODEL CONSTRUCTION

Historical data are collected from a variety of sources, primarily from within DOE. The automobile gasoline demand utilization price elasticity is consistent with that used in the Sweeney/MEFS model (79-254).

DATA USED IN RUNNING MODEL

Some exogenous variables that may be used in the forecasting techniques are seasonal dummy variables, time, and heating and cooling degree days. The forecast for gasoline consumption is driven by Federal Highway Administration gasoline consumption data. Data Resources, Inc. data are use for stock of automobiles and fuel efficiency.

REFERENCES

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Hopkins, F.; Nelson, E.; Sitzer, S.; Wagner, S., Projections of U.S. petroleum supply/demand by quarters through 1980, Analysis Report AR/IA/79-37, U.S. Department of Energy, Report no. DOE/EIA-0184/12, August 1979.

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COMPUTER REQUIREMENTS

Model documentation, including variable descriptions, forecasting techniques, and accounting equations, is referenced above. The system is currently operated and maintained by the Short-Term Analysis Division.

MOBILE SOURCE EMISSIONS MODEL (MOBILE1)

MOBILE1, the Mobile Source Emissions Model, was developed in 1978 by the U.S. Environmental Protection Agency (EPA) and Computer Sciences Corporation. It is intended to be used to automate the calculation of combined vehicular emissions factors, given a large variety of options and variables. These emissions factors may be used to evaluate the ability of air pollution control strategies in meeting vehicle exhaust emission standards established by the EPA.

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KEYWORDS

Air pollution/air quality, emissions

OBJECTIVE OF MODEL

Different vehicular emissions characteristics exist for types of highway vehicles, engine and fuel types, time periods, geographic locations, route speeds, etc. In order to calculate the emissions factors for the formulation of localized emission estimates required for air quality modeling or for the evaluation of air pollutant control strategies, these various factors must be taken into account. The EPA has set up a procedure for doing these calculations, using some 300 pages of tables and formulas, which can be very tedious. It has also provided the MOBILE1 program for automating the calculations.

RELATIONSHIP TO OTHER MODELS

This model may be used in conjunction with the Automobile Exhaust Emission Modal Analysis Model (74-219), also maintained by the EPA.

ASSUMPTIONS

The method for determining composite automobile-emission factors is based on the EPA's Federal Test Procedure (FTP), which involves running the vehicle at specific speeds for specific periods of time and at specific temperatures. Emissions are collected in bags and the grams of pollutants for each portion of the FTP are measured. The conditions under which light-duty vehicles are tested involve: a specific ambient temperature, humidity, and average speed; percentages of cold, hot start, and average stabilized operation; no air conditioning in use; a driver but no passengers, luggage, or trailer; and the vehicle is not in an inspection/maintenance program, but does receive typical in-use maintenance.

LIMITATIONS AND BENEFITS

Composite emissions factors are calculated for three regions: low altitude, California, and high altitude (over 4000 feet); for six vehicle types: light-duty (automobiles), light-duty gasoline-powered trucks up to 6000 lbs., light-duty gasoline-powered trucks 6000-8500 lbs., heavy-duty gasoline-powered trucks, heavy-duty diesel-powered trucks, and motorcycles; for three pollutants: hydrocarbons, carbon monoxide, and oxides of nitrogen; and for calendar years 1970 to 1999. Corrections for speed, temperature, and operating mode may be made when these differ from those of the FTP conditions. Credits may be made for vehicles in inspection/maintenance programs. Additional correction factors may be made for light-duty vehicles for air-conditioning, extra loading, trailer towing, and humidity. Additional factors for heavy-duty vehicles take into account the weight-power ratio. Composite emission factors from idling vehicles, measured in grams/minute, may optionally be generated. For hydrocarbon emissions, composite crankcase and evaporative factors, and total or non-methane factors may also be calculated.

STRUCTURE

The calculation of composite emissions factors for light-duty vehicles, using the complete FTP method is given by:

$$E_{npstwh} = \sum_{i=n-19}^n C_{ipn} \times M_{in} \times R_{ipstwh} \times A_{ip} \times L_p \times U_{ipw} \times H_{ip}$$

where:

E_{npstwh} = composite emission factor in grams/mile for calendar year n , pollutant p , average speed s , ambient temperature t , fraction cold operation w , and fraction hot start operation h

C_{ipn} = FTP mean emission factor for the model year i light-duty vehicles during calendar year n , for pollutant p

M_{in} = fraction of annual travel by the model year i vehicles during calendar year n

R_{ipstwh} = temperature, speed, and hot/cold correction factor for model year i vehicles, for pollutant p , average speed s , ambient temperature t , fraction cold operation w , and fraction hot-start operation h

A_{ip} = air conditioning correction factor for model year i vehicles, for pollutant p

L_p = vehicle load correction factor for pollutant p

U_{ipw} = trailer towing correction factor for model year i vehicles, for pollutant p , and for fraction of cold operation w

H_{ip} = humidity correction factor for model year i vehicles, for pollutant p

The light-duty vehicle emission rate is calculated from a linear function:

$$C_{ipn} = A_{ip} + B_{ip} \times Y_{in}$$

where:

C_{ipn} = FTP mean emission factor in grams/mile, as above

A_{ip} = zero mileage exhaust emission rate of pollutant p , in grams/mile, for model year i vehicles

B_{ip} = emission deterioration rate per 10,000 miles, for pollutant p , for model year i vehicles

Y_{in} = the cumulative mileage of model year i vehicles in calendar year n , divided by 10,000

Formulas and tables have been compiled for each of the other terms in the composite emission factor equation (E). Similar but not identical equations and tables are provided for each of the other vehicle types. Different sets of tables are provided for each of the regions: low and high altitudes, and California.

MODEL CONSTRUCTION

The data used for the various composite, mean, and correction factors are derived from several EPA tests and studies. The function of the model is an accounting one, to produce combined factors from the internal factor data and the user input.

DATA USED IN RUNNING MODEL

The data that may be input to the program include: fractions of total VMT for each of the six vehicle types, annual rates of mileage accrual distributions by vehicle type, vehicle registration distributions, modified emission factors, inspection/maintenance program data, region, calendar year, average speeds, ambient temperature, catalyst equipment data; and data on the mix of VMT among different vehicle types, air conditioning, loading, trailer towing, humidity, and average gross vehicle weight and cubic inch displacement by vehicle type.

REFERENCES

Guthman, L.E., User's guide to MOBILE1: Mobile Source Emissions Model, U.S. Environmental Protection Agency, Report no. EPA-400/9-78-007, August 1978.

Mobile source emission factors, U.S. Environmental Protection Agency, Report no. EPA-400/9-78-005, March 1978. NTIS no. PB 295-672.

COMPUTER REQUIREMENTS

A variety of input and output format options are available. Complete instructions, including examples, a program explanation, and a program listing, are provided in the documentation. The program is written in FORTRAN and uses 200 kilobytes of space on an IBM 370/158 computer. On this machine a 1000-link data set was analyzed in 47 seconds of CPU time. The program is transferrable to other machines with minor or no modifications.

AUTOMOTIVE MANUFACTURER RISK ANALYSIS

A risk analysis model of the automotive industry was developed in 1979 for the National Highway Traffic Safety Administration by H.H. Aerospace Design Company. It uses accounting methods and cost assumptions to assess the probable impact of the automotive fuel economy standards on the financial health of the domestic automobile manufacturers. Its results generally indicate weakening of the smaller companies by 1985.

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KEYWORDS

Industrial financial performance, market share, fuel economy, automobile supply, pricing

OBJECTIVE OF MODEL

The model uses information about the automotive industry to assess the impact of the automotive fuel economy standards on the profitability or financial performance of the manufacturers, while accounting for various uncertainties.

RELATIONSHIP TO OTHER MODELS

This model uses several portions of the Wharton EFA Automobile Demand Model (77-046): new car demand projections by size class; total U.S. automobile demand; and the capital cost per mile equations. Some portions of the Wharton model are incorporated into the structure of this model, while some Wharton model outputs are used as exogenous input to this model.

ASSUMPTIONS

The risk to the industry is categorized into two classes of uncertainty: contextual (exogenous), including economic or overall business conditions and marketing environment (automotive sales); and endogenous, including technology and manufacturing conditions. Sensitivity analysis can be done in which the effects of changes in the endogenous uncertainties are assessed, if only their probability distributions are known and if the contextual variables are fixed in a defined scenario. It is assumed that there is no, or uniform, inflation; analysis is done in 1976 dollars. Manufacturing costs follow historical trends; increased costs due to pollution or safety requirements are not included, but those due to fuel economy standards are. New technologies to improve fuel economy are scheduled by the manufacturers, and it is assumed that they meet the standards every year. Their strategies include downsizing, material substitution, and rates of implementation of technological improvements. The size classes of cars modeled are full-size, mid-size, compact, and subcompact.

LIMITATIONS AND BENEFITS

Because of data availability limitations, the model results should only be used to analyze the relative impact on the passenger car operations of the four major U.S. manufacturers, who are labeled G, F, C, and A. The impacts on foreign manufacturers are not assessed; they are treated as one entity. Monte Carlo simulation is used when it is assumed that only the probability distributions are known of the variables measuring the manufacturers' technological risk or capabilities, and the measures of manufacturing risk, which is the cost of implementing the technology. In these probability cases uniform or truncated normal distributions may be used. Four summary measures of performance for the last period (1985) are produced: after-tax profit, retained income, long-term debt, and fuel economy without mix shifts.

STRUCTURE

The model is divided into 7 modules, for marketing, fuel economy, variable costs, capital costs, price, finances, and proforma generator (income, cash flow, and balance statements). Economic risk is assessed by varying the total demand for cars. Marketing risk is assessed by varying foreign and domestic market shares, foreign product mix, and price cross-elasticities between classes. Manufacturing risk is assessed by varying the capital costs and variable costs of production due to fuel economy measures.

The sales volume of each manufacturer is a function of the market share for each, assumed constant over time, and the foreign share and total demand, which are variable inputs. Fuel economies of each size-class are related to their weight. The fleet-weighted average fuel economy for each manufacturer is a function of the previous year's size-class market shares, the fuel economy changes due to technology improvements, and emission and safety regulations. If this average is

greater than the standard, then the size-class market shares are set to the previous year shares. If not, then the product mix is changed: proportional shifts are made from larger to smaller classes until the average fleet fuel economy, based on the shifted proportions for each class for the current year, meets the standard.

Material and labor costs are related to the size-class share and sales volume of each manufacturer. The capital costs of implementing technological improvements are related to the penetration of the improvements, their cost, and sales volumes.

The price module borrows from the Wharton auto model capitalized cost per mile concept and the shares by size-class equations, but uses them with an iterative search procedure to solve for new car prices that satisfy two conditions: (1) average car price remains constant over time, and (2) the price differential between size-classes is such that the product mix to the market is just sold.

The financial module keeps track of the capital assets of each manufacturer: land and buildings, machinery and equipment, and tooling. Fuel-economy-related investments and depreciation affect the level of assets. Interest on the long-term debts and dividends paid by each manufacturer are calculated.

The proforma generator module calculates before-tax profit for each manufacturer as a function of revenue, and of variable and fixed costs. The cash flow statement and balance sheet are generated using straightforward accounting identities; results include equity capital, long-term debt, and retained earnings.

MODEL CONSTRUCTION

Data is provided for nominal-case assumptions concerning a variety of parameters; these are derived mostly from NHTSA's fuel economy standard rulemaking efforts. They include: schedules for downsizing and material substitution, by size-class and manufacturer; schedule for implementation of technological improvements; market shares of the manufacturers and of foreign cars; product mix by manufacturer and size-class; current fuel consumption; fuel economy gains from technological improvements; regulatory standards; manufacturing costs data; costs related to fuel economy measures; and financial data by manufacturer.

DATA USED IN RUNNING MODEL

Several different cases under a nominal scenario are reported: a base scenario; optimistic and pessimistic cases; and a probabilistic case. In these cases the fuel-economy-related costs and gains from technological improvements are varied. In the probabilistic case a range of values is input and the probabilities of selected values are output. Alternative scenarios tested involved altering capital expenditures, not meeting the fuel economy standards, higher standards,

79-425

altered foreign product mix and manufacturer market share, and economic risk (a change in demand).

REFERENCE

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COMPUTER REQUIREMENTS

The program is written in FORTRAN and is operational on the Harvard Business School PDP-10 computer. The documentation includes sample output, instructions, and listings of the input data files and the program.

SEPARABLE CONVEX PROGRAMMING MODEL FOR AUTOMOBILE PRODUCTION

The Separable Convex Programming Model was developed at the University of Detroit in 1978. Its purpose is to determine the optimum car production levels for a manufacturer under fuel economy regulation.

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KEYWORDS

Industrial financial performance, fuel economy, automobile design, fleet size

OBJECTIVE OF MODEL

The objective of this model is to aid planning of automobile production to maximize profits while at the same time recognizing the constraints of the Energy Policy and Conservation Act on minimum fleet fuel economy.

RELATIONSHIP TO OTHER MODELS

There is no relationship to other models.

HISTORICAL BACKGROUND

This model is now basically a theoretical model. The necessary data to run this model have not been obtained from the auto companies.

ASSUMPTIONS

The model has two major assumptions: (1) As time progresses, the results of the latest research and development work leading to the redesign of the automobile will be available to car manufacturers as input parameters in the determination of an optimal production mix. (2) After a certain level of car model production is reached, the profit margin on every additional model produced drops to a new constant value from a previous constant value. As a result of the second major assumption, the profit vs. car production graph is separated into two parts, one part before the profit margin per cars drops for each car model, and the other part after. The resulting profit curve is a convexly kinked line consisting of two connecting sections, hence the

name "separable convex." The change in profit margin per car produced after a certain level of production is assumed to be related to increased labor costs due to overtime pay. A profit curve could be made up of any number of linear segments, other than with two segments as shown in the Structure section below, provided that the entire curve is convex.

STRUCTURE

In order to meet the regulation for the minimum fuel economy average for the fleet of cars produced by an auto company while maximizing profit, the following profit equation is maximized subject to constraints of production capacity, sales commitments, and minimum corporate fleet fuel economy standards. The output sought is the optimum number of cars produced for each model of car and the profit obtained by selling these models.

$$P_{\max} = \max \left[\sum_{i=1}^n P_{i1} X_{i1} + P_{i2} X_{i2} \right]$$

where:

P_{\max} = maximum profit

n = number of car models produced

P_{i1} = profit per car produced for each car model before drop in profit per car

X_{i1} = number of cars produced for each car model before drop in profit per car

P_{i2} = profit per car produced for each car model after drop in profit per car

X_{i2} = number of cars produced for each car model after drop in profit per car

This profit maximizing equation is subject to the following five constraints:

$$\frac{\sum_i \text{MPG}_i X_i}{\sum X_i} \geq \text{CAFE}$$

$$X_i \geq \text{SALECOM}_i$$

$$X_{i1} \leq \text{PRODCAP}_{i1}$$

$$X_{i2} \leq \text{PRODCAP}_{i2}$$

$$\text{PRODCAP} \geq \sum_{i=1}^n X_{i1} + X_{i2} \geq \text{SALECOM}$$

where:

MPG_i = EPA miles per gallon for each car model i

X_i = number of cars produced for each model i before and after drop in profit per car ($X_i = X_{i1} + X_{i2}$)

CAFE = corporate average fuel economy

SALECOM_i = sales commitment for each car model i

PRODCAP_{i1} = production capacity for each car model i before drop in profit per car

PRODCAP_{i2} = production capacity for each car model i from after the drop in profit per car until final production capacity is reached

PRODCAP = total production capacity for all models (equals the sum of PRODCAP_{i1} and PRODCAP_{i2} for all models i)

SALECOM = total sales commitment for all models ($= \sum \text{SALECOM}_i$)

MODEL CONSTRUCTION

This is a linear programming model that was constructed using hypothetical data.

DATA USED IN RUNNING MODEL

Data required for running the model are manufacturing costs, sales commitments, production capacity, and profit. All these variables are needed for each make and model of car.

REFERENCE

Miranda, C.F.; Rhomberg, E.J.; Tummala, V.M., Separable convex programming model for automobile production, University of Detroit, July 1978.

COMPUTER REQUIREMENTS

This model uses a standard Simplex Algorithm. It has been run on the University of Detroit computer system.

ACCIDENT TREND MODEL

The Accident Trend Model was developed in 1975, by the Center for the Environment and Man, for the National Highway Traffic Safety Administration. It describes the overall risk of accidental deaths in automobile crashes as a function of changes in accident frequency trends and in characteristics of the automobile population.

SPONSOR

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KEYWORDS

Accidents

OBJECTIVE OF MODEL

The accident-severity component of this model describes how the frequency of automobile occupant injury or death changes with certain changes in characteristics of the automobile population. The accident-trend component of the model describes how the number of automobile occupant deaths would have changed over time had there been no changes in the automobile population. Both components can be combined to calculate changes in deaths resulting from changes in automobile population and the trend. This model was developed as part of two larger studies that explore the various factors affecting the accident trend and how deaths in the future would change under various assumptions on the use of small cars, on travel speed reductions, and on changes in vehicle use that might result from a limited availability of gasoline.

HISTORICAL BACKGROUND

Subsequent to this study, further work in this area was done by the Center for Environment and Man, which resulted in the Highway Submodel of the Transportation Safety Analysis Model, reported under 76-047. The current study was sponsored as a part of the Automobile Energy Efficiency Project of DOT.

ASSUMPTIONS

It is assumed for the accident-severity model that seatbelt use is negligible in cars older than the 1964 model year, and that seatbelt use declines with vehicle age. The accident trend has been shown to depend on vehicle age distribution, and thus indirectly on vehicle miles traveled and speed. Future trends may not follow this assumption, because of the 55 mph speed limit.

VALIDATION

The reports describe extensive experiments on correlating the trends in accidents with automobile size and weight, by state, speed, vehicle miles traveled, etc.

LIMITATIONS AND BENEFITS

Severe problems exist with regard to the aggregation of accident data, making it difficult to estimate the effects of changes in overall vehicle miles traveled on deaths, the relation between travel speed (such as the 55 mph speed limit) and accident frequency (there is a well established relation between speed and accident severity), and the effect of a ban on travel on Sundays.

STRUCTURE

The accident-severity component of the model expresses changes in the fatality risk due to changes in the mix of cars of different size, car improvements by model year, and the availability and use of seatbelts:

$$R_i^1 = \left[\sum_k \left(\sum_j r_{ij} w_{jk} a_{ij} p_j S_{ij} \right) w_k \right] / \left[\sum_k \left(\sum_j r_{ij} w_{j0k} a_{ij} p_j^0 S_{ij}^0 \right) w_k \right]$$

where:

R_i^1 = overall injury risk for car occupants in single-car crashes in calendar year i , relative to that for a car population of the same age composition but with the weight, frequency, and seatbelt usage distributions for the base year

r_{ij} = number of cars of model year j registered in calendar year i

w_{jk} = fraction of cars of model j in weight class k . It is assumed that cars of different weight classes survive over time in the same manner.

a_{ij} = frequency of occupant injury in single-car crashes per registered automobile per year, relative to cars of the current model year, for cars of age i minus j , a usage factor by age

p_j = factor describing the frequency of occupant injury in cars of model year j relative to that for a base year. It is assumed that this frequency is the same for all car weight classes for any given model year.

S_{ij} = effect of seatbelt use, declining with vehicle age i minus j

w_k = frequency of injury for occupants of cars of weight class k relative to an arbitrary basis, model year independent

$w_{j_0k} = w_{jk}$ for base year j_0

P_j^0 = model year factor for model year $j_0 - (i - j)$

S_{ij}^0 = seatbelt factor for age $i - j$ and for model year $j_0 - (i - j)$

For car-car crashes the injury risk also depends on the relative differences in weight between the two cars, making the formulations very complex. Car-truck crashes are similar to car-car crashes. The overall risk is a combination of that for each type of crash, and the "adjusted" number of car occupants killed: the number that would have been killed had there been no changes in the automobile population.

The accident-trend component of the model:

$$Z_i = \frac{8174}{(530)} + \frac{2.15}{(0.38)} (X_{1i}) + \frac{0.8}{(0.11)} (X_{2i}) - \frac{0.14}{(0.08)} (X_{3i})$$

where standard errors are in parentheses, and

Z_i = number of "adjusted" car occupant deaths in year i

X_{1i} = number of cars of current model year registered in year i

X_{2i} = number of cars one through three years old in year i

X_{3i} = number of cars four years old or older in year i

All of the X 's are in thousands. Also taken into account in the overall car occupant fatality risk are 1000 deaths annually in car-train collisions, in which neither car size nor vehicle improvements affect the risk.

A "speculative" model was also estimated in which adjusted car occupant deaths are a function of vehicle miles traveled and the deviation in the index of industrial production in each year.

MODEL CONSTRUCTION

The trend equation (Z) is specified for the years 1950-1960. Separate estimations were made for the periods 1957-67 and 1961-71. Each predicts adequately for other periods, except for the period after

1967, following the introduction of federal motor vehicle safety standards. Values for these factors were also empirically estimated: frequency of death or injury by car age, relative risk by model year, and risk reduction by car age, for single- and two-car accidents.

DATA USED IN RUNNING MODEL

Input data needed describe vehicle registrations, weight class by model year percentages, seatbelt factors, registrations by age, usage factors, model year factors, weight factors, including factors for single-vehicle, two-vehicle, and car-truck accidents.

REFERENCE

Joksch, H.C., Accident trend model, U.S. Department of Transportation, Report no. DOT-HS-805-420, March 1975.

Joksch, H.C., Analysis of the future effects of fuel shortage and increased small car usage upon traffic deaths and injuries, two volumes, U.S. Department of Transportation, Report no. DOT-TSC-OST-75-21,21A, January 1976.

COMPUTER REQUIREMENTS

The computer program is written in FORTRAN and requires 40 K bytes of core storage for execution. The documentation contains a program listing and input instructions.

DEMAND FOR PASSENGER CAR TRANSPORT SERVICES AND FOR GASOLINE

A model of the national demand for passenger car transport services and for gasoline was developed in 1979 by staff at Gulf Oil Corporation and the University of Pittsburgh. This econometric model describes the demand for gasoline, passenger cars, car quality, and miles driven.

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KEYWORDS

Fuel consumption, weight, automobile demand, vehicle miles traveled

OBJECTIVE OF MODEL

The model describes the demand for passenger cars, for miles traveled, and for the attributes or qualities of cars. In this case quality is measured by the average weight of cars. The demand for gasoline can then be estimated, if the average efficiency of the fleet of cars is known. The independent variables are income, the stock of cars, and the prices of cars, miles driven, and fuel.

RELATIONSHIP TO OTHER MODELS

There is no relationship to other models.

ASSUMPTIONS

When the quantity of gasoline demand is defined as the miles driven divided by the fuel efficiency, and the cost of driving is the price of gasoline divided by the efficiency, then it is shown that the sum of the elasticity of gasoline consumption with respect to efficiency and the elasticity of gasoline consumption with respect to the price of gasoline is -1. The user cost of a car is defined to be a function of the price of a standard car, the depreciation rate, and the interest rate. The long-run demand specifications must be modified for short-run estimation. This involves a stock adjustment process: new car registrations are a function of stock adjustment and depreciation

factors, income, user cost of a car, user cost of miles driven, and cost of quality, as well as the existing stock of cars. The weight of a car is used as a proxy for quality, since options added to a car increase its weight, and weight was found to be correlated with efficiency.

STRUCTURE

Each of the equations were estimated using either the cost per mile of driving the existing stock, or of driving the stock of new cars, or the price of gasoline. The set of equations using cost per mile is presented here.

$$R_t = 55.80 + \frac{10.29}{(5.09)} (Y_t) - \frac{6.85}{(4.96)} (PK_t) - \frac{0.968}{(2.90)} (PM_t) - \frac{0.101}{(4.95)} (K_{t-1}) \\ - \frac{2.16}{(3.96)} (X_t)$$

$$R^2 = 0.82 \quad DW = 1.98 \quad \rho = -0.369$$

where absolute values of t-ratios are in parentheses, and

R_t = new car registrations per capita, in 1000s of cars

Y_t = per capita real disposable income in 1000s of dollars, in period t

PK_t = user cost of new cars, equal to the real price of new cars, 1967=100, adjusted by Moody's Aaa bond yield and rate of physical depreciation of cars

PM_t = per mile cost of driving a car from the existing stock of cars

K_{t-1} = stock of cars per capita, end of quarter, in 1000s of cars, in period t-1

X_t = dummy variable to account for the effect of the oil embargo of late 1973 and early 1974

ρ = estimate of the coefficient of first order serial correlation

$$M_t = -42.09 + \frac{7.58}{(3.24)} (Y_t) - \frac{1.163}{(3.77)} (PM_t) + \frac{0.0871}{(5.11)} (K_{t-1}) \\ + \frac{0.0085}{(1.73)} (L_{t-1}) - \frac{0.996}{(2.60)} (X_t)$$

$$R^2 = 0.98 \quad DW = 1.92 \quad \rho = .356$$

where:

M_t = miles per capita driven, in period t

L_{t-1} = weighted average weight of new cars, in pounds per car, adjusted by the number of cars registered in period $t - 1$

$$L_t = 3174.0 + 404.96 (Y_t) - 232.6 (PK_t) - 21.74 (PMR_t) - 123.39 (X_t) - 108.36 (T_t)$$

(2.43) (1.56) (1.41) (0.76) (2.40)
(3.60)

$$R^2 = 0.68 \quad DW = 2.14 \quad \rho = 0.536$$

where:

L_t = weighted average weight of new cars, in pounds per car, adjusted by the number of cars registered in period t

PMR_t = per mile cost of driving new cars

T_t = dummy variable to account for weight reduction of cars, for any given level of quality, in 1975-76

Gasoline demand is found by dividing miles driven, M_t , by fuel efficiency, E_t . Short- and long-run elasticities for the variables in the model are also presented in the paper.

MODEL CONSTRUCTION

The model was estimated with a linear specification, using quarterly data from 1969 I to 1976 III. Sources for the data were: Survey of Current Business for income, interest rate, gasoline demand, car price, and the consumer price index; Bureau of Labor Statistics for price of gas; Ward's Automotive Yearbook for stock of cars. Cars were divided into eight size classes and the car model with the greatest number of registrations in the class in each model year was used to represent the class. The overall efficiency of new cars is a function of the weighted average of registrations over the entire sample period. Depreciation is an average equal to 0.0234. Fuel efficiency data for new cars came from the Automobile Club of Italy's World Cars, then these were averaged with the efficiency of the existing stock, after deflating 20% to account for the difference in new car estimates and actual car performance.

REFERENCE

Reza, A.M.; Spiro, M.H., Demand for passenger car transport services and for gasoline, Journal of Transport Economics and Policy, 13(3):304-319, September 1979.

CONAES INTEGRATING 40-SECTOR MODEL

The Integrating 40-Sector Model of the U.S. energy economy was developed by a task force of the Demand and Conservation Panel of the Committee on Nuclear and Alternative Energy Systems, in 1979. It was used to analyze several scenarios of energy use and price out to the year 2010, by integrating the projections for three major sectors: buildings, industry, and transportation.

AUTHOR

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KEYWORDS

Energy consumption, fuel consumption

OBJECTIVE OF MODEL

The economy is divided into forty sectors. This input-output model forms an internally consistent picture of energy flow between these sectors, and predicts the total energy demand in each sector and for all sectors in the year 2010. Five of the sectors are for transport: rail, bus, truck, water, and air; one is for motive power; and one is for motor vehicles and equipment.

RELATIONSHIP TO OTHER MODELS

The report in which the integrating model appears contains sections describing modeling activity on the building, industry, and transportation sectors. Some of the results from these sector submodels are integrated with the integrating input-output model. Econometric techniques are also used to make projections to the year 1990.

HISTORICAL BACKGROUND

The Committee on Nuclear and Alternative Energy Systems (CONAES) of the National Research Council began in 1975 to undertake a study of the U.S. prospective energy economy during the period 1985-2000. The Demand and Conservation Panel of the committee was charged with exploring the range of energy demand that is possible out to the year 2010, examining the opportunity for saving energy, and recommending policy initiatives that can affect demand and conservation. Five resource groups were organized: to look at the three basic sectors of buildings, industry, and transportation; to check the projections of those three with an

integrating input-output model; and to use econometric techniques to model energy demand projections to 1990.

ASSUMPTIONS

Primary energy comes from fossil fuel, hydropower, nuclear, solar, and geothermal sources. The technology of producing any type of good or service is defined by specifying the inputs required to produce one unit of output. Energy can be conserved by reducing inputs or replacing them with non-energy inputs. The changes in inputs that were possible were based on the estimated response of energy use to price levels, given by industry experts. This subjective rather than economic approach was used because of a lack of price elasticity data, and because of the uncertainty associated with long-term economic projections, which require forecasts of technological innovation that are essentially arbitrary.

VALIDATION

Several different scenarios of the changes in energy use and prices were used, ranging from a reduction to a doubling of per capita energy use. The same population conditions were used for each scenario, while policies were varied.

STRUCTURE

The interrelations between the sectors comprise a 40 x 40 matrix of input-output coefficients, a typical element being the amount of input from one sector to produce one unit of output by another sector. The matrix defines the state of technology by indicating the energy intensity (the energy required for a unit of output) for the products and services of each sector. When the energy intensities are multiplied by the outputs of all the sectors and are totaled, the total energy demand for the system is found.

MODEL CONSTRUCTION

Energy technology data come from a U.S. Department of Commerce, Bureau of Economic Analysis study of 1967 data, supplemented by more recent information. Fuel consumption data come from the resource groups of the CONAES study. Rather than specifying all possible production technology changes, only the energy input fraction parameters were calculated that have the most important effect on energy demand. For example, it was shown that only 10% of the energy cost of a car is due to the fuel and electricity consumed by the automakers, while over a third is due to the steel used. For specifying auto production techniques in 2010, it was therefore more important to accurately describe the size, weight, and material composition of the car than it was to describe degree of mechanization of the assembly line.

REFERENCE

Alternative energy demand futures to 2010, Study of Nuclear and Alternative Energy Systems, National Academy of Sciences, 1979.

WORLD DEMAND FOR GASOLINE

A model of the world demand for gasoline was developed in 1975 by faculty at Ohio University and Hamilton College. It uses cross-section data from forty countries to determine the long-run demand for gasoline used by commercial vehicles and cars in a country.

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KEYWORDS

Fuel consumption

OBJECTIVE OF MODEL

The quantity of gasoline demanded in a country in the long run is modeled as a function of price, number of cars and commercial vehicles, and per capita income, using cross-section data from forty countries.

RELATIONSHIP TO OTHER MODELS

There is no relation to other models.

HISTORICAL BACKGROUND

Prof. Koshal did an earlier study on the long-run demand for gasoline in the U.S. using cross-section data, but with rather small variations in the price of gasoline. This study uses the same general method but with wider price variations.

ASSUMPTIONS

Since the price of gasoline in almost all countries is directly or indirectly controlled by the government, even though the world gasoline industry is oligopolistic, it is reasonable to assume that the quantity demanded is determined just by demand and not generally by supply constraints.

The number of vehicle equivalents in a country is assumed to equal three times the number of registered commercial vehicles plus the number

of registered cars. This is justified because commercial vehicles consume almost three times as much gasoline as cars.

VALIDATION

The elasticities that are derived indicate that in the long run a ten percent increase in price would be accompanied by about a 9.9% decrease in gasoline demand in low-income countries and 12.3% in high-income countries. A ten percent increase in income would produce increases in gas consumption of 4.9 and 3.3% in low- and high-income countries, respectively. This suggests that gasoline tends to be more of a "necessity good" in high-income than in low-income countries. The nearly unitary price elasticity value suggests that in the long run further price increases would not bring substantial extra revenue to the oil producing countries.

LIMITATIONS AND BENEFITS

Most studies of gasoline demand make use of data that has rather small variations in the price of gasoline, and therefore makes them useful for policy purposes only when there are small gasoline price changes in the alternate policies. In this study there are much wider variations: from 18.3 cents (U.S.) per gallon in 1970 in the Philippines, to 78 cents (U.S.) in Italy.

STRUCTURE

The model is estimated three times, using 1970 data from 20 high-income countries (per capita income at least 700 dollars), from 20 low-income countries, and for all forty.

Low income:

$$\begin{aligned} \log(Q) = & -0.2154 - 0.9875 [\log(P)] + 0.8314 [\log(VC)] \\ & \quad (5.68) \quad (11.85) \\ & + 0.4875 [\log(Y)] \\ & \quad (3.03) \end{aligned}$$

$$R^2 = 0.9447 \quad \bar{R}^2 = 0.9343 \quad F = 91.07$$

where t-ratios are in parentheses, and

Q = quantity of gasoline demanded in gallons

P = price per gallon in cents (U.S.)

VC = number of automobile equivalents

Y = per capita income in U.S. dollars

75-464

High income:

$$\log(Q) = 0.8528 - 1.2310 [\log(P)] + 0.8817 [\log(VC)] + 0.3310 [\log(Y)]$$

(4.15) (22.23) (2.49)

$$R^2 = .09826 \quad \bar{R}^2 = 0.9793 \quad F = 300.77$$

Total:

$$\log(Q) = 0.866 - 1.1160 [\log(P)] + 0.8625 [\log(VC)] + 0.3107 [\log(Y)]$$

(9.13) (24.16) (4.56)

$$R^2 = 0.9782 \quad \bar{R}^2 = 0.9764 \quad F = 539.09$$

REFERENCE

Koshal, R.K.; Bradfield, J., World demand for gasoline: Some empirical findings, Keio Economic Studies (Tokyo), 14(1):41-48, 1975.

ONTARIO L_{EQ} TRAFFIC NOISE PREDICTION METHOD

This empirical model of traffic noise was developed in 1976 at the Ontario Ministry of Transportation. It uses the energy-equivalent sound level as a noise measure, which is shown to be as good or better than other measures. Nomographs are provided for simple predictions.

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KEYWORDS

Noise pollution

OBJECTIVE OF MODEL

Noise along a highway is described as a function of the volume of traffic, distance to the edge of the roadway from the observer, and average speed of the traffic. The measure used for noise is L_{eq} , the energy-equivalent sound level. The model is to be used in highway engineering and design studies at a variety of locations.

RELATIONSHIP TO OTHER MODELS

There is no interaction with other models.

HISTORICAL BACKGROUND

Most of the data base for this model was developed in 1970-73 for the original Ontario highway noise prediction method, by the same author.

VALIDATION

The standard error of this model was found to be similar to that of other models. It was validated using data from a study of sound measurements on freeways and arterials in southern California. The studies used for comparison include the model used by the National Cooperative Highway Research Program (a later version of which is described under 76-089), and the Highway Noise Policy Model (74-208). Greater accuracy in traffic noise prediction models would require the introduction of complex environmental, topographic, and traffic flow variables.

LIMITATIONS AND BENEFITS

The use of L_{eq} as a noise measure is supposed to be as good as or better than L_{10} , the sound level that is exceeded 10% of the time. L_{eq} allows noise in different environments to be compared, is more understandable as a measure, does not depend on the sequence in which noise events occur, is easier to measure, may be adopted as a standard, and can allow for the addition of sound levels from different sources, which would be useful in noise analyses of joint rail and highway corridors. The adoption of a widely recognized unit makes the work in other countries accessible; the trend in the United States and Europe is toward the use of L_{eq} . It provides simple, reliable predictions of traffic noise for day-to-day planning and design purposes; but it is less suitable for analyzing various strategies of vehicle noise control than theoretical models.

STRUCTURE

The empirical equation found to best predict the noise caused by highway traffic is:

$$L_{eq} = 49.5 + 10.2 [\log_{10}(V_C + 6 V_T)] - 13.9 [\log_{10}(D)] + 0.21 (S)$$

$$R^2 = .89 \quad SEE = 2.24 \text{ dBA}$$

where:

L_{eq} = energy-equivalent sound level during one hour, in dBA

V_C = total volume of automobiles (highway vehicles with four tires only), in vehicles per hour

V_T = total number of trucks (with six or more tires), in vehicles per hour

D = distance to the edge of the pavement of the first traffic lane, in meters

S = average speed of traffic flow during one hour, in km/hour

Correction factors may be applied to account for ground conditions, grade, intervening structures, and noise barriers, as specified in highway design guides.

A modified form of the model enables the prediction of day-night sound levels:

$$L_{dn} = 38.2 + 10.2 [\log_{10}(AADT + [T\% AADT/20])] - 13.9 [\log_{10}(D)]$$

$$+ 0.21 (S)$$

where:

L_{dn} = equivalent A-weighted sound level during 24 hour period with a 10 dBA weighting applied to the equivalent sound level from 10 pm to 7 am, in dBA

AADT = annual average daily traffic, vehicles per day

T% = average percentage of trucks during a typical day

D = distance from the edge of pavement, meters

S = average traffic speed during a typical day, Km/hour

Nomographs are provided so that L_{eq} and L_{dn} may easily be found.

MODEL CONSTRUCTION

Data used in estimating the model were from observations made at 182 locations along various highways in Ontario between 1970 and 1976. Traffic volumes were at least 100 vehicles per hour, so that background noise would not predominate, and microphones were located four feet above the ground. For each position the data collected were traffic volume, speed, distance, road and site geometry, and weather conditions. Observations were made under a variety of conditions and vigorous attention was not given to data accuracy, but such wide-ranging data should be applicable to a variety of commonly encountered situations.

DATA USED IN RUNNING MODEL

To use the L_{eq} nomograph, one must know the number of cars and trucks per hour, the average speed on the road segment, and a distance from the edge of pavement for the noise observer. To use the L_{dn} nomograph one must know the average daily traffic volume, the percentage of trucks, speed, and distance from the pavement. Traffic data are generally available by highway sections and are updated annually.

REFERENCE

Hajek, J.J., L_{eq} traffic noise prediction method, Transportation Research Record 648, pp. 48-53, 1977.

CRASH INJURY PREDICTION MODEL

The Crash Injury Prediction Model was employed in a study that concludes that there are net benefits from reducing vehicle weight. It was developed at the National Highway Traffic Safety Administration (NHTSA) in 1978.

This injury prediction model provides a direct measure of the average injury change as a function of average vehicle weight change. This measure is expressed in dollars by using standard economic methods and the standard societal costs of motor vehicle accidents developed by NHTSA. The relationship between injury cost and weight is then compared with the relationship between fuel cost and average vehicle weight; thus the fuel and crash injury costs can be compared in a common unit. The model was also used to examine the potential interaction between vehicle size and passive restraints.

SPONSOR

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KEYWORDS

Accidents, weight

OBJECTIVE OF MODEL

The model predicts the expected automobile occupant injury severity as a function of crash parameters such as vehicle weight. The elasticity of injury with respect to weight can thus be determined. Along with the elasticity of fuel consumption with respect to weight and the costs of fuel and injury, the net cost or benefit of vehicle weight reduction can be determined.

RELATIONSHIP TO OTHER MODELS

There is no interaction with other models.

HISTORICAL BACKGROUND

This study expands on earlier work on crashes and vehicle size and weight by the author and by others. The model was originally prepared by the author while on leave to the NHTSA from St. Olaf College. Further work was done at St. Olaf.

ASSUMPTIONS

Vehicle size, which is strongly correlated with vehicle weight, has two effects on injury severity. The "hostile" effect is that of a heavier car striking a lighter one, which absorbs larger decelerations regardless of the impact velocity of each vehicle. If the weights of all cars were reduced proportionately, the "hostile" effect will not increase. The "protective" effect depends on the car's volume; larger cars provide more "crush distance" to protect passengers. This effect is reduced if car volume is reduced, but not if weight can be reduced while volume is not.

VALIDATION

The model was validated by using it to predict severe injury and death rates for a new accident vehicle population.

Different estimation methods were attempted in order to remove bias from the model. The elasticity of injury with respect to average vehicle weight was found to lie in the range of -0.47 to -0.86. The use of any value within that range does not change the conclusions of the study. The model was estimated using another data base. The differing results are attributed to the different type of data collected.

Using studies of injury rates and costs, the expected injury cost per one million miles was obtained. Assuming a gas price of 90 cents per gallon and consumption of 16 miles per gallon, the elasticity of fuel cost with respect to vehicle weight was found to be 1.03. Using average vehicle weights, a 1% decrease in vehicle weight resulted in a net benefit of 448 dollars per million miles of vehicle travel. The total savings for a 20% reduction in vehicle weight would be 896 dollars per vehicle over its lifetime.

Another estimation and application of the model computed the net effectiveness of restraints by vehicle size. Observations on the use of seat belts were used to test the potential effectiveness of air bags or other passive restraints. A conclusion is that these will reduce injuries more in larger cars, partly because large-car occupants tend to be older than those of smaller cars, and restraint effectiveness increases with increasing occupant age.

STRUCTURE

The crash force imposed on a vehicle occupant is proportional to the change in vehicle velocity resulting from the crash. This velocity was shown to be a function of the weights of the two vehicles involved, their reported impact velocities, and the direction of the resultant velocity vector after impact, relative to the initial direction of the case vehicle.

Assuming a 20% seatbelt utilization rate, the composite injury prediction model is:

$$Y = -0.71 + \frac{0.098 (\Delta V_1)}{(32.0)} + \frac{0.012 (A)}{(9.47)} + \frac{0.17 (D)}{(3.70)} + \frac{0.23 (R_f)}{(4.69)} \\ - \frac{0.12 (\Delta W_5)}{(-2.07)} - \frac{0.21 (\Delta W_6)}{(-3.89)} - \frac{0.31 (\Delta W_7)}{(-5.64)} - \frac{0.39 (\Delta W_8)}{(-6.19)}$$

where t-statistics are in parentheses, and

Y = predicted average accident occupant injury severity measured by the overall Abbreviated Injury Scale (AIS)

ΔV_1 = estimated change in the case vehicle velocity as a result of the crash, in miles per hour

A = occupant age in years

D = 1 if occupant is driver, = 0 else

R_f = 1 if occupant is in right front seat, = 0 else

ΔW_5 = 1 if vehicle is in weight range of 2200-2899 pounds, = 0 else

ΔW_6 = 1 if 2900-3599 pounds

ΔW_7 = 1 if 3600-4299 pounds

ΔW_8 = 1 if vehicle is greater than 4299 pounds

Problems in the measurement error of ΔV_1 are discussed. Separate sets of coefficients are estimated for¹ different types of crash configurations, using both one- and two-stage least squares, and with different weightings of variables.

The expected AIS is then used to compute the estimated fatality and severe injury rates. The probability of a fatality is estimated as:

$$Z = 0 \text{ if } Y \leq 1.38$$

$$Z = \frac{0.031}{(0.040)} - \frac{0.086}{(0.042)} (Y) + \frac{0.046}{(0.011)} (Y)^2 \quad \text{if } 1.38 < Y < 5.62$$

$$Z = 1.0 \text{ if } Y \geq 5.62$$

$$R^2 = 0.13 \quad N = 663$$

where standard errors are in parentheses, and

Z = estimated probability of a fatality for a towaway crash

Y = estimated expected AIS, as above

MODEL CONSTRUCTION

The data for estimation of the model came from the Crash Performance Injury Report (CPIR) database maintained by the University of Michigan Highway Safety Research Institute. This was verified by using data from the Restraint System Evaluation Project (RSEP) data file. Data were limited to crashes that occurred beginning in 1970 and with 1969 model year vehicles through 1975 model year-vehicles, including passenger cars, pickups, and vans. The relative proportions of different crash configurations were obtained from the National Crash Severity Study (NCSS) data base.

The calculations for the economic effect of vehicle weight change and of the cost of injuries and fatalities come from several studies and NHTSA.

REFERENCES

Carlson, W.L., Empirical crash injury modeling and vehicle-size mix, U.S. Department of Transportation, Report no. DOT HS-803 349, May 15, 1978.

Carlson, W.L., Crash injury prediction model, Accident Analysis and Prevention 11:137-153, 1979.

Carlson, W.L., Quantitative analysis of policy decisions, Accident Analysis and Prevention 12:41-53, 1980.

DISAGGREGATE AUTOMOBILE OWNERSHIP CHOICE

This disaggregate model of automobile ownership choice was first published in 1975 by General Motors Research Laboratory. The model has been used to estimate the relative sensitivities of urban automobile ownership levels to income, automobile costs, efficiency of automobile and public transit, and locations of residences and trip destinations.

AUTHOR

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KEYWORDS

Automobile demand, fleet size

OBJECTIVE OF MODEL

The objective of this model is to explain the demand for ownership by households based on individual household consumption, residential location, income, and transportation accessibility.

RELATIONSHIP TO OTHER MODELS

There is no relationship to other models.

HISTORICAL BACKGROUND

The model is based on a theory proposed in 1973. Sensitivity analysis of alternative definitions of transportation accessibility, each one using different proxies for attractiveness of destination, was performed in 1976. Elasticities of automobile ownership with respect to disposable income and transportation accessibility of destinations by automobile and public transit were published in 1977. Also, in one paper, households were divided into four sociodemographic segments.

ASSUMPTIONS

The theory underlying the model postulates that a household trades off reduced consumption of goods and services other than transportation for increased accessibility to opportunities when deciding whether to own one or more automobiles.

In calibrating the model, households were divided into segments based upon the maximum number of automobiles they were assumed to consider. This maximum number of automobiles was generally equal to the number of driver-aged household members, except in some low-income households, where a constraint on the maximum number of automobiles owned was made on the basis of disposable income available to meet auto costs.

VALIDATION

Chi-squared statistics were used to test the joint null hypothesis that the consumption and transportation coefficients are equal to zero. T-statistics support the significance of each individual coefficient, while the chi-squared statistics serve to reject the joint null hypothesis.

All computed results are within 2.5% of the actual, with the exception of the relatively rare case of households with a maximum choice of two autos that choose to own zero autos; these households were overpredicted by 37.5%.

STRUCTURE

The model contains two multinomial logit components, the consumption component and the transportation accessibility component. These components encompass the explanatory variables. The consumption component includes household disposable income, fixed costs of automobile ownership, automobile operating costs, and public transit fares. The accessibility component includes travel times by automobile from the household's location to all possible trip destinations, travel times by public transit to all possible destinations, and the attractiveness of the destination. Destination attractiveness is a function of the total employment and population at the destination, defined as a traffic analysis zone. The dependent variables are the probabilities that a given household will choose to own a particular number of automobiles. The results are shown in the first table below.

Elasticities of the expected number of households owning a given number of automobiles and elasticities of the aggregate stock of automobiles are presented in the second and third tables below.

MODEL CONSTRUCTION

Model calibrations were performed using random subsamples of households interviewed in the Detroit Transportation and Land Use Study (TALUS) of 1965. These subsamples are intended to be representative cross-sections of 1965 Detroit area households. Separate subsamples were used for model calibration and for calculation of goodness-of-fit. A maximum likelihood estimation technique was employed to estimate this econometric model.

CHOICE MODEL RESULTS
(t-statistics in parentheses)

MODEL PARAMETER	CHOICE CONSTRAINT SEGMENT		
	0,1 Autos	0,1,2 Autos	1,2,3+ Autos
Coefficient on transportation accessibility term	0.526 (13.6)	0.471 (22.6)	0.252 (16.9)
Coefficient on consumption term	2.13 (11.6)	6.96 (11.4)	8.02 (11.7)
Constant	0.598 (6.37)	1.43 (16.9)	0.816 (10.2)
Choice to which constant assigned	0 Autos	1 Auto	2 Autos
Chi-squared statistic for likelihood explained by model, 3 degrees of freedom	127	116	96.4

If the model were re-estimated for a different metropolitan area, data of the type typically collected in Urban Transportation Planning System (UTPS) studies would be required. The case study application presented used home interview, transportation network, and land use data from the 1965 TALUS home-interview survey.

REFERENCES

Burns, L.D.; Golob, T.F.; Nicolaidis, G.C., Theory of urban households' automobile ownership decisions, General Motors Corporation, Report no. GMR 1785, January 16, 1975.

Golob, T.F.; Burns, L.D., Effects of levels of transportation service on automobile ownership in a case study urban area, General Motors Research Laboratories, Report no. GMR-2506, November 1977.

Burns, L.D.; Golob, T.F., Role of accessibility in basic transportation choice behavior, Transportation, 5:175-198, 1976.

ELASTICITIES: TOTAL SAMPLE

VARIABLE	ELASTICITY OF EXPECTED NUMBER OF HOUSEHOLDS				Elasticity of Aggregate Stock of Automobiles Held by All Households
	Owning 0 Autos	Owning 1 Auto	Owning 2 Autos	Owning 3 Autos	
Consumption Term: Disposable Income (Negative of Fixed Costs of All Autos)	-0.94	-0.08	0.49	0.89	0.29
Transportation Accessibility Term:					
Travel by Auto to All Destinations	0.30	0.05	-0.21	-0.21	-0.10
Travel by Auto to Destinations in City of Detroit Only	0.11	0.02	-0.08	-0.08	-0.04
Travel by Public Transit to All Destinations	-0.17	-0.01	0.10	0.09	0.05
Travel by Public Transit to Destin- ations in City of Detroit Only	-0.10	-0.01	0.06	0.06	0.03

ELASTICITIES OF AGGREGATE STOCK BY SOCIODEMOGRAPHIC SEGMENT

SOCIODEMOGRAPHIC SEGMENTS	ELASTICITIES OF AGGREGATE STOCK OF AUTOMOBILES		
	Disposable Income	Area-Wide Auto Travel Time	Area-Wide Transit Travel Time
Total Sample	0.51	-0.14	0.07
Segment 1: Single-Person Households (16% of Sample)	0.68	-0.19	0.11
Segment 2: Younger Families (40% of Sample)	0.48	-0.12	0.06
Segment 3: Inner-City Residents (15% of Sample)	0.77	-0.20	0.13
Segment 4: Older Families (29% of Sample)	0.66	-0.16	0.07

NEW MOTOR TRUCK DEMAND IN THE UNITED STATES, 1935-1955

The demand for three size-classes of new motor trucks was estimated for a report to the Ford Division in 1956. Demand is described in terms of the increment in registrations over the previous year, so the results may be used to project short-term demand in subsequent years.

SPONSOR

Ford Motor Company
Ford Division

AUTHOR

Daniel B. Suits
University of Michigan
Department of Economics

KEYWORDS

Trucks

OBJECTIVE OF MODEL

The demand for three size-classes of trucks is modeled: light trucks with a gross vehicle weight of 10,000 pounds and under, medium trucks of 10,001 to 16,000 pounds, and heavy trucks over 16,000 pounds. The model is used to calculate the expected demand for each type of truck in 1956. This is a historical example of an industry-sponsored, publicly available research effort in econometric motor vehicle demand modeling.

RELATIONSHIP TO OTHER MODELS

There is no relationship to other models.

HISTORICAL BACKGROUND

The model author subsequently moved to Michigan State University. For other work by him, see: 58-033, S-62-104, and S-61-160.

ASSUMPTIONS

Twice as much significance was placed on the data from the post-war period, because the more recent data were of better quality and the model author wanted the model to be weighted in the direction of the then current trend.

VALIDATION

Predicted and actual values of new registrations for each class and of increases over the preceding year are plotted. The calculated values follow the actual ones almost exactly, particularly over the post-war period.

STRUCTURE

Demand for light trucks:

$$\Delta \log(L) = 3.287 [\Delta \log(G)] - 1.875 [\Delta \log(S_L)] - .934 [\Delta \log(P_L)] \\ - .021904 - .107333 (\Delta X)$$

where:

L = new registrations, light trucks

G = real gross national product, in 1947 dollars

S_L = stock of light trucks, January 1

P_L = real price of light trucks, average price paid by farmers for 1/2 ton pick-up divided by index of prices paid by farmers

ΔX = first differences of dummy variable representing abnormality of the light truck market, = 1 in 1947, 1948, and 1952, = 1/2 in 1951, = 0 in all other years

$\Delta \log$ = first difference in the logarithms of a variable

Demand for medium trucks:

$$\Delta \log(M) = .594 [\Delta \log(F)] + 2.515 [\Delta \log(D)] - 1.452 [\Delta \log(S_M)] \\ - .652 [\Delta \log(P_M)] - .017003 - .180167 (\Delta Z) + .045244 (\Delta X)$$

where:

M = new registrations, medium trucks

F = real net income of farm operators

D = composite real index of construction activity, wholesale trade, and retail trade

S_M = stock of medium trucks, January 1

P_M = real price of medium trucks

Z = dummy variable representing a shortage of medium trucks, = 1 in 1941 and 1946

X = dummy variable representing an effective shortage of light trucks, = 1 in 1946, 1947, and 1948

Demand for heavy trucks:

$$\Delta H = .1633 (\Delta G) + .0311 (\Delta T) - .3071 (\Delta S_H) - 1.368$$

where:

H = new registrations, heavy trucks, thousands

G = real gross national product, billions of 1947 dollars

T = index of freight carried by class I motor carriers of property, 1935 = 1000

S_H = stock of heavy trucks, January 1, thousands

Unlike the other two equations, the one for heavy trucks is in linear form. The years 1942-1946 were deleted as irrelevant. For medium and light trucks the estimated coefficients are also interpreted as demand elasticities. For heavy trucks, a one percent increase in real gross national product tends to change the demand by 0.4 percent, the index of highway freight tonnage by 2.1 percent, and the stock of heavy trucks by -2.3 percent.

MODEL CONSTRUCTION

Least squares regression was used to estimate the equations. First differences, the increase or decrease in a variable value over the preceding year, are used to center the analysis on changes in demand rather than on absolute levels. This focuses concern on short-run analysis, permits the use of data that were constructed by reference to year-to-year movements rather than absolute magnitudes, and minimizes the impact of the jump in values between the pre-war and post-war periods. The period analyzed was 1935-1955, because of data availability. The years 1942-1945 were considered irrelevant and were not used. Dummy variables were applied to abnormal years, when the truck markets were distorted by production allotments.

The compilation of the data used in the estimation, the sources of the data, and their values are explicitly described in the report.

REFERENCE

Suits, D.B., Demand for new motor trucks in the United States 1935-1955, Ford Motor Company, October 1956.

PARTIAL ADJUSTMENT MODEL OF GASOLINE DEMAND

The Partial Adjustment Model of Gasoline Demand was developed at the United States Federal Reserve System and published in 1980. It is used to examine the structural stability of gasoline demand since the 1973-74 oil embargo and to compute the welfare effects of increased gasoline taxation.

AUTHOR

Myron L. Kwast
Federal Reserve System
Board of Governors

KEYWORDS

Fuel consumption

OBJECTIVE OF MODEL

An aggregate demand equation of gasoline demand was estimated over the years 1963-1977 and for the sub-periods 1963-1972 and 1975-1977, the first period being before the 1973-4 oil embargo and the second period being after the oil embargo.

RELATIONSHIP TO OTHER MODELS

There is no relationship to other models.

ASSUMPTIONS

According to the author, "... ignoring the supply side," as was done in this model, "is reasonable if the supply function may be assumed to be more variable than the demand equation. This allows the regression procedure to 'identify' the demand equation." The model allows this assumption.

VALIDATION

A variety of statistical tests were performed on the stability of the regression coefficients, and particularly the price elasticity across the pre- and post-embargo years. These tests favor the conclusion that no change in the coefficients in the post-embargo period have resulted from the oil embargo. Statistical t-tests indicated that the South Central and West terms are not significantly different and that the North Central and Northeast terms are equal, indicating that, ceteris paribus, gasoline demand is higher in the Sunbelt and West than in the Midwest and Northeast.

LIMITATIONS AND BENEFITS

The long-run price elasticity of gasoline demand was computed to be -1.59. Since most previous estimates of this elasticity have been around -.7 or less, the author views the model's elasticity as implausibly large. A possible explanation offered is that the dynamic structure of the partial adjustment model is oversimplified. The low price elasticity of demand suggests that the welfare cost of gasoline tax is, compared to that of income taxes, relatively small.

STRUCTURE

Aggregate gasoline demand in this model is dependent on real gasoline price, real income, population, previous period consumption of gasoline, and dummy variables for the United States region and for 1973-4, the oil embargo years. The one-equation econometric model is presented below.

$$\begin{aligned} \ln(G_t) = & \rho B_0 + \rho B_1 [\ln(P)] + \rho B_2 [\ln(Y)] + \rho B_3 [\ln(\text{POP})] \\ & + \rho B_4 [\ln(\text{DOE})] + \rho B_5 (\text{NE}) + \rho B_6 (\text{NC}) + \rho B_7 (\text{W}) \\ & + \rho B_8 (\text{SC}) + (1 - \rho) [\ln(G_{t-1})] + U_t \end{aligned}$$

where:

G_t = aggregate demand for gasoline in year t

G_{t-1} = aggregate demand for gasoline in the previous years

ρ = coefficient of autocovariance ($0 < \rho < 1$)

ρB_0 = constant measuring the effect of the Southeast regions on the level of aggregate gasoline demand

P = real price of gasoline

Y = real income

POP = population

DOE = dummy variable for the 1973-74 oil embargo

NE, NC, W, SC = dummy variables for the Northeast, North Central, West, and South Central regions of the United States, respectively

U_t = disturbance term

80-531

MODEL CONSTRUCTION

The data used to estimate this log-linear partial adjustment econometric model are annual observations on each of the 48 contiguous states and the District of Columbia for the years 1963-1977.

REFERENCE

Kwast, M.L., Note on the structural stability of gasoline demand and the welfare economics of gasoline taxation, Southern Economic Journal 46(4):1212-1220, April 1980.

FOREST SERVICE VEHICLE OPERATING COST MODEL

This model for estimating the operating costs of vehicles on National Forest logging roads was developed by the University of California Institute of Transportation Studies in 1975. It was prepared for the U.S. Forest Service.

SPONSOR

U.S. Forest Service
Transportation Analysis Group

AUTHOR

Jean M. Follette, R.J. Tangeman, and Leonard Della-Moretta
University of California
Institute of Transportation Studies
Berkeley, California

KEYWORDS

Vehicle user costs/vehicle operating cost, fuel consumption

OBJECTIVE OF MODEL

The model estimates running costs for logging trucks. It is to be used for timber appraisal and to serve planning and design needs related to low-standard roads in National Forests. It provides a more accurate analysis of roading alternatives on logging roads than previously used methods. Careful attention is paid to vehicle acceleration and deceleration behavior, instantaneous energy balances, and fuel consumption. A tire wear estimation methodology based on slip at the tire-road interface is used. Although of restricted utility, the model is an example of a transportation cost-estimating methodology in use by a federal agency.

RELATIONSHIP TO OTHER MODELS

There is no relationship to other models.

HISTORICAL BACKGROUND

The original research that produced many of the functional relationships in the model, the cost data development, and the tire wear theory development was done by the U.S. Forest Service and Hodges Transportation, Inc.

ASSUMPTIONS

It is assumed that the average truck operator drives at a maximum speed within the limits of comfort and safety, on tangent and curved road sections. Logging truck drivers do not take sight distance into consideration when determining their speed. Vertical curve sight distances are also not considered.

Fixed costs are based on 180 working days per year at 12 hours per day; they include amortization and insurance. Dependent costs are incurred when a truck is in operation regardless of whether it is moving; these include wages, fringe benefits, industrial insurance, administrative costs, lubrication, repair, and maintenance costs.

Fuel use by logging trucks is related to power consumption by a constant multiplier of .04 gallons of diesel fuel per brake-horsepower-hour. Tire costs can result in up to 15% of total costs.

Other assumptions are made for the non-logging-truck vehicle types.

STRUCTURE

Two sizes of logging trucks may be represented, loaded or unloaded, and three other vehicles: a two-ton car, a two-and-a-half-ton pickup, and a six-ton truck. Other vehicle types may be described by the model user. Three road surface types are taken into consideration: earth, gravel, and asphalt. The model takes into account road gradient, curvature, surface, width, and air resistance, and vehicle weight and horsepower in determining the speeds possible on each section of road.

The explicit consideration of vehicle acceleration and deceleration makes it possible to determine the instantaneous power consumption associated with any mode of vehicle operation. Tire wear is a function of slip at the tire/road interface, and depends on surface type, vehicle type, and speed. When a section of road is configured such that large pieces of tire will be torn off, the model indicates that the section should be redesigned. Tire replacement and costs are calculated. Costs are built into the model operation but may be altered by the user. An inflation index, new surface type, new vehicle type, delay time, and new cost categories may be specified.

The model outputs speed and cost profiles for one or both directions on a road. Distance may be plotted against grade, radius, elevation, speed, total cost per mile, fuel use per mile, and energy used at the tire/road interface. Limiting and maximum speeds, entering and exiting speed, length, and travel time for each section of road are printed, as are fuel cost and consumption, tire cost, amortization insurance, wages, overhead, lubrication, repair, maintenance, and total section costs for each vehicle type.

DATA USED IN RUNNING MODEL

Input data required include: type of vehicles, speeds, and fuel costs. Optional inputs are cost coefficients, inflation index, rolling resistance, limiting gradient speeds, relative slip curve values, and vehicle description. For each section of road these are required: roadway gradient, radius of curvature, surface type, maximum permissible speed, maximum curve speed, side slope on curve, distance from center lane to base of side slope, superelevation, and width of road.

REFERENCE

Follette, J.M., Vehicle operating cost model user's guide, University of California, Institute of Transportation Studies special report, December 1975.

COMPUTER REQUIREMENTS

The program for the model may be run in either conversational or batch mode. It is operational on the computer system of Computer Sciences Corporation.

MOTOR-CAR PRICING AND DEMAND

This model of automobile pricing and demand was developed at the Cambridge University Department of Applied Economics and in the United States with support from a Commonwealth Fund Fellowship. It was published in 1954. The model is used for ex-post forecasting of car prices for the years 1947-52. This forecast is compared to actual values.

AUTHOR

M.J. Farrell
Cambridge University
Department of Applied Economics
Cambridge, England

KEYWORDS

Automobile demand, pricing, fleet size

OBJECTIVE OF MODEL

The objectives of this model are to estimate automobile demand as a function of income, car prices, and various utility measures, or to measure car prices as a function of automobile demand, income, and utility measures. This model is historically significant in the development of automobile demand modeling, in that it considered used cars and treated the market for cars as a set of interrelated markets for a series of close substitutes instead of as a single market for a homogenous commodity.

RELATIONSHIP TO OTHER MODELS

There is no relationship to other models.

ASSUMPTIONS

Every household is assumed to own a new car if its income is above a certain distinct level, depending on the utility measures of the household. It will own a used car if the household income is below this level. The aggregate demand is built up by adding together all of the individual demands based on household income and utility. In order to aggregate, two assumptions are made: (1) the distribution of individual incomes is fixed through time, and (2) utility is a random variable, distributed normally, and is independent of income. Households are assumed to own only one car. The model assumes two things about the purchase price of a car. First, it assumes that dealers take no profit from sales, and second, that the price relevant to the demand equations

is simply the purchase price of the car, and not the maintenance and running costs.

VALIDATION

In comparing predicted prices to actual prices, the author reached the following conclusions. In 1947 and 1948 actual new-car prices were much lower than predicted and other prices were much higher. In 1949 there was a remarkably close agreement between actual and predicted prices, except for six-year-old cars. In 1950 and 1951 predicted prices were systematically lower than the actual prices. In 1952 new car prices were overestimated, but all other prices were underestimated.

LIMITATIONS AND BENEFITS

The model author stated that adequate data were not available for an analysis that distinguished among makes of cars. Fluctuations in new car prices due to quality changes were not entirely eliminated. Where the fluctuations were reduced, the methods used involved a great many arbitrary and ad hoc adjustments.

STRUCTURE

The model is a sum of six equations, each estimating separately the demand or price for each vintage year, up to six years old. Cars older than six years are grouped with six-year-old cars.

Each equation is a double integration. The first or inside integral is a logarithmic function of the utility measures with the upper and lower limits set by logarithmic functions of car price and income. The second or outside integral contains the income distribution measure. The dependent variable of these equations is the number of cars in use of a given age, but an exogenous prediction of automobiles in use could also be made, and the dependent variable would then be car price.

MODEL CONSTRUCTION

This econometric model was constructed with 1922 to 1941 annual data. Through 1933, automobile fleet size data are from a paper by C.F. Roos (38-688). Thereafter, the data used were obtained by interpolating the figures of R.L. Polk and Co. for July 1, as given in Automobile Facts and Figures. The cost of living index is taken from Dewhurst, et al., America's Needs and Resources, 1947. The disposable income index is calculated with data from Dewhurst et al. and from the 1941 Survey of Spending and Saving in Wartime. This 1941 survey of 1300 urban families is used for the other income and utility measures. Price data were from the National Used Car Market Report Red Books.

54-542

REFERENCE

Farrell, M.J., Demand for motor-cars in the United States, Journal of the Royal Statistical Society 117(2):171-201, 1954.

BRAND DEMAND MODEL FOR FARM TRACTORS IN THE UNITED KINGDOM

The Brand Demand Model for Farm Tractors in the United Kingdom was developed in 1970 while the authors were at the University of Warwick and the University of Manchester. The objective of the model is to relate the demand for a particular brand or model tractor to its characteristics. The authors employ a two-equation model to accomplish this objective. Estimates of the market share elasticities by manufacturer are presented.

AUTHOR

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University of Warwick
Coventry, England

A.J. Rayner
University of Manchester
England

KEYWORDS

Pricing, market share

OBJECTIVE OF MODEL

The objective of the models is to explain the demand for farm tractors by brand based on the characteristics associated with the different brands. Several two-equation models are developed and estimated. Within each model, one equation relates the price of a model tractor to its characteristics. The other equation estimates market share (by model or manufacturer) as a function of price differences unexplained by quality differences and other non-price variables, e.g., advertising.

RELATIONSHIP TO OTHER MODELS

This model has no known relationship to any other model.

HISTORICAL BACKGROUND

The authors attributed the approach to a suggestion made by Griliches (see 61-682). The authors previously wrote articles using this approach on the U.K. tractor market. Other models by Cowling are described under 72-700 and 71-702. The methodology of this model has potential application to models of the U.S. automobile market and manufacturer market share.

ASSUMPTIONS

In contrast to other hedonic price studies, the authors "accept that a commodity market can be realistically characterized as one where differences in price between brands cannot be fully explained by quality differences." The authors used the unexplained price differences to explain the demand for various brands.

VALIDATION

The authors compared their estimated market share elasticities to those estimated by other researchers.

LIMITATIONS AND BENEFITS

This study and the resulting models were exploratory in their development of demand functions for various tractor models and manufacturers. Previous empirical studies of the demand for branded goods in the economic literature had not considered the quality variation among brands.

STRUCTURE

The structure of each model consists of two estimated equations. One equation expresses brand price as a function of the brand's qualitative characteristics. The other equation expresses the quantity demanded of a particular brand as a function of the quality-adjusted price of that brand relative to the average quality-adjusted price for the commodity in that time period, and to other variables. A third equation, an identity, can be added to derive commodity demand by summing the quantities demanded for each brand.

Equation one in its general mathematical form is:

$$P_{it} = f(V_{it}, U_{it})$$

where:

P_{it} = price of brand i at time t

V_{it} = vector of characteristics associated with brand i at time t

U_{it} = disturbance term for brand i at time t

The second equation in its general form is as follows:

$$Q_{it} = g(U_{it}, X_t, Z_{it}, e_{it})$$

where:

Q_{it} = quantity demanded of brand i at time t

U_{it} = disturbance term from equation one; it represents that part of brand price unexplained by its qualitative characteristics

X_t = vector of variables explaining the total market for all brands of the commodity

Z_{it} = a vector of non-price variables specific to the sales of brand i

e_{it} = disturbance term

Under certain assumptions, this equation can be converted into a market-share equation, and the X_t vector can be eliminated from the equation.

The empirical application of the model was the tractor market in the United Kingdom. The price-quality relationships related the adjusted price of a tractor to its belt-horsepower and whether it had a dummy variable. The relationship was estimated for each year from 1948 through 1965. Only a single equation is presented in this article. Detailed results are presented in another paper by Rayner (Price-Quality Relationships in a Durable Asset: Estimation of a Constant Quality Price Index for New Farm Tractors, 1948-65. Journal of Agricultural Economics, pp. 231-50, May 1968.). The estimated equation for the market shares of the various tractor models has the following general form:

$$S_{it} = B_0 + B_1 (U'_{it}) + B_2 (N_{it}) + B_3 (t_i) + B_4 (TL) + B_5 (S_{it-1}) + e_{it}$$

where:

S_{it} = market share of the model i at time t

U'_{it} = (deflated or undeflated) represents the quality-adjusted price ratio (or difference) of model i to all models available at time t

N_{it} = dummy variable, equal to one in the year of introduction of model i , otherwise zero

t_i = the number of years since model i was introduced

TL = an interaction variable between time and large tractors

e_{it} = disturbance term

B_i = coefficients to be estimated

The market share equation is estimated using linear and semilog mathematical forms. Alternative forms (deflated or undeflated) of the quality-adjusted price ratio were also incorporated into the equations to be estimated. The authors also estimated a model sales (as opposed to market share) equation.

Manufacturer's market share equations were estimated to explain the share performance of the five manufacturers that were considered (these equations are distinct from the model market-share equations). These equations were used to derive market-share elasticities for manufacturers, for both the short and long runs.

MODEL CONSTRUCTION

The major U.K. tractor manufacturers supplied the sales data used to estimate the model. While the price-quality relationships were estimated for each year over cross-section data, the model and manufacturer market share equations were estimated, in effect, by pooling 17 years (1948-65) of cross-sections of manufacturers.

REFERENCE

Cowling, K.; Rayner, A.J., Price, quality, and market share, Journal of Political Economy, 78:1292-1309, 1970.

LINEAR AND LOGIT AUTOMOBILE DEMAND MODELS USING SEEMINGLY-UNRELATED ESTIMATION

Models of automobile demand, using the seemingly unrelated estimation technique, were developed at the State University of New York at Buffalo as a Ph.D. thesis and published in 1979. The models are part of a study to assess the effects of a fuel efficiency incentive tax. The model parameters are used in an impact analysis to determine the effect of this tax on the resulting increasing automobile purchase price and on decreasing disposable income.

AUTHOR

Daniel M. Hamblin
State University of New York at Buffalo
Graduate School

KEYWORDS

Automobile demand, pricing, vehicle user costs/vehicle operating costs, model assessment, national economic impact

OBJECTIVE OF MODEL

The objective of these two models is to forecast household demand for the five size categories of automobiles as a function of old and new car prices, supernumerary income, and housing costs.

HISTORICAL BACKGROUND

There is no direct relationship to other models, though techniques used previously are employed in these models, including those of Chow (S-57-413), Carlson (78-312), and Farrell (54-542).

The model author discusses the strengths and weaknesses of these models, with Carlson's model being reviewed in greater depth. Several other models are discussed: Roos and Szeliski (38-688), de Wolff (36-683), Johnson (78-204), Hamburger (67-631), Hess (77-074), Suits (58-033), Westin (71-049), Wykoff (73-010 and 70-209), and Juster and Wachtel (72-205).

ASSUMPTIONS

The development of the two models is based on the assumption that a consumer possesses a utility function that he maximizes subject to a budget constraint. This function is assumed to be separable into the utility provided by the services of automobiles and housing, and the utility provided by other services. The logit model supposes that consumers choose a particular size-class of car based upon its

characteristics relative to those of other classes. In the model regressions, it is assumed that omitting certain multicollinearity-causing variables does not add systematic variation in the disturbances.

VALIDATION

For the ordinary least squares estimation of the linear model, the author states that, except for the intermediate class, the model has a respectable ability to explain variance and no evidence of serial correlation exists, though there are some wrong and unexpected signs on the coefficients. With the seemingly unrelated estimation, all price variables have correct signs, and 27 out of 37 coefficients are significant at the 10% level, as compared to the ordinary least squares method with 22 significant coefficients out of 37.

For the logit model, the weighted least squares and the seemingly unrelated regression estimates compare in significance at the 10% level with 22 and 26 coefficients, respectively, out of 29 total coefficients. In an attempt to reduce serial correlation, both models resulted in reduction of statistical efficiency.

LIMITATIONS AND BENEFITS

Because of a lack of data, intermediate cars were given the same user costs as standard cars. As a result, the price advantages of buying an intermediate-size car are understated, so that sales that were actually the result of lower user costs do not show up as such. This could partly account for the poor ordinary least squares estimation of the intermediate class in the linear model.

STRUCTURE

Two models were developed; one is a linear model and one is a logit model. Demand is simulated for each of five automobile size-classes for both models. The basic format of the linear and logit model equations are shown below. Some variables in the five submarket equations are omitted or altered in an effort to reconcile removing multicollinearity with theoretical justification of the structure.

Basic Linear Equation

$$S_i = B_0 + \sum_{i=1}^5 B_i (P_i^N) + \sum_{i=6}^{10} \sum_{j=1}^5 B_i (P_j^0) + B_{11} (H) + B_{12} (YSUP) \\ + B_{13} (X_{i,t-1}) + u$$

where:

S_i = sales of cars in class i in one year

B_i = regression coefficients

p_i^N = price of new car services of class i

p_j^O = price of old car services in new car equivalents of class i

i = 1, 2, 3, 4, or 5 = subcompacts, compacts, intermediates, standards, or luxury cars, respectively

H = price of housing services

YSUP = income less taxes and subsistence living costs

$X_{i,t-1}$ = stock of cars of class i in year t-1

u = disturbance term

Basic Logit Equation

$$\ln\left(\frac{S_i}{R_i}\right) = B_0 + B_1 \left[\ln\left(\frac{p_i^N}{p_r^N}\right)\right] + B_2 \left[\ln\left(\frac{p_j^N}{p_i^N}\right)\right] + B_3 [\ln(H)] + B_4 [\ln(YSUP)] \\ + B_5 \left[\ln\left(\frac{X_{i,t-1}}{R_{i,t-1}}\right)\right]$$

where:

R_i = sales of cars not in class i in a given year

p_r^N = new car price of cars not in class i

p_j^N = new car price of a class j automobile

$R_{i,t-1}$ = stock of cars not in class i in the previous year

Parameter estimates for the two equation forms, the five classes, and two estimations of each equation (132 parameters total) are presented in the paper.

MODEL CONSTRUCTION

Both the logit and linear econometric models are estimated with the seemingly unrelated regressions method. In addition, the linear model is estimated with ordinary least squares and the logit model is estimated with weighted least squares. The main data source for these models is Ward's Automotive Yearbook. Real average price of an auto size class was computed using retail price data in Ward's and in the Automotive News Almanac. Vehicle owning and operating cost data are from a paper published by the U.S. Department of Transportation entitled Cost of Owning and Operating an Automobile: 1976 (S-79-572). Size

class was determined by wheelbase with the exception of the luxury class, which was defined as all automobiles whose real purchase price exceeded 3,100 dollars in 1959 dollars.

REFERENCE

Hamblin, D.M., Automobile demand models for evaluating the impacts of fuel-efficiency energy policies, Ann Arbor, Michigan: University Microfilms International, 1978. Ph.D. dissertation submitted to the State University of New York at Buffalo.

HIGHWAY FUEL CONSUMPTION MODEL (HFCM): MEDIUM
AND HEAVY-DUTY TRUCK FUEL DEMAND MODULE

The Light Duty Vehicle Fleet Fuel Consumption Model (78-368) was expanded in 1980 by Energy and Environmental Analysis, Inc. for the Department of Energy. The Medium and Heavy-Duty Truck Fuel Demand Module of the resulting Highway Fuel Consumption Model estimates truck fuel consumption by using an accounting methodology.

SPONSOR

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KEYWORDS

Fuel consumption, vehicle miles traveled, fuel economy, market share

OBJECTIVE OF MODEL

The Highway Fuel Consumption Model generates fuel economy, registrations of vehicles, vehicle miles traveled (VMT), and fuel consumption by vehicle and engine type. The truck module does this for three size classes of trucks.

RELATIONSHIP TO OTHER MODELS

The truck module and the light-duty vehicle model (78-368) make up the Highway Fuel Consumption Model.

HISTORICAL BACKGROUND

In 1978 Energy and Environmental Analysis, Inc. developed the Light Duty Vehicle Fleet Fuel Consumption Model (LDVFFCM) (78-368) for the Department of Energy. It was designed to forecast passenger car and light truck fuel consumption through 1995. That model has been used to find trends in fuel consumption in light of fuel economy standards, to assess the relative importance of cars and light trucks in estimating total fuel consumption, and to analyze the impact of federal conservation policies. To model the trends in total highway fuel

consumption, the model structure was expanded in 1980 to include medium- and heavy-duty trucks.

VALIDATION

Comparisons were made between model predictions and actual experience for the 1975-1978 period for trucks. Actual data, however, contain a degree of uncertainty and are not entirely consistent with the scheme employed by the model. Data used as input may also be considered obsolete. Since there were no current accurate data available on diesels, it was difficult to calibrate the model to estimate fuel demand by fuel type. There are also no adequate historical data on truck fuel economy.

LIMITATIONS AND BENEFITS

The model is not able to account for improvements in the fuel economy of diesel trucks, except as they are reflected in data on truck fleet characteristics. Fixed survival curves and fixed annual VMT per truck vintage curves are used. These can not reflect changes in behavioral or economic parameters, however, which truck demand would be sensitive to. Trucks seem to have longer life expectancies in more recent years than the model accounts for. Thus, it is probably understating the trend in fleet average fuel economy and is thereby overstating fuel consumption.

STRUCTURE

The structure of the model is nearly identical to that of the LDVFFCM. An accounting methodology is used to derive fuel consumption without relying on behavioral equations; the model is deterministic.

The classes of trucks included are: medium duty (10,001-19,500 pound gross vehicle weight), light-heavy (19,501-26,000), and heavy-heavy duty (over 26,001 lbs.). Since some trucks operate for up to 30 years (as determined by the survival rate), data from 1946 to the present are required.

The model outputs: average new vehicle fuel economy, new vehicle registrations with spark ignition or diesel engines, average fleet fuel economy, fleet registrations by engine type, total vehicle miles traveled (VMT), and fuel consumption disaggregated by gasoline and diesel fuel. The calculation procedures are:

$$TVMT_j = \sum_t \sum_i \sum_k \sum_j RG_{ij} \times PCT_{ijt} \times SP_{kj} \times VMT_{kjt}$$

where:

$TVMT_j$ = total VMT for vehicle type j (one of the three categories of medium and heavy-duty trucks)

RG_{ij} = registrations of vehicles in year i of vehicle type j

PCT_{ijt} = percentage of vehicle type j registrations in year i of fuel type t

SP_{kj} = survival (percent of new vehicle registrations left on the road) of age k and vehicle type j

VMT_{kjt} = vehicle miles traveled of age k, vehicle type j, and fuel type t

$$TFC_t = \sum_t \sum_i \sum_k \sum_j RG_{ij} \times SP_{kj} \times VMT_{kjt} \times PCT_{ijt} / MPG_{ijt}$$

TFC_t = total fuel consumed of type t (gasoline, diesel)

MPG_{ijt} = fuel economy of registrations of vehicles in year i and vehicle type j and fuel type t

$$AMPG_j = TVMT_j / \sum_t \sum_i \sum_k \sum_j (RG_{ij} \times PCT_{ijt} \times SP_{kj} \times VMT_{kjt} / MPG_{ijt})$$

$AMPG_j$ = average fleet MPG for vehicle type j

DATA USED IN RUNNING MODEL

The model inputs historical data and future estimates of these variables: annual new vehicle registrations, survival of new vehicles reflecting their retirement over time, annual VMT per vintage vehicle year capturing the effect of decreasing VMT per vehicle with age, new vehicle average fuel economy, and annual diesel penetration of new vehicle registrations. The sources and values of all the input data for medium and heavy trucks are shown in the model report.

REFERENCE

Medium and heavy-duty truck fuel demand module, final report, Energy and Environmental Analysis, Inc., May 28, 1980.

COMPUTER REQUIREMENTS

The model is currently in operation on the U.S. Department of Energy computer system. A guide to the program operation is included in the report.

MACHINE-INTENSIVE APPROACH TO LAG
DETERMINATION FOR CONSUMER DEMAND ANALYSIS

This technique for estimating the distributed lags in a consumer demand analysis of short-run and long-run income and price elasticities was developed at the Bureau of Labor Statistics in 1969, for the Office of Naval Research.

SPONSOR

U.S. Department of Defense
Office of Naval Research

AUTHOR

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KEYWORDS

Fuel consumption, automobile demand

OBJECTIVE OF MODEL

A novel lag-determination procedure, called the machine-intensive approach, was used to determine the income and price elasticities for the demand of 23 categories of consumer goods. Some of the categories are: petrol and oil, new cars, tires, user-operated transportation services, local transportation, and inter-city transportation. The use of a computer made it possible to do the extensive calculations necessary to determine the implications of distributed lag theory.

RELATIONSHIP TO OTHER MODELS

There is no relationship to other models.

ASSUMPTIONS

The time trend used in the relations may be considered to represent changes in tastes, changes in the age composition of population, and any gradual (as opposed to cyclical) long-term change in the distribution of income. For new car demand, purchases lagged one year are specified. The price variable for cars is equal to the price deflator for cars multiplied by one plus twice the interest rate and divided by the price of other goods, in order to reflect the effect on monthly payments of an increase in the interest rate.

LIMITATIONS AND BENEFITS

Explicit consideration was given to the problem of structural change, or changes in the values of the parameters of the estimated relations. A method was employed to isolate periods in which there was no structural change. The statistical results offer substantial evidence, the model author said, that lags do play an important role in consumer demand analysis.

STRUCTURE

Demand relations are specified as:

$$q_t = a + c \sum_{i=1}^n w_i (X_{t-i-1}) + b \sum_{j=1}^m d_j (P_{t-j+1}) + f(t) + g(z)$$

where:

q_t = quantity demanded, personal consumption expenditures for the goods in question in year t in 1958 dollars divided by U.S. population

X_t = real income, total personal consumption expenditures in year t in 1958 dollars divided by U.S. population

P_t = price in year t of goods in question (1958 = 1.0) divided by the price of all goods

t = time trend

z = any other factor that may influence the demand for the goods in question. For user-operated transportation services, purchased local transportation, and purchased inter-city transportation minus airline transportation, this represents per capita car stocks.

w_i = weights for the distributed lag in income

d_j = weights for the distributed lag in price

Any two sets of w_i and d_j lag structures may be tested repeatedly until the best-fitting relation is found that has the minimum residual variance. For this study seven lag structures were employed, chosen from binomial probabilities, making a total of 49 regressions.

Twenty-three categories of goods and services were estimated. Some are presented in the table below. The paper presenting the model also lists the short-run and long-run estimated price and income elasticities.

ESTIMATES OF PRICE AND INCOME COEFFICIENTS AND
VARIOUS OTHER STATISTICS FOR GOODS AND SERVICES
(standard errors in parentheses)

Category	Constant	b	c	f	g	\bar{R}^2
Petrol and oil	32.09 (6.05)	-41.45 (7.69)	0.0999 (0.0057)	0.860 (0.167)		0.998
New cars and net purchases of used cars	241.86 (31.5)	-204.14 (24.60)	0.1581 (0.011)	0.5989 (0.115)	-26.44 (3.75)	0.995
Tires and tubes	188.04 (14.01)	-14.70 (8.85)	0.00117 (0.0068)			0.896
User-operated transportation services	-0.758 (0.4113)	-0.352 (0.183)			0.646 (0.062)	0.976
Purchased local transportation	31.4 (0.754)	-13.28 (2.15)	0.00697 (0.00104)		-0.022 (0.0021)	0.996
Purchased inter-city transportation minus airline transportation	15.17 (1.10)	-5.00 (0.83)	0.00131 (0.00079)		-0.00989 (0.0011)	0.984

For petrol and oil, c is the coefficient for car stocks per capita; income was not significant. For new cars and net purchases of used cars, f is the coefficient of q_{t-1} and g is the coefficient of average age of cars, to reflect institutional (and perhaps technological) attitudes towards the desired age at which a car should be traded in. For tires and tubes, f is the coefficient for car stocks per capita.

MODEL CONSTRUCTION

Distributed lags were estimated with a new lag-intensive approach. It overcomes the problem of a lagged dependent variable and is capable of determining a different lag profile for each variable. The relations were estimated using least squares in log-linear and linear form, and with and without a time trend. Annual data covering the 1946-1965 period were used. The source of the consumer expenditure data was the U.S. Department of Commerce, Office of Business Economics, National Income Division.

REFERENCE

Heien, D.M., Income and price lags in consumer-demand analysis, Journal of the Royal Statistical Society 132(2):265-271, 1969.

URBAN SIZE AND STRUCTURE AND PRIVATE EXPENDITURES FOR GASOLINE

Researchers in the Washington, D.C. area published a paper in 1975 describing their exploration of the correlation between expenditures on gasoline and a large variety of measures of the size and character of urban areas.

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KEYWORDS

Fuel consumption

OBJECTIVE OF MODEL

Retail gasoline sales are related to the size, growth rate, region, racial makeup, transit use, and industries of urban areas. The objective of the model is to investigate the economies or diseconomies of urban size on per capita private expenditures for fuel.

RELATIONSHIP TO OTHER MODELS

There is no relationship to other models.

ASSUMPTIONS

Generally, the greater the population of a metropolitan or urban area, (1) the larger will be its surface area; (2) the greater will be the utilization of public and mass transit, which presumably reduces dependence on autos; (3) there will be a multiplication of centers of diverse activities, especially of employment and shopping, which can shorten commuting and shopping trips; and (4) density will be increased, which favors mass transit, aggravates auto congestion, and tends to reduce the average length of trips. Variables describing population density and size were used to measure the strength of these forces.

Region was introduced as an explanatory variable because older Eastern cities are more compact. Rate of growth is intended to show how development of public transit lags behind population growth. Price of

gasoline and income were also expected to have some effect on fuel consumption.

To further improve the predictive power of the model, indicators of the metropolitan areas' classifications as manufacturing and diversified industry centers were added. Port cities were found to be significant, probably because of concentration of manufacturing activities and because the telescoping of the periphery from 360 to 180 degrees may economize on circumferential transportation. Cities that tend to sell a lot of gasoline to non-residents, such as tourists, required the use of a hotel variable.

Most of the density variables tested, income, and price of gasoline were found to not be significant. The results suggest that further examination of density variations at the subcounty level of detail would be fruitful.

STRUCTURE

The following equation was estimated:

$$\begin{aligned}
 \text{GAS / POP} = & 51.5450 - 0.2036 (\Delta P\%) - 0.0117 (\% \text{CENCY}) \\
 & (43.9841) \quad (0.0896^{**}) \quad (0.0746) \\
 & + 0.2278 (\% \text{NW}) + 0.0033 (\text{MEDY}) + 0.1230 (\% \text{POV}) \\
 & (0.1165^*) \quad (0.0020) \quad (0.7108) \\
 & + 16.0508 (\text{W}) - 10.8490 (\text{NE}) + 9.7149 (\text{NC}) \\
 & (3.8910^{**}) \quad (5.4032^*) \quad (4.5612^*) \\
 & + 0.0065 (\text{MANF}) + 5.3273 (\text{DIV}) - .0027 (\text{P}) \\
 & (3.1316) \quad (2.6693^*) \quad (.0010^{**}) \\
 & - 15.7417 (\% \text{P16}) + 0.0002 (\text{CENDEN}) - 0.0008 (\text{DENOUT}) \\
 & (16.5400) \quad (0.0004) \quad (0.0011) \\
 & - 9.3278 (\text{PORT}) + 0.0691 (\text{HOTEL}) + 0.0063 (\%65) \\
 & (2.6279^{**}) \quad (0.0131^{**}) \quad (0.0047) \\
 & + 0.2391 (\text{PRICE}) - 0.1196 (\text{PTRAN}) \\
 & (0.8942) \quad (0.0363^{**})
 \end{aligned}$$

$$R^2 = 0.5962 \quad N = 134 \quad F_{19,114} = 8.053^{**}$$

where standard errors are in parentheses, *(**) denotes that the coefficient is significantly different from zero at the 0.05 (0.01) level of confidence according to the t-statistic with 115 degrees of freedom, and

GAS/POP = per capita sales of gasoline

$\Delta P\%$ = percentage change in population 1960-70

%CENCY = percent of SMSA population in the central city

%NW = percent of SMSA population non-white

MEDY = median family income

%POV = percent of SMSA families below the poverty line

W = 1 if census region West, = 0 otherwise

NE = 1 if census region Northwest, = 0 otherwise

NC = 1 if census region North Central, = 0 otherwise

MANF = 1 if manufacturing SMSA according to Rand-McNally city code, =
0 otherwise

DIV = 1 if diversified manufacturing SMSA according to Rand-McNally
city code, = 0 otherwise

P = 1970 population

%P16 = percent of the population 16 and older

CENDEN = population per square mile of the central city

DENOUT = population per square mile outside the central city

PORT = 1 if sea or lake port, = 0 otherwise

HOTEL = per capita receipts in 1967 for hotels, motels and tourist
courts

%65 = percent of population 65 and older

PRICE = average price per gallon of gasoline

PTRAN = percent of workers using public transit for work trips

MODEL CONSTRUCTION

The sample was made up of 134 standard metropolitan statistical areas (SMSA) with 1970 populations of 200,000 or greater. Retail sales of gasoline and lubricants, excluding sales to bus companies, were obtained from the 1967 Census of Business.

REFERENCE

Stewart, C.T., Jr.; Bennett, J.T., Urban size and structure and private expenditures for gasoline in large cities, Land Economics LI(4):365-373, November 1975.

ECONOMETRIC APPROACH TO FORECASTING THE MARKET POTENTIAL OF ELECTRIC AUTOMOBILES

An econometric model that uses descriptions of physical attributes, prices, and manufacturers of automobiles to determine their market share was developed at the Electric Power Research Institute and the State University of New York at Buffalo and published in 1977.

SPONSOR

Electric Power Research Institute

AUTHOR

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KEYWORDS

Market share

OBJECTIVE OF MODEL

This hedonic econometric model is designed to predict the potential shares of the total automobile market of different makes or models of cars. It is used to simulate the market potential for electric automobiles, given their price, performance and comfort attributes, and manufacturer.

RELATIONSHIP TO OTHER MODELS

This model uses some of the same data series as a pricing and demand model by Ratchford, described under 79-701.

ASSUMPTIONS

It is assumed that consumers react to goods as bundles of characteristics, that there is an objective "consumption technology." A quantity of a good, such as electric autos, could be defined as a number of repetitions of a particular bundle of characteristics. If the expenditures for a group of goods are known, a "relative shares" system of demand equations for differentiated goods within the group may be defined. Continuity is taken as a reasonable approximation to the demand for various differentiated autos, in as much as the data are aggregates rather than observations on individual households that

purchase autos as discrete bundles. Consumers are viewed as basing the choice between alternative autos on the relative attractiveness of the autos' attributes. Weight is inappropriate as an attribute since it is neither desirable nor undesirable in itself. Since there is no way of estimating the effect on demand of the limited range or cruising speed of electric autos, it is assumed that technology improves to the point where electric cars are at least as good as the worst of gasoline autos.

LIMITATIONS AND BENEFITS

The results show that the model captures only about 50% of the variation in the relative shares. Price, performance, and manufacturer's identity were found to be important determinants of the relative shares of new cars. The analysis could have been improved, the authors felt, by testing for changes in the demand functions over time, by considering dynamic behavior in the determination of model shares, and by including variables that were omitted such as overall body length and width. There is also a data development problem with differences within car models.

STRUCTURE

The quantity of a car relative to that of an arbitrarily chosen base car depends on characteristics and prices that vary across models and those characteristics that vary across manufacturers (dealer service quality, styling, reputation), as shown in the following equation.

$$\log\left(\frac{n_{jt}}{n_{bt}}\right) = a + d_0 [\log(P_{jt}/P_{bt})] + d_1 [\log(Z_{j1t}/Z_{b1t})] + \dots \\ + d_r [\log(Z_{jrt}/Z_{brt})] + c_1 (M_1) + \dots + c_k (M_k)$$

where:

n_{jt} = quantities of automobiles sold of model j in year t

n_{bt} = quantity of automobiles sold of the base model b in year t

P_{jt}, P_{bt} = prices in year t of models j and b, respectively

$Z_{j1t} \dots Z_{jrt}$ = quantities of attributes 1...r in year t for model j

$Z_{b1t} \dots Z_{brt}$ = quantities of attributes 1...r in year t for base model b

$M_1 \dots M_k$ = dummy variables representing manufacturers 1...k

The intercept, a, estimates the magnitude of preferences for all manufacturers k (\neq b) relative to the preferences for the base automobile b.

The attributes employed as independent variables were: list price of middle-of-the-line four door sedan version of each model; front leg room, a proxy for front seat comfort; rear leg room, a proxy for rear seat comfort; acceleration, number of seconds to go from 0 to 60 miles per hour; passing speed, number of seconds to go from 45 to 65 miles per hour; average fuel consumption, in miles per gallon for normal driving, translated to energy costs in solutions to permit a direct comparison with electric automobiles; and dummy variables to indicate automatic transmissions, ride quality, handling quality, and frequency of repair. Other dummy variables indicate the brand name of the car: Ford, Chrysler, A.M.C., G.M., Volkswagen, other import.

The base model used was the full-size Chevrolet. Several different estimations were attempted, with variations in the variables included, and with and without the dummies indicating brand name. The results indicate that autonomous preferences for manufacturers explain considerably more of the variation in relative shares than the performance attributes, and imply that an electric car would have a much greater chance of succeeding on the market if it were made by Ford, Chevrolet, or Volkswagen than if it were made by Chrysler, A.M.C., or some non-Volkswagen import or some relatively unknown manufacturer. Passing speed was also found to be significant.

The sample of car models was broken up into subsamples of subcompacts and other. Electric cars currently under development are relatively small vehicles designed mainly for commuting and intracity use and will most likely resemble and compete with subcompacts. The equation was reestimated with the subcompact sample, with Volkswagen being the base car. This showed Volkswagen to be the most preferred brand, price to have more impact, and characteristics such as leg room and acceleration to be less important.

The ratio of a particular vehicle to the base vehicle, found from the equation above, is converted into a share of the total market, all of the shares summing to equal one. Hypothetical electric cars are then described with assumptions concerning each of physical attributes and the identity of the manufacturer. A near-term car, that could be brought onto the market in the next several years, and a mid-term car, that is more advanced and would perhaps appear in 1991-2000, are described. The predicted market shares of these cars in the 1973 market is found with the best of the estimated equations, using both the total market and subcompact car samples. One of several results is that the near-term electric auto would capture 1% of the subcompact market if it were made by a new manufacturer or 0.2% of the total market, using the subcompact sample estimation. Using the total market sample estimation, this car would capture 0.03% of the total market. If the car were made by Chevrolet, it would have a significantly larger share.

MODEL CONSTRUCTION

Data used to estimate the parameters were obtained for a total of 420 observations, 352 U.S. domestic cars and 68 foreign, over the period 1960-73 with approximately 30 models in any given year. The domestic

registrations for a year were obtained from Automotive News Almanac. The objective characteristics of each model of car were obtained from Consumer Reports. Ordinary least squares was used to estimate the equation.

REFERENCE

Crow, R.T.; Ratchford, B.T., Econometric approach to forecasting the market potential of electric automobiles, in International Studies of the Demand for Energy, ed. W.D. Nordhaus, pp. 45-64, New York: North Holland, 1977.

HOUSEHOLD AUTOMOBILE EXPENDITURE

A model of household automobile expenditure was developed at the University of Connecticut and was published in 1980. The model is part of research to determine the effects of permanent and transitory income on automobile purchases.

AUTHOR

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KEYWORDS

Automobile demand

OBJECTIVE OF MODEL

The objective of the model is to estimate household automobile expenditure as a function of permanent and transitory income, present ownership of cars and other durable goods, household debt, family composition, and the change in the wife's participation in the labor market.

HISTORICAL BACKGROUND

This model is based on an earlier model by Levedahl on durable goods expenditure that was first published in 1976. The present model specifically estimates the durable goods expenditure of automobiles. Additionally, the model assumes a particular shopping strategy employed by households.

ASSUMPTIONS

The model specifies the household's decision to purchase or sell as based on the unit value of the automotive stock price. The household is assumed to make a purchase if this price is less than a defined level and it divests if it exceeds that level. The household is assumed to most likely know what type of automobile it will purchase before entering the marketplace, but it does not rule out an impulse purchase, since the model is based on the probability of a purchase. Permanent and transitory income is used in place of the usual income measure of yearly salary. The amount the household will spend on a car is said by the author to depend on its expectation of its long-term future income, i.e., permanent income, and not on its actual income that may vary from year to year.

VALIDATION

According to the model author, t-tests supported the hypothesis that, relative to its level, the pattern of income receipts (measured by transitory income) determines the timing of automobile purchases, but not the level of expenditure once a purchase is made.

No measure of permanent income works significantly better than the rest for determining probability of purchase, but evidence points to expected income as the best predictor of automobile expenditure for high school graduates.

STRUCTURE

The probabilities of purchase and purchase expenditure are modeled as the dependent variables for two separate groups of households, those with heads that are high school graduates, and those with household heads that are college graduates. Five measures of permanent income are used for the two dependent variables and the two classes of households, yielding 20 distinct equations. These permanent income measures are (1) expected income reported by households for the following year, (2) two-year average income with declining weights, $2/3$ times the current year plus $1/3$ times the previous year, (3) estimated income defined for each household as average income per household for its age-education class, (4) three-year average income centered on the current year and incorporating the previous-year income and the expected income of the following year, and (5) current income, introduced as an alternative to separating income into its permanent and transitory components.

The econometric expenditure equation having the best performance is shown here.

$$\begin{aligned} \text{EXPEND} = & -1473.82 - 607.24 (\text{STOCK}) - 772.94 (\text{NPAY}) + 502.67 (\text{IPAY}) \\ & - 732.12 (\text{WNWOR}) - 395.64 (\text{PY}) - 9.45 (\text{SQPY}) + 129.19 (\text{TYOLD}) \end{aligned}$$

$$R^2 = .25$$

where:

EXPEND = automobile expenditure by households headed by a person graduated from high school but not from college

STOCK = total automobile stock (in physical units) owned by the household, calculated assuming a depreciation rate of 25 percent per year

NPAY = number of automobiles owned that are currently being financed with installment payments

IPAY = number of automobiles currently owned that were purchased using installment payments (either presently being paid or totally paid up)

WNWOR = change in the wife's labor force participation, = 1 if wife worked in the current year but not in the previous year, = 0 if there is no change

PY = permanent income (expected income for the following year)

SQPY = squared permanent income

TYOLD = transitory income of older households

The variables in the 10 econometric probability of purchase equations for high school graduates are: NAUTOS, DURABLES, NC016, WNWOR, NPAY, PY, TYOLD, and TYOUNG. (TYOLD and TYOUNG are not included in the equation using the current income measure for permanent income.) The variables in the equation for college graduates are: NAUTOS, NC016, IPAY, MPAY, NCHILD, ISDEBT, PY, TYOLD, and TYOUNG. Variable definitions are as above or as follows:

NAUTOS = number of automobiles owned

DURABLES = number of durable goods owned by the household other than automobiles

NC016 = number of children 16 years or older

NCHILD = number of children in the family

MPAY = method used to purchase the household's primary automobile, = 1 if installment payments were used, = 0 if not

ISDEBT = outstanding installment debt, other than automobile debt, owned by the household, in thousands of dollars

TYOUNG = transitory income of younger households

MODEL CONSTRUCTION

The data used in constructing this model consists of a sample of husband and wife households chosen from the Consumer Anticipation Survey (CAS), a joint National Bureau of Economic Research/Bureau of the Census project performed from 1968 to 1970. The format consisted of asking a household what value it expected a particular variable to take and then recording the realized value at a later visit. A 708 household sample was taken from the survey of 3364 households.

REFERENCE

Levedahl, J.W., Impact of permanent and transitory income on household automobile expenditure, Journal of Consumer Research 7(1):55-65, June 1980.

DOE ALTERNATIVE LIGHT-DUTY TRUCK FUEL ECONOMY MODEL

The U.S. Department of Energy and Energy and Environmental Analysis, Inc. developed in 1980 a light-duty truck fuel economy model as a part of its review of the U.S. Department of Transportation's proposed fuel economy standards for light-duty trucks. The model is used to predict the baseline fuel economies of the vehicles expected to be available in 1985. The effect of technology improvements may be added to the baseline values.

SPONSOR

U.S. Department of Energy
Office of Policy and Evaluation
Washington, D.C.

AUTHOR

Energy and Environmental Analysis, Inc.
1111 North 19th Street
Arlington, Va. 22209

KEYWORDS

Fuel economy, trucks

OBJECTIVE OF MODEL

This three-variable engineering model predicts the fuel consumption per vehicle mile, and therefore the fuel economy, of models of light-duty trucks that have a base manual 3- or 4-speed transmission and conventional oxidation catalyst emission control technology without engine electronics. The model is based on model year 1980 data and was originally used in an analysis of the model year 1981 fuel economy standards.

HISTORICAL BACKGROUND

The Department of Transportation promulgated corporate average fuel economy standards for light trucks for 1980 and 1981 and proposed standards for 1982 model year trucks and ranges of possible standards for 1983-85. Comments were invited from the Department of Energy on the Notice of Proposed Rulemaking. Energy and Environmental Analysis, Inc. supported the preparation of DOE comments on the analysis of the Rulemaking Support Paper. In this study the subjects covered were an analysis of the baseline market and technology, review of available technology improvements, the introduction of new models of light trucks, the derivation of the standards as they relate to the U.S. manufacturers, and the impacts on fuel consumption. A critique is

made of the DOT model to predict the fuel economy of light trucks, and this DOE model is evaluated as an alternative.

ASSUMPTIONS

Fuel economy is shown to be proportional to vehicle weight, the force required to overcome aerodynamic forces, engine displacement, and drivetrain design. Aerodynamic forces are shown to be proportional to vehicle frontal area, which varies with vehicle weight to the power of 2/3, assuming constant vehicle density.

VALIDATION

The model is compared with a Department of Transportation-developed model and a simple engineering fuel consumption model. The DOT model, based on a 1979 model year baseline, proved to be a relatively poor predictor of model year 1980 fuel economies. The engineering models are shown to have better explanatory power. The explanatory variables are, however, highly correlated with each other. Scatterplots of the residuals from the model estimates are used to demonstrate the better explanatory power of the DOE model.

LIMITATIONS AND BENEFITS

Predicted baseline fuel economies can be adjusted for other transmission types or for advanced technologies. The model variable relationships were arranged so as to minimize the multicollinearity between them.

STRUCTURE

The model may be completely summarized by:

$$FC = 1 / FE = \frac{1.380 \times 10^{-5}}{(.008 \times 10^{-5})} (ETW) \left[1 + \frac{0.34}{(0.044)} \left(\frac{DYN0}{M_2 \times ETW^{2/3}} - 1 \right) + \frac{0.22}{(0.053)} \left(\frac{CID \times RAR}{M_3 \times ETW} - 1 \right) \right] / NT$$

$$\text{unweighted } R^2 = .891$$

where standard errors are in parentheses, and

FC = fuel consumption, in gallons per mile

FE = EPA combined fuel economy rating, in miles per gallon

ETW = equivalent test weight of vehicle, in pounds

DYNO = setting for dynamometer power absorption unit, horsepower

80-584

M_2 = mean value of $DYNO/ETW^{2/3} = 0.061$

CID = engine displacement, cubic inches

RAR = rear axle ratio

M_3 = mean value of $(CID \times RAR)/ETW = 0.202$

NT = transmission efficiency, assessed as a penalty or advantage of the given transmission type over a chosen base transmission, = 1.05 for manual 5-speed and all overdrive transmissions, = 1.00 for all manual 3- and 4-speeds without overdrive, = .985 for torque converter lock-up, = .95 for automatic 3-speeds

REFERENCES

Technical analysis of the light duty truck fuel economy standards for 1985 model year, Energy and Environmental Analysis, Inc., May 9, 1980.

Rulemaking support paper: Light truck fuel economy standards, model years 1983-1985, U.S. Department of Transportation, December 1980.

TECHNOLOGY/COST SEGMENT MODEL (TCSM)

The Technology/Cost Segment Model was developed in 1979 by Energy and Environmental Analysis, Inc. under the sponsorship of the U.S. Department of Energy, Office of Policy and Evaluation. The model is designed to forecast the market penetration of various technologies used by automobile manufacturers in improving fuel economies.

SPONSOR

U.S. Department of Energy
Office of Policy and Evaluation
Washington, D.C. 20461

AUTHOR

Energy and Environmental Analysis, Inc.
1111 North 19th Street
Arlington, Va. 22209

KEYWORDS

Fuel economy

OBJECTIVE OF MODEL

The objective of the model is to simulate the domestic automobile manufacturers' technological responses to required increases in fuel economies of specific size-class automobiles. The model predicts which technologies will be used and accounts for the associated fuel economy/cost tradeoffs.

The inputs to the model are manufacturer, size-class, model year, and fuel economy target. The outputs of the model are total mpg improvement and total cost increment relative to baseline values. A list of technologies with increments of market penetration is also produced. The size classes considered are based on a roominess index that divides cars into three classes: small, medium, and large.

RELATIONSHIP TO OTHER MODELS

The model was originally designed to replace the technology/cost relations portion of the Faucett Automobile Sector Forecasting Model (76-016). The U.S. Department of Energy anticipates that the model will be incorporated into the supply side of the new disaggregate model that is to be developed under its sponsorship.

HISTORICAL BACKGROUND

The technological cost relations presented in this model replace the Faucett model relations originally developed by Hittman Associates, Inc.

ASSUMPTIONS

The model incorporates specific assumptions about the technologies available to each manufacturer for each size of automobile. A hierarchy of choices is specified and constraints exist concerning the market penetrations of technologies.

VALIDATION

There is no reported validation of the model. The model authors show that the discrete technological choices inherent in the design of the model are superior to a continuous fuel economy/cost tradeoff function.

LIMITATIONS AND BENEFITS

The model requires a specific increase in fuel economy for a particular manufacturer's size-class automobile. This is a limitation in the sense that the demand and non-technological supply sides of an attached model must be compatible in required inputs and outputs as well as manufacturer and size-class definitions. Neither Volkswagen nor any other foreign automakers are modeled.

STRUCTURE

The model is based on an approach that stresses the discrete segments of cost and miles per gallon for specific technologies available to manufacturers. Given a fuel economy target for an automobile, the model searches among the available technologies, and determines the optimal technologies until either the target fuel economy is attained or the available technologies are exhausted.

The model has four components.

1. Technology Data.

Eleven technologies are considered to be available over the 1979 to 1985 period. These are diesel engines, automatic transmission improvements, weight reduction through material substitution, turbocharging, aerodynamic improvements, improved lubricants, rolling resistance reduction, improved accessories and accessory drives, electronic engine control, stratified charge (PROCO) engines, and transverse front-wheel drive. For each size-class vehicle of each domestic manufacturer, the following information is specified in matrix form, for each technology: (a) percentage fuel economy improvement over the 1978 baseline; (b) unit cost in 1978 dollars; (c) date at which the

technological improvement is first available for introduction (reflects lead times and tooling constraints); (d) latest date at which the improvement can be introduced (enables the model to simulate the replacement of obsolete technologies); (e) minimum market penetrations (this constraint ensures that certain technologies will not be selected in a volume that is too small to justify the fixed costs of production, a percentage); (f) maximum market penetration, a percentage; and (g) notes which contain information on nonadditive technologies or improvements, such as downsizing, which have to be adopted in specific percentages.

2. Technology Selection Criteria.

This component consists of an ordering vector that specifies the optimal order of technology selection. Cost effectiveness is not the only selection criteria. Other criteria include manufacturer's tendency to optimize cost over the long run, vehicle performance (e.g., turbochargers), and mandatory technological introductions of manufacturers.

3. Engineering Control.

This component models the simultaneous introduction of various technologies. It accounts for four major engineering aspects of the technologies. First, engineering considerations limit the maximum market penetration or total fuel economy improvement achievable with nonadditive technologies. Second, in an attempt to gain experience, manufacturers introduce new technologies during various model years. This implies mandatory introduction schedules that ignore short-run cost effectiveness. Third, some technologies require changes across entire automobile-model lines such as in the case of material substitutions and aerodynamic drag reduction programs. These requirements imply that market penetration rates must be appropriately constrained. Fourth, the redesign of a model line is generally accompanied by the simultaneous introduction of compatible technologies. Thus, model lines that are expected to be redesigned in a particular year will incorporate several new technologies.

4. Technology/Cost Segment Algorithm.

Given the user-selected manufacturer size-class and model-year fuel economy targets, the algorithm scans the technology data matrices and the selection criteria, and selects the optimal technologies to achieve the fuel economy target.

DATA USED IN RUNNING MODEL

The inputs to the model are manufacturer, size-class, model year, and fuel economy target. Built into the model are the automobile development programs of the four domestic automakers, General Motors, Ford, Chrysler, and American Motors. The technological cost/fuel economy relationships for the various technologies are derived from several sources. The data matrices and the ordering vector reflecting

the selection criteria are flexibly designed to accommodate new information and the running of alternative scenarios.

REFERENCE

Technological/cost relations to update the DOE/Faucett model, draft, Energy and Environmental Analysis, Inc., October 1979.

COMPUTER REQUIREMENTS

The model is computer operational at Energy and Environmental Analysis, Inc.

TRANSIT ACCESSIBILITY AS A DETERMINANT OF AUTOMOBILE OWNERSHIP

This model of transit accessibility as a determinant of automobile ownership was developed at the Metropolitan Washington Council of Governments and published in 1973. Its purpose is to examine how availability of mass transit affects levels of auto ownership in a metropolitan area.

SPONSOR

District of Columbia Department of Highways and Traffic

Maryland Department of Transportation

Virginia Department of Highways

U.S. Department of Transportation
Federal Highway Administration

AUTHOR

Robert T. Dunphy
Metropolitan Washington Council of Governments

KEYWORDS

Automobile demand

OBJECTIVE OF MODEL

The objective of this model is to analyze the relation between transit accessibility and auto ownership to see how transit accessibility affects average auto ownership levels for households of different average incomes and sizes.

RELATIONSHIP TO OTHER MODELS

There is no relationship to other models.

ASSUMPTIONS

The measure of transit accessibility used in the model is the percentages of jobs in the metropolitan area that could be reached from the residential area in 45 minutes by mass transit. Because this time boundary accounted for 9 out of 10 work trips, it was assumed to be a representative boundary for commuting travel.

VALIDATION

The calculated F-ratios between automobile ownership and transit accessibility were significant at the 99 percent level of confidence for all but three categories of income and family size. Except for the highest income households of four persons or more, transit accessibility to employment appears to have a significant impact on the number of cars owned.

LIMITATIONS AND BENEFITS

This model has dealt entirely with employment-related transit accessibility. The measurement of accessibility for non-work purposes is much more complex than that for work purposes.

STRUCTURE

Since both family size and income are correlated with transit accessibility, separate equations are used for 40 sets of households, which are classified by number of persons (one, two, three, or four and over), and ten family income groupings, ranging from categories of zero to three thousand dollars a year to over 25 thousand.

A simple linear regression was formulated for each of the 40 sets.

$$Y_{is} = a + b (X)$$

where:

Y_{is} = the average number of automobiles owned by a household of a given income and size

X = the transit accessibility available to that household

a, b = regression coefficients calculated by standard least squares techniques

MODEL CONSTRUCTION

The data used to estimate this model were developed from a home interview survey conducted by the National Capital Region Transportation Planning Board (TPB) and Metropolitan Washington Council of Governments (COG) in 1968.

REFERENCE

Dunphy, R.T., Transit accessibility as a determinant of automobile ownership, Highway Research Record no. 472, pp. 63-71, 1973.

ENERGY USE IN TRANSPORTATION MODEL (ENTRANS)

The Energy Use in Transportation Model (ENTRANS) was developed in 1980 at Dartmouth College under the sponsorship of the U.S. Department of Transportation. It is a computer-based dynamic simulation model developed to analyze the interactions between energy supply and transportation-related energy use. It is intended to allow policymakers to evaluate the impacts on travel and mobility of changes in energy price and availability and to determine the impacts on energy use of transportation policies.

SPONSOR

U.S. Department of Transportation
Research and Special Programs Administration
Office of University Research
Washington, D.C. 20590

AUTHOR

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KEYWORDS

Automobile demand, fleet size, fuel consumption, fuel economy, fuel price, market share, modal split, pricing, scrappage, vehicle miles traveled, vehicle user costs/vehicle operating costs

OBJECTIVE OF MODEL

The model represents the factors affecting gasoline use in intracity passenger transportation and intercity auto trips. It may be used to analyze policies such as transit service improvements, auto fuel efficiency mandates, gasoline taxes, gasoline price changes, and carpooling incentive programs. Also scenarios may be tested such as different population growth rates, economic growth rates, and petroleum pricing and supply policies. The model projects to the year 2020.

RELATIONSHIP TO OTHER MODELS

The auto sector of ENTRANS may also be used separately in a version called the CAR1 model.

Economic inputs to ENTRANS are projected by Data Resources, Inc. Oil supply and price are forecast by the Department of Energy's FOSSIL79 and

NEP2000 models. The model report presents a critique of three models; some of their concepts are incorporated into ENTRANS: Faucett Automobile Sector Forecasting Model (76-016), Sweeney Vintage Capital Model (75-004A), and the MIT-TRANS model of travel demand at the urban area level. The consumer choice sector is borrowed from the disaggregate individual-level auto-type choice model developed by Lave and Train (77-055).

The technology cost curve parameters, relating fuel economy rating increments to manufacturing costs, were estimated using data compiled for the Wharton EFA Automobile Demand Model (77-046).

ASSUMPTIONS

Household-level travel demand is represented by assuming that households maximize the utility of travel, subject to time and money constraints, as measured by travel distance; increased travel distance provides greater utility by increasing the spatial range of opportunities for satisfaction of household needs and desires. Travel decisions are based on modal cost and speed and on number of trip makers per household and income. All modes are compared on the basis of the maximum daily miles associated with them to determine modal splits.

General scenario assumptions made are that the internal combustion engine will be used in automobiles over the model's time horizon but diesel engines will be widely used also, that standards of the 1977 Clean Air Act amendments will be met, and motor vehicle safety standards will be met without adverse impact on automobile fuel efficiencies. The auto industry is assumed to be basically competitive and to anticipate the need for meeting the fuel economy standards. The cost of improving fuel efficiency is assumed to be approximated by a continuous function that rises monotonically with increasing efficiency. To maximize total sales and to avoid losing sales to competing manufacturers, each company is assumed to minimize the lifecycle cost of auto ownership to the public.

VALIDATION

The model is calibrated to reproduce historical values of variables to within approximately 10% of the estimates of their real values over the period 1950-1979.

LIMITATIONS AND BENEFITS

ENTRANS borrows from other modeling efforts, but its authors claim that it is the only model that includes a full set of transportation/energy supply/demand components. The policies that may be simulated are: no mandated fuel economy standards; high standards after 1985; low or high penalty rates; low, medium, or high gasoline tax; excise tax on gas guzzlers; driver or vehicle based rationing of gas; carpool parking incentives or special lanes; increased federal transit capital

expenditures; increased highway construction, reconstruction, or maintenance levels; decreased transit fares; national energy plan 1 and 2; low, medium, or high oil price scenario; high or medium GNP growth rates; zero mean income growth after 1980; and high or low population growth rates.

STRUCTURE

The model has seven sectors: (1) travel, computes mode-specific travel demand and fuel use; (2) auto, represents industry/consumer response to gasoline prices and government policies; (3) transit, represents the transit sector response to changes in ridership and to various policies; (4) carpool, represents carpool-specific levels of service; (5) highway, determines the effect of highway condition and congestion on average network speed; (6) demographic, projects economic and population growth; and (7) cost, converts crude oil prices to equivalent gasoline prices.

Two parallel structures are used to model the decisions of the auto industry. The first computes the costs associated with auto production and outputs price for each of five auto size classes (subcompact, compact, intermediate, full-size, and luxury). Four cost factors influence the decision of each auto manufacturer: technology costs of fuel efficiency, gasoline costs, penalties for not meeting government mandated fuel economy standards, and government-imposed excise taxes based on auto fuel economy. The second structure finds the fuel efficiency within each class that minimizes the lifecycle costs of auto ownership by computing incremental price and fuel economy changes using the derivatives of gasoline, technology, penalty, and excise tax costs. The minimum lifecycle cost is found when a selected fuel economy drives the sum of the four component derivative cost functions to zero.

A consumer choice model is used to determine the relative utility, and therefore the market share, of an auto class. The factors involved are household income, new car price for the class, fuel economy and gasoline price (operating cost), general utility of the class, and utility of alternative classes.

Total vehicle travel distance is used to compute congestion and road deterioration effects. The transit, carpool, and highway sectors compute levels of service by mode, given modal characteristics and travel volumes. These levels of service are used by the travel sector to determine travel patterns.

The demographic sector computes household characteristics such as number of households, mean household income, number of licensed drivers per household, and number of autos per household. Inputs include the total number of autos, from the auto sector, and the distribution of autos across income classes, from the travel sector.

The cost sector uses a wellhead crude oil cost to compute the price of gasoline, including the average state fuel tax computed in the highway revenues subsector. Values for fuel use and fuel availability

from the travel sector are used to compute a price multiplier from fuel shortfall.

The output that may be plotted or printed includes auto prices, passenger miles by mode, new-car market shares, trip characteristics, demographics, new car on-the-road or EPA-measured fuel economies, generalized new-car prices, penalty costs, technology costs, transit sector response, auto vehicle miles, auto or transit maximum daily miles, highway sector response, auto fuel use, average new car and fleet fuel economies, gasoline price, etc.

DATA USED IN RUNNING MODEL

Parameter and policy scenario values are built into the model program.

REFERENCES

Adler, T.J.; Ison, J.W.; Geinzer, J.C., Interactions between energy supply and transportation-related energy use, two volumes, U.S. Department of Transportation, Report no. DOT-RSPA-DPB-50/80/7, January 1980.

Adler, T.J.; Ison, J.W., Analysis of long-term transportation energy use, draft, Dartmouth College. Submitted for presentation at the 60th Annual Meeting of the Transportation Research Board, August 1980.

Ison, J.W., Effect of government policy on future automobile fuel economy, masters thesis, Dartmouth College, Report no. DSD 203, January 1980.

COMPUTER REQUIREMENTS

The model is programmed with DYNAMO, a continuous simulation language developed by the Systems Dynamics Group at the Massachusetts Institute of Technology. Differential equations specifying the rates of flow into and out of the levels of the system are integrated over time, simulating the dynamic interaction of the variables in the system, including time delays, feedback, and non-linear causal relationships. ENTRANS is run on the Dartmouth Time-Sharing System on the Honeywell 6180 computer; runs cost about three dollars each. The model reports contain complete program documentation, including output from all policy option experiments, variable definitions, program listing, and user's guide.

LONG-RUN AUTOMOBILE DEMAND

A long-run automobile demand model was developed in 1956 at the University of Illinois. The model was designed to estimate the long-run trend of automobile sales. Determination of the trend would aid long-run investment decisionmaking for the automotive industry.

AUTHOR

Hans Brems
University of Illinois
Department of Economics

KEYWORDS

Automobile demand

OBJECTIVE OF MODEL

The objective of the model is to determine the long-run trend of automobile production. This could be compared with current output levels in helping to decide on long-run investment decisions. This model was an early exploratory study of the processes of modeling long-run automobile demand.

RELATIONSHIP TO OTHER MODELS

This model has no direct relationship to other models.

ASSUMPTIONS

In deriving the equilibrium relationship described in the Structure section below, the model author assumed that the long-run equilibrium stock of autos increases at a constant proportionate rate of growth. He assumed that the number of autos retired in period t equals the number of new cars sold in period $t-L$, where L equals the number of periods of useful life of an automobile.

VALIDATION

The model author derives ranges of estimates of the growth rate in the stock of automobiles and the useful life of an automobile. These estimates are then used by the author to show that the level of new-car sales in 1955 was higher than the level that would materialize in equilibrium.

This model and another one developed by Marc Nerlove (57-614) were the focus of several notes in the Journal of Marketing in 1957 and 1958. There are listed in the Reference section below.

LIMITATIONS AND BENEFITS

The model author notes that the equilibrium model will not produce good forecasts, except by coincidence. Deviations of a particular year from the long-run trend occur because of changes in the useful life of an auto, the uneven age distribution of the auto stock, and changes in the proportionate rate of growth in the auto stock.

STRUCTURE

The demand for new automobiles consists of two components. One is the demand for automobiles that have been retired and the other is the demand for a larger stock of automobiles. The author shows that based on these two demands, the following relationship can be derived:

$$X(t) = \frac{g S(t-1)}{1 - (1 + g)^{-L}}$$

where:

$X(t)$ = new-car demand at time t

g = proportionate rate of growth in the stock of automobiles

$S(t-1)$ = stock of automobiles at time $t-1$

L = useful life of an automobile

The two structural parameters, L and g , determine the equilibrium value of the ratio, $X(t)/S(t-1)$.

DATA USED IN RUNNING MODEL

To determine the equilibrium ratio of sales to lagged stock of automobiles requires estimates of the growth of the auto stock and the useful life of a car in periods.

REFERENCES

Brems, H., Long-run automobile demand, The Journal of Marketing XX(4):379-384, April 1956.

Brems, H., Automobile demand, The Journal of Marketing XXII(2):174-176, October, 1957.

Brens, H., Comments on Marc Nerlove, "On automobile demand: A reply", The Journal of Marketing XXII(4):416, April 1958.

Nerlove, M., Note on long-run automobile demand, The Journal of Marketing XXII(1):57-64, July 1957.

Nerlove, M., On automobile demand: A reply, The Journal of Marketing XXII(4):415-416, April 1958.

LONG-RUN DEMAND FOR AUTOMOBILES

This model of the long-run demand for automobiles was developed in 1957 while the author was at the U.S. Agricultural Marketing Service. The author derives a statistically estimable new-car sales equation from which can be deduced an equation that predicts the long-run equilibrium stock of automobiles. The estimated income and price elasticities are based on data from 1922 to 1941 and 1948 to 1953.

AUTHOR

Marc Nerlove
U.S. Department of Agriculture
Agricultural Marketing Service

KEYWORDS

Automobile demand

OBJECTIVE OF MODEL

The objective of the model is to predict long-run automobile demand. The author develops a statistically estimable new-car sales equation from which can be derived an equation estimating the long-run equilibrium stock of automobiles.

RELATIONSHIP TO OTHER MODELS

The model has no direct relationship to other models.

HISTORICAL BACKGROUND

This model was developed in response to the perceived weaknesses of the Brems Long-Run Automobile Demand Model (56-613). This article is one of the early exploratory studies on the stock-adjustment process and automobile demand.

ASSUMPTIONS

In deriving the new-car sales equation, the author assumed a constant percentage depreciation for automobiles. The depreciation rate allowed the model author to derive the stock of cars adjusted for the age composition of the stock. The long-run equilibrium stock is theoretically assumed to be a function of price, income, and other variables. The rate of adjustment of the actual stock is assumed to be proportional to the difference between the equilibrium and the actual stocks.

VALIDATION

This model and the Brems Long-Run Automobile Demand model (56-613) were the subject of several notes in the Journal of Marketing in 1957 and 1958. These notes are listed in the Reference section below.

LIMITATIONS AND BENEFITS

The author notes that the estimated model is very simplistic and probably excludes relevant variables. The theoretical specification shows that the long-run equilibrium stock equation (which cannot be statistically determined) can be deduced from a statistically estimated new-car sales equation.

STRUCTURE

From the basic assumptions the following equation was derived and estimated:

$$X(t) = 0.0046 - \frac{0.018 [p(t)]}{(0.006)} + \frac{0.006 [p(t-1)]}{(0.006)} + \frac{0.013 [y(t)]}{(0.002)} \\ - \frac{0.007 [y(t-1)]}{(0.003)} + \frac{0.268 [X(t-1)]}{(0.211)}$$

$$R^2 = 0.91$$

where standard errors are in parentheses, and

$X(t)$ = new-car purchases during period t

$p(t)$ = relative price of automobiles in period t

$y(t)$ = real disposable income in period t

The model author reports these estimated elasticities: new purchases with respect to current prices, -0.9; and new-purchases with respect to current real disposable income, +2.8.

From the new-car sales equation estimated above, the author derives the long-run demand for automobiles:

$$S^*(t) = 0.014 - 0.025 [p(t)] + 0.018 [y(t)]$$

where:

$S^*(t)$ = long-run equilibrium stock of automobiles

This implies a long-run relative price elasticity of demand for automobiles of -1.2. The long-run elasticity of demand is about +3.8.

MODEL CONSTRUCTION

The sample period of the estimated model is 1922 to 1941 and 1948 to 1953.

REFERENCES

Nerlove, M., Note on long-run automobile demand, The Journal of Marketing XXII(1):57-64, July 1957.

Nerlove, M., On automobile demand: A reply, The Journal of Marketing XXII(4):415-416, April 1958.

Brems, H., Automobile demand, The Journal of Marketing XXII(2):174-176, October, 1957.

Brems, H., Comments on Marc Nerlove, "On automobile demand: A reply", The Journal of Marketing XXII(4):416, April 1958.

FHWA LEVEL 1 HIGHWAY TRAFFIC NOISE PREDICTION MODEL (SNAP 1.0)

The FHWA Level 1 Highway Traffic Noise Prediction Model is also known as the Simplified Noise Analysis Program 1.0, or SNAP 1.0. It was developed in 1979 by Science Applications, Inc. and the Federal Highway Administration. It is to be used in highway engineering for simulating the traffic noise received near roadways. More complex site configurations may be simulated with the FHWA Level 2 model (79-634B).

SPONSOR

U.S. Department of Transportation
Federal Highway Administration
Office of Research
Environmental Design and Control Division
Washington, D.C. 20590

AUTHOR

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Science Applications, Inc.
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KEYWORDS

Noise pollution

OBJECTIVE OF MODEL

The model is designed to quickly predict traffic noise impacts for simple roadway-receiver geometries. It predicts the equivalent sound level measurement, L_{eq} , and approximates the L_{10} percentile sound level for constant speed traffic flows comprising a mix of vehicle types.

RELATIONSHIP TO OTHER MODELS

This model is intended to model traffic noise emission at sites with relatively simple geometries. For complex site geometry, the FHWA Level 2 Highway Traffic Noise Prediction Model (STAMINA 1.0) (79-634B) may be used.

HISTORICAL BACKGROUND

The methodology is based on work by the Federal Highway Administration.

ASSUMPTIONS

The model works most accurately with sites that are essentially flat. For traffic noise predictions with barrier attenuation, all traffic lanes must be parallel to each other and to the barrier but they may be at different elevations. If there is no barrier, curved roadways may be accurately modeled.

VALIDATION

The model documentation illustrates several example problems simulated with the model. One is compared with a field test with the same site configuration. The difference between the actual measured and predicted sound levels was less than three decibels.

LIMITATIONS AND BENEFITS

The model allows the user to formulate site geometry using lateral, longitudinal, and vertical coordinates rather than distances and angles as measured from a receiver. The site geometry defining traffic lanes and a barrier location need thus only be defined once. The user may then define as many locations for receivers as desired without redefining the traffic lanes and barrier locations.

STRUCTURE

The model can consider the following: up to 12 parallel traffic lanes, each described by a speed and a mix of vehicles; three vehicle types (passenger cars and light trucks, medium trucks, and heavy trucks) and an optional user-defined vehicle type; sound level adjustments for each vehicle type on each lane to simulate, for example, noise emission from traffic on grades; a "thin screen" or "earth berm" barrier that dampens noise; excess distance attenuation parameters to simulate site acoustic characteristics; and an unlimited number of receiver locations. The output consists of a table of sound level contributions from each vehicle type on each traffic lane at each receiver location, with totals and subtotals.

Locations are specified by X, Y, Z coordinates. Roadway lanes are represented as finite-length line segments. All data must correspond to the same time period, which may be 24 hours, one hour, half hour, etc. If there are grade effects, traffic flow is defined for the uphill and downhill directions.

The model is based on equations that relate the equivalent sound level at a receiver due to a vehicle on a lane to the reference energy mean emission level for the vehicle at the operating speed of the lane, the number of vehicles of that type on the lane, the reference distance used for evaluating the reference emission level, the time period applying, the average speed for the period, the excess distance attenuation factor applicable for the lane, and the distance of the

receiver from the lane. Adjustments are made for barriers. The calculations are based on physical considerations. The approximation of the L_{10} measurement, the sound level exceeded 10% of the time, is dependent on the characteristics of the site being studied.

DATA USED IN RUNNING MODEL

The parameters that may be input to the model include: time period, barrier type, maximum allowable angle to evaluate parallelism of line segments, vehicle types, vehicle acoustic source elevation, barrier geometry, lane geometry, traffic flow definition, sound level adjustments, receiver locations, and sound attenuation parameters.

REFERENCE

Rudder, F.F., Jr.; Lam, D.F., User's manual: FHWA highway traffic noise prediction model--SNAP 1.0, Science Applications, Inc., Report no. FHWA-RD-78-139, January 1979.

COMPUTER REQUIREMENTS

The model report contains descriptions of input data requirements, and program flowcharts, explanations, and listings. The program is written in FORTRAN IV and is intended to be run in batch mode.

FHWA LEVEL 2 HIGHWAY TRAFFIC NOISE PREDICTION MODEL (STAMINA 1.0)

The FHWA Level 2 Highway Traffic Noise Prediction Model is also known as the Standard Method In Noise Analysis version 1.0, or STAMINA 1.0. It was developed in 1979 by Science Applications, Inc. and the Federal Highway Administration as part of the continuing effort to refine and improve engineering methods for the prediction and abatement of traffic-generated noise from highways. It is an improved version of the TSC MOD-04 model (77-093). The FHWA Level 1 model (SNAP 1.0) is described under 79-634A.

SPONSOR

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Federal Highway Administration
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KEYWORDS

Noise pollution

OBJECTIVE OF MODEL

The model is used to predict noise emissions levels from traffic on highways, taking into consideration grades, barriers, ground plantings, and other complicating features of a site.

RELATIONSHIP TO OTHER MODELS

Sites with less complex geometries may be modeled with the somewhat simpler FHWA Level 1 Highway Traffic Noise Prediction Model (SNAP 1.0) (79-634A).

HISTORICAL BACKGROUND

This is an evolutionary development of the TSC Highway Noise Prediction Code: MOD-04, described under 77-093.

ASSUMPTIONS

The attenuation of sound intensity with distance from a line source is assumed to be in excess of classical cylindrical spreading from a source. The traffic flow noise theory employed assumes a uniform distribution of identical point sources along the finite roadway segment. Traffic flow and speed are assumed to be uniform. The attenuation of sound due to atmospheric absorption uses an empirical formula dependent on frequency and distance between the source and the receiver and is specialized for ambient temperatures around 68° F and relative humidity in the range of 50 to 70 percent. The attenuation or diffraction of sound by a barrier, always assumed to be a rigid impervious screen perpendicular to the ground plane, is determined by the difference between the path length over the top edge of the barrier and that directly from source to receiver. Attenuation of sound due to ground cover (shrubbery or trees) is assumed to be proportional to the mean path length of the sound over the ground strip from the line source. Traffic speeds are limited to the range of 30 to 65 mph due to the data limitations upon which vehicle noise emissions are based.

LIMITATIONS AND BENEFITS

The refinements made to the model to improve its prediction accuracy and utility include: revised speed-dependent noise emission levels for heavy and medium trucks; sound level adjustments may be used to simulate heavy trucks moving up grades; distance noise attenuation rates may be specified; data may be in English or metric measurements; data annotation and compatibility with TSC MOD-04; calculations of reflected sound may be bypassed; and a criterion level may be specified which is exceeded by the noise level contributions from different sources.

STRUCTURE

Up to 20 roadways may be defined for a site, with five different traffic conditions. Roadways may intersect or coincide; they are defined by a connected series of straight line segments. Vehicle speed and flow rate and noise levels are in per-hour units. Up to 20 barriers may be defined by designating their top edges as line segments. Shrubbery and trees may also be defined. Excess distance sound attenuation effects may be included by specifying "alpha" parameters for the receivers. Barriers may be modeled to reflect sound. Up to 15 receiver locations may be simulated.

The program produces output for each receiver, describing its coordinates, A-weighted octave band sound levels with and without alpha factors, overall equivalent sound level, the level exceeded 90% of the time, the level exceeded 50% of the time, the level exceeded 10% of the time, estimated standard deviation of the sound level variation during the hour, and roadway segments contributing to the total receiver sound level in excess of a specified criterion.

The model depends on physical systems equations that relate the ratio of the acoustic intensity at the receiver with respect to a reference intensity to a reference sound level at a reference distance, the distance from the roadway segment to the receiver, the source concentration (traffic flow), an excess attenuation parameter independent of distance, and an excess attenuation parameter proportional to distance from the source. This formulation is for a single vehicle type operating on a finite roadway segment. It is repeated as needed. A formula provides for the combination of effects of sound absorption and reflection or diffraction.

DATA USED IN RUNNING MODEL

The parameters that may be input include: receiver height adjustment; number of frequency bands; source height adjustment by vehicle type; traffic flow rates; mean vehicle speeds; straight line roadway segment end-point coordinates; grade adjustments; coordinates of the top of the barriers; absorption or reflection of barriers; ground cover area coordinates, dimensions, and type (shrubby or trees); receiver coordinates; noise criterion levels; and alpha parameters.

REFERENCE

Rudder, F.F., Jr.; Lam, D.F.; Chueng, P., User's manual: FHWA level 2 highway traffic noise prediction model--STAMINA 1.0, Science Applications, Inc., Report no. FHWA-RD-78-138, May 1979.

COMPUTER REQUIREMENTS

The program is written in FORTRAN IV and is run in batch mode. The model report provides program documentation including code listings and explanations, input data format description, and example problems.

ELECTRIC VEHICLE WEIGHT AND COST MODEL (EVWAC)

The Electric Vehicle Weight and Cost Model (EVWAC) was developed in 1979 for the U.S. Department of Energy by General Research Corporation (GRC). It is intended to be used to determine the costs of hypothetical vehicles.

SPONSOR

U.S. Department of Energy
Office of Transportation Programs
Washington, D.C. 20590

AUTHOR

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KEYWORDS

Vehicle user costs/vehicle operating costs, vehicle operating performance, weight

OBJECTIVE OF MODEL

The model is intended to determine the total and component operating costs and weights of electric, hybrid, or internal combustion engine vehicles, given specifications of vehicle and technology types.

RELATIONSHIP TO OTHER MODELS

The electric vehicle performance model, ELVEC, developed by GRC, is used in conjunction with EVWAC in determining the electricity consumption of electric cars. RECAP, the recharge capacity model, developed by GRC to measure impacts on electric utilities, may be used in conjunction with EVWAC and ELVEC to determine total electric car demand and supply effects on electricity consumption. RECAP may also be used with REPS (79-644) to determine the effects on air quality of electric car use and the resulting demand on electric utilities.

HISTORICAL BACKGROUND

This model is a part of a study of two- and four-passenger electric cars. Models developed earlier in the study have been updated and integrated into EVWAC, and expanded to include hybrid vehicles, light

trucks, and comparable internal combustion engine vehicles. The earlier models include the electric car cost model, ECCOST, the performance model, ELVEC, and weight estimating algorithms. The combination of these models into one computer program was intended to make analysis easier.

STRUCTURE

Three levels of technology may be modeled: recent, improved--to be available around 1985, and advanced--available by 1990. Gross weight of the electric car is divided into fixed weight (payload, trim, seats, safety items, lights, upper body structure), structure and chassis weight, propulsion weight (motor and transmission), and battery weight. The structural weight parameter is defined as including all the vehicle components that are dependent on the design gross vehicle weight, and is divided into suspension, dependent structure, and structural parts of the driveline.

Operating costs of a vehicle output by the model include: replacement batteries, repairs and maintenance, replacement tires, insurance, garage, parking, tolls, title, registration, license, fuel and oil, electricity and equivalent road tax, and capital costs. Most of these costs are dependent on vehicle life and kilometers driven. Cost of electricity is a function of vehicle energy use from the battery, battery charge/discharge efficiency, charger efficiency, electricity cost per kilowatt hour, and total kilometers driven. Battery capital cost is a function of battery life, number of batteries used over the vehicle life, battery cost less salvage value, interest rate, and battery salvage value. Initial vehicle cost is a function of dealer markup, allocation of average fixed costs and return on equity, market adjustment by vehicle size, average variable manufacturing cost, battery initial costs, and cost of safety equipment, optional equipment, and emissions equipment.

The model also outputs cost items for the basic vehicle, hybrid propulsion system, battery, total initial cost, total operating cost, cost of capital--batteries and vehicle less salvage, and total life-cycle cost. Amounts are given in dollars and in cents per kilometer. Other output parameters are battery fraction, vehicle range and energy use, battery life and replacements, curb weight, payload test weight, structure system weight, electric and internal combustion propulsion system weights, peak power available, required power, fuel tank volume, fuel economy, and petroleum use.

For an electric car the output is displayed by varying battery fractions, the fraction of total test weight in the batteries. For hybrid vehicles, the output is displayed by varying amounts of use of the internal combustion engine system. For an internal-combustion-engine vehicle the output is displayed by varying number of seconds to accelerate to 60 mph.

MODEL CONSTRUCTION

The specification of all of the factors and parameters in the model is described in the model report. Most of these data came from the Report by the Interagency Task Force on Motor Vehicle Goals Beyond 1980 and from other U.S. Department of Transportation-sponsored sources.

DATA USED IN RUNNING MODEL

The model user selects from a set of input descriptors including: technology level (recent, improved, advanced), vehicle type (two-, four-, five-, or six-passenger car, light pickup truck, low- or high-volume load van), propulsion type (electric, hybrid, internal combustion, Otto or diesel cycle), and battery type (current or advanced lead-acid; nickel-zinc; lithium/aluminum-sulfide; other, specifying the input efficiency, cost, energy, power density, and cycle or life). The user may also vary the battery fraction or weight, payload weight, accessory weight and cost, and maximum acceleration.

REFERENCES

Curtis, R., Electric vehicle weight and cost model (EVWAC), General Research Corporation, internal memorandum no. 2202, May 1979.

Hamilton, W., Energy use of electric vehicles, Transportation Research, 14A:415-421, 1980.

REGIONAL EMISSIONS PROJECTION SYSTEM (REPS)

The Regional Emissions Projection System (REPS) is a computerized model for forecasting regional air pollution to the year 2000. It was developed by the General Research Corporation (GRC) for the U.S. Department of Energy (DOE), and published in 1979. It has been used for projecting the effects of electric vehicle usage.

SPONSOR

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AUTHOR

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KEYWORDS

Air pollution/air quality

OBJECTIVE OF MODEL

The system combines national and regional economic forecasts with point-source and area-source emissions inventories to project emissions on an annual basis. The pollutants modeled are suspended particulates, sulfur oxides, nitrogen oxides, hydrocarbons, and carbon monoxide. The system was used to project the effect on emissions of electric cars making up none, 10%, or 100% of the total vehicle fleet.

RELATIONSHIP TO OTHER MODELS

The system is linked to several models maintained by GRC and to data bases maintained by various federal agencies. Another model for electric car use analysis is EVWAC (79-642).

HISTORICAL BACKGROUND

REPS was originally developed by the Environmental Projection Agency in the early 1970s. It has been improved to include updated economic projections, emissions inventories, performance standards, state implementation plans, mobile-source emissions factors, separation of light trucks from cars, improved methods for highway fuel use projections, improved program logic and more efficient code, better

geographical organization, projection of 15 fuel types and 10 fuel use categories, new output options, and new run options. Analysis and development of this system have been done in support of the electric and hybrid vehicle program of DOE.

ASSUMPTIONS

The amount of pollution produced by automobiles and electric utilities would change with widespread use of electric cars. Electric cars emit only relatively small amounts of pollutants, such as particulates due to tire wear, so the total emissions produced by conventional cars would be reduced as greater proportions of total kilometers are driven by electric cars. But power plant emissions would increase as fossil fuels are used to generate the additional electricity needed to recharge electric car batteries. The net impact would vary from region to region, depending on the location of power plants that serve the region, the fuels used in them, the kilometers driven, the characteristics of the region, local emission regulations, and vehicle mix.

Highway gasoline vehicle emissions are based on the EPA mobile source exhaust emission factors (78-424). Future vehicle kilometers traveled (VKT) are projected assuming they grow in proportion to the population in a region. Base year VKT is a function of base year fuel consumption.

LIMITATIONS AND BENEFITS

The method of REPS is said to be accurate because the base year mix of emissions is based on an inventory of point sources based on stack tests, and forecasts may be done on a point source rather than on an aggregate basis. Local forecasts are continually being reviewed and may be incorporated. A disadvantage is that the same growth factors are applied to all point sources related to a given industrial process.

STRUCTURE

For the electric vehicle analysis, the 24 air quality control regions (AQCR) (metropolitan areas) with the largest populations were selected. Levels of emissions and air quality of each AQCR were established for 1975; and emissions were projected for 1980, 1990, and 2000; with and without electric cars. Regional emissions and fuel consumption for 1975 came from the National Emissions Data System (NEDS), a data base maintained by the Environmental Protection Agency. Ambient air quality in each AQCR was estimated using the EPA's Storage and Retrieval of Aerometric Data (SAROAD) System, containing quarterly-collected local data. Future baseline projections used the REPS.

The REPS system multiplies base year emissions times change in activity level times change in emission control, to produce projected emissions. Base year emissions come from NEDS and user-supplied data. Change in activity levels come from critical industry location studies,

OBERS projections developed by the Bureau of Economic Analysis, and GRC's electric utility capacity and demand model, RECAP. Changes in emission control come from the Federal New Source Performance Standards (NSPS) that govern new and retrofit industrial equipment, NEDS, State Implementation Plan (SIP) control regulations, and user-supplied data. Changes in future air quality are calculated to be proportional to changes in future emissions, according to experience with GRC's DIFKIN Photochemical Pollution Diffusion Model (76-091). Equivalent tonnages of emissions in different regions are calculated using pollutant weighting factors from the Strategic Environmental Assessment System (SEAS) (related to 79-020).

REPS could be used to project emissions for any of 319 state portions of AQCR's. Emissions are projected as coming from point or area sources. The area transportation sources are highway and off-highway vehicles, rail locomotives, water vessels, and aircraft.

REFERENCES

Collins, M.M., Model description: Regional emissions projection system (REPS), General Research Corporation, releasable memorandum no. 2248, December 1979.

Collins, M.M.; Carriere, W.M., Projected supply of electricity for electric cars, General Research Corporation, internal memorandum no. IM-2100, July 1977.

Collins, M.M., Updated projections of air quality impacts for electric cars, General Research Corporation, internal memorandum no. 2238, July 1979.

COMPUTER REQUIREMENTS

The system is operational on an IBM 370/168 computer at Optimum Systems, Inc., which is accessible to DOE.

HEDONIC PRICE INDEXES FOR AUTOMOBILES

Griliches' Hedonic Price Indexes for Automobiles were developed in 1961 as part of an investigation into the feasibility of adjusting price indexes for quality changes. The investigation involved the use of a procedure originally developed by A.T. Court in the 1930's. Implicit prices are estimated for related characteristics of automobiles. Quality-adjusted price indexes are compared with several price indexes produced by the U.S. government.

AUTHOR

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KEYWORDS

Pricing

OBJECTIVE OF MODEL

The objective of this model is to estimate an automobile price index that is adjusted for the price changes that result from changes in the quality of cars over time. The model's estimates were compared to various price indexes produced by the federal government to show that the latter have overpredicted the rise in automobile prices for the period 1937 to 1960 because the improving quality of automobiles was ignored.

RELATIONSHIP TO OTHER MODELS

This is not related to other models.

HISTORICAL BACKGROUND

The theoretical approach was first formulated by A. T. Court in 1939 (see 38-689). Griliches investigates the feasibility and operational nature of the approach as well as the practicality of further research.

ASSUMPTIONS

Basic to the approach is the assertion that the varieties of a particular commodity can be comprehended in terms of the levels of various characteristics inherent in each variety. For example, various model automobiles can be redefined in terms of their characteristics, e.g., horsepower, length, weight, etc. Based on inspection of the data

and convenience, the author used a semilogarithmic form that related the log of the price of automobiles to the absolute levels of the characteristics (qualities).

VALIDATION

Various "pure" price indexes were calculated using the different possible weights. These "pure" indexes were compared with several price indexes produced by the federal government. The author's study shows that about three-fourths of the rise in automobile prices in the CPI from 1937 to 1960 could be attributed to quality improvements.

LIMITATIONS AND BENEFITS

As with any index, there are problems associated with the use of the various possible weights. Alternative weighting schemes were used. Selection of the characteristics is critical, as is the price data used in the regressions.

STRUCTURE

In developing the hedonic price indexes, the author first estimated the implicit prices of the relevant characteristics. This was accomplished by regressing the price of a model of automobile on the levels of relevant characteristics contained in the vehicle. A semi-logarithmic form was chosen:

$$\log(P_{it}) = a_0 + a_1 (X_{1it}) + a_2 (X_{2it}) + \dots + u_{it}$$

where:

P_{it} = price of automobile model i at time period t

X_{jit} = characteristic j (quality, property or dimension, e.g., horsepower, length) of model i at time period t

u_{it} = error term

This equation was estimated using cross-section data for the years 1937, 1950, and 1957 through 1960. Using dummy variables for various years, the author derived a "pure" price effect from pooled cross-section data.

The characteristics in the several regressions included horsepower; shipping weight; overall length; and dummy variables equaling one if the model has a V-8 engine, is a hardtop, has an automatic transmission as standard equipment, has power brakes as standard equipment, or if the model is designated a compact. Otherwise the dummy variables equaled zero. The author notes some problems associated with these characteristics. One is a problem of multicollinearity. A second one is that characteristics such as weight and power steering may be proxies

for luxury and the values of those coefficients should be interpreted cautiously.

Using information from the regressions, the author develops estimates of the implicit prices and the hedonic price indexes that control for the quality differences that occur over time. The implicit prices of various characteristics are compared over the sample period. An example is the substantial decline in the increase in prices associated with an increase in horsepower. To study the impacts of alternative weighting schemes, quality indexes using a variety of possible weights were developed. The weights used were for beginning period, adjacent year, 1954-1960 average, and end period. The quality indexes based on the alternative weights showed some substantial differences. The author also adjusted the Consumer Price Index (CPI) for quality changes. In comparing the unadjusted CPI with its quality-adjusted version, the important impact of quality change was identified. The author concluded: "For the 1937-1960 period as a whole, quality change accounted for about one-third (using end-period weights) to about three-fourths (using beginning-period weights) of the recorded price change in the CPI." He also noted the limitations in the approach and suggested some possible avenues of validation. These are the use of used-car prices (to negate the impact of a manufacturer setting an inappropriate price) and the development of confidence intervals for quality indexes. These were discussed, as well as the impact of shifts in supply conditions and tastes.

MODEL CONSTRUCTION

The data used to estimate the coefficients were obtained from the Red Book, Used Car Guide, and Ward's Automotive Reports.

REFERENCE

Griliches, Z., Hedonic price indexes for automobiles: An econometric analysis of quality change, chapter 3 of Price Indexes and Quality Change, pp. 55-87, ed. Griliches, Z., Cambridge: Harvard University Press, 1971. Also published in Readings in Economic Statistics and Econometrics, pp. 103-130, ed. Zellner, A., Chicago: Little, Brown and Company, 1968. Originally published in Government Price Statistics, Hearings, U.S. Congress, Joint Economic Committee, part 1, pp. 173-196, Washington: Government Printing Office, January 24, 1961.

The results of the study were used as a basis for the empirical portions of the article: Adelman, I; Griliches, Z., On an index of quality change, American Statistical Association Journal, pp. 535-548, September 1961.

FIRST PURCHASE AND REPLACEMENT DEMAND FOR PASSENGER CARS

This model of passenger-car purchase and replacement was developed in 1936 in an effort to explain the trend and cyclical movements associated with scrappage and auto demand. The approach distinguishes replacement demand from new-purchases demand.

AUTHOR

P. de Wolff

KEYWORDS

Automobile demand, scrappage

OBJECTIVE OF MODEL

The objective of this model is to explain the trend and cyclical movements of automobile demand in the United States based on a theoretical approach that distinguishes replacement demand from new-purchases demand.

RELATIONSHIP TO OTHER MODELS

This is not related to any other known models.

HISTORICAL BACKGROUND

The paper is an English translation of a paper entitled "De vraag naar personenautos in de Vereenigde Staten," published in De Nederlandsche Conjunctuur in November 1936. This study was one of the earliest attempts to model the determinants of automobile demand.

ASSUMPTIONS

Fundamental to the approach used in developing this model is the assumption that automobile demand can be disaggregated into replacement and new-purchases demands. Each demand is characterized by different determinants. The demand for passenger cars is defined as the difference between production and exportation and assumes a constant business inventory stock of automobiles.

VALIDATION

The author provided some forecasts for postsample years, 1935-1937, but data weren't available for comparison purposes prior to publication of his paper.

STRUCTURE

The model accounts for the long-run trends and business cycles for the replacement and new-purchases demands for automobiles. The demand for passenger cars is defined as the difference between production and exportation. Inventory adjustments are not considered. Replacement demand is determined by the number of automobiles scrapped, while new-purchases demand is a function of long-run determinants.

Scrappage is determined as follows:

$$100 \left(\frac{S - S_b}{S_b} \right) = 2.24 (J) + 1.00 (J_{-1}) - 98.5 - 1.64 (t)$$

where:

S = number of scrapped cars, in millions of cars

S_b = number of scrapped cars as calculated from age-scrappage relationships, in millions

J = non-workers' income earned during a year, in billions of dollars

J₋₁ = non-workers' income earned during a year, lagged one year

t = number of years passed since 1921 (the initial sample year)

The author assumed that S_b represents the number of cars scrapped in the absence of cyclical movements.

For the new-purchases demand, the author eliminated the cyclical movements by estimating a nine-year moving average, and then used a logistic curve adapted to the differences between production and scrappage. The logistic curve is fitted to the 1905 to 1934 period. Cyclical variations around the trend line were estimated as follows:

$$A = -0.65 (K) + 0.20 (N) + 3.36$$

where:

A = deviations between the long-run trend and new-purchase demand defined as automobile production minus scrappage, in millions of cars

K = price of cars, in hundreds of dollars

N = total corporation profits, in billions of dollars

Using the 0.65 price coefficient, the author estimated the annual price elasticities over the 1921 to 1934 period. These ranged from 1.0 in 1929 to 3.4 in 1932.

MODEL CONSTRUCTION

Data used to develop the model came from the Automobile Manufacturers Association; Behavior of the Automobile Industry in Depression, by Scoville, 1935; Statistics of Income; and Survey of Current Business.

REFERENCE

de Wolff, P., Demand for passenger cars in the United States, Econometrica, 6:113-129, April 1938.

ALTERNATIVE SPECIFICATIONS OF STOCK DEPLETION TO MODEL
DEMAND FOR CONSUMER DURABLES

These alternative models using the stock-adjustment approach to modeling consumer durable or automobile demand were developed in 1972 as part of a doctoral dissertation at the London School of Economics. The objective of the study was to examine the performance of several models based on variations of the stock-adjustment approach.

AUTHOR

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Monash University
England

KEYWORDS

Fleet size, scrappage, automobile demand

OBJECTIVE OF MODEL

The objective of these models is to predict new-car sales and the equilibrium stock of cars in the United Kingdom. Several models were estimated using different stock-adjustment approaches and two estimation techniques. The methodology has the potential for being used on U.S. data.

RELATIONSHIP TO OTHER MODELS

The models are not directly related to any other known models.

HISTORICAL BACKGROUND

For one of the models, the author employed an approach formulated by Houthakker and Taylor in their book, Consumer Demand in the United States: Analyses and Projections, Harvard University Press, 1970.

ASSUMPTIONS

The author assumed that a stock-adjustment approach for modeling quarterly automobile demand is appropriate. Three alternative specifications were tested, labeled A, B, and C.

LIMITATIONS AND BENEFITS

The author noted that the moving-average error-process models had the expected signs, but they had magnitudes that differed from the expected values. These problems may be associated with the assumptions concerning the error terms. The author notes that Model C implies an "unsatisfactory" scrappage distribution. Model A is preferred to Model C, and both specify long-term average patterns. Model B indicates that there existed significant short-run fluctuations around the long-term constant rate of stock depletion as specified in Model A. The author also notes that the parameters are "better determined" in Model B but that the implied elasticities are unreasonable.

STRUCTURE

Three alternative specifications of stock-adjustment models were included in this study. These are Model A: depreciation/scrappage is a constant proportion of stock; Model B: scrappage is a function of economic variables; and Model C: scrappage can be predicted using an estimated scrappage pattern. All models were estimated using a restricted least-squares technique. Models A and B were also estimated after assuming a moving-average error term.

All of the models are based on the following assumptions concerning adjustment of stocks to a long-term equilibrium level:

$$\Delta S_t = \rho (S_t^* - S_{t-1}) + v_{1t}$$

$$S_t^* = B_0 + B_1 (X_t) + v_{2t}$$

where:

ΔS_t = end-of-period stock at time t

S_t^* = equilibrium stock level at time t

X_t = relevant economic variable(s)

v_{it} = error terms

B_i, ρ = parameters to be estimated

Model A is based on the Houthakker-Taylor-formulated depreciation equation in continuous time, wherein depreciation is a constant proportion of the stock:

$$\dot{S}_t = q_t - d (S_t)$$

where:

\dot{S}_t = time rate of change of stock

q_t = purchase at time t

d = depreciation parameter

Using a discrete approximation to the above equation, Model A is formulated as:

$$q_t = \rho (d) B_0 + \rho B_1 (1 + d/2) \Delta X_t + \rho (d) B_1 (X_{t-1}) + (1 - \rho) q_{t-1} + u_t$$

and:

$$u_t = (1 + d/2) v_t - (1 - d/2) v_{t-1}$$

$$v_t = v_{1t} + \rho (v_{2t})$$

Model B is based on the assumption that the scrappage/depreciation rate (d) is a function of economic variables:

$$S_t = q_t + S_{t-1} - d_t (S_{t-1})$$

where:

d_t = a function of economic conditions at time t

After reformulating the above equation and incorporating the stock adjustment process, Model B is:

$$q_t = \rho (d) B_0 + \rho B_1 (\Delta X_t) + \rho (d) B_1 (X_{t-1}) + d_1 (\Delta Y_{1t}) - d_1 (1 - \rho) \Delta Y_{1t-1} + (1 - \rho) q_{t-1} + u_t$$

and:

$$u_t = v_t - (1 - d) v_{t-1}$$

where:

Y_i = economic variables defined such that the sum of ΔY_{it} for all i is approximately equal to zero

Model C is based on the assumption that new-car sales may be explained in part by the age distribution of the existing stock. Under this approach one would expect a sales boom year to produce a scrappage boom year after a certain length of time (i.e., average vehicle lifetime). The model is based on the following equations:

$$\Delta S_t = q_t - q_t^S$$

$$q_t^S = b_0 (q_t) + b_1 (q_{t-1}) + b_2 (q_{t-2}) + \dots$$

where:

$$q_t^S = \text{scrappage}$$

After incorporating the assumption that the pattern of scrappage is likely to follow an "inverted U" shape, the author formulated the following equation:

$$q_t = \rho B_0 (1 + a_1 + a_2) + \rho (B_1) X_t + \rho (a_1) B_1 (X_{t-1}) \\ + \rho (a_2) B_1 (X_{t-2}) + (1 - \rho + a_2) q_{t-1} - a_2 (1 - \rho) q_{t-2} + u_t$$

and:

$$u_t = v_t + a_1 (v_{t-1}) + a_2 (v_{t-2})$$

The table below contains the transformed estimation results with only two economic variables, income and price. These results are based on the restricted least-squares estimation. Those estimates based on the assumption of a moving-average error term are not presented. The dependent variable is new-car registrations per 100 population. Standard errors are in parentheses.

Coefficient	Model A	Model B	Model C
B_0 (constant)	-10.00 (4.94)	-11.65 (4.31)	-13.19 (7.13)
B_1 (Income per capita)	19.45 (8.39)	22.79 (7.33)	26.09 (12.35)
B_2 (real price)	-2.46 (1.67)	-3.01 (1.46)	-3.72 (2.34)
ρ	0.243 (0.092)	0.267 (0.080)	0.197 (0.089)
d	0.0956 (0.0440)	0.0796 (0.0278)	
d_3 (index of current and lagged income)		-0.703 (0.205)	
a_1			-0.679 (0.163)
a_2			-0.236 (0.167)
Durbin-Watson	2.25	2.27	1.94
R^2	0.973	0.979	0.974

MODEL CONSTRUCTION

The models were estimated using quarterly data from 1956 III to 1967 I. The sources of data are The Motor Industry of Great Britain, Economic Trends, and Monthly Digest.

REFERENCE

Williams, R.A., Demand for consumer durables: Stock-adjustment models and alternative specifications of stock depletion, Review of Economic Studies, 39:281-295, July 1972.

EXPLORATORY MODELS OF DOMESTIC AUTOMOBILE DEMAND

Exploratory models of domestic automobile demand were developed in 1938 at the Institute of Applied Econometrics. Several models were developed to examine the factors affecting automobile demand and to obtain estimates of how the separate factors combine to determine sales. Price and income elasticity ranges were estimated.

AUTHOR

C. F. Roos and Victor von Szeliski
Institute of Applied Econometrics

KEYWORDS

Automobile demand, fleet size

OBJECTIVE OF MODEL

The models examine the role of various determinants of the demand with the goal of estimating price and income elasticities.

RELATIONSHIP TO OTHER MODELS

These are not related to any other known models.

HISTORICAL BACKGROUND

These models were developed in one of the earliest studies of automobile demand. The model authors examined the strengths and weakness of two models, one by P. de Wolff (see 36-683) and an unpublished, unreferenced time trend study.

ASSUMPTIONS

The authors explored various model specifications and decided that a nonlinear sales relationship was appropriate. The authors assumed that a maximum ownership level could be determined. This was a forerunner to the desired-stock approach used in many recently developed stock-adjustment vehicle-demand models.

VALIDATION

The authors examined the performance of several model specifications over a historical period. Using those results as guidelines, they formulated their models on the appropriate determinants.

LIMITATIONS AND BENEFITS

The authors recognized that although their models fit the observations well, other models or formulas might be devised which may also fit the data. The models developed are shown to be improvements over previous models.

STRUCTURE

This study was wide in coverage and involved the following areas affecting automobile demand: new-owner sales, replacement sales, maximum ownership level, definition and measurement of various factors, scrappage and the pressure for replacement, retail sales demand functions, and seasonal variations in sales. Models were developed in the course of study, and several are presented below.

The authors examined many factors governing changes in automobile demand. These included: national income, cost of living, new-automobile price, used-car prices and stocks, cars in operation, used car allowances, financing terms, highway carrying capacity and car servicing facilities, operating costs, purchasing power sources other than income, dealers' used-car stocks, the prices of goods competitive with automobiles, the style factor, seasonal variation and new-model stimulus, price-change anticipation, field stocks and production, and the combination effect of the short- and long-term factors.

The authors formulated several models of the maximum ownership level:

$$M_1 = \text{POP} \times [0.087 + 0.000252 (I)]$$

$$M_2 = F \times [0.378 + 0.00068 (I)] (C)^{-0.3}$$

$$M_3 = F \times [0.500 + 0.000544 (I)] (D)^{.3}$$

where:

M_i = maximum ownership level

POP = population

I = real supernumerary income per capita with income defined as "disposable income less necessitous living costs"

F = number of families

C = vehicle replacement costs

D = durability

For new-car sales the authors formulated the following relationship, using data from 1919 to 1938:

$$S = I^{1.20} \times P^{-0.65} [0.0254 \times \text{STOCK} \times (M_3 - \text{STOCK}) + .65 (X_2)]$$

where:

S = new-car sales

I = supernumerary income

P = price

STOCK = stock of cars in operation

M_3 = maximum ownership level

X_2 = replacement pressure determined from the age distribution of automobile

As noted above, the authors explored many relationships and some of them were statistically estimated. Examples of these are factors of demand, replacement sales, and new-owner sales. The many other relationships are too numerous to be presented here. Most of these are single-equation models.

MODEL CONSTRUCTION

The authors used a number of data sources in developing their model. They attempted to compare, where possible, the alternative data series for various variables. Data used came from several sources, including the Automobile Manufacturers Association, Bureau of Labor Statistics, Bureau of Public Roads, General Motors Corporation, R. H. Donnelley Corporation, National Industrial Conference Board, the National Bureau of Economic Research, and the Department of Commerce.

REFERENCE

Roos, C.F.; von Szeliski, V., Factors governing changes in domestic automobile demand, The Dynamics of Automobile Demand, pp. 21-95, General Motors Corporation, December 1938.

HEDONIC PRICE INDEXES

A hedonic price index model was developed in 1938 at the Automobile Manufacturers Association. The objective of the study was the development of a "pure" price index that controlled for quality changes. The model was developed as an attempt to control for certain changes in the specifications of automobiles. This study pioneered the field of price indexes and quality change. A by-product of the study was the estimation of the implicit prices of various automobile characteristics.

AUTHOR

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KEYWORDS

Pricing

OBJECTIVE OF MODEL

The objective of the model is the measurement of the relationship between price and time, while holding quality (or usefulness) of automobiles constant. The author pioneered the approach wherein the price of a good is related to its characteristics or specifications.

RELATIONSHIP TO OTHER MODELS

This model is not related to any known models.

HISTORICAL BACKGROUND

This study was the pioneering article in the development of hedonic price indexes. Later work has built upon the approach presented here. Many are gathered in a book edited by Z. Griliches entitled Price Indexes and Quality Change (S-71-687).

ASSUMPTIONS

The approach is based on the assumption that the significance of automobiles' characteristics can be measured through associating the variations in the levels of characteristics and prices of various make and model automobiles within some time period. For the regression analysis, the author assumed a logarithmic form for the dependent variable and the actual vehicle specifications for the independent variables.

VALIDATION

The author linked the results from several time periods over the 1920-39 period to show the declining trend in automobile prices.

LIMITATIONS AND BENEFITS

The author noted that the usefulness of the regression results is limited because only the most easily available data were used for the example. The relevant vehicle characteristics need to be expanded to include measures of comfort, performance, dependability, and operating costs. The approach of using each vehicle make/model as an observation for the regression analysis ignores the sales level of (consumers' response to) the variety of product offerings.

A benefit to the approach is the estimation of the implicit prices associated with the various characteristics that define an automobile. Implicit prices are an indication of what aspects of the vehicle are valued most by consumers.

STRUCTURE

The model developed by the author involves a single equation that relates the log of an automobile price to its specifications. One version of the model includes time trend variables. The specifications or characteristics examined by the author are length, weight, and horsepower. The general equation is:

$$P = k + b_1 (W) + b_2 (L) + b_3 (H) + b_4 (t_1) + b_5 (t_2)$$

where:

P = vehicle price

k = constant

W = weight

L = length

H = horsepower

t_i = trend factors (dummy variables for years)

b_i = coefficients to be estimated

The author reported the regression results in the table below.

Years	Percent Change in Price				Coefficient of Multiple Correlation (R)
	per Inch	per Hundred Pounds	per Horsepower	per Year	
1920-25	2.01	2.35	0.80	-12.4	.96
1925-30	1.82	4.02	0.30	-7.1	.96
1930-35	0.31	5.66	0.55	-7.4	.95
1935-37	0.01	5.76	0.53	-2.5	.97
1937-39	0.15	2.95	0.71	+2.5	.93

MODEL CONSTRUCTION

The regression analysis was based on advertised vehicle prices. The source of the other data is undocumented.

REFERENCE

Court, A.T., Hedonic price indexes, with automotive examples, The Dynamics of Automobile Demand, pp. 99-119, General Motors Corporation, December 1938.

HOUSEHOLD VEHICLE HOLDINGS AND VALUE OF HOLDINGS

This model of household vehicle holdings and the value of holdings was developed in 1970 at the University of British Columbia under the sponsorship of the Canada Council. The objective of the model is to account for changes in car holdings, holdings themselves, and the value of the holdings associated with the demographic and economic characteristics of a spending unit. This disaggregate vehicle holdings model is based on multi-period cross-section survey data.

SPONSOR

Canada Council
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Ottawa, Ontario K1P 5V8
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AUTHOR

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KEYWORDS

Automobile demand, pricing

OBJECTIVE OF MODEL

The objective of this model is to account for changes in car holdings and the holdings themselves, and the value of holdings associated with the different events. The model is based on the hedonic demand theory that presumes the demand for a good can be determined by examining the demand for the variety of services that the good renders to a consuming unit. The model is estimated with U.S. data.

RELATIONSHIP TO OTHER MODELS

This model has no known relationship to any other model.

HISTORICAL BACKGROUND

The model is based on the theoretical approach presented by Kelvin J. Lancaster in "A New Approach to Consumer Theory" Journal of Political Economy, 74:132-157, 1966.

ASSUMPTIONS

The model authors assumed a logit model for the probability distribution of the alternatives in two equations.

LIMITATIONS AND BENEFITS

The model authors noted that the estimated coefficients are imprecise, probably because of collinearity. However, they conclude that the model successfully accounted for holdings and changes in car holdings, and associated expenditures.

STRUCTURE

The formal model is based on maximization of a consumer's utility function. Elements in the function included car services, other goods, and assets. Utility is maximized subject to a budget constraint that includes income, monetary assets, value of the stock of automobiles, value of other goods, and in one version, the transactions cost of changing automobile holdings.

Two statistical models were used in the study. For the probability aspects, the authors used an extension of the logit model as developed by Henri Theil in "A Multi Normal Extension of the Linear Logit Model," International Economic Review, 10:251-60, Oct. 1969. In that model, the probability of alternative j occurring at observation t , $P(A_{jt})$, is:

$$P(A_{jt}) = \exp[X_t (B_j)] / \sum_{i=0}^k \exp[X_t (B_i)], j = 1, \dots, k$$

$$B_1 = 0$$

where:

X_t = vector of independent variables

B_j = vector of coefficients

The second model that was applied to the expenditure aspects of the study is specified as follows:

$$P_t = Z (Y_j) + E_t$$

where:

P_t = amount

Z = vector of independent variables

Y_j = vector of coefficients that are appropriate when alternative j is chosen

E_t = normally distributed error term

The distribution of P_t is truncated such that P_t can not take on negative values.

Using the probability model, (or Simultaneous Alternatives Model as named by the authors), the following coefficients were estimated by means of a maximum likelihood technique:

- Current and lagged disposable income
- Current disposable income squared
- Amount in savings bonds, savings accounts and checking accounts
- Age of head of spending unit
- Number of adults in spending unit
- Number of children
- Location dummy, = 1 if central city, 0 otherwise
- Dummy variable for car holdings at time of previous survey
- Value of "first" car in survey
- Value of additional cars
- Ages of cars

For the changes in car holdings, the dependent probability variables involve selling a car, replacing a car, and purchasing an additional car. For the changes in the number of cars held, the dependent probability variables involve the holding of one, two, or three cars. Both models were estimated for 1961 and 1962. These alternatives were simultaneously estimated with each function of a subset of the selected independent variables.

Using the expenditure model, the amounts spent on replacements and additions were estimated as functions of subsets of the socio-economic variables. As above, the model was estimated for 1961 and 1962.

MODEL CONSTRUCTION

The models are based on cross-section data obtained from the 1960, 1961, 1962 Surveys of Consumer Finances conducted by the Survey Research Center of The University of Michigan.

REFERENCE

Cragg, J.G.; Uhler, R.S., Demand for automobiles, Canadian Journal of Economics, 3(3):386-406, August 1970.

AUTOMOBILE STYLE CHANGE

This model of automobile style changes was developed in 1971 while the authors were at the University of Virginia and Virginia Commonwealth University. The model was developed as part of a study examining the impact of style change on profitability and market share. Part of the study also examined the use of style change as a market weapon by large manufacturers against smaller manufacturers.

AUTHOR

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George Hoffer
Virginia Commonwealth University
Richmond, Va.

KEYWORDS

Automobile design, industrial financial performance, market share, automobile supply

OBJECTIVE OF MODEL

The objective of the model is to predict the impact of style changes on the market shares and profits of the Big Three automakers in low- and high-priced fields.

RELATIONSHIP TO OTHER MODELS

This has no known relationship to any other model.

HISTORICAL BACKGROUND

The study was in part a test of a hypothesis developed by J.A. Menge in 1962 (Style Change Costs as a Market Weapon, Quarterly Journal of Economics 76:632-47). Menge suggested that style changes could be used as a market weapon by large manufacturers because of their relative cost advantages.

ASSUMPTIONS

One of the equations relates market share to style costs and vehicle prices. This approach assumes that the excluded variables affect all manufacturers equally. A similar assumption was also employed for the models that have profitability as a function of only style costs and

prices. That is, the level of sales and the determinants of the level were assumed to have equal impacts on the market shares and profitability of all manufacturers. The model authors noted that because of the expected autocorrelation, the equations appear in first-difference form.

VALIDATION

The model authors suggested a priori values for certain estimated coefficients and compared those values to the estimated ones. The comparison of coefficient values was a test of several hypotheses that were presented. The authors noted that Menge's style hypothesis was not necessarily confirmed.

LIMITATIONS AND BENEFITS

The authors found that the relative price and style changes can affect the market shares in both the high- and low-priced fields. The payoff of style changes was about breakeven for low-priced cars. For high-priced cars, no firm appeared to profit. As for some of the assumptions, a limitation of the profitability equations is that the authors used firm-wide profits and sales, not the profits accruing from the sale of the pertinent automobile models.

STRUCTURE

Equations were estimated with market shares and profitability as dependent variables. Three car models, Chevrolet, Ford, and Plymouth, were chosen for the low-priced field. Three models were also selected for the high-priced field: Cadillac, Lincoln, and Imperial. No other brands/models were considered. For each field, the equations were estimated using data for pairs of the brands and, where feasible, a single brand.

The market share equation is specified as follows:

$$\Delta M_{i,t} = a_0 + a_1 (\Delta D_{i,t}) + a_2 (\Delta P_{i,t}) + U_{a,t}$$

where:

$$\Delta M_{i,t} = M_{i,t} - M_{i,t-1} = \text{gain in brand } i \text{ share of total market (in units sold) in period } t$$

$$\Delta D_{i,t} = \Delta C_{i,t} - \sum_{j \neq i} \Delta C_{j,t}$$

= difference between the style change outlays of firm i and those of all other firms

$$\Delta P_{i,t} = P_{i,t} - P_{i,t-1} - \frac{1}{n-t} \sum_{j \neq i} (P_{j,t} - P_{j,t-1})$$

= difference between the price change of firm i and the average of the other firms' price changes for period t

a_i = coefficients to be estimated

$U_{a,t}$ = a normally distributed random error

The single-equation model for the profitability of the style changes is specified as follows:

$$\Delta R_{i,t} = b_0 + b_1 (\Delta C_{i,t}) + b_2 \left(\sum_{j \neq i} \Delta C_{j,t} \right) + b_3 (\Delta P_{i,t}) + U_{b,t}$$

where:

$\Delta R_{i,t}$ = expected gain in brand i profit in period t

$\Delta C_{i,t}$ = outlay required for style change by brand i in period t

$\Delta C_{j,t}$ = outlay required for style changes by brand other than brand i in period t

$\Delta P_{i,t}$ = difference between price increase of firm i and average price increase of the other firms

b_i = coefficients to be estimated

$U_{b,t}$ = normally distributed random error

Each of the equations is estimated several times, using different brand combinations within both the high- and low-priced fields. The estimated coefficients and their related statistics are presented in the paper.

MODEL CONSTRUCTION

The sources of data used in the regressions were Moody's Industrial Manual, Automotive Industries, Consumer Reports, and Changing Times. The sample period for high-priced cars was 1955 to 1966 and was 1954 to 1959 for low-priced cars.

REFERENCE

Sherman, R.; Hoffer, G., Does automobile style change payoff, Applied Economics, 3:153-165, 1971.

AUTOMOBILE CONSUMPTION BY STATES, 1940-1950

This model, which relates the consumption of automobiles to depreciation and income cross-sectionally by states, was developed in 1957 at Duke University, with funding partly from the Rockefeller Foundation.

SPONSOR

Rockefeller Foundation
New York, N.Y.

AUTHOR

Robert A. Bandeen
Duke University
Durham, N.C.

KEYWORDS

Automobile demand

OBJECTIVE OF MODEL

The consumption of automobiles is related to income by using data from each state for the two years 1940 and 1950 as cross-sectional observations. The objective was to study the relationship between income and consumption of durable goods, of which automobiles are relatively important. This is a historical example of an attempt to model automobile demand with cross-sectional data.

RELATIONSHIP TO OTHER MODELS

There is no relationship to other models.

HISTORICAL BACKGROUND

This model was part of the Study of Differences in State Per Capita Incomes at Duke University. The model author subsequently worked for the Canadian National Railways.

ASSUMPTIONS

The consumption of automobiles during a year is defined as the depreciation of new and used autos registered during the year. Depreciation is assumed to be a function, in a particular year, of the prices of new and used cars coupled with their age and make

distribution. Consumption is assumed to be a function of consumer's income. Used-car age composition and depreciation pattern and the new-car trade-name mix are assumed to remain constant over the period studied.

VALIDATION

New car purchases for 1953 were predicted using the estimated formula and the differences between 1950 and 1953 of state per capita income and population density in each state. Aggregate 1953 auto consumption was then obtained by multiplying the per capita figures by 1953 state population. The state percentage differences between predicted and actual values have a weighted standard deviation of 8.2 percent around a weighted mean of -0.7 percent.

LIMITATIONS AND BENEFITS

The income sensitivity of auto consumption differs from the more familiar sensitivity of new-car purchases, which ignores used-car depreciation. In this model new-car consumption is postulated as the residual of total consumption less used-car consumption, and will fluctuate more widely with income.

STRUCTURE

The estimated depreciation of a specific make and model year used car was based on the difference in the "average base value" of a standard 4-door sedan from one year to another, correcting for general price changes and differences between model and calendar years. State population density is introduced as a variable to reflect changes among the states during the period studied. It shows that a smaller portion of income is devoted to automobile consumption in the more densely populated states, probably because of parking problems and the availability of alternative means of transportation. The following formula was estimated showing the differences between the two years:

$$C_{50}/C_{40} = .95 (Y_{50}/Y_{40})^{.89} (P_{50}/P_{40})^{-.30}$$

$$R^2 = .84$$

where:

C_t = state per capita automobile consumption in year t, 1940 or 1950

Y_t = state per capita income

P_t = state population density

New-car consumption is the residual of the total consumption found above, less the used-car consumption, which is estimated from the number of used cars registered in a state and their price.

The income sensitivity of auto consumption is found to be about 0.9.

MODEL CONSTRUCTION

The years 1940 and 1950 were selected for their relative freedom from abnormal influences. Data came from R.L. Polk, Automotive News Almanac, Ward's Automotive Reports, and Red Book's National Used Car Market Reports. The data used in estimation are presented in the paper. Least-squares regression was used.

REFERENCE

Bandeem, R.A., Automobile consumption, 1940-1950, Econometrica, 25:239-48, April 1957.

CONSUMER CAPITAL GOODS PRICE AND QUALITY CHANGE

The price and quality changes of consumer capital goods were modeled in 1967 at the Wharton School of Finance and Commerce of the University of Pennsylvania. The paper was commissioned by the Price Statistics Committee of the Federal Reserve Board. The objective of the models is to investigate the price and quality changes of automobiles.

SPONSOR

Federal Reserve Board
Price Statistics Committee
Washington, D.C.

AUTHOR

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Wharton School of Finance and Commerce
Department of Economics
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KEYWORDS

Pricing

OBJECTIVE OF MODEL

Several single-equation models were estimated in the course of an empirical investigation into price and quality changes in consumer durable goods, specifically automobiles and refrigerators. (Each good has its peculiarities and only autos are discussed in this summary.) Pure-price indexes for the sample period were developed from regressions that relate vehicle price to various vehicle attributes, such as horsepower, weight, and length.

RELATIONSHIP TO OTHER MODELS

These models have no interaction with any other models.

HISTORICAL BACKGROUND

This study built on the work by A.T. Court (38-689) and Griliches (61-682) in the field of hedonic price indexes. It provided evidence of the importance of manufacturer market shares in hedonic price modeling. The study concentrated on five issues: functional form of the relation between price and attributes; the extent of homogeneity of the price-attributes relation among manufacturers; the meaning of the estimated

coefficients of the relation; the feasibility of routinely constructing quality-corrected price indexes; and the empirical results over the sample period.

An earlier version of this paper is: Dhrymes, P.J., On the measurement of price and quality changes in some consumer capital goods, American Economic Review 57:501-518, 1967.

ASSUMPTIONS

Fundamental to the approach employed is the assumption that a price of an automobile can be explained in part by the levels of characteristics inherent in the automobile.

VALIDATION

The author employed statistical techniques to test the hypothesis that the price-attribute relation is homogenous among manufacturers. His finding of heterogeneity of pricing behavior has implications for the application of the model in producing quality adjusted (hedonic) price indexes. The study results suggested that estimated coefficients of the various attributes are best viewed as the manufacturer's evaluation of the role of the attributes in an overall price strategy rather than the market's (consumer) implicit evaluation of such attributes.

LIMITATIONS AND BENEFITS

The author noted that a limitation in the approach is the exclusion of several important variables such as frequency-of-repair. These specification errors may create doubt about the results. A major benefit is that the results show the need for using market shares of the various manufacturers in estimating the price effects.

STRUCTURE

The single-equation models developed in this study related vehicle price to various vehicle attributes such as horsepower, length, and weight. Three possible alternative forms for the equations were examined: linear, semilog, and double log. After estimating equations in the alternative forms, the semilog form was selected. Because the data by manufacturers were rather clustered, the author employed a principal-components technique to overcome the difficulty. The principal components of the variables, weight, length, displacement, and brake horsepower, were obtained for each manufacturer. The components were obtained from the correlation matrix of the four variables. The two largest roots derived in the technique in general account for over ninety-seven percent of the sum of the four characteristic roots. Using this approach, versions of the following general equation were estimated

for each of three manufacturers over six different years and for two other manufacturers over four different years.

$$\ln(P) = a_1 + a_2 (Z_1) + a_3 (Z_2) + a_4 (C) + a_5 (MOD) + a_6 (DOR) \\ + a_7 (ATR) + a_8 (PS)$$

where:

P = price of the vehicle

Z_i = principal components of weight, length, displacement, and brake horsepower, $i = 1, 2$

C = dummy variable, = 1 if model of car has 8 cylinders, = 0 otherwise

MOD = production (in units of 100) of relevant basic model

DOR = dummy variable, = 1 if model has two doors, = 0 otherwise

ATR = dummy variable, = 1 if model has automatic transmission as standard equipment, = 0 otherwise

PS = dummy variable, = 1 if model has power steering as standard equipment, = 0 otherwise

a_i = coefficients to be estimated

Using the "prices" of attributes obtained in such regressions, the author estimates the quality and price components movement during the sample period. The quality-adjusted price indexes were calculated using two methods, one that estimates the standardized price of "quality" embodied in the average model, and the other that estimates the price over time for a given "quality." These results are presented in the article.

MODEL CONSTRUCTION

Sources of data for estimation of the model include: Ward's Automotive Reports and Automotive Industries. The sample years are 1953, 1957, 1961, 1962, 1963, and 1964.

REFERENCE

Dhrymes, P.J., Price and quality changes in consumer capital goods: An empirical study, Price Indexes and Quality Change, pp. 88-149, ed. Griliches, Z., Cambridge: Harvard University Press, 1971.

EXPLORATION OF AUTOMOBILE QUALITY CHANGE

This exploratory model of automobile quality change was developed in 1963-64 while the author held a Ford faculty fellowship at Brown University. Support for the study was provided by the Ford Foundation and the Brown Computing Laboratory. The objective of the study was to develop a new method of measuring the quality and price changes of automobiles. The exploratory model is based on used-car prices and estimated depreciation rates rather than on new-car prices and characteristics, as is employed in the usual hedonic price index approach.

SPONSOR

Ford Foundation
New York, N.Y.

AUTHOR

Phillip Cagan
Brown University
Providence, R.I.

KEYWORDS

Pricing, scrappage

OBJECTIVE OF MODEL

The objective of this model is to estimate quality and "pure" price changes associated with automobiles. The model was developed as an exploratory method of measuring quality and price changes based on used-car prices as opposed to new-car prices.

RELATIONSHIP TO OTHER MODELS

This has no known relationship to any other model.

HISTORICAL BACKGROUND

This study is one of many that attempt to develop quality-adjusted price indexes. It is a departure from other studies in that it is based on used-car prices and the hedonic price index technique based on the regression of price on vehicle attributes is not employed. The model author was later at Columbia University.

ASSUMPTIONS

Because the model is based on the used car market, the author needed to make certain assumptions about quality and depreciation. First, quality improvements are assumed to endure to benefit subsequent owners and are reflected in used car prices. Second, the depreciated values for a particular car are assumed to approximate a certain average rate of decline over a period of years. Third, the value of a model of car over time approximates a declining exponential curve.

VALIDATION

The model author compared the quality change index developed in his study to the index developed by Griliches using a hedonic price index technique (see 61-682). Although there are different derivations and model coverage, the indexes were noted to have "considerable similarity." The author also compared his quality-adjusted price index to that of the Consumer Price Index. He concluded that the comparison of the two price indexes showed the importance of the need for further research on quality change.

LIMITATIONS AND BENEFITS

The approach is limited by the requirement of a functioning second-hand market. This limits its application to only a few goods. The approach is also limited in the sense of timeliness. Unlike new-good prices, used-good prices are available only with some delay to allow the market to function. The author also noted that extension of the data beyond the models used in this study would have been useful. Monthly, rather than quarterly, data could also be used. Using used-car prices has its benefits in that it reflects the market valuation of quality changes rather than possibly identifying the manufacturer's pricing policies as indicated in list prices.

STRUCTURE

Used-car prices are composed of three elements: (1) a "pure" price index reflecting general purchasing power of a dollar, applicable to all cars; (2) a quality index, representing the merits of particular year models; and (3) a depreciation factor, representing the value of a particular model as a fraction of its original value. With quality assumed constant over the life of the car, the price vector for a model year is:

$$P_t (Q_i), \quad P_{t+1} (Q_i) d_{i,1}, \quad P_{t+2} (Q_i) d_{i,2}, \quad \dots$$

where:

P_t = pure price index at time t

Q_i = quality index for model year i cars

$d_{i,k}$ = value of model i at age k as a fraction of its original value

The model author assumed that the depreciated values for a certain car approximate a certain average rate of decline over a period of years. That is,

$$d_{i,1} \times d_{i,2} \times \dots \times d_{i,L} = D^{\left(\sum_1^L k\right)}$$

where:

D = average rate of decline in value over L years

The ratios of the prices of two successive model years in each of L consecutive periods is:

$$\frac{P_{t+n} (q_{i+1}) d_{i+1,k-1}}{P_{t+n} (Q_i) d_{i,k}} \quad \text{where } k = n = 1, \dots, L$$

and have the geometric mean:

$$\frac{q_{i+1}}{q_i} \left(\frac{d_{i+1,1} \times d_{i+1,2} \times \dots \times d_{i+1,L-1}}{d_{i,1} \times d_{i,2} \times \dots \times d_{i,L}} \right)^{1/L} = \frac{q_{i+1}}{q_i \times D}$$

With a value for D and setting $Q_0 = 1$, a quality index can be calculated. The author estimated values for D by examining those successive model years during the period 1947 to 1960 and using 16 successive quarters for the geometric means. The estimated depreciation rates ranged from 21.0 to 29.8 percent per year depending on make, number of cylinders, and price of car. Using these D values by make of car, the author derived estimates for quality and price changes over the period 1954 to 1960. The results indicate that prices adjusted for quality rose about 2.6 percent per year over that period. The appendix to the article contains a proposal for estimating depreciation drift, which is the tendency for the average rate of depreciation of successive model years to change slightly.

MODEL CONSTRUCTION

This model was estimated using data from the Official Used Car Guide of the National Automobile Dealers Association and Consumer Reports.

REFERENCE

Cagan, P., Measuring quality changes and the purchasing power of money:: An exploratory study of automobiles, Price Indexes and Quality Change, pp. 215-239, ed. Griliches, Z., Cambridge: Harvard University Press, 1971.

INTERNATIONAL DIESEL ENGINE PRICE COMPARISONS

Models of comparison of international diesel engine prices were developed in 1969 under the partial sponsorship of the National Science Foundation through grants to the National Bureau of Economic Research. The objective of the study was to develop new methods of measuring price competitiveness in the international trade of diesel engines. Several single-equation models were developed using an hedonic price approach relating the price of an engine to the level of its attributes.

SPONSOR

National Science Foundation

AUTHOR

Irving B. Kravis and Robert E. Lipsey
National Bureau of Economic Research

KEYWORDS

Automobile supply, pricing, trucks

OBJECTIVE OF MODEL

This study sought to develop new methods of measuring price competitiveness in international trade. In the course of the study, several models were developed to estimate diesel engine prices based on observations of different engines that contain varying levels of certain engine attributes, such as weight.

RELATIONSHIP TO OTHER MODELS

These models have no known relationship to any other models.

HISTORICAL BACKGROUND

Based on an hedonic index approach pioneered by A.T. Court (see 39-689), the authors of these models applied the technique to engine prices and attributes available in France, West Germany, the United Kingdom, and the United States. Through the use of the technique, the authors were able to estimate the relative price advantage of engine production in the various countries.

ASSUMPTIONS

The models are based on the hedonic approach that assumes that the price of a good can be allocated to the levels of attributes in the good. Furthermore, the importance of the various determinants can be identified through the use of a regression technique using cross-section data. Because the attribute list imperfectly represents all of the important attributes, the authors noted that they had to assume that the relation between the missing attributes and the true utility attributes does not differ across countries, or if it does, the differences do not affect the price comparisons.

VALIDATION

In the process of developing the "best" models, the authors used a set of criteria that involved both economic and statistical considerations. These criteria governed the inclusion and exclusion of variables and the functional form of the estimated equation.

LIMITATIONS AND BENEFITS

A benefit of this approach is its capability of measuring price differences between countries, even when comparable engines are not produced in all countries. A limitation of the models is that all of the relevant attributes may not have been included in the regressions. This specification error, caused in part by the unavailability of data, could have led to questionable results. The authors noted that this may have in part produced the result that U.S. engines are relatively more expensive than the European ones.

STRUCTURE

In developing the single-equation models, the authors experimented with several specifications and data handling techniques. The primary relationship is that the price of an engine is a function of the levels of its attributes. The attributes considered by the authors are mean effective pressure (the amount of pressure that operates on each cylinder), displacement, weight, and revolutions per minute (rpm). To obtain mean effective pressure, the authors used an engineering relationship that involved horsepower, displacement, rpm, and mean effective pressure. Because of this engineering relationship, only three of these related variables can be included in a regression. The model authors chose to exclude horsepower, for several reasons.

For the equations, the authors fitted several mathematical forms: linear, semilog, inverse semilog, and double log. After estimation, the inverse semilog and double log forms were selected as preferable, because they estimated the percentage price difference between countries. Of these two, the double log form was preferable because of its multiplicative relationship among the independent variables.

Three types of regressions were tried. The first type involved pooling all data with the assumption that the attribute prices are equal across all countries. The general functional form is:

$$P = f(M, D, W, R, K, G, F)$$

where:

P = price of an engine

M = mean effective cylinder pressure

D = displacement

W = weight

R = revolutions per minute

K = dummy variable for U.K. engines

G = dummy variable for German engines

F = dummy variable for French engines

The second type was to fit a separate regression for each country:

$$P_i = f_i(M, D, W, R)$$

where:

P_i, f_i = prices and functions particular to a single country, United Kingdom, United States, West Germany, or France

The third type is referred to as "flexible pooling." The data were pooled, but interaction variables were used to allow for international differences in the prices of the attributes. That general function is:

$$P = f'(M, D, W, R, K, G, F, KM, KD, KW, KR, GM, GD, GW, GR, FM, FD, FW, FR)$$

The results of several of the regressions are presented in the report. The authors concluded that the reasonable regression results show a U.K./U.S. price ratio that ranged from .68 to .70 and a German/U.S. price ratio of .81 to .85 (the U.S. = 1.00).

MODEL CONSTRUCTION

The data used to estimate the single-equation models were from 1962 and concern 73 automotive diesel engines. The data were supplied by firms manufacturing diesel engines.

REFERENCE

Kravis, I.B.; Lipsey, R.E., International price comparisons by regression methods, chapter 5 of Price Indexes and Quality Change, pp. 150-179, ed. Griliches, Z., Cambridge: Harvard University Press, 1971.

VINTAGE QUALITY CHANGE

This model of the quality change of vintages of vehicles was developed in 1971 while the author was at the Massachusetts Institute of Technology. The model was developed to determine pure price and quality change of pickup trucks over the 1961 to 1967 period. The equations are based on second-hand market price data for several vintages. One of the equations is based on a modified hedonic price theory approach.

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KEYWORDS

Pricing, trucks

OBJECTIVE OF MODEL

The objective of this model is to explain the prices of used pickup trucks as a function of quality change, deterioration, and depreciation. One of the equations developed extends the approach by using a modified hedonic price model that relates quality change to the characteristics of the truck. The model was developed in a study that attempted to measure quality change based on vintage price data.

RELATIONSHIP TO OTHER MODELS

This model is not related to any other known models.

HISTORICAL BACKGROUND

The author noted that the paper is essentially a "formalization and refinement" of work by Phillip Cagan (see 64-695). Unlike many models of quality change, the model developed in this study is based on the prices of used vehicles.

ASSUMPTIONS

Several assumptions (hypotheses) regarding the change in quality over time were tested, such as exponential and non-exponential quality change trends. The hedonic price equations are based on the assumption that quality change is a function of the characteristics of light trucks.

VALIDATION

The author compares the results of the quality-adjusted price indexes for pickup trucks derived in the study to several other indexes: Wholesale Price Index for motor trucks, Consumer Price Indexes for new and used cars, and a list price index. The results of the comparison indicated that the index based on data from the used-truck market may measure actual transaction prices for new trucks better than does the list price or the Wholesale Price Index for trucks. In addition, the comparison showed that the rising unit price of pickups during the 1961-67 period was probably not a result of quality improvement.

LIMITATIONS AND BENEFITS

The benefit of this model is the removal of several constraints existing in the model developed by Cagan. Furthermore, additional hypotheses about the time path of quality change can be tested with this model. This quality change model is one of the few models concerning pickup trucks or second-hand market data.

STRUCTURE

Based on the hypothesis that the price of a capital good is equal to the present value of its future services, the author formulated the following behavioral equation:

$$P_{t,a} = b_{t-a} (P_t) \sum_{s=0}^{n-a-1} \left(\frac{1}{1+r}\right)^s M_{a+s}$$

where:

$P_{t,a}$ = the price at time t of a capital good of age a

b_{t-a} = an index of embodied technical change

P_t = rental price of capital services uncorrected for disembodied technical change

N = life in years of capital good

r = interest rate (assumed constant over time)

M_{a+s} = an index of deterioration at an age of a good

After a change of variables, the equation to be estimated is:

$$\log(P_{t,a}) = \log(\bar{P}_t) + \log(b_{t-a}) + \log(D_t) + U_{t,a}$$

where:

$P_{t,a}$ = observed price of a used capital good

\bar{P}_t = quality-corrected price index

b_{t-a} = index of embodied technical change

D_t = index of depreciation

$U_{t,a}$ = random disturbance

All right-side variables are dummy variables, and the estimated coefficients are the logs of the three indexes. Several normalization assumptions are required prior to estimation. Using this model the author performed several regressions under alternative assumptions and normalizations. These concerned the path of quality change and the relation between the two makes studied (Chevrolet and Ford) for the years 1961 to 1967.

An example of a regression equation is presented in the table below.

REGRESSION RESULTS FOR CONSTANT RATE OF QUALITY CHANGE
CHEVROLET PICKUP TRUCKS

Year	Price Index		Age (years)	Depreciation Index	
	$\log(\bar{P}_t)$	\bar{P}_t (dollars)		$\log(D_a)$	D_a
1961	7.318	1508	1	0	1.000
1962	7.355	1564	2	-0.181	0.834
1963	7.334	1532	3	-0.367	0.693
1964	7.419	1667	4	-0.552	0.576
1965	7.467	1749	5	-0.771	0.463
1966	7.489	1788	6	-1.027	0.358
1967	7.466	1747			

Standard error of regression = 0.060. Standard errors of parameters = 0.032. $R^2 = 0.980$.

The author also developed a modified hedonic price model under the assumption that quality change is a function of the characteristics of capital goods. Examples of the characteristics are weight, power, and size. Using information on the characteristics, the author constrained the earlier models to allow for no quality change to occur between certain model-year trucks. Additional regressions were performed with a

set of characteristic variables included in the equation. The following characteristics were included: wheelbase, weight, ratio of bore to stroke, horsepower, torque, and tire width.

From the estimated models, the author developed several indexes of quality change. These were used in developing quality-adjusted price indexes.

MODEL CONSTRUCTION

Regression results were based on data from the National Automobile Dealers Association Official Used Car Guide.

REFERENCE

Hall, R.E., Measurement of quality change from vintage price data, Price Indexes and Quality Change, pp. 240-271, ed. Griliches, Z., Cambridge: Harvard University Press, 1971.

WEST GERMANY/U.S. HEDONIC TRUCK PRICES

Hedonic models of international truck prices were developed in 1976 by Charles River Associates, Inc. under the sponsorship of the Motor Vehicle Manufacturers Association of the United States, Inc. The study assesses the impact of changes in U.S. and foreign trade barriers on the U.S. truck industry. In the course of the study, a hedonic price model is formulated that relates the price of a truck to its horsepower and gross vehicle weight.

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KEYWORDS

Pricing, trucks

OBJECTIVE OF MODEL

The objective of the models developed in this study is to predict the price of an identical European-style truck produced in Europe by European manufacturers and produced in the U.S. by U.S. manufacturers. The model was developed as part of a study assessing the impact of changes in U.S. and foreign trade barriers on the U.S. motor truck industry. The study concentrates on the potential exports to the European Economic Community member countries.

RELATIONSHIP TO OTHER MODELS

The models have no known relationship to any other models.

HISTORICAL BACKGROUND

This study was performed in conjunction with another study involving a hedonic price approach. That other study concerned the trade and manufacturing of automobiles only and is entitled Cost-Benefit Analysis of the Effects of Trade Policies on Product and Labor Markets in the U.S. Automobile Industry, by Charles River Associates Inc. under the sponsorship of the U.S. Department of Labor. Several models were

developed in the automobile study including the CRA Hedonic Market Shares Model (see 76-025). The hedonic truck price model presented here is not based on the CRA Hedonic Market Shares Model, but rather on the hedonic price index literature.

ASSUMPTIONS

The different hedonic price regressions involve various assumptions about the price-characteristic relationships in West Germany and the U.S. In the course of the study, the authors assumed that the model results based on West German prices were indicative of truck prices elsewhere in Europe.

VALIDATION

Based on predicted prices computed by the estimated equations, the authors suggested that the U.S.-built medium- and heavy-duty trucks could be sold in Europe if service and marketing facilities were adequate and if the tariffs of the European Economic Community were eliminated.

LIMITATIONS AND BENEFITS

The authors noted that the regression results should be cautiously interpreted for several reasons. First, factors other than horsepower and weight are important determinants of price and fuel economy. Because of the lack of data, these factors were not included in the regressions. These other factors may indicate other dimensions of demand not considered by the authors. Second, list prices may overstate the relative cost advantages for U.S. producers. European producers are fewer in number and this may lead to a higher mark-up on European-produced trucks. Third, the cross-section data does not consider the market shares of the various models of trucks, only the characteristics of each available model.

The major benefit of the approach is that comparable models of trucks can be priced according to their place of production based on available currently produced truck models. That is, even though U.S. manufacturers do not currently produce a European-style truck, the potential price of such a truck can be predicted based on its characteristics, i.e. weight and horsepower.

STRUCTURE

To examine the price competitiveness of the U.S.-manufactured trucks in Europe, the authors developed several single-equation hedonic price models to predict prices of comparable imported and domestic trucks. Hedonic price equations were estimated with truck price as a function of gross vehicle weight (GVW) and horsepower. These equations, once estimated, can be used to estimate the cost of producing European-style

trucks in the U.S. for the European market. Equations were estimated using cross-section data of U.S. and West German model trucks. Separate equations were estimated for each of the three different weight classes: light (GVW < 10,000 lbs.), medium (10,000 lbs. \leq GVW \leq 33,000 lbs.), and heavy trucks (GVW > 33,000 lbs.). Equations were estimated by pooling all models from both countries and including a dummy variable for the U.S., and separately for each country of manufacture by dropping the country-specific dummy variable. An example of the regressions is the equation for medium trucks:

$$\log(\text{PRICE}) = 8.435 + 0.00004189 (\text{GVW}) + 0.002635 (\text{HP}) - 0.2213 (\text{US})$$

(226.1) (16.81) (7.656) (7.897)

where t-statistics are in parentheses, and

PRICE = list price for European trucks; estimated West German price for U.S. trucks (sum of list price and transport cost for diesel trucks; sum of list price and transport cost multiplied by 1.47 for gasoline trucks)

GVW = gross vehicle weight

HP = brake horsepower

US = dummy variable for American trucks; equal to one if made in U.S., zero otherwise

In the course of the study, the authors also estimated several equations relating U.S. gasoline-truck prices to U.S. diesel-truck prices. Both linear and semilog forms were estimated. The semilog form was preferred and is presented below. The equation was estimated for the U.S. trucks in the 21,000 lbs.-28,000 lbs. weight class.

$$\log(\text{PRICE}) = 7.083 + 0.00008716 (\text{GVW}) + 0.0004465 (\text{HP})$$

(31.12) (7.046) (0.58)

$$+ 0.4731 (\text{DIESEL})$$

(9.49)

where t-statistics are in parentheses, and

PRICE = list price

GVW = gross vehicle weight

HP = horsepower

DIESEL = dummy variable for diesel truck; equal to one if diesel-powered, zero otherwise

This regression estimates a 47% higher price for trucks powered by diesel engines.

MODEL CONSTRUCTION

The estimations were based on data from the Truck Blue Book, International Automotive Industries, Nutzfahrzeug, and International Harvester.

REFERENCE

Analysis of the effects of trade policy changes on the U.S. truck industry, final report, Charles River Associates, Inc., April 1976.

HEDONIC PRICE INDEXES FOR UNITED KINGDOM CARS

Hedonic price indexes for cars sold in the United Kingdom were developed at the University of Warwick in 1972 with the support of a grant from the Centre for Industrial Economic and Business Research, University of Warwick. The objective of the models is to produce quality-adjusted price indexes and unadjusted price indexes to show the advantages of the former.

SPONSOR

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Centre for Industrial Economic and Business Research
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AUTHOR

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KEYWORDS

Pricing

OBJECTIVE OF MODEL

The objective of the models is to produce quality-adjusted (hedonic) price indexes. The price indexes were estimated based on regressions that had car price as the dependent variable and levels of attributes as the independent variable.

RELATIONSHIP TO OTHER MODELS

This model has no known relationship to any other model.

HISTORICAL BACKGROUND

These models were based on earlier work by the authors and other researchers, Court (see 38-689) and Griliches (61-682).

ASSUMPTIONS

As with other hedonic price index studies, the authors hypothesized that the price of cars can be explained by the qualities or attributes inherent in the cars. The estimated implicit prices of the attributes can then be used to evaluate changes in the quality of cars and the development of a "pure" price index.

VALIDATION

As an effort to validate the use of hedonic price indexes, the authors calculated alternative hedonic price indexes and compared the results to other indexes describing year-to-year changes in price. The five indexes compared by the authors are:

- (1) a "crude" price index that is simply the average price, weighted by numbers sold;
- (2) the "established models" index that does not "account for changes in quality-adjusted price brought about by the introduction of new models, or improvements in old models";
- (3) an unweighted index based on a price series, supplied by the Board of Trade, that considers quality adjustment based on cost to manufacturer of the improvement;
- (4) a chain index based on hedonic price relatives between periods; and
- (5) an alternative hedonic price index that is based on the median shadow price estimate for each characteristic.

The authors show that the hedonic price indexes have minimal differences and that the two hedonic price indexes have a lower trend and a higher coefficient of variation than the unadjusted series. The authors also tested four alternative indexes of quality change by performing a set of regressions that have the quality index as a function of the size-class market shares of new vehicles sold in Great Britain. Size-class was determined by engine size. The authors found that only the two hedonic quality indexes yielded significant regressions. The authors expected that a good quality index indicating the trend of the average-quality car should be responsive to changes in the size-class market share.

LIMITATIONS AND BENEFITS

The authors note that data limitations placed restrictions on the possible attributes that could be included in the equations. The authors note that they would have preferred to include measures of acceleration, durability, road holding, and, for earlier years, an independent suspension variable.

STRUCTURE

The single-equation models proposed and estimated by the authors related the price of a car to the levels of its attributes. Two functional forms were considered and regressions were performed for both. These two functional forms are:

$$P_i[X_i] = a_{i0} + a_{i1} (X_{i1}) + a_{i2} (X_{i2}) + \dots + a_{i7} (X_{i7}) + U_i$$

$$\log_{10}(P_i[X_i]) = b_{i0} + b_{i1} (X_{i1}) + b_{i2} (X_{i2}) + \dots + b_{i7} (X_{i7}) + V_i$$

where:

$P_i[X_i]$ = price of car model i

X_{i1} = brake horsepower of model i

X_{i2} = dummy variable equal to 1 if power-assisted brakes are standard, 0 otherwise

X_{i3} = length in inches

X_{i4} = dummy variable equal to 1 if model possesses at least four forward gears, 0 otherwise

X_{i5} = dummy variable equal to 1 if model has a luxurious standard of trim, 0 otherwise

X_{i6} = "passenger area" = "leg room" x "elbow room"

X_{i7} = fuel consumption in miles per gallon

a_i, b_i = coefficients to be estimated

The cross-section regression results for each functional form are presented for the years 1956 to 1968. The authors calculated the hedonic price indexes based on the results of the linear form because of the "generally greater significance and explanatory power of the linear form gave ... an index with slightly less sampling variance, and which was computationally simpler." The authors used the hedonic price regressions to develop alternative "pure" price indexes. These indexes are compared with others (see Validation section).

MODEL CONSTRUCTION

Data used in estimating the single-equation models were obtained from Motor, Autocar, car manufacturers, and The Motor Industry of Great Britain 1970.

REFERENCE

Cowling, K.; Cubbin, J., Hedonic price indexes for United Kingdom cars, Economic Journal 82:963-978, September 1972.

AUTOMOBILE CHARACTERISTICS DEMAND

This model of the demand for automobile characteristics was developed in 1980, being partially supported by the American Marketing Association. The objective of the model is to estimate the supply and demand functions for vehicle attributes based on cross-section data on vehicle offerings, consumer choices, and characteristics. The authors are at the State University of New York at Binghamton and Buffalo.

SPONSOR

American Marketing Association

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KEYWORDS

Pricing, automobile demand, automobile supply

OBJECTIVE OF MODEL

The objective of the model is to estimate demand and supply functions for product characteristics. Based on the model, estimations can be derived for price elasticities of demand as well as demand variations for various types of consumers.

RELATIONSHIP TO OTHER MODELS

This model uses some of the same data series as a market share model by Ratchford, described under 77-574.

HISTORICAL BACKGROUND

This model is based on a characteristics demand framework developed by Kelvin Lancaster (Consumer Demand: A New Approach, New York: Columbia University Press, 1971), and the theoretical model developed by Sherwin Rosen (Hedonic Prices and Implicit Markets: Product

Differentiation in Pure Competition, Journal of Political Economy 82:34-55, 1974.). This study operationalizes Rosen's theoretical model.

ASSUMPTIONS

In formulating this model, the authors used the assumptions that consumers maximize utility and producers maximize profits. The hedonic price approach to the estimation of the marginal prices of vehicle characteristics assumes that implicit prices of characteristics can be obtained from the cross-section of models of automobiles.

VALIDATION

The authors compared the performance of the model with that of LINMAP estimates. This model performed relatively poorly, and this was considered in light of the performances of other cross-section models.

LIMITATIONS AND BENEFITS

The authors noted that empirical estimates are an encouraging first step and that future research may improve the model's performance. They also noted that the "primary value of the model lies in description rather than the prediction of individual choices."

STRUCTURE

Developing a demand model for vehicle characteristics requires the consumers' marginal valuation of alternative amounts of those characteristics. To develop those marginal valuations, the model authors first estimated the marginal prices of the characteristics by estimating with regression the relationships between prices and the characteristics based on price/characteristic bundles observed in the market place. The double log functional form was selected because marginal prices should vary with levels of characteristics, and the ratios of the marginal prices of any two characteristics should not be constant. The authors estimated the following price/characteristic relationship based on 1976 cross-section data of 28 models:

$$\begin{aligned} \ln(P) = & 6.5970 + 0.0349 [\ln(D)] + 0.1492 [\ln(H)] \\ & (0.3318) \quad (0.0231) \quad (0.04337) \\ & + 0.2391 [\ln(R)] + 0.0664 [\ln(1/PT)] + 0.0334 [\ln(LV)] \\ & (0.4511) \quad (0.0387) \quad (0.0326) \\ & + 0.2674 [\ln(RLR)] \\ & (0.1171) \end{aligned}$$

$$R^2 = 0.684$$

where standard errors are in parentheses, and

P = price of the model of car

D = engine displacement

H = handling, scaled 1-5, obtained from Consumer Reports

R = ride quality, scaled 1-5, obtained from Consumer Reports

PT = passing time, time to go from 45 to 65 mph

LV = luggage volume

RLR = rear leg room

Marginal prices were obtained from the above estimated equation and were used as dependent variables to estimate a system of six demand and six supply equations. The supply and demand equations have the following general forms:

$$\frac{dP(z)}{dZ_i} = c_i - d_i (Z_i) + \sum_j c_{ij} (X_j) + ed_i$$

$$\frac{dP(z)}{dZ_i} = g_i + h_i (Z_i) + \sum_k g_{ik} (W_k) + es_i$$

where:

$P(z)$ = price of the car model characteristic

Z_i = quantity of car model characteristic i

X_j = consumer characteristics

W_k = manufacturer dummy variables

ed_i, es_i = random errors

c, d, g, h = coefficients to be estimated

Supply and demand functions were estimated for each of the vehicle characteristics in the hedonic price/characteristics equations above. The consumer characteristics included in the demand equations are: income, education of head of household, number of showrooms visited, number of other cars considered, type of driving for which the new car was used, expected life of new car in years, amount of work the consumer likes to do by himself on the car, occupation of head of household, total family size, number of automobiles owned, life-cycle state, home ownership, and garage ownership. Two results of the models are that long-distance travel is an important factor affecting vehicle choice, and that in 1976 foreign manufacturers had a cost advantage in supplying size and performance attributes.

MODEL CONSTRUCTION

The model was estimated on data from a questionnaire developed by the author and from various issues of Consumer Reports, Edmund's New Car Prices (1976), Edmund's Foreign Car Prices (1976), and the Federal Energy Administration's Gas Mileage Guide (1976, 1977).

REFERENCE

Agarwal, M.K.; Ratchford, B.T., Estimating demand functions for product characteristics: The case of automobiles, Journal of Consumer Research 7:249-262, December 1980.

QUALITY ADJUSTMENT MODEL OF MARKET SHARES IN OLIGOPOLY

This quality adjustment model of market shares in oligopoly was developed in 1971 at the Bureau of Labor Statistics. The objective of the model is to predict producer market shares based on quality differences in the different varieties of product and advertising expenditures.

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KEYWORDS

Pricing, market share

OBJECTIVE OF MODEL

The objective of the model is to predict producer market shares based on advertising expenditures and quality differences in the various varieties of the product, e.g., automobiles. Hedonic price regressions are used to produce residuals that are an estimate of unmeasured quality differences. These residuals are hypothesized to be related to the market shares of the various manufacturers.

RELATIONSHIP TO OTHER MODELS

This model has no known relationship to any other model.

HISTORICAL BACKGROUND

The approach employed in this study is based on the earlier work of Cowling and Raynor (see 70-544), and Cowling and Cubbin (see 72-700). The suggestion for this line of investigation is from Griliches (see S-71-681 and 61-682).

ASSUMPTIONS

The approach involves an assumption that a product can be disaggregated into constituent characteristics and that these characteristics enter the utility functions of consumers. The varieties of a product are distinguished by their levels of characteristics. The price of a product is, therefore, the price of the bundle of characteristics.

VALIDATION

The authors compared their results with the estimates derived in the earlier study on the U.K. car market (72-700). The comparison indicated that the British and American markets are best explained by different functional forms. The coefficients of the residual variable were generally not statistically significant at the standard levels and sometimes had the wrong sign. The results suggested that subsidiary hypotheses need to be explored, one of which concerns the effectiveness of the hedonic quality function fitted to the U.S. data.

LIMITATIONS AND BENEFITS

The model is one of the few attempts to model automotive manufacturer market share in the United States. The comparison of the models of the U.S. and U.K. markets is an indication of the differences between the two markets and the difficulties in applying similar methodologies in different markets.

STRUCTURE

Using the hedonic quality measurement technique, the implicit prices of characteristics can be estimated from the following general form regression:

$$P = (X) b + e$$

where:

P = vector of price for various varieties of a product, e.g., automobile

X = matrix of values of their characteristics

b = an estimate of the set of implicit prices for the characteristics

e = conventional error vector

Three factors affect market shares of the product varieties: the distribution of income, distribution of tastes, and the "e" values from the above equation. The "e" was hypothesized to be important because the estimated set of implicit prices, b, are averages, and the prices of the characteristics charged by producers are expected to converge (or

else market share would change). The authors hypothesized that when e is greater than zero (implicit prices higher than average) lower sales should result, and when e is less than zero higher sales should result. The empirical portion of the paper tests the hypothesis that the change in market share is a negative function of the value of the residual from the hedonic price function.

Four share equations were estimated for the U.S. market. The two basic equations are presented below. For the other equations, the authors eliminated the lagged share variable. This substantially lowered the explanatory power of the equation. The following equation was estimated over the 1960-65 period:

$$\begin{aligned} \ln(\text{SHAR}) = & -1.082 + 1.709 (\text{WTRSDL}) + 0.428 [\ln(\text{ADSHAR})] \\ & (-3.573) \quad (1.219) \quad (5.784) \\ & + 0.276 [\ln(\text{LGSHAR})] \\ & (6.306) \end{aligned}$$

$$R^2 = 0.418$$

where t-statistics are in parentheses, and

SHAR = the market share

WTRSDL = weighted residual variable

ADSHAR = advertising share

LGSHAR = the lagged market share

The linear equation form of the above equation was estimated for each year 1960 to 1965 and a pooled 1960-65 data set. As above, the equation was also estimated for lagged share. The following estimated equation is based on the pooled data:

$$\text{SHAR} = -0.001 + 0.050 (\text{WTRSDL}) + 0.264 (\text{ADSHAR}) + 0.770 (\text{LGSHAR}) \\ (0.002) \quad (0.024) \quad (0.061) \quad (0.030)$$

$$R^2 = .914$$

where standard errors are in parentheses, and the variable definitions are the same as above.

MODEL CONSTRUCTION

The estimated equations are based on data from Ward's Automotive Yearbook and Advertising Investments.

REFERENCE

Triplett, J.E.; Cowling, K., Quality-adjustment model for determining market shares in oligopoly, presented at winter 1971 meeting of Econometric Society in New Orleans, Bureau of Labor Statistics, working paper no. 4, December 1971.

AUTOMOBILE HEDONIC QUALITY MEASUREMENT

This model for measuring the quality of automobiles was developed in 1969 at Washington University. The objective of the model is the derivation of quality-adjusted price indexes for automobiles.

AUTHOR

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KEYWORDS

Pricing

OBJECTIVE OF MODEL

The objective of the model is to develop a quality-adjusted price index for automobiles for the years 1960-65. The relationships between the price of a car and its attributes are estimated based on cross-section data. The regressions also produced pure price estimates that can be used in a time series.

RELATIONSHIP TO OTHER MODELS

This model has no known relationship to any other model.

HISTORICAL BACKGROUND

The basic approach used in developing these models is based on the work by Court (38-689) and Griliches (61-682). This is one of several basic studies that contributed to the state of knowledge in hedonic price modeling.

ASSUMPTIONS

The hedonic price technique is based on several assumptions. First, the identified characteristics were assumed to be the major elements in quality change as perceived by the consumers. Second, cross-section model data was assumed appropriate for use in the estimations. Third, the use of the cross-section data to derive quality indexes that are employed to adjust a time series was based on "the hypothesis that the quality of product improves by the incorporation into the cheaper product varieties of features or attributes which, in a previous period, were obtainable only on the more expensive varieties."

VALIDATION

The author compared the results of the hedonic price model to the Consumer Price Index and concluded that Griliches' conclusion of upward quality bias during the period 1954-1960 could not be extended to other periods or other components of the CPI. The author also examined the role of weight in the regression and concluded that its inclusion has some difficulties.

LIMITATIONS AND BENEFITS

The author observed the limitations to the hedonic price approach and the use of proxies in the price-attribute relationship. Some of these limitations are in the form of assumptions and are discussed above. The author noted that if quality is not introduced gradually (i.e., all automobiles have the same improvement, such as a mandatory safety feature), then the quality indexes may be biased. The author also noted that the characteristic weight is actually an undesirable attribute. Including weight in a hedonic price model is to use it as a proxy for other desirable characteristics such as size and luxury. A problem with including weight as a proxy for other characteristics is that the relationships between weight and those other characteristics may change over time (e.g., a shift to lightweight materials). This problem could bias the quality estimates.

STRUCTURE

Following the approach by Court and Griliches, the author estimated the following relationship between automobile prices and characteristics:

$$\ln(P) = X (b)$$

where:

P = vector of prices

X = matrix of automobile specifications

b = coefficients to be estimated

The equation is fitted to cross-section data for each year in the period 1960-65. The following equation for 1962 is representative of the estimated equations:

$$\begin{aligned} \ln(P) = & 6.434 + \begin{matrix} 0.010 & (HP) & + & 0.240 & (W) & + & 0.028 & (L) & + & 0.041 & (V) \\ & (0.029) & & (0.045) & & (0.015) & & (0.029) & & & \end{matrix} \\ & + \begin{matrix} 0.078 & (HT) & + & 0.000 & (AT) & + & 0.319 & (PSB) & + & 0.109 & (C) \\ & (0.035) & & (0.063) & & (0.062) & & (0.029) & & & \end{matrix} \end{aligned}$$

$$R^2 = .940$$

where:

P = price of car

HP = advertised horsepower in hundreds

W = shipping weight in thousands of pounds

L = length in tens of inches

V = dummy variable equal to 1 if engine is a V-8, 0 otherwise

HT = dummy variable equal to 1 if car is a four-door hardtop, 0 otherwise

AT = dummy variable equal to 1 if automatic transmission is included in price, 0 otherwise

PSB = dummy variable equal to 1 if power steering and brakes are included in price, 0 otherwise

C = dummy variable equal to 1 if vehicle is a compact, 0 otherwise

To derive estimates of quality change over time, the author introduced a time trend variable and estimated the equations over data for pairs of adjacent years. Using these single-equation models, the author estimated that prices adjusted for quality rose about 7.2% over the 1960-65 period.

Using a stepwise regression procedure, the author found that three variables (weight, and the dummy variables for power steering/brakes and compacts) accounted for over 90% of the variance in price. Based on these findings, he formulated the "truncated" model and estimated a quality-adjusted price index. He found that the two models produced very close results. Using the results, the author explored the theoretical implications of using weight as a proxy for other variables. One difficulty that was noted is the gradual shifting in the proxy relationships.

MODEL CONSTRUCTION

The primary data sources for this econometric model used in estimating the equations were Automotive Industries, Automotive News, Ward's Automotive Reports, and Consumer Reports.

REFERENCE

Triplett, J.E., Automobiles and hedonic quality measurement, Journal of Political Economy 77:408-417, June 1969.

3.0 ASSOCIATED LITERATURE ABSTRACTS

REFERENCES

Austin, T.C.; Michael, R.B.; Service, G.R., Passenger car fuel economy trends through 1976, Society of Automotive Engineers, Paper no. 750957, October 1975.

Murrell, J.D., Light duty automotive fuel economy...trends through 1978, U.S. Environmental Protection Agency, Society of Automotive Engineers Technical Paper 780036, 1978.

Murrell, J.D., Light duty automotive fuel economy...trends through 1979, Society of Automotive Engineers Technical Paper Series, no. 790225, March 1979.

Murrell, J.D.; Foster, J.A.; Bristor, D.M., Passenger car and light truck fuel economy trends through 1980, SAE Technical Paper Series no. 800853, June 1980.

KEYWORDS

Fuel economy

PERFORMING ORGANIZATION

U.S. Environmental Protection Agency
401 M. Street, S.W.
Washington, D.C. 20460

ABSTRACT

These are a series of papers prepared by the U.S. Environmental Protection Agency (EPA) on the fuel economy of automobiles. The most recent paper presents an accumulation of previous fuel economy analyses, with data for car models, light trucks, and motorcycles through 1980. The earlier reports contain descriptions of EPA tests and data bases, analysis techniques, and harmonic sales weighting of fuel economy data.

Information is disaggregated by weight class, vehicle size-class, manufacturer, mpg range, domestic vs. import, gasoline vs. diesel, and 49 states vs. California.

Changes in fuel economy are shown to result separately from system optimization, new engine and vehicle combinations, and model mix shifts. Yearly changes in average fuel economy ratings are analyzed. Fuel economy ratings for older cars, from before emission standards and EPA measurements, are refined. Actual sales figures are used in finding averages. Year to year trend analysis is possible with the consistencies in the data. Interactions between vehicle technology, fleet physical attributes, and fuel economy standards are discussed.

REFERENCES

Kulp, G.; Shonka, D.B.; Collins, M.J.; Murphy, B.J.; Reed, K.J., Transportation energy conservation data book: Edition 4, Oak Ridge National Laboratory, Report no. ORNL-5654 Special (edition 4 of ORNL-5198), September 1980.

Greene, D.L.; O'Connor, T.P.; Patterson, P.D.; Rose, A.B.; Shonka, D.B., Regional transportation energy conservation data book: Edition 1, Oak Ridge National Laboratory, ORNL-5435 Special, September 1978.

Shonka, D.B., Transportation energy conservation data book: Edition 3, Oak Ridge National Laboratory, Report no. ORNL-5493 Special (Edition 3 of ORNL-5198), Feb. 1979.

Ehrenshaft, A.R.; Barber, B.Y.; Carroll, P.J.; Plemons, L.K.; Purnell, P.A.; Weaver, R.S., Transportation energy conservation data book: A selected, annotated bibliography: Edition 3, U.S. Department of Energy, Report no. ORNL/EIS-146, November 1978.

Howard, E.B.; Barber, B.Y.; Jordan, A.C.; Seaborn, C.C., Transportation energy conservation data book: A selected, annotated bibliography: Edition 2, Oak Ridge National Laboratory, Report no. ORNL/EIS-114, part II of ORNL-5320, October 1977.

Kulp, G.; Greene, D.L.; Walton, G.H.; Collins, M.J.; Shonka, D.B.; Blue, J.L., Regional analyses of highway energy use, Oak Ridge National Laboratory, Report no. ORNL-5587 Special, April 1980.

Shonka, D.B.; Loebel, A.S.; Patterson, P.D., Transportation energy conservation data book: Edition 2, Oak Ridge National Laboratory, Report no. ORNL-5320, October 1977.

KEYWORDS

Energy consumption, fuel consumption, data

SPONSOR

U.S. Department of Energy
Office of Conservation and Solar Energy
Office of Transportation Programs
Division of Transportation Systems Utilization
Analysis and Assessment Branch
Washington, D.C.

PERFORMING ORGANIZATION

Oak Ridge National Laboratory
Energy Division
Regional and Urban Studies Section
Oak Ridge, Tenn. 37830

ABSTRACT

This series of publications by Oak Ridge National Laboratory and the U.S. Department of Energy serves as an encyclopedia of energy consumption and supply data. The transportation modes covered include: highway, air, rail, marine, pipeline, and non-motorized vehicles. Some of the subjects covered include: transport networks; cost of vehicle ownership; ownership by households; travel characteristics; energy efficiency, intensity, and resource conservation; government taxes, expenditures, programs, regulatory activities, and research; energy production, imports, prices, and reserves; alternative fuels; population and economic characteristics affecting transportation demand; regional characteristics of each mode; regional consumption comparisons; and international comparisons. Subjects specific to highway transportation include: vehicles in operation, scrappage, fuel efficiency, automobile fleets, commercial highway energy use, buses, trucks, and local and intercity household travel.

Each volume contains hundreds of tables and figures, indexed by title, keywords, and mode. Also included are glossaries, cross-reference listings, definitions of regions, sources, conversion tables, and other reference aids.

A set of companion publications provide annotated bibliographies to literature on transportation and energy. Also provided are indexes by author, corporate author, sponsor, keyword, report number, and permuted title. Reviews of selected studies are also included.

S-75-226

REFERENCE

Study of potential for motor vehicle fuel economy improvement: policy assessment panel report, no. 1 of seven panel reports, U.S. Department of Transportation and U.S. Environmental Protection Agency, January 10, 1975.

KEYWORDS

Fuel economy

PERFORMING ORGANIZATION

U.S. Department of Transportation
Washington, D.C. 20590

U.S. Environmental Protection Agency
Washington, D.C. 20460

ABSTRACT

This is the first of seven reports prepared by special panels of a task force established under the joint chairmanship of DOT and EPA. The task force was established to conduct a study of the feasibility of a fuel economy improvement standard of 20% for new motor vehicles produced in the 1980 time frame. This report focuses on the merits and deficiencies of several implementation strategies and enforcement mechanisms by which fuel economy improvements can be elicited. The strategies analyzed are: fuel economy labeling; production weighted average standards: common standard, uniform percentage improvement, and variable improvement standard; class standards, uniform or variable improvement; and vehicle taxation, excise tax or annual fuel efficiency taxes. The criteria used to evaluate these strategies were: impact on producers: flexibility, incentive for post-1980 improvement, and comparative impact on producers; impact on consumers: increase in first cost of auto, distribution of cost increases, maintenance of consumer choice, and safety costs; and impact on administration of the standard: reliance on the market, cost of administration, and effectiveness of ensuring achievement of improvement.

Other panel reports in this series are described under S-75-173, S-75-174, and S-75-617.

REFERENCE

Manne, A.S.; Richels, R.G.; Weyant, J.P., Energy policy modeling: A survey, Operations Research, 27(1):1-36, Jan.-Feb. 1979.

CONCERNING MODEL:

PIES (75-004); BESOM (78-378); SRI-Gulf (73-261)

KEYWORDS

Energy consumption, model assessment

PERFORMING ORGANIZATION

Stanford University (Manne, Weyant)
Stanford, Calif.

Electric Power Research Institute (Richels)
Palo Alto, Calif.

ABSTRACT

This survey provides an exposition of seven techno-economic models that are representative of recent work on energy policy. Several microeconomic concepts related to energy conservation and to energy-economy interactions are discussed. Three representative medium-term models are examined which deal with pricing, import policy, and investment decisions, and four studies dealing with longer-term issues such as alternative research and development strategies for a transition away from depletable energy resources. The models discussed are: Project Independence Evaluation System (75-004); Kennedy World Oil Model; Baughman-Joskow Regionalized Electricity Model (REM); A Linear Programming System (ALPS); Brookhaven Energy System Optimization Model (BESOM) (78-378); Energy Technology Assessment Model (ETA) and ETA-MACRO; and SRI-Gulf Energy Model (73-261).

REFERENCE

Pollard, J.K.; Rudman, L.M., Catalog of on-going and recently completed studies of: 1. Motor vehicle sales, 2. Vehicle miles travelled, 3. Fuel consumption, U.S. Department of Transportation, October 1978.

KEYWORDS

Automobile demand, vehicle miles traveled, fuel consumption

PERFORMING ORGANIZATION

U.S. Department of Transportation
Transportation Systems Center
Energy Demand Analysis Branch
Kendall Square
Cambridge, Mass. 02142

ABSTRACT

This document is a catalog of abstracts of ongoing and recently completed studies and projects, most of which are sponsored by the Department of Transportation. The studies are grouped according to one of three topics to which they most strongly relate, including fuel consumption. Project titles, authors, project description, and a description of outputs are presented for each study.

Some of the studies included are those by A.T. Kearney (78-290), International Research and Technology/Office of Technology Assessment (S-79-221), Charles River Associates (76-025), Wharton EFA (77-046), Chilton Company (S-79-484), this inventory, Jack Faucett Associates (76-016), Oak Ridge National Laboratory (S-77-616, 78-263), Transportation Systems Center (S-79-232), and Energy and Environmental Analysis (78-368).

REFERENCE

McAdams, H.T., Fuel economy of automotive vehicles: A compendium of statistical applications, Falcon Research and Development, June 1978.

KEYWORDS

Model assessment, fuel economy

SPONSOR

U.S. Department of Energy
Conservation and Solar Applications
Transportation Programs
20 Massachusetts Ave. N.W.
Washington, D.C. 20545

PERFORMING ORGANIZATION

Falcon Research and Development
One American Drive
Buffalo, N.Y. 14225

ABSTRACT

In this work, previously developed statistical methodology was applied to put into perspective test-based and on-road (in-use) estimates of fuel economy. The requirements were to resolve fundamental questions pertaining to measures of effectiveness for fuel economy, bases of stratification and aggregation of data, and confounding of variables in the fuel-economy data base; formulate specific hypotheses aimed at evaluating differences between in-use gas mileage numbers and those reported in EPA tests and specify appropriate tests of significance for these hypotheses; estimate confidence bounds applicable to gas mileage numbers for evaluative ranking of vehicles according to fuel economy; and provide technical assistance in the application of selected statistical techniques.

This report is developed as a series of four application papers, each of which touches on one or more of the significant data-analysis issues pertaining to in-use, fuel economy assessment. Application Papers No. 1, No. 2, and No. 3 (A Multiple Regression Approach to the Analysis of Fuel-Economy Data, Principles of Statistical Estimation and Influence in Simple Linear Regression, Estimation and Influence in Multiple Linear Regression) address the question of commonality of data sources and put covariance analysis in a framework of multiple regression. (Covariance analysis provides a means for comparing the regression lines for various data sources with a view toward deciding whether the several sources can logically be pooled. Whether the several sources can be regarded as having a common intercept, a common slope, or both is the central thrust

of such analysis.) Each data source is considered as a "dummy" variable capable of assuming the values of 0 or 1 only. (The value of 1 denotes that a specific data point belongs to the data source under consideration, whereas the value 0 denotes that the point does not belong to the data source.) Application Paper No. 4 (A Weighted Least-Squares Approach to Regression Analysis) explains how to formulate and test hypotheses pertaining to the commonality of data sources.

Five types of fuel-economy data on in-use vehicles were available for analysis: (1) on-road consumer driving; (2) on-road fleet driving; (3) on-road fuel-economy test driving; (4) in-use dynamometer tests; and (5) owner estimates of fuel economy. [Author's summary modified]

REFERENCE

Knorr, R.E.; Millar, M., Projections of direct energy consumption by mode: 1975-2000 baseline, Argonne National Laboratory, Report no. ANL/CNSV-4, August 1979.

CONCERNING MODEL:

TEC Model (S-78-385); TECNET (79-020); Fleet Accounting Model (77-295A); Wharton EFA Mark I (78-436)

KEYWORDS

Energy consumption, modal split

SPONSOR

U.S. Department of Energy
Assistant Secretary for Conservation and Solar Applications
Office of Transportation Programs
Washington, D.C.

PERFORMING ORGANIZATION

Argonne National Laboratory
Energy and Environmental Systems Division
9700 South Cass Avenue
Argonne, Ill. 60439

ABSTRACT

This paper presents energy consumption projections for each of the major transportation modes and submodes. The projections are predicted from a continuation of current trends with no additional conservation programs beyond the fuel economy standards mandated by the Energy Policy and Conservation Act. Each mode or submode is projected independently, either by means of a series of the authors' simple demand models and trend extrapolations, or by relating the outputs of more complex models to economic variables and travel costs. However, because of anticipated changes in personal vehicle fuel economy, fuel prices, modal shift, and a lower than historic economic growth rate, projected growth rates in transportation and energy consumption depart from historic patterns. The projections are also compared to other efforts. [Author's abstract and executive summary modified]

The modes included are: automobiles (three size-classes; fleet and non-fleet; intercity, local, and commuting operation), personal light trucks, two-wheeled vehicles (moped, mid-size and large motorcycles), snowmobiles, recreational vehicles, buses (school, transit, intercity),

trucks (commercial light, medium, heavy, heavy-heavy, government), rail (freight; passenger: transit, commuter, intercity), water (domestic cargo, recreational boating), air (general aviation, domestic passenger, international, freight), and pipelines.

Some of the sources for projections are: Data Resources, Inc. macro model, DuPont highway gasoline consumption forecast, Energy Information Administration Annual Report to Congress 1978, Exxon energy outlook projections, Laird Durham truck and freight activity projections, McNutt/Dulla projections (S-79-371), National Transportation Policy Study Commission (S-79-396), Oak Ridge light truck forecasts (T-79-671), Office of Technology Assessment (S-79-221), Transportation Energy Conservation Division (S-79-196), TEC model (S-78-385), TECNET model (79-020), Fleet Fuel Accounting Model (77-295A), and Wharton EFA motor vehicle model (78-436).

REFERENCE

Stucker, J.P., Effects of fuel economy mandates and taxes on drivers: Impacts by income groups, presented at the 1978 Conference of the Western Economic Association, Honolulu and Hilo, Hawaii, June 20-26, 1978. Rand Corporation, Report no. P-6127, August 1978.

CONCERNING MODEL:

Response of the Domestic Automobile Industry to Mandates for Increase Fuel Economy (77-056); Consumption of Gasoline by Households Model (77-087A); Household Expenditures on Automobile Ownership and Operation (77-087B)

KEYWORDS

Fuel economy, vehicle user costs/vehicle operating costs

SPONSOR

National Science Foundation

Federal Energy Administration

Energy Research and Development Administration

PERFORMING ORGANIZATION

Rand Corporation
Santa Monica, Calif. 90406

ABSTRACT

This study predicts the economic effects across income groups of combinations of government policies designed to conserve gasoline. The policy combinations considered are: fuel economy mandates, a gas guzzler tax, fuel economy mandates plus a twenty-five cent per gallon gasoline tax, and fuel economy mandates plus a fifty cent per gallon gasoline tax.

The Rand Response of the Auto Industry to Fuel Economy Mandates Model (77-056) is used to simulate the pricing and fuel economy effects of the policies on the cars offered by the domestic auto industry, assuming the industry jointly maximizes profits.

The outputs of price and fuel economy were then input to the Household Expenditures on Automobile Ownership and Operation Model (77-087B) for several income groups. The technique used to examine distributional aspects of the gasoline taxes is detailed in the Consumption of Gasoline

S-78-387

by Households Model (77-087A). These policy combinations were found to change driving costs very little across all income classes.

REFERENCE

Green, P.E.; Rogers, P.W., Study of consumer automotive preference with regard to fuel economy measures, U.S. Department of Transportation, Report no. DOT-TSC-NHTSA-78-38, September 1978.

KEYWORDS

Fuel economy, industrial financial performance

SPONSOR

U.S. Department of Transportation
National Highway Traffic Safety Administration
Office of Research and Development
Washington, D.C. 20590

PERFORMING ORGANIZATION

Rogers National Research, Inc.
5800 Monroe Street
Sylvania, Ohio 43560

ABSTRACT

This paper quantitatively determines the effects of "downsizing" (reductions in size and weight) on the demand for 1977 General Motors standard size cars. The analysis focuses on statistical tests to determine differences between the average attitudinal, behavioral, and demographic groups; buyers of downsized cars and buyers of non-downsized cars. Multivariate analysis was used to select from a group of fifty variables those that significantly distinguished (at the 0.05 level) between groups of people who purchased downsized and non-downsized cars.

Surveys of new car buyers in the same months of 1976 and 1977 were used to construct a national probability sample. Those who purchased the downsized cars did so to obtain better fuel economy, as well as increased maneuverability and ease in parking. It was concluded that General Motors increased its market share by increasing fuel economy through downsizing. [Author's abstract modified]

S-75-411

REFERENCE

Lee, D.B. Jr., Costs of urban and suburban passenger transportation modes, University of Iowa, Working paper no. 14, April 1975.

KEYWORDS

Vehicle user costs/vehicle operating costs, modal split, data

PERFORMING ORGANIZATION

University of Iowa
Institute for Urban and Regional Research
Center for Urban Transportation Studies
102 Church St.
Iowa City, Iowa 52242

ABSTRACT

This paper details the operating costs for transportation modes in dollars per vehicle per year and cents per passenger mile. Unresolved problems in cost estimation are discussed, such as environmental costs and peak-period costs. Comparisons are made between costs for auto, bus, rail, and rapid transit modes as they would apply to the Washington, D.C. metropolitan area. Costs are classified as total cost, user charges, operating labor, vehicle capital, environmental, highway, parking, and fuel costs. Problems in the financing of urban transportation are discussed, such as pricing and subsidies, and public versus private costs. The methodology for calculating vehicle operating costs, a component of many automobile demand models, is outlined.

REFERENCE

Krishnan, K.S., Development of a quantitative measure of "vehicle size", General Motors Corporation, Report no. GMR-2979, May 1979.

KEYWORDS

Weight, automobile design, data

PERFORMING ORGANIZATION

General Motors Corporation
General Motors Technical Center
General Motors Research Laboratories
Warren, Mich. 48090

ABSTRACT

Vehicle size is a commonly used concept in automobile demand and market share modeling. This paper presents a method to combine fifteen vehicle characteristics that are commonly used alone to measure vehicle size, using data from 1976 model year General Motors cars. By the method of principal components, linear combinations can be made of the fifteen characteristics to yield two measures of vehicle size.

One of these measures has high positive correlations with the thirteen characteristics measuring exterior size, such as wheelbase, curb weight, and overall length. This measure is termed by the author as "Overall Exterior Car Size." The second measure of vehicle size has a high positive correlation with legroom, and high negative correlation with headroom and overall height. Since a car with relatively little headroom and overall height, and long legroom (as in a sports car) would give a high value for this measure, it is termed by the author as "Sportiness."

REFERENCE

Abernathy, W.J.; Ginsburg, D.H., Proceedings on the workshops on technological change in the U.S. automobile industry October 1977 through April 1978 and the symposium on technology, government and the automotive future October 19-20, 1978, U.S. Department of Transportation, Report no. DOT-TSC-NHTSA-79-33, July 1979.

KEYWORDS

Industrial financial performance, vehicle manufacturing resource utilization, fuel economy, market share, emissions, automobile design

SPONSOR

U.S. Department of Transportation
National Highway Traffic Safety Administration
Office of Research and Development
Washington, D.C. 20590

PERFORMING ORGANIZATION

Harvard University
Graduate School of Business Administration
Soldiers Field Road
Boston, Mass. 02163

ABSTRACT

The purpose of the meetings reported on here was to explore the implications of technological change in the U.S. automotive industry in support of improved policy formulation to meet emerging national needs. Workshops were conducted in the areas of: (1) motor vehicle regulatory process, (2) consumer as a factor in motor vehicle innovation, (3) the supply industry as a factor in motor vehicle innovation, (4) changing incentives for motor vehicle research and development, and (5) role of national and multinational corporations in motor vehicle innovation. The five key issues emerging from these workshops were the federal research and development policy in the motor vehicle sector, product rating information for consumers, regulatory decision-making, regulation and international trade, and transportation policy. These papers are potentially useful in providing direction for policy-oriented automobile sector modeling. The papers presented were:

Finkelstein, M.M., Consumer safety information as a government policy tool.

John, R.R.; Coonley, P.S.; Ricci, R.C.; Rubinger, B., Mandated fuel economy standards as a strategy for improving motor vehicle fuel economy.

Ketcham, B.; Pinkwas, S., Beyond autocracy: The public's role in regulating the auto.

Leone, R.A.; Jackson, J.E., Toward more effective organization for public regulation.

Pearce, M.C., International competition in the world automotive industry.

White, L.J., Automobile emissions control policy--Success story or wrongheaded regulation.

Wilkins, M., Multinational automobile enterprises and regulation: An historical view.

Claybrook, J., Concluding remarks: Regulation and innovation in the automobile industry.

Dempsey, E.C., Status of the automotive supply industry: A review of industry trends from the trade literature.

S-79-422

REFERENCE

U.S. automotive industry trends for the 1980s--A delphi forecast, Arthur Andersen and Co., 1979.

KEYWORDS

Automobile design, industrial financial performance, market share, vehicle manufacturing resource utilization

PERFORMING ORGANIZATION

Arthur Andersen and Company
69 W. Washington St.
Chicago, Ill. 60602

ABSTRACT

The detailed results are reported of a survey of experts in the automobile field to forecast future trends. The Delphi forecasting process is used, which involves polling panelists on a list of questions asking what they think the emerging trends are. Responses are anonymously fed back to the panelists and the questions and responses are repeated, until a consensus forecast is reached. Emerging trends through the 1980s and up to 1995 were forecast by panels concerned with technological, market, and management trends. Experts on the panels were from vehicle manufacturers, auto parts suppliers, and fuels and materials suppliers, and work as corporate managers, marketing or sales managers, and engineers. Results are classified into the areas of technological trends (engines, drive trains, components, vehicle operations and maintenance), government regulations, market outlook for autos and parts (future U.S. market volume, business conditions, international markets), investment climate, labor market outlook, and strategic planning practices for auto parts suppliers. For example, it is forecast that there will be certain percentages of smaller, diesel, and electric vehicles in 1990, and certain wage rates for assembly workers. An explanation of the Delphi forecasting method is also included.

REFERENCE

Anderton, D., Review of diesel combustion models for NOx and smoke emissions, U.S. Department of Transportation, Report no. DOT-TSC-OST-76-57, October 1977. NTIS no. PB 276-350.

KEYWORDS

Emissions, model assessment, trucks, automobile design

SPONSOR

U.S. Department of Transportation
Office of the Assistant Secretary for Systems Development and Technology

Office of Noise Abatement
Washington, D.C. 20590

PERFORMING ORGANIZATION

University of Southampton
Institute of Sound and Vibration Research
Southampton
England

ABSTRACT

This report provides a critical review of the current state of knowledge regarding nitrogen oxide formation relevant to diesel engine combustion, presents some measurements of diesel engine exhaust, provides a critical review of the current state of knowledge regarding smoke or soot formation and oxidation, and provides a review of the current state-of-the-art of diesel combustion modeling related to the prediction of the effect of design and operating variables on exhaust smoke and NOx. It is applicable internationally. Six models are considered in some detail and their strengths and weaknesses are indicated. The review suggests that available models do not incorporate a sufficiently detailed description of the fundamental mixing and chemical kinetic processes occurring in diesel engines. An annotated bibliography of other diesel emissions models is included. The models reviewed in detail were originally presented in papers published by the Society of Automotive Engineers, the Institute of Mechanical Engineers, the University of Southampton, and the University of Manchester.

S-79-443

REFERENCE

Kent, J.H.; Mudford, N.R., Motor vehicle emissions and fuel consumption modeling, Transportation Research, 13A:395-406, 1979.

CONCERNING MODEL:

Automobile Exhaust Emission Modal Analysis Model (74-219)

KEYWORDS

Fuel consumption, emissions

SPONSOR

New South Wales State Pollution Control Commission

PERFORMING ORGANIZATION

University of Sydney
Department of Mechanical Engineering
Sydney, New South Wales 2006
Australia

ABSTRACT

The objective of this work was to model emissions and fuel consumption of Australian vehicles in Sydney traffic conditions, to evaluate the accuracy of the predictions, and to compare the results with other studies. Twenty-eight vehicles were tested and the emission functions of speed and acceleration were derived from dynamometer test emission rates, using the U.S. EPA Federal Driving Cycle. The model was found to be accurate to about 10% for the group of vehicles, but errors of 30-40% occurred for individual vehicles. The model used is the Automobile Exhaust Emission Modal Analysis Model (74-219), sponsored by the U.S. Environmental Protection Agency, with a separate equation for cruise mode, when acceleration is zero. Fuel consumption is found by the carbon balance method, in which fuel consumed is a function of emission rates and fuel density. A survey of driving patterns in Sydney traffic was done to record speed versus time, over a range of traffic conditions where vehicle densities were relatively high, for subsequent emissions predictions. Emission and fuel consumption predictions using this data were correlated with measured average speed.

REFERENCE

Munson, M.J.; Mufti, R.K., Assessing the impact of transportation energy policies on travel behavior: A preliminary approach, Transportation Research 13A:407-416, 1979.

KEYWORDS

Fuel consumption, model assessment

SPONSOR

New Jersey Department of Transportation
Transportation Bldg.
1035 Parkway Avenue
Trenton, N.J. 08625

Tri-State Regional Planning Commission

PERFORMING ORGANIZATION

Princeton University
Transportation Program
Princeton, N.J. 08540

ABSTRACT

This paper examines a number of energy conservation policies grouped in seven classes, and assesses, at a general level, their likely transportation impacts. These policies involve: (1) increasing the cost of auto travel relative to travel by other modes; (2) limiting the supply of gasoline; (3) physically limiting the use of cars; (4) changing auto characteristics; (5) changing characteristics of alternate modes to cars; (6) affecting the geographic distribution of trip ends; and (7) attempting to directly change travel patterns. Aggregate, disaggregate, simultaneous, and sequential demand forecasting techniques of modeling consumer response to the seven classes of policies are discussed and the ability of specific existing models to assess policy effects is examined. Some of these models use data from the 1974 energy shortage to assess the impact of the shortage on highway and transit travel, to draw conclusions regarding modal shift and elasticity of demand.

Other studies dealt more directly with the modeling of modal choice under the gasoline shortage. According to the authors, gasoline rationing or unavailability have each been addressed in only one study. In addition, the impact on modal choice of policies such as increased prices of auto travel, limits on auto use, and changes in characteristics of non-auto travel is not addressed in the literature.

S-79-445

Approaches for future work to model the effects of limits on the availability of gasoline through government control (rationing) and market control (scarcity) are suggested.

REFERENCE

Button, K.J.; Fowkes, A.S.; Pearman, A.D., Some outstanding problems in the causal modeling of car ownership at the local level, Transportation Planning and Technology 5:205-213, 1979.

KEYWORDS

Automobile demand, model assessment

SPONSOR

Social Science Research Council
605 Third Avenue
New York, N.Y. 10016

PERFORMING ORGANIZATION

Loughborough University (Button)
Department of Economics
England

University of Leeds (Fowkes)
Institute for Transport Studies
England

University of Leeds (Pearman)
School of Economic Studies
England

ABSTRACT

This paper examines three aspects of local car-ownership econometric modeling: specification of the income variable, dummy variables, and coefficient estimating techniques.

Sigmoid log-logit relationships have generally been found superior to linear relationships between car ownership and gross income. At the household level, household gross income is the simplest income variable to use. Household disposable income would be a better income measure, but information on adjusting gross income is difficult to obtain. Subsistence, threshold, and permanent income effects are considered and found not presently useful in explaining car ownership. The authors state that it is necessary to deflate income by a price index and the best deflator is an index of car prices.

Dummy variables are used to explain regional differences in a behavioral model. A coefficient is estimated, and the variable is assigned a value of 1 for data from specific regions to explain car travel needs of differing population densities. Another type of dummy variable is a

time trend, increasing every year by one from a base year assigned the value of one. This improves the overall fit of the model and represents some dynamic influence not reflected in other variables, perhaps a familiarization process as society becomes more car oriented. An example of these two types of dummy variables is presented in a model fitted to British data.

Three methods of calibrating the coefficients of a log-logit model of car ownership are explained (Maximum Likelihood, Non-Linear Least Squares, and Minimum Logit Chi-squared) and their relative merits discussed. A model is fitted with each of the three methods and the coefficients are compared.

REFERENCE

Energy modeling for an uncertain future, Study of Nuclear and Alternative Energy Systems, supporting paper 2, National Academy of Sciences, 1978.

KEYWORDS

Fuel consumption, model assessment, national economic impact, energy consumption

PERFORMING ORGANIZATION

National Research Council
Committee on Nuclear and Alternative Energy Systems
Modeling Resource Group Synthesis Panel
Washington, D.C.

ABSTRACT

The goal of this study is to assist in formulating energy policy by examining comprehensive energy-economy models and their results. The six models, most of which have transportation sectors, used in the study are the Brookhaven Energy Optimization Model (BESOM) (78-378), Dynamic Energy System Optimization Model (79-384), SRI-Gulf Energy Model (73-261), Project Independence Evaluation System (PIES), World Energy Model (75-004B), and the Energy Technology Assessment (ETA) model. An appendix to the report describes these models in detail.

Sensitivity analysis for given models and across models is performed. Model results on feedback from energy use to GNP and real income are presented, as well as several other model outputs, and intermodel output differences are explained.

An exploratory decision analysis technique for evaluating research and development programs concerning energy technologies using the model results is presented. This technique is then applied to nuclear fission power research and development.

S-77-458

REFERENCE

Kaiser, R.; Wasson, R.P.; Daniels, A.C.W., Automobile scrappage and recycling industry study, overview report, U.S. Department of Transportation, Report no. DOT-TSC-OST-77-11, September 1977.

KEYWORDS

Scrappage

SPONSOR

U.S. Department of Transportation
Office of the Assistant Secretary for Systems Development and Technology

Office of Systems Engineering
Washington, D.C. 20590

PERFORMING ORGANIZATION

H.H. Aerospace Design Co., Inc.
Civil Air Terminal
Bedford, Mass. 01730

ABSTRACT

This report summarizes the results of an overview study, done within the framework of the U.S. DOT Automotive Energy Efficiency Program, on the automobile scrappage and recycling industry, based on an extensive literature search and discussions with industry and government officials. Topics covered include materials consumption by the auto manufacturing industry, disposal of obsolete autos, the wrecking and scrap industries, materials recovery, public policies and future trends related to material reclamation from junked automobiles, abandonment of vehicles, processing and recovery of ferrous and non-ferrous scrap and the market for it, and the processing of deregistered automobiles.

A section is devoted to modeling the deregistration or scrappage of automobiles. Historical data from R.L. Polk and the MVMA is used to determine the probabilities that cars will be scrapped in each year of their life. These probabilities may be used with new auto registration or sales data to predict the number of cars scrapped in a calendar year. It is shown that 57.9% of the new cars of any model year will be scrapped when they are 8 to 12 years old. The mean life of an auto is 9.8 years, with a standard deviation of 3.6 years.

REFERENCE

Hartgen, D.T., Behavioral models in transportation: Perspectives, problems, and prospects, New York State Department of Transportation, Preliminary research report no. 152, May 1979.

KEYWORDS

Model assessment

PERFORMING ORGANIZATION

New York State Department of Transportation
Planning Division
Planning Research Unit
State Campus
Albany, N.Y. 12232

ABSTRACT

This paper provides an introduction to the history and potential of the behavioral travel demand modeling methodologies that have been under development in the U.S. since the late 1960s. Three general methodological structures are described and critiqued: disaggregate models, attitudinal models, and household based structures. The attributes and capabilities of each are listed, and the reasons why their implementation by transportation planners has been slow are discussed. Implementation problems include overstatements of the capabilities of the methods, institutional reluctance to change, and a shifting emphasis of planning towards process and away from analysis. The experience of the New York State Department of Transportation with these new methodologies, and prospects for their wider use are discussed. Numerous references are cited on the origins of the methodologies.

S-79-475

REFERENCE

Mouchahoir, G.E.; Nawrocki, R., Transportation/energy analyses methodologies, ITE Journal, pp. 28-34, December 1979.

KEYWORDS

Model assessment, energy consumption

PERFORMING ORGANIZATION

MITRE Corporation
Environment Division
McLean, Va.

ABSTRACT

Several methodologies for analyzing the consumption of energy in transportation are reviewed. The types of data required, examples of their use, and advantages and disadvantages are given for each. The issues dealt with are aggregate national, site-specific local, and detailed local in scope. The aggregate statistical approach describes the total energy consumption of transportation modes, including vehicle manufacture and infrastructure construction. Aggregate simulation models, such as TECNET (79-020), estimate total energy use by each node, including economic, demographic, and environmental conditions. Site-specific travel simulation models, such as UTPS, combine several models to describe the fuel consumption of specified transit or highway networks. Methodologies used in case studies of land use-energy analyses determine the energy consumption of transportation and urban land use: through the use of activity allocation models that determine the impact of transport systems on spatial development; by travel models that simulate future travel by the sequence of trip generation, trip distribution, modal split, and traffic assignment; and by models that calculate energy consumption by alternative modes. Simulation methodologies are used to determine the energy consumption of hypothetical urban forms. Detailed analysis methodologies, such as the driving cycle approach, simulate vehicle, road, and operation parameters. Traffic simulations trace the trajectory and operation of vehicles through a network. The statistical regression approach describes operating and maintenance costs of systems when fewer of the physical parameters are known, as in the driving cycle approach.

REFERENCE

Demerjian, K.L., Oxidant modeling status, Transportation Research Record 670, pp. 1-5, 1978.

KEYWORDS

Model assessment, air pollution/air quality

PERFORMING ORGANIZATION

U.S. Environmental Protection Agency
Environmental Sciences Research Laboratory
Research Triangle Park, N.C.

ABSTRACT

This paper describes the ongoing methodology of the St. Louis Regional Air Pollution Study, which is intended to provide highly resolved spatial and temporal emissions and ground monitoring data for use in model verification studies. The plan is to study mathematical models that are reactive photochemical air quality simulation models, which consider hydrocarbons, carbon monoxide, nitric oxide, nitrogen dioxide, and ozone. Once verified in the St. Louis study, these models could be used elsewhere. These models can provide a better understanding of chemical and physical properties associated with air pollution, be used to evaluate the effectiveness of current and future emission control regulations in achieving ambient air quality standards, identify major sources contributing to pollution, determine air quality compacts of alternative plans for transportation and land use, and evaluate optimum siting of instrument stations for air quality monitoring networks. The different forms of these models, all limited to urban scales and are deterministic in nature are: three dimensional grid model based on numerical solution of the atmospheric diffusion equation; two dimensional grid model based on the solution of the vertically integrated atmospheric diffusion equation; trajectory model based on a moving column of air in which vertical diffusion and chemical reaction take place; and single well-mixed cell with coupled ordinary differential equations that include emission, advection, entrainment, dilution, and chemical reactions.

REFERENCE

McNutt, B.D.; McAdams, H.T.; Dulla, R., Comparison of EPA and inuse fuel economy results for 1974-1978 automobiles--An analysis of trends, Society of Automotive Engineers, Technical paper no. 790932, October 1979.

KEYWORDS

Fuel economy

PERFORMING ORGANIZATION

U.S. Department of Energy (McNutt)
Washington, D.C.

Falcon Research and Development Co. (McAdams)
Buffalo, N.Y.

Energy and Environmental Analysis, Inc. (Dulla)
Arlington, Va.

ABSTRACT

The measurement of the fuel economy of automobiles by the U.S. Environmental Protection Agency differs from actual in-use fuel economy as observed by various sources. This paper reports on the continuing effort by the U.S. Department of Energy and others to quantify this difference, using the latest data. This paper updates the work that was reported in earlier papers, described under S-78-123 and S-79-371.

Data were added for the 1978 model year. A covariance analysis was used to identify variability among individual data sources; it was shown that the variation among sources was small relative to the variation within sources and the sources pooled by model year. An unweighted linear regression in gallons-per-mile space was used to evaluate the impact of the EPA to on-road relation on attainment of fuel economy standards and projection of fuel demand. The results were compared to other studies and used to project the impact on fuel demand. Some conclusions are: the size of the EPA to on-road fuel economy for 1974-78 model year cars ranges from about two mpg for a 15 mpg rated car, up to about eight mpg for a 27.5 mpg rated car; the shortfall for some EPA mpg ratings has increased with time; the sales-weighted average mpg shortfall has increased over time; in 1985 an EPA rated car of 27.5 mpg will achieve 19.2 mpg under present technologies; and there is less shortfall for diesel-powered cars.

REFERENCES

Cantwell, C., Light duty truck characteristics, Historical data base, U.S. Department of Transportation, Report no. DOT-TSC-NHTSA-79-37, December 1979.

Cantwell, C., Light truck characteristics, Historical data base, U.S. Department of Transportation, Report no. DOT-TSC-NHTSA-80-22, November 1980.

KEYWORDS

Trucks, data

SPONSOR

U.S. Department of Transportation
National Highway Traffic Safety Administration
Office of Research and Development
Washington, D.C.

PERFORMING ORGANIZATION

Chilton Company
201 King of Prussia Road
Radnor, Pa. 19089

ABSTRACT

The Transportation Systems Center maintains a database on light-duty trucks. These reports describe the scope, definition, collection, and recording of data on domestic and imported light-duty trucks sold in the U.S. during the model years 1955 through 1977. This type of vehicle is said to be in an evolutionary period, in which the character, use, population, and market penetration have changed.

Information is included in the data base for each model of truck that is manufactured domestically, is imported and the sales exceed 15,000 units annually, or is a popular model of import between 2,000 and 15,000 units sold annually. Some 80 attributes are used to describe each model, including name, transmission type, engine size, wheelbase, weight, capacity, fuel economy, performance, production volume, price, options, and cost of options.

Although the data base and data sources are described, the reports do not display any data. The information presented is potentially useful in building models relating to light-duty trucks.

REFERENCE

Anderson, M., Effects of federal regulation on the financial structure and performance of the domestic motor vehicle manufacturers, U.S. Department of Transportation, Report no. DOT-TSC-NHTSA-78-49, November 1, 1978.

KEYWORDS

Industrial financial performance

SPONSOR

U.S. Department of Transportation
National Highway Traffic Safety Administration
Office of Research and Development
Washington, D.C. 20590

PERFORMING ORGANIZATION

U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge, Md. 02142

ABSTRACT

This study deals with the corporate level financial operations of the domestic motor vehicle companies. Background research into financial performance was aimed at summing collective pressures from a variety of governmental sources to illustrate how these pressures are likely to interact with normal conditions of business in affecting financial performance. The primary goals of the study were (1) to establish the actual financial environment in which government regulatory spending takes place, and to define some of the major limits on this system in order to help assess the capabilities for future corporate spending programs; (2) to illustrate that regulatory costing must be performed within this corporate context if it is to more fully measure costs and financial pressures; (3) to survey briefly the financial histories and risks of these corporations; and (4) to survey some of the most important corporate-related costs of regulation, and to show that costs can be absorbed only within bounds defined by financial performance and legal or accounting realities. The authors indicate that this study is not intended to be an engineering costing survey, to predict sales, market performance, or competitive dynamics, to be an investment analysis, to predict a company's ability to meet a specific regulatory schedule nor to study policy alternatives, nor is it intended to introduce econometric or computer modeling techniques.

Subjects covered include: international issues and world markets; sales forecasts; costing and spending; processes affected by new regulations; financial operations, goals and capabilities; equity valuation and the cost of capital; sources and uses of cash flows; range of financial risk; proforma analysis; and incremental investment costing. In each subject area an analysis is done of each of the big four U.S. automakers.

In one section a computer simulation method is used to illustrate the future range of financial risk that may be possible for the automakers. This is done by projecting into the future the probabilities of events that have already occurred under normal business conditions. The levels of risk are shown to increase directly with increased product development spending. The output of this method is "financial pressure," which requires a need for external funding. Each funding is represented by a set of attributes, approximately equivalent to a balance sheet, that define the "average" structure of business over the past ten years, removing the behavioral pressures from recessions and peak sales years. Cyclical pressures are then defined in the three major classes of input variables, sales, profits, and capital spending. These are used to calculate corporate performance under a variety of conditions, all of which have existed in the past. The output takes the form of probabilistic mass functions of simulated financial pressures in the peak spending years for various levels of capital spending by each of the companies. The spread of the probabilities, not their concentration, is meant to illustrate how large a range of financial conditions can be produced by previously defined business conditions, and therefore, the range of contingencies a company must be able to meet. The analysis shows that all companies will experience increased pressures and could be expected to seek some additional external funding during a recession year, since much of their cash flow will be directed toward enforced capital spending.

Another section of the report uses sales of new autos as predicted by the DRI long-term model.

REFERENCE

Podar, M.K., Benefit-cost analysis of fuel economy standards for passenger cars, model years 1981-84, Pennsylvania State University, May 1978.

KEYWORDS

Fuel economy, national economic impact

PERFORMING ORGANIZATION

Pennsylvania State University
Department of Economics

ABSTRACT

This dissertation was written by an economist at the National Highway Traffic Safety Administration. It describes the process used in determining the fuel economy standards for cars built by U.S. manufacturers in model years 1981-84. The principles of cost-benefit analysis are described, as are the determination of the maximum feasible average fuel economy levels, a microeconomic impact assessment, the demand and the price elasticity of demand for new automobiles, the impact on competition and industry behavior, capital expenditures and their sensitivity, and a macroeconomic assessment. It is concluded that the fuel economy standards that were promulgated will have a salutary effect on the individual car buyer and on the national economy. The fuel economy improvements will result in operating cost savings, and the magnitude of additional manufacturer capital expenditures will be relatively small.

REFERENCE

Greenberger, M.; Richels, R.G., Assessing energy policy models: Current state and future directions, Annual Review of Energy 4:467-500, 1979.

CONCERNING MODEL:

Regional Electricity Model

KEYWORDS

Model assessment

PERFORMING ORGANIZATION

Johns Hopkins University (Greenberger)
Department of Mathematical Sciences
Baltimore, Md. 21218

Electric Power Research Institute (Richels)
Energy Analysis and Environment Division
Systems Program
3412 Hillview Avenue
Palo Alto, Calif. 94303

ABSTRACT

The "energy crisis" has spawned a large number of policy analysis models. This paper outlines the types of model analysis and assessment activities. Models (a large variety are used as examples) are classified according to the methodology used on the demand and supply sides: accounting, econometric, exogenous, optimization, process representation, and system dynamics. Two kinds of model analysis are described: those focusing on the model and those focusing on policy issues and uses of the model. A taxonomy is described in which those involved in model analysis may be model developers, users, analysts, or a mixed group. Analyses may be "natural," as part of ongoing work; "ad hoc," as when a project is organized expressly for the purpose; or "institutionalized," when analytic activity is established on a continuing basis. Model developers work on model creation, in modeling groups and workshops, and on own-model assessment and standards. Model users may engage in ongoing staff work, consultant's reports, and ongoing review. Third-party analysts may engage in spontaneous peer review and dissertations, organized review, and model assessment laboratories. Joint efforts include work in the marketplace of ideas, meetings, and ongoing forums. Examples are given of each type of work. Independent assessment includes the tasks of verification, validation, and assessment of usability and documentation. An experiment in model assessment is described, of the Baughman-Joskow Regional Electricity Model.

S-80-503

REFERENCE

Aggregate elasticity of energy demand, Stanford University, Report no. EMF 4 volume 1, August 1980.

CONCERNING MODEL:

PIES (75-004); EPM (78-462); BESOM (78-378); LITM (77-242); Sweeney (75-004A, 79-254); Faucett (76-016); WEFA Mark I (78-436)

KEYWORDS

Energy consumption, fuel consumption, model assessment

SPONSOR

Electric Power Research Institute

PERFORMING ORGANIZATION

Stanford University
Terman Engineering Center
Energy Modeling Forum
Stanford, Calif. 94305

ABSTRACT

A major study was conducted whose goal was to describe the aggregate price elasticity of demand implicit in energy demand models. An Energy Modeling Forum working group conducted experiments with 16 detailed models of the energy sector (some with transportation sectors), developing consistent estimates of 15-, 25-, and 35-year energy demand elasticities implicit in each. The comparison of results is descriptive; there is no attempt to produce a single best estimate. Since energy includes a number of heterogeneous commodities, each with a separate price, prices and quantities must be aggregated to calculate a single elasticity. Several alternative indexes for aggregation were examined: Paasche, Laspeyres, Tornquist, and Btu-weighted. Primary and secondary points of measurement were compared. Elasticities were found to vary significantly across sectors, among models, and among assumed policy regimes. Recommendations for model development standards are made. Energy system models compared include PIES/MEFS (75-004), Livermore Energy Policy Model (78-462), Pindyck model, Griffin OECD, FOSSIL1, and Baughman-Joskow Regionalized Electricity Model (REM). Energy-economy models include ETA-MACRO, BESOM (78-378) and Hudson-Jorgenson (LITM) (77-242), and the Parikh Welfare Equilibrium Model. Sectoral models studied include the ORNL-Hirst Residential Model, Jackson Commercial Model, Sweeney Transportation Model (75-004A and 79-254), Faucett Automobile Sector Forecasting Model (76-016),

Brookhaven Buildings Energy Conservation Model (BECOM), ISTUM, and Wharton EFA Motor Vehicle Demand Model (78-436).

This volume is based on papers by several authors. The citations for the drafts of some of these papers follow.

Borison, A.; Sweeney, J.L.; Wilson, T., Determining the price elasticity of demand for "energy": The theory and practice of aggregation, Stanford University, Working paper no. EMF 4.3, draft 5, November 1979.

Hogan, W.W.; Fromholzer, D., On estimating the elasticity of substitution for primary energy: Documenting negative results with traditional methods, Stanford University, Working paper no. EMF 4.1, draft, July 1977.

Hogan, W.W.; Weyant, J.P., Experiment designed to determine the elasticity of substitution between energy and other inputs by measuring the price elasticity implicit in energy models, Stanford University, Working paper no. EMF 4.0, draft, March 1978.

Lau, L., Quantification of uncertainty in elasticity estimates from the econometric models, Stanford University, Working paper no. EMF 4.8, draft, December 1979.

Lau, L.; Fromholzer, D., Elasticity estimation with dynamic models, Stanford University, Working paper no. EMF 4.12, draft, December 1979.

Manne, A.S.; Wilson, T.F., Econometric experiment of 1973, Stanford University, Working paper EMF 4.5, May 1979.

Nissen, D., Energy system elasticities, Stanford University, Working paper no. EMF 4.6, draft 2, May 1979.

Sweeney, J.L., Price and quantity change decomposition for aggregated commodities, Stanford University, Working paper no. EMF 4.7, draft 2, January 1980.

Weyant, J.P.; Wilson, T.F., Comparison of models employed in the EMF demand elasticity study, Stanford University, Working paper no. EMF 4.2, draft 2, September 1978.

REFERENCE

Automotive fuel economy program: fourth annual report to the Congress, U.S. Department of Transportation, Report no. DOT HS-805 279, January 1980.

KEYWORDS

Fuel economy

PERFORMING ORGANIZATION

U.S. Department of Transportation
National Highway Traffic Safety Administration
Washington, D.C. 20590

ABSTRACT

The activities of the National Highway Traffic Safety Administration in the fuel economy program during 1979 are reviewed. They include the following: re-evaluation and confirmation of the 1981-84 automobile fuel economy standards; standards for 1981 model year light trucks; recommending that auto manufacturers producing fewer than 10,000 vehicles per year be exempt from the standards; recommending that the application of credits toward reducing penalties that were earned for exceeding standards be extended from one to three years; recommending that manufacturers whose U.S. production of autos began after the standards law in 1975 be allowed to average their domestically produced cars that have 75% U.S. content with their foreign-produced autos, to avoid inadvertently discouraging foreign manufacturers from using high U.S. content in the vehicles they produce in the U.S. An automotive fuel economy conference was sponsored. The Cooperative Automotive Research Program was begun to support basic research. Fuel economy improvement beyond 1985 was studied.

Earlier annual reports on the automotive fuel economy program are described under: S-77-139, S-78-140, and S-79-141.

REFERENCE

Gass, S.I., Validation and assessment issues of energy models, proceedings of a workshop held at the National Bureau of Standards, January 10-11, 1979. U.S. Department of Commerce, NBS Special publication no. 569, February 1980.

CONCERNING MODEL:

SEAS (79-020), PIES (75-004), MEFS (S-78-419), SRI-Gulf (73-261)

KEYWORDS

Model assessment

SPONSOR

National Bureau of Standards
Center for Applied Mathematics
Operations Research Division
Washington, D.C. 20234

U.S. Department of Energy
Energy Information Administration
Washington, D.C. 20461

PERFORMING ORGANIZATION

National Bureau of Standards
National Engineering Laboratory
Washington, D.C. 20461

ABSTRACT

This report is the proceedings of a workshop on the validation and assessment issues of energy models, held at the National Bureau of Standards, Gaithersburg, Md., January 10-11, 1979. The workshop was designed to be a forum in which the theoretical and applied state-of-the-art of validation and assessment, with emphasis on energy models, could be discussed. Some twenty-nine papers are presented in these proceedings. Some of the topics discussed are taxonomy and structure of assessment and validation, the relationship between model assessment and policy research, independent third-party model assessment, improvement of the modeling process, model evaluation methods, and assessment of specific models. Some of the models discussed are the Strategic Environmental Assessment System (SEAS), Project Independence Evaluation System (PIES) (75-004), Midterm Energy Forecasting System (S-78-419), and SRI-Gulf Energy Model (73-261).

S-77-523

REFERENCE

Gass, S.I., Utility and use of large-scale mathematical models, proceedings of a workshop held at the National Bureau of Standards, April 28-29, 1977. U.S. Department of Commerce, NBS Special publication no. 534, May 1979.

KEYWORDS

Model assessment

SPONSOR

National Bureau of Standards
Center for Applied Mathematics
Operations Research Division
Washington, D.C. 20234

PERFORMING ORGANIZATION

National Bureau of Standards
National Engineering Laboratory
Washington, D.C. 20234

ABSTRACT

The workshop examined the problem of how to improve the use and utility of large-scale mathematical models in the federal government. This volume presents the papers and much of the discussion that took place at the workshop and a summary of directions for needed research. Participants included: A.J. Goldman, S.I. Gass, G.D. Brewer, G. Fromm, S. Bonder, D. Meadows, D. Maxim, A. Pugh, R. Larson, J.M. Chaiken, J. Barrett, Harvey Greenberg discussing the Federal Energy Administration experience with the Project Independence Evaluation System (75-004), David Kresge on the Electric Power Research Institute/National Bureau of Economic Research Energy Model Assessment Project, William Hogan on the Energy Modeling Forum, B. Crissey, J. Mulvey, and S. Dickhoven. Also included are a bibliography on model assessment, the workshop program, and a list of attendees.

REFERENCES

Asin, R.H., 1977 nationwide personal transportation study: User's guide for public use tapes, U.S. Department of Transportation, April 1980.

Asin, R.H., Characteristics of 1977 licensed drivers and their travel, 1977 Nationwide Personal Transportation Study Report 1, U.S. Department of Transportation, Report no. FHWA/PL/80/007, October 1980.

Strate, H.E., Nationwide personal transportation survey: Annual miles of automobile travel, report no. 2, U.S. Department of Transportation, April 1972.

KEYWORDS

Vehicle miles traveled, data

PERFORMING ORGANIZATION

U.S. Department of Transportation
Federal Highway Administration
Office of Highway Planning
Highway Statistics Division
400 Seventh St. SW
Washington, D.C. 20590

ABSTRACT

The purpose of the 1977 Nationwide Personal Transportation Study was to address the full range of trips and travel in the United States, along with the related social and economic characteristics of the tripmaker. Information was collected from households on all trips taken during a designated 24-hour period, and some additional detail was collected on all trips of 75 miles-or-more during the preceding 14-day period. Information was collected on the use and availability of public transportation facilities, types of motorized vehicles available to the household, characteristics of the trips taken, including mode, purpose, miles traveled, time required, and persons on the trip. One of the unique features was the attempt to estimate the amount of travel in urban and rural areas by the use of mapping during the home interview. The study was conducted by the Bureau of the Census under the sponsorship of the Department of Transportation. It was a part of the expanded scope of the National Travel Program, which is part of the Census of Transportation. This census is conducted every five years by the Census Bureau and includes the National Travel Survey.

The user guide presents information on the study, designed to update the earlier study done in 1969. It describes the background, scope, purpose of the study, information on the sampling methods, and collection and processing procedures; describes the estimating procedures used to create weighted data; and includes documentation of each of the eight

tape files made available on the public use tape. In addition, recoding and triplinking procedures for use in recoding of the 1977 study trip purposes for comparability with the 1969 trip purposes and for preparing data summaries for the two periods are also included. The guide includes a glossary of technical terms, copies of the questionnaire, and an order form with description and price of the public use tapes. [Author's introduction modified]

The reports that were planned for publication on the 1977 NPTS cover the subjects of licensed drivers, private vehicle ownership and physical characteristics, purpose of trips and travel, home-to-work trips and travel, vehicle occupancy, vehicle utilization, travel and the family life cycle, multi-occupant vehicle travel--public and private, rural vs. urban travel, mapping as a travel data collection technique, survey description and tables of variance, discretionary travel, household travel rates, and person-trip characteristics. The report on licensed drivers shows their distribution by place of residence, number of household drivers, number of household vehicles, and household income.

REFERENCE

Rouse, M.; Basham, W., 1975 automotive characteristics data base, U.S. Department of Transportation, Report no. DOT-TSC-OST-76-27, October 1976.

KEYWORDS

Fuel consumption, fuel economy, fleet size, data

SPONSOR

U.S. Department of Transportation
Office of the Assistant Secretary for Systems Development and Technology

Office of Systems Engineering
Washington, D.C. 20590

PERFORMING ORGANIZATION

U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge, Mass. 02142

ABSTRACT

The Automotive Characteristics Data Base (ACDB) was created on the Transportation Systems Center computer system in order to support studies requiring quick responses, the on-going Automotive Energy Efficiency Program, and the Voluntary Fuel Economy Monitoring Program. It may potentially be used to support modeling activities. 216 vehicles in the 1975 new car fleet were described by 50 attributes, including fuel economy performance, acceleration performance, emissions controls and levels, engine and drivetrain characteristics, interior and exterior dimensions, price, and production of models and vehicle configurations. Some of the uses to which the data base has been put are: analysis of domestic vs. import vehicle fuel economies for the Senate Committee on Commerce and the House Joint Committee on Internal Revenue Taxation; fuel economy by production quarter for the Federal Energy Administration; and various other studies for the Department of Transportation, Energy Research and Development Administration, and the Motor Vehicle Goals Beyond 1980 Study Panels on Automotive Design, Marketing and Mobility, Automotive Manufacturing, and Maintenance and Safety.

The report presents crosstabulations, histograms, plots, and regression analyses for a large variety of characteristics, all produced by the data base system. A user's guide to the system is also included.

REFERENCE

Annual report to Congress 1979, three volumes, U.S. Department of Energy, Energy Information Administration, Report no. DOE/EIA-0173(79)/1,2,3, 1980.

CONCERNING MODEL:

Faucett (76-016), ORNL State Level (78-263), LDVFFCM (79-368), MEFS (78-419), DGEM (78-243), LEAP (77-286), REPS (79-644), STIFS (79-418)

KEYWORDS

Energy consumption

PERFORMING ORGANIZATION

U.S. Department of Energy
Energy Information Administration
Washington, D.C.

ABSTRACT

This is the Energy Information Administration's third annual report. Volume One: Activities, contains descriptions of the agency's energy data operations, energy systems support, energy information validation, program development, applied analysis, energy information services, and planning and management activities. The agency's organization; energy data gathering forms; statistical publications; analysis, technical, and model documentation reports; and its models are listed.

Volume Two: Data, provides an encyclopedic compilation of quantifiable data on energy use including petroleum, natural gas, electricity, coal nuclear power, and solar and geothermal energy. An extensive subject index provides access to the 200 pages of tables and charts.

Volume Three: Projections, discusses the EIA's international energy assessment, short-term energy supply and demand (1980-81), mid-term (1985-1995), and long-term (2000-2030).

Among the 59 models used for projections are the: Transportation Sector Model, DOE/Faucett Automobile Sector Model (76-016), State Level Transportation Energy Demand Model (78-263), Light Duty Vehicle Fuel Consumption Model (79-368), Mid-term Energy Forecasting System (78-419), Dynamic General Equilibrium Model (78-243), Long-term Energy Analysis Program (77-286), Regional Emission Projection System (79-644), and the Short-term Integrated Forecasting System (79-418).

Short booklets containing synopses of the report are also provided.

REFERENCE

Eggert, R.J.; McCracken, P.W., Forecasting the automobile market, in How Business Economists Forecast, eds. Butler and Karesh, Englewood Cliffs, N.J.: Prentice-Hall, Inc., pp. 313-333, 1966.

KEYWORDS

Automobile demand

ABSTRACT

This article identifies different factors influencing the forecasting of automobile demand. Long-run and short-run forecasting problems are examined. Long-run forecasting aspects discussed include increasing GNP, automobile scrappage rate, discretionary income, desired stock adjustment, and the effects of income distribution, education level, residential location, and technological and product developments. Short-run forecasting aspects discussed include business recessions that tend to induce a sharp postponement of trading for new cars and that depress auto sales with a lag, used car stocks that serve as an indicator, seasonal sales variations, surveys that measure buyer intent, trends in fleet purchasing, sales stimulus of all-new models, and credit term changes.

Forecasting methodology is discussed. Statistical methods are said to offer increasing advantages, but are limited in modeling the full complexity of automobile demand. Forecasting often lags behind in results during fast-moving periods of the market. Model results of Chow (S-57-413) and Suits (58-033) are offered as evidence. The judgment of a seasoned analyst is deemed as a continuously valuable ingredient in the forecasting process.

REFERENCES

Limaye, D.R.; Steigelmann, W.; Davis, T.D., Review of energy models and forecasts applicable to Pennsylvania: Executive Summary, Synergic Resources Corporation, Report no. 7043-2, March 1980.

Colville, G.; Limaye, D.R., Review of energy models and forecasts applicable to Pennsylvania: Working paper XII: Review of transportation energy demand models, Synergic Resources Corporation, Report no. 7043-14, March 1980.

KEYWORDS

Energy consumption

SPONSOR

Commonwealth of Pennsylvania
Governor's Energy Council

PERFORMING ORGANIZATION

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ABSTRACT

This study represented an intensive effort from the perspective of energy policy analysis to review existing models and forecasts developed or used by government agencies, approaches used by electric and gas utilities, major policy issues facing the Commonwealth of Pennsylvania, and major energy data sources relevant to the development of policy-oriented models and forecasts. A range of supply/demand forecasts were synthesized, and a modeling approach for Pennsylvania was defined.

The working paper on transportation energy demand models includes: a discussion of the modeling process; a list of the factors influencing transportation fuel consumption (economic, demographic, transportation); a list of 35 data series definitions, their sources, and their coverage (U.S. or by state); a discussion of problems related to data availability and quality; a list of broad coverage data sources; a discussion of some major modeling issues; and a comparison of estimated gasoline price elasticities from 13 modeling efforts. This information would be potentially useful to a model builder. Also included are abstracts of models: Light-Duty Vehicle Fuel Consumption Model (78-368), State-Level Transportation Energy Demand Model (78-263), Faucett Automobile Sector Forecasting Model (76-016), and Energy Information Administration Transportation Sector Model and Short-Term Gasoline Consumption Model (78-336).

REFERENCE

Weaver, C.R., Impact of environmental, energy, and safety regulations and of emerging market factors upon the United States sector of the North American automotive industry, U.S. Department of Commerce, August 1977.

KEYWORDS

Industrial financial performance, vehicle manufacturing resource utilization, automobile demand, national economic impact

PERFORMING ORGANIZATION

U.S. Department of Commerce
Domestic and International Business Administration
Bureau of Domestic Commerce
Office of Business Research and Analysis

ABSTRACT

This report is a broad summary of the U.S. automotive industry and its relationship to international and federal regulatory impacts, as of late 1976. It includes an introduction to the industry and its operation, a discussion of the impact of safety, environmental, and energy regulations on the auto industry through the year 1985, and a discussion of imports of parts and components from expanding automotive industries outside of the U.S. and Canada. Specific subjects covered include: the role of the motor vehicle in U.S. transportation, the role of the motor vehicle in the U.S. economy, the structure of the industry, government regulations, technological factors, alternate materials and fuels, product development, consumer demand for automobiles, capital requirements of the auto manufacturers and their sources of finance, and international trade effects and implications. Material in this report was drawn from a variety of federal and industry sources.

REFERENCES

Greene, D.L.; Loebel, A.S., Vehicle-miles of travel statistics, lifetime vehicle-miles of travel, and current state methods of estimating vehicle-miles of travel, Oak Ridge National Laboratory, Report no. ORNL/TM-6327 Special, February 1979.

Gezen, A.; Khan, S.S., Existing data on vehicle-miles traveled in the United States, final report, TERA, Inc., July 1977.

Gezen, A.; Khan, S.S.; Mellen, N.F., Lifetime VMT and current state practices to estimate VMT, final report, TERA, Inc., October 1977.

KEYWORDS

Vehicle miles traveled, data

SPONSOR

U.S. Department of Energy
Office of Conservation and Solar Applications
Transportation Energy Conservation Division
Data Analysis Branch
Washington, D.C.

PERFORMING ORGANIZATION

Transportation and Economic Research Associates (TERA), Inc.
1901 North Fort Meyer Drive
Suite 888
Arlington, Va. 22209

Oak Ridge National Laboratory
Oak Ridge, Tenn. 37830

ABSTRACT

The TERA, Greene, and Loebel (1979) report is based, in part, on the work by Gezen and Khan (1977) and by Gezen, Khan, and Mellen (1977). Summaries of each of these are presented below. These reports indicate the problems inherent in vehicle miles traveled (VMT) data and the methods of VMT data estimation. The study by TERA, Greene, and Loebel (1979) is a review of current statistics on vehicle miles of travel in the United States and it identifies and evaluates sources of national VMT data for highway, rail, and air travel. From available information, VMT statistics by form of travel have been compiled for 1975. Vehicle lifetime VMT is estimated separately for passenger cars and trucks.

A survey of state practices in estimating VMT shows that states use one of three methods: (1) the fuel consumption method; (2) the traffic

count method; or (3) a combination of the two. An analysis of state VMT statistics indicates a surprising degree of consistency among the three methods despite significant differences in the variability of the estimates produced by the three methods. [Authors' abstract modified]

The report by Gezen, Khan, and Mellen (1977) examines lifetime vehicle miles of travel (LVMT) and documents current methodologies used by states to estimate aggregate vehicle miles traveled (VMT). Approaches to estimating car and truck LVMT are developed and the results are presented for the years 1967 to 1976. Over the period the average LVMT for trucks was approximately 125,000 miles. For cars, the average LVMT was approximately 95,000 miles. Average retirement ages are also presented.

In the second half of the document, the authors describe the methodologies used by the fifty states and the District of Columbia in compiling and reporting highway VMT data to the Federal Highway Administration. States use three basic methodologies to estimate VMT: traffic counting and fuel consumption, or a combination of the two. Brief descriptions of each state's methodology are presented.

The report by Gezen and Khan (1977) clarifies the definitions of published VMT data and provides a comparative analysis of various reported VMT statistics. Various sources compile and publish vehicle miles traveled (VMT) statistics in the United States. Depending upon the available means for collecting or estimating VMT, the scope or coverage of reports, and the population to be surveyed and the uses for which the data is desired or anticipated, the published figures for VMT differ, even within a mode. Additional problems are encountered in the labeling or description of published data. Primary sources of data for various vehicles (car, truck, train and plane) are identified. Recommended improvements to the VMT data include: the establishment of a uniform system of collecting highway VMT data by the states, reporting of detailed information useful in conducting energy conservation impact studies, and the extension of the data to include water and pipeline transportation. [Authors' introduction modified]

S-79-592

REFERENCE

Ullman, J.E., Cost of owning and operating automobiles and vans 1979, U.S. Department of Transportation, 1980.

KEYWORDS

Vehicle user costs/vehicle operating costs, data

PERFORMING ORGANIZATION

U.S. Department of Transportation
Federal Highway Administration
Office of Highway Planning
Highway Statistics Division
Vehicles, Drivers and Fuels Branch
Washington, D.C.

ABSTRACT

This is the type of reference work that may potentially be frequently used as an input to automobile sector analyses and models. It is one of a continuing series of pamphlets. It breaks down the costs of owning and operating 1979 models of various size-classes of vehicles into several components, for each year of the vehicle's life. A worksheet is provided for converting costs to any locality.

The components of total cost are: depreciation, maintenance and repairs, replacement tires, accessories, gasoline, oil, insurance, parking and tolls, garaging, and taxes (state and federal, gasoline, registration, titling, and sales tax). Costs are broken down into total cost and cost per mile, operating and ownership costs, cost by age of car per year, and total for the 10-year and 100,000 mile life of the typical car. Types of cars represented are standard size, compact size, subcompact size, and passenger van.

REFERENCE

Rabe, F.T., Review of procedures for determining corporate average fuel economy, two volumes, U.S. Department of Transportation, Report nos. DOT-HS-805 396,7, July 1979.

KEYWORDS

Fuel economy

SPONSOR

U.S. Department of Transportation
National Highway Traffic Safety Administration
Washington, D.C. 20590

PERFORMING ORGANIZATION

EIC Corporation
55 Chapel Street
Newton, Mass. 02158

ABSTRACT

This is a study of potential problems arising from uncertainties in estimates of corporate average fleet fuel economy (CAFE), which is compared with established standards as required by the Energy Policy and Conservation Act of 1975. The current Environmental Protection Agency procedure for determining CAFE is based on a representative approach of vehicle selection from the automobile manufacturer fleets rather than a statistical sampling approach. This has the advantages of cost, predictability of results, and the ability to employ vehicles and data already available from the Emissions Certification Program. It is shown to be not precise enough, however, to determine CAFE to within 0.1 mile per gallon and could possibly result in erroneous penalties or credits applied because of the several sources of bias or error that may be introduced into the estimates.

The subjects covered in this study are: a review of CAFE estimation: accuracy, confidence levels, types of errors, fleet stratification, class variance, and institutional constraints; alternative statistical procedures: optimal sample vehicle allocation, optimal stratum definition, regression estimation, replication testing, iterative sampling; the magnitude of fuel consumption variability; and the costs of the different estimation procedures. Studies of fuel economy modeled as a function of engine and vehicle characteristics are reviewed.

REFERENCES

Collins, M.J.; Greene, D.L.; Haese, R.L.; Lambdin, H.D.; Chen, E., Automobile monthly mpg and market share newsletter, Oak Ridge National Laboratory, June 1980, September 1980.

Holcomb, M.C.; Chen, C.K.E.; Greene, D.L.; Haese, R.L.; Lambdin, H.D., Motor vehicle quarterly mpg and market share newsletter: MPG and market share data system 1st quarter--Model year 1981, Oak Ridge National Laboratory, Report no. 81/1, February 1981.

KEYWORDS

Fuel economy, market share, data

SPONSOR

U.S. Department of Energy
Office of Transportation Programs
Analysis and Assessment Branch

PERFORMING ORGANIZATION

Oak Ridge National Laboratory
Transportation Energy Analysis Group
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Oak Ridge, Tenn, 37830

ABSTRACT

This periodical may serve as a potential source of data for short-term automobile market share modeling. The Oak Ridge Monthly MPG and Market Share (3MS) data system was developed for the U.S. Department of Energy to monitor changes in the composition and fuel efficiency of new car sales. Sales statistics for domestic automobiles are obtained from "Passenger Car Sales in the U.S. Reported by U.S. Manufacturers," tabulated monthly by the Motor Vehicle Manufacturers Association. Import sales are currently obtained from tables published monthly in Automotive News. These are mapped to corresponding Environmental Protection Agency-designed vehicle classes and mpg values obtained from the EPA/DOE Gas Mileage Guide for the respective model year. Station wagons are included with passenger cars of the same size class, while light trucks and vans are excluded.

Some of the tables included describe: sales by size class; domestic and foreign sales by year; market shares and sales-weighted efficiencies of autos by EPA class, by month and by manufacturer; twenty most popular 1980 models of automobiles; X-body car sales; total model year sales, market shares, and sales-weighted efficiencies of domestic or imported autos by EPA class, by year; percentage of sales by class, by year, and

by make; light truck registrations by make and year; and auto models by designated class. [Author's abstract modified]

S-80-601

REFERENCE

Hogan, W.W.; Weyant, J.P., Combined energy models, interim report, Electric Power Research Institute, Report no. EA-1420, May 1980.

CONCERNING MODEL:

Midterm Energy Forecasting System (S-78-419), SRI-Gulf Energy Model (73-261), Brookhaven Energy System Optimization Model (BESOM) (78-378); Long-term Interindustry Transactions Model (LITM) (77-242)

KEYWORDS

Energy consumption, model assessment

SPONSOR

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John F. Kennedy School of Government
Energy and Environmental Policy Center
79 Boylston Street
Cambridge, Mass. 02138

Stanford University (Weyant)
Terman Engineering Center
Energy Modeling Forum

ABSTRACT

The methodology employed in different combined energy modeling efforts is explained in a general, theoretical context, to reveal a common framework for organizing models, establishing properties of their solutions, and manipulating the models in the study of particular policy and planning problems. The many modeling techniques found in practice are described; it is shown how these techniques can be applied to other models; and an approach is outlined for the development and application of combined models. The results are meant to serve as a guide to the use of the many models developed by and available to energy decisionmakers in the electric power industry, other energy industries, and the public sector. Some of the subjects covered are: consistency of theory, natural data organization, modular design, decentralized implementation, efficient computation, optimization in a network of

models, decomposition, solutions, fixed coefficients, mathematical programming, production/cost function duality, approximations, price level determination, points of measurement, flows and stocks, optimality conditions, and algorithms. It is shown how large models are constructed through the careful integration of separate descriptions of components, and that separate development of components can result in optimal overall system solutions.

The models discussed include dynamic models of the energy economies of Mexico and the Ivory Coast, the Baughman-Joskow electric utility sector model, the Project LINK international trade model, and the energy models with transportation sectors including the Midterm Energy Forecasting System (S-78-419), the SRI-Gulf Energy Model (73-261), the Hudson-Jorgenson model (LITM) (77-242), and the Brookhaven Energy System Optimization Model (78-378).

S-80-609

REFERENCE

Weyant, J.P., Quantitative models in energy policy, Policy Analysis 6(2):211-234, Spring 1980.

CONCERNING MODEL:

Project Independence Evaluation System (75-004); SRI-Gulf Energy Model (73-261)

KEYWORDS

Energy consumption, model assessment, national economic impact

SPONSOR

National Science Foundation

Electric Power Research Institute

ABSTRACT

The author of this paper examines the extent to which large-scale models were used to analyze two proposed energy policies in the Ninety-fourth Congress: oil price decontrol and synthetic fuels commercialization. Two models that were used are the Project Independence Evaluation System (75-004) and the SRI-Gulf Energy Model (73-261). It was concluded that these models were successfully used because of (1) the high-level organizational position of model builders and advocates; (2) inclusion in the analytical framework adopted of all the impacts thought to be important by the decisionmakers; and (3) compatibility between the options and criteria considered in the analysis and those used in the policy debate.

REFERENCE

Study of potential for motor vehicle fuel economy improvement: fuel economy test procedures panel report, report no. 6 of seven panel reports, U.S. Department of Transportation and U.S. Environmental Protection Agency, January 10, 1975.

KEYWORDS

Fuel economy

SPONSOR

U.S. Senate
Committee on Commerce
Washington, D.C. 20510

PERFORMING ORGANIZATION

U.S. Department of Transportation
Washington, D.C. 20590

U.S. Environmental Protection Agency
Washington, D.C. 20460

ABSTRACT

This is the sixth of seven panel reports prepared by a task force under the joint sponsorship of the U.S. Department of Transportation and the Environmental Protection Agency to conduct a feasibility study of fuel economy improvement measures for new 1980 motor vehicles. This report focuses on the means of measuring fuel efficiency. The subjects covered include: the test driving cycle and its relation to actual vehicle operation; ambient conditions, such as wind, temperature, humidity, and barometric pressure, and their effects; road conditions, such as surface and grade; test locations: road, test track, or dynamometer; determining fuel consumption by fuel weight, fuel volume, or by carbon balance; vehicle road load determination: drawbar force, rear wheel or drive-shaft torque, coast-down timing, manifold pressure, fuel flow rate, or wind tunnel testing; and current test procedures: proposed Society of Automotive Engineers test, EPA test, and track-based procedures.

Other panel reports in this series are described under S-75-173, S-75-174, and S-75-226.

REFERENCES

Hooker, J.N.; Rose, A.B.; Greene, D.L., End use energy consumption data base: Transportation sector, U.S. Department of Energy, Report no. DOE/EIA/CR-7405-01, February 1980.

Hooker, J.N., Some problems of definition raised by a transportation energy data base, Changing Energy Use Futures, I:286-293, ed. Fazzolare, R.A. and Smith, C.B., Second International Conference on Energy Use Management, Los Angeles, Calif., October 22-26, 1979. New York: Pergamon Press.

KEYWORDS

Energy consumption, fuel consumption, data

SPONSOR

U.S. Department of Energy
Energy Information Administration
Assistant Administrator for Program Development
Office of the Consumption Data System
Washington, D.C.

PERFORMING ORGANIZATION

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ABSTRACT

A data base with potential for use in model development has been constructed which shows the end use energy consumption of transportation modes, broken down by year, mode, sector, use, range, carrier, region and state, and income. Detailed explanations are given of end use energy consumption, transportation energy use, the data types, the classification of energy use, the methods of data estimation for each mode, and the technicalities of gathering the data. The data collected are for the period 1967-1976 and may be used to support modeling efforts. Installation and use of the computer data tapes and programs are explained. A large sample of the data tables is presented in the report.

A section of the data base is related to automobiles. Fuel consumption by trip type or use is described. Other modes are air, rail, bus, truck, motorcycle, marine, natural gas pipeline, liquids pipeline, and military fuel uses.

A related paper discusses an issue related to the construction of the data base.

REFERENCE

Boyle, S.E.; Hogarty, T.F., Pricing behavior in the American automobile industry, 1957-71, The Journal of Industrial Economics, 24(2):81-95, December 1975.

KEYWORDS

Pricing

PERFORMING ORGANIZATION

Virginia Polytechnic Institute and State University

ABSTRACT

This paper attempts to demonstrate that collusive pricing behavior was present in the automobile industry in the 1957-1971 period. A model is set forth in which the price of a commodity is a function of the amounts of the characteristics it possesses. The coefficients on the amounts of the characteristics would represent implicit prices or the consumers' evaluations of the characteristics. They also represent incremental costs of producing the characteristics if the industry is perfectly competitive. If the industry were a non-collusive oligopoly, the coefficients would vary and could represent the firms' subjective evaluations of consumer preferences. If the industry were collusive, the coefficients would represent the cartel member's subjective evaluations and be the same for all member firms. Competition is implied when the price variable is measured as transactions prices and collusion is implied if list prices are used. Price-setting leadership is the means of effecting the same price/quality relationship without overt collusion.

List price is related to three quality characteristics: comfort, performance, and a dummy variable for power steering (brakes). The index of comfort was front seating room and the index of performance was horsepower divided by car weight. The relationship was regressed using a multiplicative log-linear form for each year 1957-1971, resulting in high explanatory power and coefficients that are reasonably stable over time. A standard homogeneity or F-test was then used to test the hypothesis that the coefficients in a year are the same for all manufacturers and thus that there is a collusive behavior. Comparison of the resulting F-values and critical values at the 0.05 level showed that all three of the major auto assemblers set prices consciously or otherwise in accordance with the model coefficients, except in 1958-59, when Chrysler seems to have "cheated" in its pricing while GM and Ford remained loyal. The authors asserted that the cartel behavior resulted from the Automotive Information Disclosure Act of 1958, which eliminated the practice of "price packing," that is, dealers adding large amounts to the manufacturer's suggested retail price and obscuring boundaries on prices to be charged. The act in effect set maximum public prices and

relatively fixed minimum prices, and made price "cheating" by a cartel member easier to detect. The authors explain also that General Motors performs the role of price leader; that Chrysler had attempted to "cheat" through a program of discounts on sales of fleets of autos, which was subsequently stopped by loyal cartel members GM and Ford; that the entry of foreign imports into the market and the U.S. assemblers' reaction was further evidence of a cartel; and that the industry's profit situation may also support the assertion.

REFERENCE

Richardson, B.C.; Golomb, D.H.; Luckey, M.M.; Suits, D.B., Assessment of the Wharton EFA automobile demand model, Transportation Research Record 764, pp. 89-96, 1980.

CONCERNING MODEL:

Wharton EFA Automobile Demand Model (77-046)

KEYWORDS

Model assessment

SPONSOR

Motor Vehicle Manufacturers Association
300 New Center Bldg.
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PERFORMING ORGANIZATION

University of Michigan
Highway Safety Research Institute
Policy Analysis Division
Ann Arbor, Mich. 48109

ABSTRACT

The Wharton EFA Automobile Demand Model was developed in 1976 by Wharton Econometric Forecasting Associates, Inc., for the Transportation Systems Center of the U.S. Department of Transportation. This stock-adjustment econometric model is a large-scale model of automobile demand. It has been widely used by federal agencies in policy analyses. However, no major analyses of the model were performed before it was applied and, in some instances, the model was used inappropriately. This paper reports the results of an analysis of the model. The structure of the model was examined. An attempt was made to reconstruct the key time-series equations of the model, the forecasting ability of the model was examined, and sensitivity testing was performed. Computer tapes of the model and data used in the analysis were obtained from the Transportation Systems Center. The analysis uncovered several major problems with the model. New-car sales are partitioned into size classes by using an unjustifiable approach, and some major policy variables (for example, gasoline price) are employed unrealistically in the model. These and other problems combine to seriously weaken the forecasting and policy analysis capabilities of the model. Because of this, policy analysts should use the model only with extreme caution. [Authors' abstract]

S-80-626

REFERENCE

Richardson, B.C., Methodological issues in analyzing automotive transportation policy models: Two case studies, Proceedings of the 1979 DOE Statistical Symposium, U.S. Department of Energy, Report no. CONF-791016, pp. 154-162, September 1980.

CONCERNING MODEL:

Wharton EFA Automobile Demand Model (77-046); Faucett Automobile Sector Forecasting Model (76-016)

KEYWORDS

Model assessment

SPONSOR

Motor Vehicle Manufacturers Association

PERFORMING ORGANIZATION

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ABSTRACT

A method for evaluating large-scale econometric models is outlined. Justification for the method and experience with it are explained. The two automobile demand and use models that were analyzed are the Wharton Econometric Forecasting Associates Automobile Demand Model (77-046) and the Jack Faucett Associates Automobile Sector Forecasting Model (76-016). The five primary tasks in the model analysis framework are model structure analysis, model equation reconstruction, submodel and full model evaluation, and model comparison. Test procedures are explained, such as static and dynamic simulations; the use of statistics such as root mean squared error and simulation R^2 ; and n-period-ahead forecasts. Experience with problems is discussed, including inadequate model documentation, incompatible or inconsistent computer programs, difficult-to-identify data, multiple versions of a model, and the peculiarities of a model's structure that impact on the ability to do evaluations of it.

REFERENCE

Murrell, J.D., Passenger car fuel economy: EPA and road, a report to the Congress, U.S. Environmental Protection Agency, Report no. EPA 460/3-80-010, September 1980.

KEYWORDS

Fuel economy, data

PERFORMING ORGANIZATION

U.S. Environmental Protection Agency
Office of Air, Noise, and Radiation
Office of Mobile Source Air Pollution Control
Emission Control Technology Division
2565 Plymouth Road
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ABSTRACT

This report represents a compilation of the current state of knowledge on the influences on automobile fuel economy. The primary issues it addresses are the measurement of fuel economy by the EPA, the use of this measurement by fuel demand analysts and auto consumers, and the variance of this measurement from in-use or on-the-road measurements of fuel consumption.

The subjects covered include: the "free market" period prior to 1975; the use of the EPA mpg as a "comparison yardstick" in the "voluntary mpg improvement" period 1975-1977; the use of EPA mpg as an "absolute yardstick" in the "mandatory mpg improvement period" 1978 and later; methods of in-use data analysis and presentation; representativeness of in-use data: imported cars, fleet- and consumer-driven cars, odometer mileage nonuniformities; time trends in the shortfall between EPA and in-use mpg; the attribution of overall "slip" between the measurements of mpg to vehicle slip, road slip, production slip, test vehicle condition, travel environment, travel characteristics, road vehicle condition, simulation variance, vehicle design features, and model year differences; sources of vehicle slip data; the influences on vehicle slip of odometer mileage, mpg tilt, production slip, and vehicle condition; the attribution of test vehicle condition to engine tune, malfunctions, fuel properties, fuel density, fuel octane rating, knock sensors, fuel volatility, and additives; the influences on mpg road slip of ambient temperature, barometric pressure/altitude, wind and aerodynamics, road gradient, road surface and condition, road curvature, vehicle speed, traffic volume, trip length, trip average speed, warmup effects, average miles per day, population of region, acceleration intensity, wheel condition, tire size, tire pressure, lubricants, and vehicle weight load; the influences on simulation variance of dynamometer loading, tire/dynamometer interaction, weight class

distributions, transmissions, power accessories, open windows versus air conditioner operation, and vehicle cooling; the attribution of measurement slip to the EPA carbon balance method, in-use fuel economy determination methods, and the calculation of fleet car mpg and consumer mpg; fuel economy effects in combination: mathematical implications and engine map considerations; the average fleet mpg by year in the past and projections for the future; the effects of vehicle age on relative fuel economy; and approaches to consumer adjustment of EPA mpg: questionnaires and formulae.

Four major conclusions are reached: On the average, fuel economy label and mileage guide figures (EPA) have been higher than in-use fuel economy since 1976; the exact relationship is shown. Shortfalls vary with mpg and model year. The actual improvement in road mpg from 1974 to 1979 was 28%. Three broad categories of factors are responsible for the difference between EPA and in-use mpg: the travel environment, weather and road conditions, representativeness of the EPA test vehicles and procedures, owner travel driving habits, and vehicle maintenance.

Also included are comments on draft versions of the report from citizens, industry, and other federal agencies. Appendices to the report describe: the method for averaging fuel economy data; examples of averaging and regression analysis methods; the energy balance for a synthetic motor oil; the relation between home-to-work trip and non-work travel speeds; computation of travel characteristics and effects: factors related to annual vehicle miles traveled, trip length and frequency, average vehicle speed and regional VMT, relative fuel economy, and cold start fraction; U.S. average road fuel economy for passenger cars from 1936 to 1978; and fleet fuel consumption implications. References are provided for all sources of information.

REFERENCE

Gruhl, J.; Gruhl, N., Methods and examples of model validation--An annotated bibliography, preliminary, Massachusetts Institute of Technology, Report no. MIT-EL 78-022 WP, July 1978.

KEYWORDS

Model assessment

PERFORMING ORGANIZATION

Massachusetts Institute of Technology
Energy Laboratory
Model Validation Group
Cambridge, Mass. 02139

ABSTRACT

This report consists of a large number of references, categorized in the areas of: general model validation methods, procedures, and methods; statistical and dynamic model validation techniques; validation of energy and electric power models; economic and financial models; world and management models; government, political, institutional, and criminology models; resource, environment, and scientific model validation; social, urban, and transportation model validation; educational, psychological, and marketing model validation; and health, medical, and physiological model validation. Despite the title, there are no annotations with the citations in this report. It is marked "to be annotated."

S-69-655

REFERENCE

May, F.E., Adaptive behavior in automobile brand choices, Journal of Marketing Research, IV:62-65, February 1969.

KEYWORDS

Automobile demand, market share

SPONSOR

University of Missouri
Research Council
Columbia, Mo.

PERFORMING ORGANIZATION

University of Texas
Austin, Texas

ABSTRACT

This article presents information useful for modeling automobile brand choice or demand. It postulates that consumer decisions to repurchase or change a currently owned automobile make are determined by the sequence of the consumer's previous ownership experiences with present and past makes. The hypothesis is supported by analysis of a sample of new-car purchases. Data used were those developed through interviews by the Public Opinion Survey Unit of the University of Missouri in 1966. 139 household heads were included. The following relationships were shown to hold: (1) The search for additional alternatives depends on which automobile make is first considered in the purchase decision. (2) Among searchers who considered at last one alternative to the make first considered, a repurchase or switching from the currently owned make depends on the number of visible alternatives. (3) There is a direct relationship between repurchase of the currently owned make and the previous ownership of that make. (4) The choice of the first make considered in the purchase process depends on previous ownership experience with the currently owned make. [Author's abstract and conclusion modified]

REFERENCE

Cunningham, W.H.; Crissy, W.J.E., Market segmentation by motivation and attitude, Journal of Market Research, IX:100-102, February 1972.

KEYWORDS

Automobile demand, market share

PERFORMING ORGANIZATION

University of Texas (Cunningham)
Marketing Administration
Austin, Texas

Michigan State University (Crissy)
Marketing Administration
Lansing, Mich.

ABSTRACT

The objective of this study is to explore the foreign/domestic market segmentation of the U.S. compact car market with respect to several characteristics of new-car purchases. These characteristics were selected socioeconomic, demographic, motivational, and attitudinal variables. The sample was drawn from individuals who purchased Mavericks, Volkswagens, Toyotas, and Renaults in the period February to May 1970 in Ingham County, Michigan. The authors report three implications of their research: (1) the compact car market is segmented on the basis of socioeconomic, demographic, motivational, and attitudinal characteristics; (2) inverse factor analysis is applicable to research in market segmentation; and (3) the compact car market appears to be two markets, one for foreign cars and one for American cars. This study is potentially useful in modeling brand choice and manufacturer market share.

REFERENCE

Richardson, B.C.; Barnett, W.S.; Dahl, C.A.; Roberts, D.C.; Joscelyn, K.B., Overview of selected national-level energy/transportation mathematical models, Ann Arbor, Michigan: UMI Research Press, Report no. UM-HSRI-80-47, 1980.

CONCERNING MODEL:

Sweeney (79-254), HFCM (80-563), Faucett (76-016), HGDM (78-263), TECNET (79-020, 79-309), SRI-Gulf (73-261), EPM (78-462), GEMS (77-283), LEAP (77-286), BESOM (78-378), DESOM (79-384), MARKAL (78-398), TESOM (79-383), LITM (77-242), I-0 (78-361)

KEYWORDS

Energy consumption, model assessment

SPONSOR

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PERFORMING ORGANIZATION

University of Michigan
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Policy Analysis Division
Ann Arbor, Mich. 48109

ABSTRACT

Many national-level mathematical models have been developed as an aid in studying the relationship between energy and the economy. These models are generally dynamic multi-sector models capable of simulating alternative energy policies and economic and technological scenarios. This report presents the results of a review of national-level energy models that contain transportation sectors. It identifies and briefly describes the transportation sectors in the context of each overall model. Key aspects of these components are compared. Some transportation components focus on the automobile sector, while other models consider several modes.

Four energy modeling systems are included in the report: The Midterm Energy Forecasting System (MEFS) (S-78-419), including the Sweeney Model (79-254), the EEA Highway Fuel Consumption Model (HFCM) (80-563), the Faucett Automobile Sector Forecasting Model (76-016), and the ORNL Highway Gasoline Demand Model (78-263); the Strategic Environmental

Assessment System (SEAS) and its component the Transportation Energy Conservation Network Revised (79-020 and 79-309); the SRI-Gulf Energy Model (73-261) and its derivatives, the Livermore Energy Policy Model (EPM/LLL) (78-462), the Generalized Equilibrium Modeling System (GEMS) (77-283), and the Long-Term Energy Analysis Program (LEAP) (77-286); the Brookhaven National Laboratory Modeling System, including the Brookhaven Energy System Optimization Model (BESOM) (78-378), the Dynamic Energy System Optimization Model (DESOM) (79-384), the Market Allocation Model (MARKAL) (78-398), the Time-Stepped Energy System Optimization Model (TESOM) (79-383), the Long-Term Interindustry Transactions Model (LITM) (77-242), the Dynamic Generalized Equilibrium Model (DGEM) (78-243), and the Center for Advanced Computation/Brookhaven Energy Input-Output Model (78-361).

Information on each model was organized by the following categories: model name, overview, uses, input data, output data, modeling structure and techniques, relationship to other models, computer requirements, transportation component, and references. The major model systems are compared as to their forecast horizon, policies that can be simulated, policy impact variables, technique, economic aspects, input, output, status, and uses. An annotated bibliography is also included with references to 37 other fuel consumption models.

REFERENCE

Third automotive fuel economy research contractors' coordination meeting, summary report, U.S. Department of Transportation, December 1-2, 1980.

KEYWORDS

Fuel economy

PERFORMING ORGANIZATION

U.S. Department of Transportation
National Highway Traffic Safety Administration
Technology Assessment Division
Washington, D.C. 20590

ABSTRACT

A comprehensive research and analysis program is underway at the National Highway Traffic Safety Administration (NHTSA) to support fuel economy standards rulemaking activities. Implementation is carried out through private sector contracts and the Transportation Systems Center (TSC). Contractors' coordination meetings are held to provide an opportunity for interaction. The first and second Automotive Fuel Economy Research Contractors' Coordination Meetings were held in 1978 and are reported under S-78-122. This 1980 meeting consists of reports in the areas of Industry Analyses, Driver Energy Conservation, Heavy Duty Trucks, Consumer Research and Market Demand, Vehicle Weight Reduction, Diesel Engine Studies, and Spark Ignition and Drivetrain Improvements. The Industry Analyses papers are: "U.S. Automobile Regulation: An Examination of the Foreign Experience and Its Implication for U.S. Policy" by the Center for Policy Alternatives; "The Japanese Automobile Industry--An Economic Overview" by the University of Michigan; "Assessment of Manufacturing Changes in the Automotive Industry" by TSC; and "Employment and Economic Effects of Changes in the Automotive Industry--A Plant and Community Study" by NHTSA and TSC. The Consumer Research and Market Demand papers are: "Changes in Motor Vehicle Buyer Attitudes and Market Behavior" by Rogers National Research; "Consumer Behavior Towards Fuel Efficient Vehicles" two studies, by Market Facts, Inc. and National Analysts; "Consumer Acceptance of Research Safety Vehicle Attributes" by The Prism Corporation; and "Methods for Improving Demand Forecasting" by Charles River Associates.

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Griliches, Z.; ed., Price indexes and quality change: Studies in new methods of measurement, Cambridge, Mass.: Harvard University Press, 1971.

Griliches, Z., Hedonic price indexes revisited, Introduction to Price Indexes and Quality Change, pp. 3-15, Cambridge: Harvard University Press, 1977.

KEYWORDS

Pricing

SPONSOR

Federal Reserve Board
Price Statistics Committee
Washington, D.C.

National Science Foundation
Washington, D.C.

PERFORMING ORGANIZATION

Harvard University
Department of Economics
Cambridge, Mass.

ABSTRACT

This book is a collection of papers concerning the field of price indexes and quality change. These papers on hedonic price indexes were reprinted as a collection to facilitate the communication of research results. Many of the papers deal with the indexing of motor vehicle prices, and those price index models appear elsewhere in this inventory. The papers presented in this book are:

Hedonic Price Indexes Revisited, by Zvi Griliches

Taste and Quality Change in the Pure Theory of the True-Cost-of-Living Index, by Franklin M. Fisher and Karl Shell

Hedonic Price Indexes for Automobiles: An Econometric Analysis of Quality Change, by Zvi Griliches (61-682)

Price and Quality Changes in Consumer Capital Goods Market: An Empirical Study, by Phoebus J. Dhrymes (67-693)

International Price Comparisons by Regression Methods, by Irving B. Kravis and Robert E. Lipsey (69-696)

Quality Bias in Price Indexes and New Methods of Quality Measurement, by Jack E. Triplett

Measuring Quality Changes and the Purchasing Power of Money: An Exploratory Study of Automobiles, by Phillip Cagan (64-695)

The Measurement of Quality Change from Vintage Price Data, by Robert E. Hall (71-697)

The book is indexed and contains a bibliography.

The introduction to this book provides an overview of the hedonic price index literature. Hedonic price indexes were developed in an attempt to produce a "pure" price index that does not contain the price changes of a good attributable to changes in its quality. Fundamental to the approach is the hypothesis that "the multitude of models and varieties of a particular commodity can be comprehended in terms of a much smaller number of characteristics or basic attributes of a commodity such as 'size', 'power', 'trim', and 'accessories'" for automobiles. The approach asserts that the price of a commodity can be related to the levels of various characteristics inherent in the commodity. Regressions are usually run with price being related to the level of the characteristics. The author notes that the approach has three important issues: the relevant characteristics, the form of the relationship between prices and characteristics, and the estimation of the "pure" price change from such data. Included in the paper are references to the prior research involving automobile prices, tractor prices, and diesel engine prices. As an example, the author compares two price indexes for 1966 and 1967 automobiles to show how the different approaches produce different conclusions.

This study would potentially be helpful to those researchers developing or whose studies substantially depend on price indexes, and to those using a hedonic demand modeling approach.

REFERENCE

Train, K., Consumers' responses to fuel-efficient vehicles: A critical review of econometric studies, Transportation, 8(3):237-258, September 1979.

CONCERNING MODEL:

Chase Model of Automobile Demand (74-002A), Train Structured Logit Model (T-80-653), Lave and Train Model of Auto-Type Choice (77-055)

KEYWORDS

Automobile demand, pricing, market share, model assessment

PERFORMING ORGANIZATION

Cambridge Systematics, Inc./West
Berkeley, Calif.

ABSTRACT

In an effort to conserve fuel, Congress required that auto manufacturers increase the average fuel efficiency of the vehicles they sell. The extent to which this policy is successful in conserving fuel depends on how consumers respond to the more fuel efficient vehicles. The present paper reviews previous economic research on automobile demand and examines what this research can tell us about how consumers will respond. Three categories of research are reviewed, namely aggregate econometric studies, disaggregate econometric studies, and hedonic price analyses. It is shown that insufficient variation and too large covariation among automobile characteristics (such as price, weight, and length) are problems that hinder each type of analysis. Two methods to alleviate these problems are proposed for further research. [Author's abstract]

Models discussed include: the Chase Econometrics Model of Automobile Demand (74-002A), Train structured logit model of automobile ownership and mode choice (T-80-653), Lave and Train disaggregate model of auto-type choice (77-055), and Dewees' Hedonic Price Study.

4.0 INDEXES

A Guide To The Indexes

The models and documents in this Inventory are indexed by six categories:

Personal authors	Keywords
Organizational authors	Model names
Sponsors	Report titles

In the case of joint authorship or sponsorship each author or sponsor is listed separately. Not all documents have both personal and organizational authors and sponsors, and therefore, not all of them appear on each list. Most models and documents have more than one keyword, and therefore, appear under several keywords in that index.

The indexes in this volume (starting on pg. 315) contain citations to both the models and the associated literature (S-documents) that are summarized in this report in Sections 2.0 and 3.0, respectively. The indexes are cumulative with respect to the two previous volumes of the inventory:

Richardson, et al. 1979. An Inventory of Selected Mathematical Models Relating to the Motor Vehicle Transportation System and Associated Literature.

Richardson et al. 1980. An Inventory of Selected Mathematical Models Relating to the Motor Vehicle Transportation System and Associated Literature - First Supplement.

The indexes identify models and documents by their accession codes. Each model or document is assigned a five-digit number. The first two digits represent the year in which the report was written, and the last three the order in which the reports were received by the University of Michigan Staff. It is the last three digits by which the documents and models are ordered in the various Inventory reports. For example, 74-005 follows 75-004.

Some accession codes carry the suffix A, B, or C. These suffixes note distinct submodels of a large model and may be considered as stand-alone models.

In the indexes, the accession codes may be followed by (79) or (80).

(79) indicates that the model or document is summarized in the 1979 volume of the Inventory. That is the first Inventory in the series.

(80) after the accession code indicates the document is summarized in the 1980 volume of the Inventory which is the First Supplement. If there are no numbers in parentheses following the accession code, the model or document is contained in the present volume of the Inventory, the Second Supplement.

Examples:

78-211 (80) is a model written in 1978, is the 211th document collected, and is summarized in the first supplement by Richardson et al. (1980).

S-80-609 is a supplementary document written in 1980, is the 609th document collected, and is summarized in the present volume.

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ABSTRACT

This is the second supplement to a volume that presents (1) descriptions of selected mathematical models (econometric, physical, accounting, etc.) relating to the motor vehicle transportation system, and (2) abstracts of associated documents that relate to models and the policies analyzed by the models. The models included generally have the potential for use in automotive transportation policy analyses. Complete references and summaries are given for the models and associated literature. The models are further described, indicating their objectives, structure, data and computer requirements, and other relevant information. Indexes included may be used to identify models and documents according to model name, report title, keywords, personal and organizational authors, and sponsors. Twenty-six subject areas are covered, including: automobile demand, fuel consumption and economy, air pollution, vehicle size-class market share, and vehicle miles traveled.

