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UMI RESEARCH PRESS

Published by UMI Research Press,
an imprint of University Microfilms
International, Ann Arbor, Michigan 48106.
Printed and bound in the United States
of America.

UM-HSRI-79-2

Library of Congress Cataloging in Publication Data

An Analysis of Wharton EFA automobile demand model.

(Transportation research, policy analysis studies)
1. Automobile industry and trade—United States—Mathematical models. 2. Motor vehicles—United States—Mathematical models. 3. Supply and demand—Mathematical models. I. Golomb, D. Henry, 1950- II. Wharton Econometric Forecasting Associates. III. Series.

HD9710.U52A68 338.4'7'62922220973 79-23876
ISBN 0-8357-1083-1

ACKNOWLEDGMENT

The efforts of many people were involved in completing this study and producing this report. Their assistance and cooperation are gratefully acknowledged.

This document is one of the workproducts of a more general study of mathematical models relating to the motor vehicle transportation system. The general research design was developed by Kent B. Joscelyn and Barbara C. Richardson, the co-principal investigators of the project. Michael M. Luckey and D. Henry Golomb further developed and implemented the specific technical approach. Barbara C. Richardson and James H. Saalberg provided technical supervision. Lawrence D. Segel assisted D. Henry Golomb in the computer programming aspects of the project.

Other staff members of the HSRI Policy Analysis Division assisted in preparing this report. In addition to those named above, Murray Greyson, Thomas C. Anderson, David C. Roberts, Prakash B. Sanghvi, W. Steven Barnett, and William W. Wheeler of the Policy Analysis Division reviewed and critiqued the text. External reviewers included Professors R. S. Hanna, Daniel H. Hill, Saul H. Hymans, Stephen M. Pollock, Daniel B. Suits, and William J. Wrobleski.

Administrative support was coordinated by Jacqueline B. Royal. Anne L. VanDerworp coordinated word processing and report production. Jackie L. Stadler, Deborah M. Dunne, and Teresa M. Chase typed portions of the report. The report was edited by James E. Haney and Joan H. Kmenta.

Several people provided information for this study. Particular thanks go to Stewart E. Butler and Ronald Mauri of the Transportation Systems Center of the U.S. Department of Transportation, and Colin J. Loxley of Wharton Econometric Forecasting Associates, Inc.

The Motor Vehicle Manufacturers Association (MVMA) Ad Hoc Committee on Federal Simulation Models served as an advisory committee for this project during fiscal year 1978. Members included Richard H. Shackson, chairman, James F. Marquardt, Jack H. Merritt, and Samuel M. Zentman. Alternate committee members were Neil E. South and Irene E. Szopo. During fiscal year 1979 the MVMA Subcommittee on Federal Simulation Models served as an advisory group to this project. Members include Jack H. Merritt, chairman, Sol Drescher, Thomas N. Ronayne, and Neil E. South. Lawrence E. Slimak and Christian van Schayk of the MVMA served as staff for the committees.

Without the cooperation, support, and critical reviews provided by these individuals, the study would not have been possible. The responsibility, however, for any errors in this report lies entirely with the authors.

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Co-principal Investigator

Barbara C. Richardson
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EXECUTIVE SUMMARY

This document reports the results of an analysis of the 1977 version of the Wharton Econometric Forecasting Associates (EFA) Automobile Demand Model. The analysis, performed by the Highway Safety Research Institute (HSRI) of The University of Michigan, was sponsored by the Motor Vehicle Manufacturers Association and was part of a larger HSRI study entitled "Analytical Study of Mathematical Models of the Motor Vehicle System."

The Wharton EFA Automobile Demand Model is an econometric model of long-term automobile demand. In the model automobile demand is represented by a stock-adjustment process. The model is designed to forecast the size and composition of U.S. automobile demand and stock and other variables over the long term, given projected vehicle characteristics and general economic and demographic conditions. Other significant outputs that may be derived with additional assumptions include forecasts of fuel consumption, industry employment, and tax revenues flowing directly from sales and vehicle operations. The model contains about 400 equations and over 600 variables.

The purpose of this report is to analyze specific capabilities of the model: the model's ability to forecast the long-run size and composition of U.S. automobile demand and stock, in total and by type of vehicle, and its ability to predict the response of these long-run variables to changes in economic, technological, and demographic conditions.

Method

The HSRI analysis consists of four steps:

- Model structure analysis

- Equation reconstruction
- Submodel evaluation
- Full model evaluation

Model structure analysis involves examining the theory and logic underlying the model. The analysis was applied to the model as a whole, and to the components--i.e., related groups of equations--that make up the model. The components of the model were grouped into the following sets:

- Miles per gallon equations
- New car price equations
- Capitalized cost per mile equations
- Desired stock and desired stock share equations
- Actual demand for new cars and for automobile travel, total scrappage, and used car market equations
- Actual stock by age and type of car equations including new car stock equations

These groupings were chosen because they correspond to the major subroutines of the Wharton EFA automobile model computer program.

As part of the structural analysis, the organization and operation of the model are outlined. This outline includes complete details of the input and output of the model. The analysis also includes a comprehensive detailing of the equations of each of the components of the model, and a detailed examination of the identities of the model.

In the second step, **equation reconstruction**, the behavioral equations of the model are analyzed in a two-stage process. First, the equations are reconstructed by means of a regression package on The University of Michigan computer system. The reestimated coefficients and summary statistics are checked against those reported by the model authors. This reconstruction is an attempt to ascertain that the version of the model and data received by HSRI are the same as those documented in the Wharton EFA auto model report. The second step involves examining the specification of the individual equations in order to understand the complete structure of the model.

The results of the equation reconstruction task were mixed. HSRI staff were able to replicate closely or exactly about seventy-five percent of the equations attempted. These include, for example, new car registrations, vehicle miles traveled (VMT), auto scrappage, and some new car stock share equations. HSRI staff were unable to reproduce, for example, the luxury new car stock share equation and the domestic new car stock share equations. The model authors suggested that the likely cause of this discrepancy was a revision in selected data series used in estimating the equations between the times of actually building the model and preparing the model program tape for delivery to the sponsor, the Transportation Systems Center of the U.S. Department of Transportation. Poor documentation made it impossible to reconstruct the cross-sectional equations of the model.

Analysis of the specification of the model equations in the second step indicates that **the signs of the estimated parameters of the equations are generally consistent with economic theory.** However, in no case is an equation in the Wharton EFA auto model derived a priori from theory; most are justified after the fact.

In the **submodel evaluation**, the third step in the HSRI study, the forecasting behavior and dynamic properties of submodels are analyzed. Submodels are individual equations or groups of equations within the full model. Three sets of submodels that contain the highly related, key equations of the model are analyzed. These submodel sets are:

- New car sales, scrappage, VMT per family, and desired stock per family equations
- New car market shares and desired stock shares equations
- Capitalized cost per mile equations

The forecasting behavior analysis involves examining how well the simulated values of a submodel over a given period match the known historical values for that period. The analysis of dynamic properties involves examining the response of the submodel variables to specified changes in the independent variables and estimated parameters. Although the results of these individual experiments are interesting, their most important value lies in the insights they provide into the operations of the full model.

The fourth step, **full model evaluation**, produces crucial information with which to assess the model. The full model evaluation extends the three submodel analyses outlined above in order to completely understand the dynamic properties and forecasting behavior of the full model. The analysis of the forecasting behavior of the full model is performed over the same period as in the submodel analyses so that direct comparisons can be made. Comparisons of simulations of the full model also are made for two different historical periods to examine how well the model tracks different historical episodes. In another series of experiments, analyses are made of the tendency of the model to accumulate forecasting errors as the forecasting horizon increases.

Dynamic properties of the full model are studied in a manner similar to that used in the submodel evaluation. Most of the experiments involve testing how the model's predictions of the full model respond to the same exogenous variables that are tested in the submodel evaluation. This permits comparisons to be made between the submodel and full model experiments.

Results

One objective of the model is to forecast the long-run level of new car demand, travel demand, scrappage, and the size and composition of the U.S. automobile stock. Another objective is to predict responses of the market to changes in the inputs to the model. **The HSRI analysis indicates that the Wharton EFA authors failed to meet these objectives.**

The model is, in general, incapable of forecasting accurately. In simulations over the period to which the model was fitted, yearly errors average 9.5% in new car sales, 14.5% in scrappage, and over 30% in new car stock shares. In addition, the model equations for travel demand and scrappage have a tendency to accumulate large forecasting errors as the forecasting horizon is lengthened.

The flaws in the basic assumptions behind the new car stock share equations also lead to an extremely poor prediction of the share of imports in new car sales. Thus, the model should not be used to explore penetration of imports into the U.S. new car market.

Although inaccurate in forecasting short-run changes, the model does have some usefulness in predicting trends of new car sales, automobile travel demand, and scrappage. However, the model is incapable of predicting trends in new car sales by size class. In fact, forecasts of new car sales by class are so poor that any application of the model that involves these forecasts would be entirely misleading. Among the important variables that depend on these forecasts are **average fleet fuel economy** and **average new car fuel economy.**

Another result is that the equations that generate price and sales of used cars by age are not based on sound theory.

The model is insensitive to changes in policy-related input variables although the direction of the effects produced by altering input variables are, for the most part, reasonable and consistent with economic theory.

In summary, this version of the Wharton EFA Automobile Demand Model does not do what it was designed to do. The model does follow the trends of such variables as:

- **new car sales,**
- **automobile travel demand, and**
- **scrappage.**

The model does not follow the trends of:

- **new car sales by type and**
- **stock of cars by type and age.**

Model output (e.g., average fleet and average new car fuel economy) that depend on forecasts of the variables indicated above are not reliable.

Two newer versions of this model are under development. These are being designed to incorporate light trucks and vans into the model and to correct some of the shortcomings of the original version. Draft documentation of the new versions is available at the time of this writing, although computer tapes of the model are not. From the information available it appears that, with few exceptions, the limitations of the model raised in this report are not being adequately addressed in the newer versions.

CONTENTS

1.0 INTRODUCTION

This report presents the results of an analysis of the Wharton Econometric Forecasting Associates (EFA) Automobile Demand Model (Schink and Loxley 1977)(1). The analysis was performed between July 1977 and June 1978 by the Highway Safety Research Institute (HSRI) of The University of Michigan, under the sponsorship of the Motor Vehicle Manufacturers Association (MVMA), and was part of a larger study entitled "Analytical Study of Mathematical Models of the Motor Vehicle System" that has been underway since early 1977.

1.1 Background

The utilization of complex mathematical models to analyze, forecast, simulate, and evaluate the impacts of existing or proposed public policies has become common in recent years. Given the complexity of the real world, policies are difficult to evaluate when large numbers of interrelated factors must be taken into account and integrated.

A mathematical model may be defined as a set of equations or algorithms. The model may include submodels that are subsets of equations of the complete model. The use of mathematical models has obvious attractions for conscientious policymakers. The models are designed to distill the most important relationships into a systematic reflection of the world, so that large masses of data can be reduced to useful key values and statistics in an organized, efficient, and timely way. In the transportation sector this attraction has led to the extensive development, in the last decade, of mathematical models of various aspects of the motor vehicle transportation system that center on the problems of an adequate national highway system, highway safety, environmental pollution, energy consumption, and other areas of concern.

Increasingly, the federal government has been using these models, many of which it has sponsored, as tools in the research that leads to the formulation of policies, regulations, and legislative decisions related to the motor vehicle industry. Notable recent examples include the use of models in the 1974 Project Independence Study by the Federal Energy Administration (Jack Faucett Associates and Interagency Task Force on Energy Conservation 1974) and by the 1976 Federal Task Force on Motor Vehicle Goals Beyond 1980 (U.S. Department of Transportation 1976) to produce estimates of future automobile demand, vehicle miles of travel, gasoline consumption, and vehicle dynamics.

Recognizing that model development is increasing and that models are frequently being used in federal efforts to solve critical economic, resource, and social problems, the Highway Safety Research Institute in early 1976 initiated a preliminary inquiry into the use of models in policy formulation related to the motor vehicle transportation system, where "policy" refers to any rule, regulation, piece of legislation, or executive directive. During that study, approximately thirty models were identified. They deal with vehicle production and resource accounting, vehicle miles of travel, automobile sales and pricing, vehicle fleet attributes, and energy factors. It was evident at the end of the preliminary study that the number of relevant models was large and continuing to grow. Furthermore, to make meaningful evaluations of models would entail implementing and exercising the models on a computer to determine their capabilities and limitations.

On the basis of the results of HSRI's preliminary study, the MVMA agreed to sponsor a more extensive effort to expand the inventory of relevant models and to commence detailed analysis and evaluation of selected models that were thought to be particularly important to policy formulation processes at the federal level. This larger "Analytical Study of Mathematical Models of the Motor Vehicle System" began in early 1977.

Based on the information gathered during the model inventory portion of the project, it was obvious that the Wharton EFA Automobile Demand Model was one of the most widely used models of its type in policy analyses. It was, therefore, chosen as the first model to be analyzed. This document is the report on the HSRI analysis of the logic and structure of the model and on the actual computer implementation and running of the model by HSRI project staff.

Two other work products of the Analytical Study of Mathematical Models of the Motor Vehicle System were recently completed: a model inventory that encompasses extensive summary information on seventy-eight mathematical models dealing with various aspects of the motor vehicle system (Richardson et al. 1978) and a report that presents a summary of all project activities during fiscal year 1978 (Richardson and Joscelyn 1978). A third publication that is being completed coincident with this report presents the results of a study of the applications of the Wharton EFA Automobile Demand Model in federal policy formulation (Saalberg, Richardson, and Joscelyn 1979).

1.2 Objectives

The Analytical Study of Mathematical Models of the Motor Vehicle System has five broad objectives: (1) to identify and analyze mathematical models relating to the motor vehicle transportation system models, (2) to provide the capability to exercise selected models on a computer, (3) to exercise models under alternative future conditions, (4) to modify or develop models in response to specific requirements, and (5) to develop an understanding of the contexts in which they are being used as part of the policy development process.

This report addresses a portion of the first objective above. More specifically, the objective of this analysis of the Wharton EFA auto model is to assess the capabilities of the model with regard to meeting its stated purposes of (1) forecasting the long-run size and composition of U.S. automobile demand and stock, in total and by type of vehicle, and (2) accurately predicting the response of these long-run variables to changes in major economic, technological, and demographic conditions.

1.3 Background on the Wharton EFA Automobile Demand Model

The Wharton EFA Automobile Demand Model was developed in 1976 under the sponsorship of the Transportation Systems Center (TSC) of the U.S. Department of Transportation. The project was initiated specifically to provide that federal agency and others with a better analytical tool for investigating the potential impacts of proposed policies and regulations on the motor vehicle industry and on the economy in general.

The Wharton EFA auto model has been operational since early 1977, and it was used almost immediately in studies related to energy conservation. It has been employed to evaluate the probable economic and fuel consumption impacts of the 1981-1984 passenger automobile fuel economy standards (the so-called "gas guzzler" tax and fuel efficiency rebate provisions of the administration's 1977 "gas guzzler" tax proposal), the administration's consumption-related gasoline tax proposal (also part of the 1977 energy plan), and the introduction of electric vehicles. In addition to energy-related studies, the model was used in at least one investigation of a safety-related matter, namely, the passive-restraint air bag.

Relatively few agencies within the federal government have directly applied the model or its outputs to date, but the power and position of these agencies in the policy-making process gives substantial importance to any method they employ. The greatest use of the model has been in the Department of Transportation (DOT), specifically in the National Highway Traffic Safety Administration (NHTSA), which is responsible for establishing and enforcing vehicle fuel economy standards as well as safety regulations. The Wharton EFA auto model has also been used in the Office of Intermodal Transportation, which performs key policy studies and analyses within the Office of the Assistant Secretary for Policy and International Affairs; and in the Transportation Systems Center, the research arm of the DOT. Analyses based directly on the model have also been conducted by the International Trade Commission for the Senate Finance Committee and by a research arm of Congress, the Office of Technology Assessment.

1.4 Technical Approach to the Analysis

The Wharton EFA auto model is a long-run multiple-equation econometric model. An econometric model is composed of equations that summarize relationships among economic variables and quite often the relationships among economic and demographic variables. The parameters are statistically estimated from historical data relevant to the sector of the economy that the model is intended to describe. While econometric models describe relationships that exist among variables, they may also be used to forecast future events (changes in the endogenous variables) that occur as a result of changes in the exogenous variables in the model. There are two points that must be noted here. First, the use of such a model as a forecasting tool assumes that the same structural relationships among variables that existed in the past will exist at least approximately in the future. Second, in order to have any confidence in the forecasted values of the endogenous variables for future years, the user must have confidence in the forecasted values of the exogenous variables which are input to the model.

Clearly these two conditions do not always hold. There is no guarantee that future relationships will duplicate (or even be similar to) the past. Indeed it is likely that the passenger automobile fuel economy standards required by Title V of the Energy Policy and Conservation Act of 1975 may alter the historical relationships between new car sales and various macroeconomic indicators. Since the econometric models that constitute the Wharton EFA auto model do not explicitly incorporate this type of policy variable, there is little reason to expect the model to predict well for the period covered by Title V standards. The model will be capable of forecasting accurately if and only if public policy measures such as Title V operate primarily through variables included in the econometric submodels on which the overall model is based. If this is the case, then these variables can be said to be proxies for the public policy variable. Whether there are sufficiently detailed measures included in the models to act as proxies for all the structural changes that are likely to happen in the future is highly dubious. This uncertainty increases greatly as the forecast period is extended further into the future.

In addition, the values of the independent variables used as input to the model are based on forecasts whose degree of accuracy remains unknown until they become historical realizations. Nevertheless, barring any drastic and unforeseen events, econometric models may be used successfully in long-term forecasting as long as the limitations on the accuracy of the forecasts are recognized.

There is more than one version of the Wharton EFA Automobile Demand Model. The model analyzed in this paper is the version that was operational on the computer of the Transportation Systems Center in July 1977. During the course of this analysis it was found that some minor portions in the final report of the model (Schink and Loxley 1977) were different from the model as it appeared on the magnetic tape obtained by HSRI staff from TSC. The analysis presented here is based on the best information that was available from both TSC and Wharton EFA. There are inconsistencies between the documentation and the data received from TSC. These inconsistencies obviously have created problems in this analysis, especially in the attempt to reconstruct the equations of the model. These problems are addressed in Section 3.

Two newer versions of the model are currently under development: the Wharton EFA Motor Vehicle Demand Model: Mark I and Mark II. These versions are being designed to update and improve the original version and to include light trucks and vans in addition to passenger automobiles. Draft documentation on these versions is available (Loxley et al. 1978; Loxley, Osiecki, and Rodenrys 1978), although computer tapes of the model are not. Review of these documents suggests that even though the model is being revised the analysis reported here will nevertheless be useful since many of the basic criticisms deal with problems inherent in the model that are not being addressed in these revisions. Two aspects of model criticized here, which are being revised in the newer versions, are the vehicle miles traveled and the foreign and domestic shares equations. The HSRI analysis staff plans to conduct further analyses of the changes to the model as more complete documentation becomes available.

Four steps were followed in analyzing the Wharton EFA auto model. Since the complete model is generally used in policy analyses, this HSRI analysis aimed at understanding the structure and dynamics of the full model. The information obtained during the performance of each of the first three steps of model analysis provided additional insight into the full model.

First, in model structure analysis, the logic and theory of the full model were examined. Interrelationships among variables and equations of the model were explored with the aid of flow diagrams.

Second, reconstructing the key equations of the model, using a multiple linear regression package, served the purposes of (1) providing a clear understanding of the data and equations used in the model, (2) checking the accuracy of the equation specifications and coefficients as indicated in the original model report, and (3) providing statistical information pertaining to the quality of the equations.

Since the Wharton EFA model is so large and complex, the breakdown of the model into submodels for analysis purposes facilitated an understanding of the dynamics and forecasting behavior of the complete model. In the third step, submodel evaluation, the dynamic properties of the submodels were analyzed by examining the response of the submodel to specified changes in the independent variables or estimated parameters; their forecasting behavior was studied by comparing the results of submodel runs over a historical period with actual observed values of the dependent variables.

Finally, the forecasting behavior and dynamic properties of the full model were examined. A test was also made to determine whether the model tends to accumulate errors.

It is clearly not practical to analyze all aspects of such a large model. The HSRI project team believes, however, that the analysis performed adequately covers the most important aspects of the Wharton EFA auto model.

1.5 Organization of Report

This report is organized as follows. Section 1, the introduction, includes a statement on the background of the project and its objectives, a brief background statement about the Wharton EFA auto model, and a summary of the technical approach. Section 2 presents the analysis of the structure of the Wharton EFA auto model, a discussion of the theory underlying the model, and a description of the model and its major computational blocks. In Section 3, the reconstructed equations are presented and discussed. Section 4 describes the submodels that were selected for analysis and the results of their evaluation. Section 5 presents the evaluation of the full model, including discussions of its dynamic properties and forecasting behavior. Section 6 summarizes the study's findings, and the conclusions are presented in Section 7.

2.0 STRUCTURE OF THE WHARTON EFA AUTOMOBILE DEMAND MODEL

2.1 Introduction

The Wharton EFA auto model is a large and complex econometric model that contains over eighty statistically derived equations and three hundred identities. The paramount output of the model is a forecast of the size and composition of long-run automobile demand (sales) and total stock, given future vehicle characteristics and economic and demographic conditions and/or assumptions that are fed into the model at the beginning of a simulation. Other outputs include forecasts of vehicle fuel efficiencies, new car prices, used car prices, and used car market transactions.

Although the model is complex, much of the basic theory underlying it is typical of auto demand models that have been constructed over the past twenty years. The central concept underlying the model is that the automobile market operates by a stock adjustment process. Fundamental to the working of a stock adjustment process is the assumption that gross expenditures on a commodity such as automobiles, measured in units sold, can be calculated from the difference between a "desired" stock and the stock already in existence, also taking into account the need to replace old stock as it wears out. Desired stock, a key concept in stock adjustment models, refers to the long-run "steady state" or equilibrium level that exists if all factors affecting automobile demand are held constant into the indefinite future.

Five size classes of vehicles are defined in the model: subcompact, compact, mid-size, full-size, and luxury. The desired total stock of automobiles and the desired stock of cars in each size class are, essentially, the number of cars that would be in existence if the consuming public owned and operated all the cars it needed, wanted, and could pay for under existing price and income conditions.

With this logical basis, desired stock and desired shares are derived within the model, using equations based on cross-section data by state for 1972. The use of the desired stock and desired share variables in this manner is an innovative variation of the stock adjustment approach. The values of the desired variables are determined by key demographic, income, and vehicle cost variables. The demographic variables include number of households and licensed drivers per household. The income variables include real disposable income per family and the percentage of U.S. families earning over $15,000 in 1970 dollars. Vehicle costs include both the cost of the initial purchase and the accumulated operating costs over the average useful life of a vehicle.

Given the desired stock, subtracting the number of vehicles already in existence and those vehicles that are wearing out or scrapped for other reasons, the difference represents potential new car sales. Similarly, given the desired share of a vehicle size class and the gap between the desired share and actual share of that size class of vehicle on the road, the new car share of that size class of vehicle can be calculated. In simplest terms, this is how the model operates.

The Wharton EFA model's equations were divided by HSRI into six large computational blocks that correspond to the major subroutines of the model's computer program. These blocks are:

- Block A - miles per gallon equations
- Block B - new car price equations
- Block C - capitalized cost per mile equations
- Block D - desired stock and desired stock share equations
- Block E - actual demand equations
- Block F - actual stock equations

In the following subsections the theory and logic underlying the model are discussed. Wharton EFA's innovative approaches incorporated in the model are emphasized. Following that, the organization and operation of the model are discussed. This includes detailed examinations of the six computational blocks.

2.2 Theoretical Background

The Wharton EFA model operates essentially as a stock adjustment model of automobile demand. Although the Wharton EFA model authors incorporated a number of innovations, the stock adjustment approach to modeling automobile demand dates back to the 1950's (Chow 1957). This section summarizes the stock adjustment approach, its development, and the innovations Wharton EFA made to it.

Since about 1956-1957, most automobile demand models have evolved from the Chow and Nerlove stock adjustment models. However, mention should be made of a pioneering study of automobile demand conducted by Roos and von Szeliski (1939). Their model divides automobile demand into two components, new ownership demand and replacement demand. New ownership demand is estimated with reference to the rate at which ownership levels approach a saturation level, while replacement demand is assumed to depend on the rate of used car scrappage.

In 1957 Gregory Chow specified automobile demand in the following general way, which has since been widely copied. Chow first assumes that the desired stock of cars depends on economic variables (income and relative price), and that the speed at which actual stock adjusts to desired stock is a linear function of their difference.

Mathematically these two assumptions are

$$K^* = f(\text{Income, Relative Price})$$

and

$$K - K_{-1} = h(K^* - K_{-1})$$

where

K^* = desired stock of cars

K = actual stock of cars

h = adjustment coefficient

The adjustment to equilibrium desired stock is not considered to be instantaneous because of uncertainty about the level of targeted demand, because of transaction costs, and because of decision and purchasing lags.

To explain automobile demand Chow then makes use of the relationship

$$S = K - K_{-1} + d(K_{-1}),$$

where

S = new car sales

K = actual stock of cars

d = depreciation rate

Substituting the first equation into the second, Chow arrives at his stock adjustment model for new car sales:

$$S = h(K^* - K_{-1}) + d(K_{-1}).$$

For the income variable Chow experiments with both real disposable income and a measure of permanent income, which he finds works slightly better. For the new car price variable Chow constructs his own price index based on newspaper advertisements.

At about the same time Chow was publishing his automobile demand model, Nerlove (1957) published a similar model in response to a forecast proposed by Hans Brems (1956). Brems had described long-term trends in automobile demand as depending on new owners and replacement owners, without regard to cyclical or price influences. Nerlove replaces Brems's assumption that the stock is always at equilibrium with an assumed stock adjustment process.

While Nerlove seems to win the theoretical debate as to the proper general specification of automobile demand, his particular estimates are not believable, primarily because automobile demand depends on more than just price and income variables. In fact, cyclical economic variables are now considered of paramount importance in estimating the demand for new cars. Similarly, the price of used cars, the price of gasoline, and credit market conditions can be presumed to influence new car sales.

With respect to credit market conditions, Daniel Suits (1958) introduced a variable into the automobile demand equation to reflect credit conditions. Credit market conditions should be an important influence on new car sales since the majority of new car buyers borrow money to pay for their new car. Suits devises a price variable to approximate the average monthly payment for a new car; he claims that the credit condition is so important that if it is not included, the price elasticity of the demand for new cars becomes positive.

Generally then, in a stock adjustment approach, an expression for desired stock is formulated that assumes desired stock is a function of economic and demographic conditions. Desired stock refers to the equilibrium level of stock that would exist if all factors affecting the demand for it were held constant into the indefinite future. New purchases for a period, say a year, are calculated as the sum of the difference between desired stock and stock already on hand, and the depreciation of old stock.

However, it can be argued that consumers in general do not adjust their stock of vehicles to the desired level within a one-year period. A consumer may be unwilling to change his stock because of anticipation of changes in the current levels of economic variables, or his budget may have been committed to other items, such as installment payments of life insurance premiums. Thus an assumption is made that consumers will achieve only a fraction of the change to the equilibrium level.

Based on the assumptions outlined, a stock adjustment model of new car purchases can be formulated as follows:

$$X_t^* = a + b\ (e_1) + c\ (e_2) + g\ (d_1) + h\ (d_2) \qquad (2.1)$$

where

X_t^*	=	desired stock in year t
e_1, e_2	=	economic variables
d_1, d_2	=	demographic variables
a,b,c,g,h	=	constants

Then

$$X_{new} = K\ (X_t^* - X_{t-1}) + (1 - S)\ X_{t-1} \qquad (2.2)$$

where

X_{new}	=	new car sales
K	=	stock adjustment factor
X_{t-1}	=	stock on hand at the beginning of year t
S	=	survival rate

To solve equation 2.2 for new car sales, estimates are needed for desired stock, the stock adjustment factor, and the survival rate. Since the desired stock for a year is generally not known, an explicit estimation of desired stock was eliminated by substituting equation 2.1 for X_t in equation 2.2, yielding

$$X_{new} = (K)\ a + (K)\ b\ (e_1) + (K)\ c\ (e_2) + (K)\ g\ (d_1) + (K)\ h\ (d_2) + (1 - S - K)\ X_{t-1} \qquad (2.3)$$

Since the historical values of X_{new}, e_1, e_2, d_1, d_2, and X_{t-1} are known, (K)a, (K)b, (K)e, (K)g, (K)h, and (1 - S - K) can be determined by regression analysis or some other technique. Equation 2.3 represents a typical stock adjustment model for new car sales.

While the Wharton EFA auto model is essentially in the tradition of stock adjustment models, it differs in three ways from previous models of this type that deal with new car demand: (1) the way desired stock is constructed, (2) the form of the stock adjustment equation for new car sales, and (3) the way scrappage is integrated into the stock adjustment process. These three differences are presented briefly in the following subsections. In addition, two other innovative approaches are used that are very important to the output of the model. These approaches are (1) the procedure for estimating new car market shares by size class and (2) the concept of capitalized cost per mile to characterize vehicle costs. These five original concepts are described in the following subsections.

2.2.1 Desired Stock Equation. The theoretical concepts used in the Wharton EFA model for deriving desired stock are innovative. These innovations include the use of a separate equation to estimate desired stock as opposed to bypassing its explicit estimation as is done in the model represented by equation 2.3 above. This separate equation is estimated using a cross-sectional analysis.

The authors of the Wharton EFA auto model argue that classical economic theory indicates that the determinants of desired stock cannot be derived from time series data. The authors argue that in order to analyze the characteristics of consumer decision making, the choice and technology available must be held constant.

The Wharton EFA auto model uses 1972 cross-section data by state to estimate the desired stock equation. The authors selected this year because of their belief that in 1972, in general, and across states, the desired stock of automobiles was approximately equal to the actual stock. In that year, the economy was fairly stable; the rates of unemployment and inflation were at moderate levels; pollution controls had yet to make an impact; and small domestic cars had been present in the market for several years. Desired stock is a critical concept in the Wharton EFA auto model, and therefore it is analyzed extensively later in this report (see Equation Reconstruction in Section 3.3 and Submodel Evaluation in Section 4.2).

2.2.2 Form of New Car Sales Equation. The second way in which the Wharton EFA auto model differs from previous stock adjustment models is that Wharton EFA model does not use a conventional stock adjustment form of the equation for new car sales. Previous models expressed new car sales as a function of scrappage and the difference between desired stock and the beginning-of-the-year stock of cars. In the Wharton EFA auto model, new car sales are formulated as a "rate" relative to the beginning-of-the-year stock, less current scrappage, and this rate is expressed as a function of the desired stock relative to the beginning-of-the-year stock less scrappage. Thus, as desired stock increases relative to the stock of cars on the road, new sales tend to increase.

The Wharton EFA authors chose to fit their new car sales equation to a "rate" of new car sales. They probably believed that this estimated equation would be better at predicting changes in new car sales than the standard form of the equation, which was fitted to new car sales alone. The "rate" form of the equation isolates the changes in new car sales that are not caused solely by the upward trend changes in actual stock. Thus the equation corrects for the strong upward trend in new car sales and auto stock through the historical period.

2.2.3 Form of the Scrappage Equation. A third original concept in the Wharton EFA auto model is the specification of the scrappage equation. The authors constructed the scrappage equation so that yearly scrappage was also affected by the stock adjustment process. This is done by formulating scrappage as a "rate" relative to the beginning-of-the-year stock plus new car sales; this rate is expressed as an inverse function of the desired stock relative to the beginning-of-the-year stock plus new car sales. Thus, an increase in desired stock relative to the stock of cars on the road causes scrappage to decrease and new car sales to increase. Also, since new car sales appears in the scrappage equation and scrappage appears in the new car sales equation, these two variables tend to move together in the model. This reflects historical trends.

The form of the stock adjustment equations for new car sales and scrappage may tend to create some instability in the long-run predictions, however. In fact, it is easy to show mathematically that the long-run, steady-state prediction of actual stock need not equal the long-run level of desired stock as the theory would indicate. Indeed, in general, steady state does not necessarily imply the condition that desired stock equals actual stock. Steady state only implies no change in the auto fleet from period to period, i.e., new car sales equals scrappage. However, simulations of the model indicate that the model is empirically stable--i.e., the long-run level of actual stock does tend to have an equilibrium equal to the long-run level of desired stock.

2.2.4 Estimation of New Car Market Shares. Another original concept in the Wharton EFA auto model occurs in the determination of the percentages of new car sales by size class. The Wharton EFA authors estimate the long-run equilibrium level of shares, called the desired shares of total desired stock, similar to the way in which they estimate desired stock. As with the desired stock equation, Wharton EFA estimates the desired share equations using 1972 state cross-sectional data for the independent variables. Since no useful breakdown of the 1972 stock of cars by size class exists, the Wharton EFA auto model approximates the dependent variables, the desired stock composition, by averaging the sales shares for 1971 and 1972. There is no guarantee that the desired stock by size class for the historical period is in any way equivalent to the average sales by size class for 1971 and 1972. **Since this assumption is critical to the model, the uncertainty of this equivalence strongly influences the accuracy and dynamic properties of the model.** With an estimate of desired shares, the shares of new car sales by size class are expressed as a function of the difference between the desired shares and actual shares.

This procedure for estimating new car market shares is undermined by the model authors' strong assumption that the number of new cars sold of a particular type is a function of the gap between desired and actual stock of that type. This assumption implies, possibly correctly, that the number of new luxury cars sold is a function of the number of one-, two-, or three-year-old luxury cars on the road. However, it also implies that new luxury car sales are a function of the number of older luxury cars on the road. This, however, is probably not true. This assumption is investigated throughout the remaining sections of this report, and it is evaluated in the Submodel Evaluation of Section 4.2.2.

2.2.5 Capitalized Cost Concept. The desired stock and desired share equations depend on the cost of owning and operating a car. Therefore the Wharton EFA model authors developed a concept of auto costs, called capitalized cost per mile, that (1) treats the cost incurred and benefits accrued today in owning and operating a car as being of greater value than those anticipated in the future; (2) includes the relevant costs incurred by all owners of the car--that is, not only the costs of the original owner; and (3) includes all costs of purchase and operation, including purchase cost, financing costs, insurance costs, gasoline expenditures, and so on, into the calculation weighing them according to their economic significance. Details of how capitalized cost per mile variables are calculated are presented in Section 2.3.5.

2.3 Organization of the Model.

In this section, the basic logic of the entire system of equations of the Wharton EFA auto model is described. A detailed examination of the computer program for the model that HSRI received from the DOT Transportation Systems Center was undertaken and forms the basis of this discussion.

The following subsections present the general relationship of the equations in the program, the operation of the program, and the six logical groupings of the equations within it. These discussions are accompanied by flow diagrams that illustrate the detailed logic of the various components of the program.

2.3.1 Overview. The Wharton EFA auto model is an econometric model designed to forecast long-run equilibrium levels of the size and composition of U.S. automobile demand and stock so that the economic and market impacts of alternative policies could be studied in quantified form. The model has been used to evaluate policies such as the long-term impacts of vehicle fuel economy, emission, and safety standards. These applications of the Wharton EFA auto model are discussed in a companion report (Saalberg, Richardson, and Joscelyn 1979). It should be noted that the model is not intended to evaluate the short-term impacts of such policies.

The Wharton EFA auto model divides the vehicle population into five size categories. These categories, which are referred to as size classes, are based on wheelbase and price, as follows:

1) Subcompact--up to 100-inch wheelbase and not in class 5;
2) Compact--100- to 111-inch wheelbase and not in class 5;
3) Mid-Size--111- to 118-inch wheelbase and not in class 5;
4) Full-Size--over 118-inch wheelbase and not in class 5;
5) Luxury--all "high-priced" cars.

In addition, the model distinguishes between domestic and foreign-made cars for the subcompact, compact, and luxury classes. In all, eight classes of cars are modeled: domestic subcompact, foreign subcompact, domestic compact, foreign compact, mid-size, full-size, domestic luxury, and foreign luxury.

In order to facilitate discussion and analysis of this complex model, HSRI has divided the model into six sets of logically related equations called computational blocks. These blocks correspond to the division of the Wharton EFA auto model computer program into major subroutines (2). The blocks are:

- Block A--miles per gallon equations, from which miles per gallon or fuel efficiency estimates are generated for each class of new car and for the total new car fleet.
- Block B--new car price equations, from which new car prices are estimated.
- Block C--capitalized cost per mile equations, from which the cost of operating a typical car from each class is estimated, taking into account both purchase costs and the stream of operating costs over an average ten-year lifespan, discounted back to current dollar values.
- Block D--desired shares and desired stock equations,

from which the desired shares for each class of car and for the total stock of cars are estimated.

- Block E--actual demand equations, from which total new car sales, scrappage, and used car prices and transactions are estimated.
- Block F--actual stock equations, from which actual (as opposed to desired) stock and stock by class shares are updated and estimated.

The major outputs and required exogenous inputs for each block are listed in Table 2-1. The relationship of the blocks is shown in Figure 2-1 and is summarized briefly below. A complete description of the blocks is provided in Sections 2.3.3 through 2.3.8.

In Block A, estimates of fuel economy or miles per gallon for each of the five categories of new cars are generated. Independently of Block A, Block B produces estimates of total purchase price for new cars by class and for each of the four components that make up the purchase price: transportation charges, base price, expenditures for options, and purchase taxes.

Block A and B feed into Block C to calculate the capitalized cost per mile for each class of car. The capitalized cost per mile is essentially the present value of all costs associated with the purchase, sale, and operation of a car with a ten-year lifetime and the lifetime mileage of 100,000 assumed. These assumptions are questionable and are discusssed in Section 2.3.5. Essentially, Block A with an exogenous gasoline price per gallon provides the fuel cost component of the operating costs, and Block B provides the estimate of purchase costs.

The capitalized cost per mile estimates are used in Block D to calculate the desired stock of vehicles and the desired shares of stock for each of the five size classes. These estimates are of critical importance to the model, since they constitute the targets toward which existing stock would move under the conceptual framework of the stock adjustment process. Computation of the desired share and desired stock estimates is complex; it is done on the basis of

TABLE 2-1

WHARTON EFA MODEL EXOGENOUS INPUT AND MODEL OUTPUTS BY BLOCK

Model Exogenous Input	Model Output
Auto Characteristics Assumptions Curb Weight by Class Engine Displacement by Class Fraction of Cars with 4 Cylinders by Class Fraction of Cars with 6 Cylinders by Class Fraction of Cars with Overdrive by Class Fraction of Cars with Automatic Transmission by Class MPG Efficiency Factors by Class **Economic Activity Assumption** Ratio of City to Total Vehicle Miles Traveled	BLOCK A Miles Per Gallon Estimates for New Cars by Class • City • Highway • Combined • EPA Estimates
Economic Activity and Price Assumptions Transportation Price Index Foreign Auto Export Price Base Price Ratio of Class to Fixed Weight Average Index of Input Costs Consumer Price Index Real Disposable Income Maximum Price of Installed Options by Class Total State and Local Taxes on New Cars by Class **Demographic Assumptions** Number of U.S. Families	BLOCK B New Car Price • Transportation Charges by Class • Base Price by Class • Expenditures on Options by Class • Purchase Taxes by Class • Total New Car Price by Class

TABLE 2-1 (Continued)

WHARTON EFA MODEL EXOGENOUS INPUT AND MODEL OUTPUTS BY BLOCK

Model Exogenous Input	Model Output
Economic Activity and Price Assumptions Finance Charge Discount Factor Gasoline Price Insurance Cost Index Tire Cost Index Parking, Tolls Cost Index Motor Oil Cost Index Repair Cost Index **Policy Variable** Total State and Local Taxes on New Cars by Class	BLOCK C Capitalized Cost Per Mile • Capitalized Cost Per Mile by Class
Economic Activity and Price Assumptions Ratio of Total Retail Outlets to Foreign Retail Outlets Real Disposable Income **Demographic Assumptions** Percent People Living in Metropolitan Areas Ratio of Pacific Population to Total Population Ratio of Mountain Population to Total Population Ratio of New England Population to Total Population Ratio of West South Central Population to Total Population Ratio of Resident Population, 20-29, to Total Number of Families Ratio of Families with 3 and 4 Members to All Families Number of U.S. Families Ratio of Families with 5 or More Members to All Families Licensed Drivers Per Family **Transportation Mode Assumption** Persons Traveling to Work by Non-Auto Means	BLOCK D Desired Shares and Desired Stock • Desired Shares by Class • Desired Shares/Domestic and Foreign • Desired Stock Per Family

TABLE 2-1 (Continued)

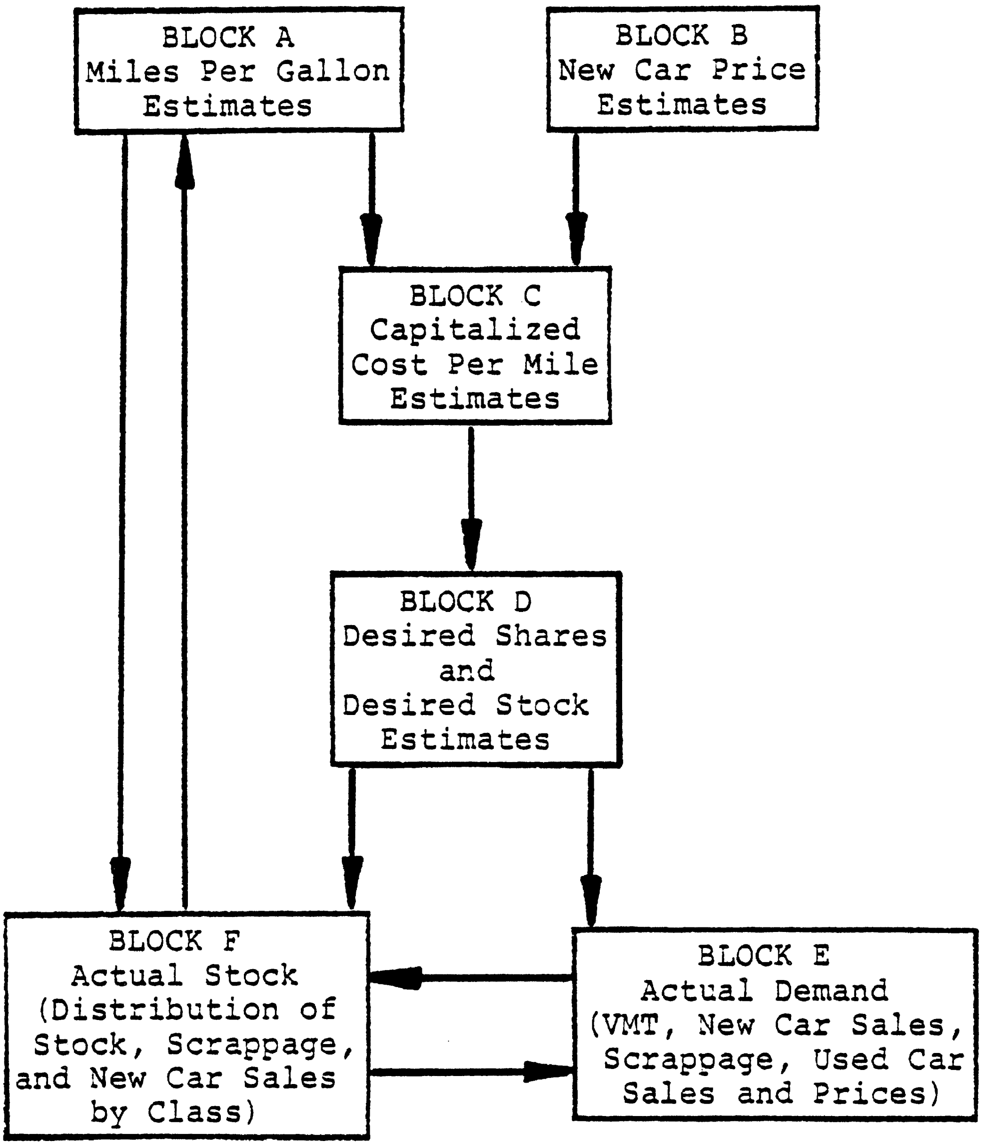
WHARTON EFA MODEL EXOGENOUS INPUT AND MODEL OUTPUTS BY BLOCK

Model Exogenous Input	Model Output
Economic Activity and Price Assumptions Gasoline Price Real Disposable Income Unemployment Rate Scrap Metal Price Index Rate of Decline in Used Car Prices by Size Class	**BLOCK E** **Actual Demand** • Total Stock • Total Vehicle Miles Traveled • New Car Sales • Scrappage • Used Car Sales by Class • Used Car Prices by Class • Number of Trade-Ins by Age

Model Exogenous Input	Model Output
Economic Activity and Price Assumptions Domestic Share of New Car Sales by Size Class Total Number of Makes of Cars by Class Real Disposable Income Number of Makes by Class Number of Dealers by Class **Demographic Assumptions** Number of Persons 25 Years and Older with 4 or More Years of College Ratio of Resident Population, 20-29, to Total Families Percent of Population in Metropolitan Areas Ratio of Pacific Population to Total Population Ratio of East North Central Populations to Total Population	**BLOCK F** **Actual Stock** • Scrappage Adjustment Factor • Scrappage Probabilities by Age • Shares of New Cars by Class • Cars in Operation by Class • Scrappage of Cars by Class • Shares of Cars by Class after Scrappage • Expected Scrappage for Older Cars • Mid-Year Stocks by Age • Average Age of Stock • Vintage-Weighted VMT

FIGURE 2-1

FLOW DIAGRAM OF THE WHARTON EFA MODEL



the relative costs of different cars, the relationships of these costs to family income, and various other economic and demographic factors. The estimate of total desired stock is derived on the basis of the desired share, weighted capitalized cost per mile, family income, the number of licensed drivers, the number of U.S. families, and other economic and demographic variables.

In Block E, total new car sales, scrappage, total stock, and total vehicle miles traveled (VMT) are estimated. Each of these estimates is dependent on the other three, making the estimates highly simultaneous. New car sales and scrappage also depend on the estimates of desired stock derived in Block D as well as on variables of Block F.

Block F contains two sets of equations: one predicting the stock of cars by class and by age, and the other predicting the number of new cars by class. The predictions for the total stock by age depend on new car sales estimated in Block E and a vehicle survival model that determines the scrappage of cars by age. The scrappage estimates in the vehicle survival model depend on the total scrappage estimate of Block E. The estimation of new car sales by size class depends on the desired stock share estimates generated in Block D and on the actual or existing number of cars on the road of that size class after scrappage, which is predicted within Block F. The estimation of the foreign and domestic shares of new car sales by size class is made exogenously, because the equations that were developed to forecast the shares produced implausible results. **This initial version of the model is incapable of predicting foreign and domestic shares.**

The complexity of the model is highlighted in the above overview. One example of this complexity is that many of the predictions generated in Block E depend on predictions generated in the following Block F. In addition, the average MPG estimates over all size classes of vehicles depend on the results of Block F, and some calculations in Block F depend on the MPG estimates from Block A. To aid the reader in understanding how calculations can be made in one block when they require variables that are estimated in a later block, an explanation of the workings of the computer program follows.

2.3.2 Model Operation. This section summarizes how the computer program of the model generates forecasts. As noted in the previous section, many variables that are needed for a prediction at one stage are, in fact, forecast further down in the program. The computer program handles this situation through the following general iterative procedure.

In a forecast simulation, all endogenous variables--that is, variables predicted within the model--are initialized to the most recent historical (i.e., known) values available. For the documented version of the Wharton EFA auto model that is analyzed in this study, the endogenous variables are initialized at the 1974 values. All lagged variables are initialized according to their historical values. A lagged variable is a variable set to its value for the year previous to the year of a given simulation. Thus, the 1974 new car price lagged one year is the 1973's new car price. The exogenous variables--that is, variables whose values are determined outside of the model--must be specified separately for each year of the forecast period. Once the endogenous variables are initialized and the values of the exogenous variables set, the computer program is said to be initialized, and it can begin to generate a forecast.

The forecast is generated by solving the equations in each block sequentially, starting with Block A and ending with Block F. If an equation requires a value for an independent variable that is, in fact, generated as the output from an equation further down in the program, the 1974 initialized value of that independent variable is used. If an equation requires the value of an independent variable that is predicted in a previously solved equation, the predicted value of that variable is used. The values of the endogenous variables generated--that is, the model predictions--are compared to the initialized values of the endogenous variables. If there are no major differences (a major difference is defined as one greater than

.05%), then these solution values become the forecast values. If there are major differences, the computer program proceeds to solve the model again. The endogenous variables in the model are reinitialized to the first iteration predictions, and no changes are made to the lagged or exogenous variables. The second set of predictions for the variables involved in the simultaneous equations is compared to the first set, and this procedure is repeated until the model converges--that is, until the differences between the sets of predictions are no greater than a specified percentage.

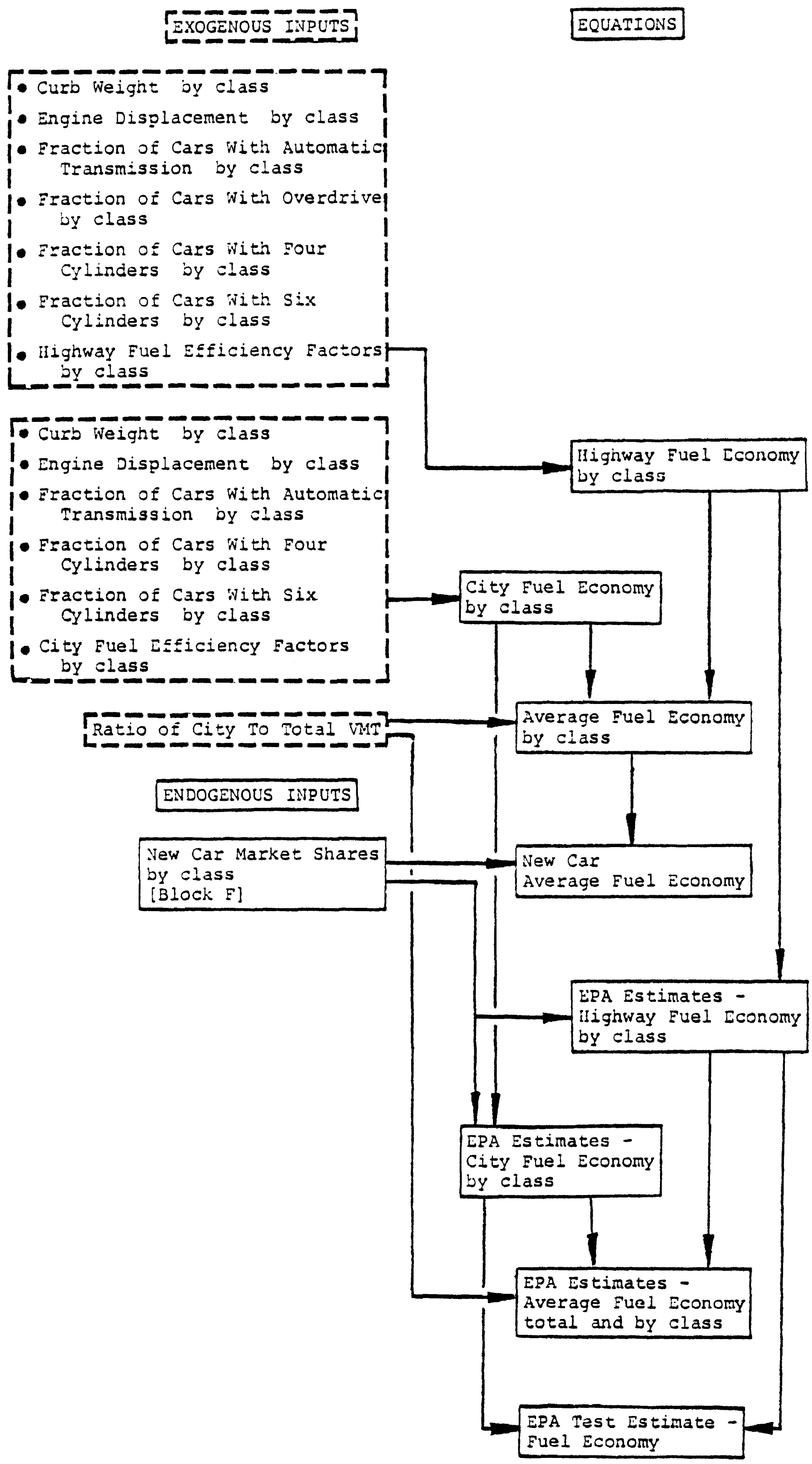
To produce a forecast for the next year, the exogenous variables are set to their prespecified values, and the lagged variables are updated. Thus, for the new run, new car price lagged one year is the forecast value of new car price generated from the immediately preceding run. The starting values of the endogenous variables are the forecast values of the previous year. With this information, the computer program can generate a forecast in an iterative procedure.

The flow diagrams in this section have been drawn to reflect accurately the order in which the equations of the model are solved by the computer program. The equations are solved in each program iteration from top to bottom as depicted in each diagram. The exogenous and lagged variables for each equation are listed on the left-hand side of the flow diagram, and the equations for the endogenous variables are listed on the right-hand side.

2.3.3 Block A - Miles Per Gallon Equations. Block A contains the fuel economy equations shown in Figure 2-2. Two sets of fuel economy estimates are simulated by the model. The first set is based on 723 individual road tests reported in Consumer Reports magazine from 1950-1975. The data reported for each test included city and highway driving miles per gallon (MPG), and the automobile characteristics: curb weight, engine displacement, horsepower, axle ratio, and body type. From these data, equations are generated for city and highway driving MPG for each class of car by regressing the fuel economy test results on the automobile characteristics. The average fuel economy

FIGURE 2-2

FLOW DIAGRAM OF BLOCK A
MILES PER GALLON EQUATIONS



for each class is calculated using the city and highway driving MPG predictions and the exogenously specified variable, ratio of city to total annual vehicle miles traveled (VMT).

The second set of fuel economy predictions estimate the Environmental Protection Agency (EPA) fuel economy ratings by class. These ratings are estimated through linking relationships that translate the Consumer Reports-based predictions for city and highway driving to the EPA predictions. In other words, given fuel economy predictions based on the Consumer Reports data, these equations generate the corresponding EPA fuel economy predictions.

A single average of EPA fuel economy ratings for city and highway driving is generated using a weighted harmonic mean formula (3), in which the averaging weights are the ratio of city VMT to total VMT and the new car market share predictions that are generated in Block F.

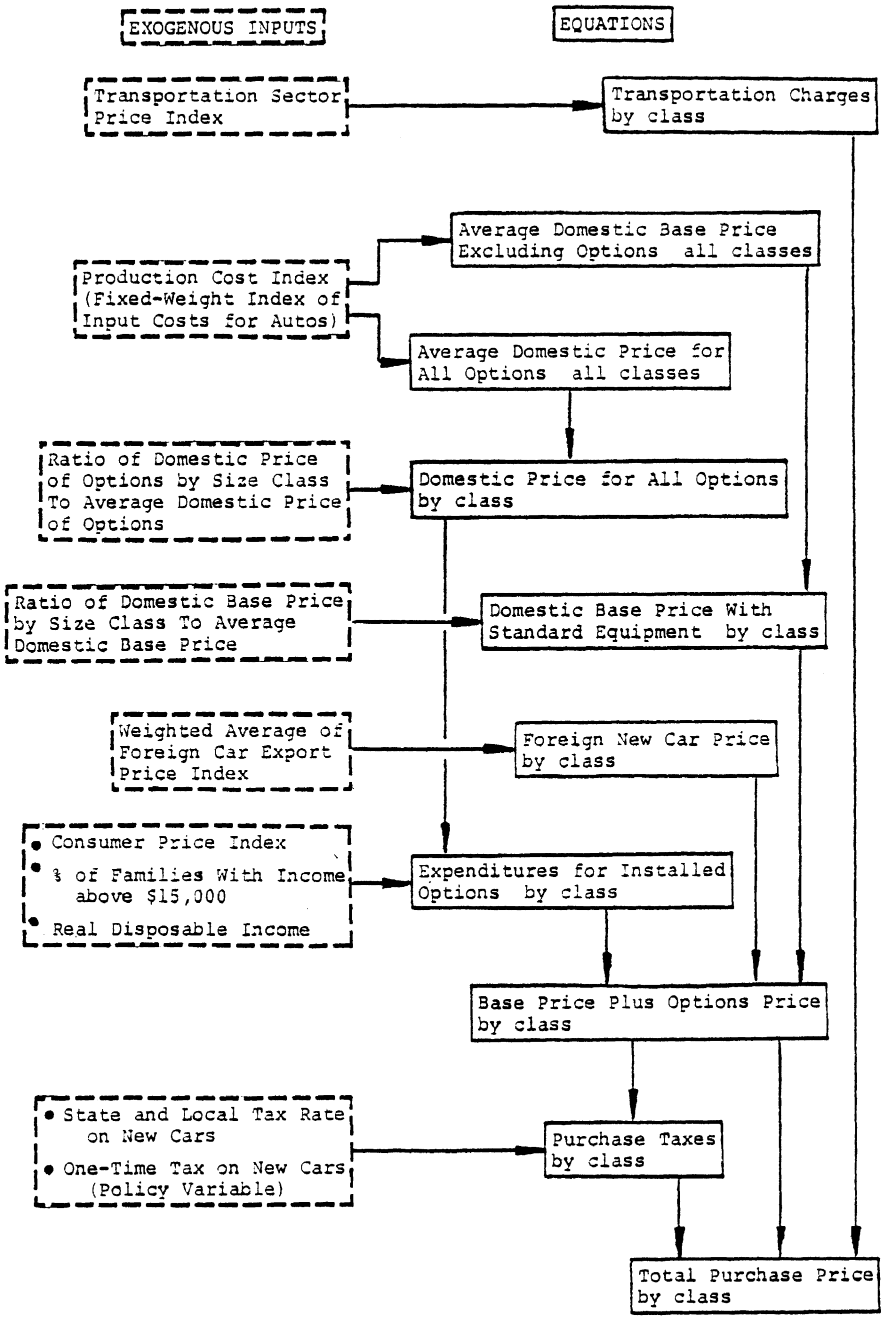
2.3.4 Block B - New Car Price Equations. Block B contains the equations for total purchase price of a new car by class. Four components make up the total purchase price in the model. These components are transportation charges, base purchase price, expenditures for options, and purchase taxes. Figure 2-3 presents a flow diagram of Block B.

The first predictions simulated in the block are the transportation charges by class of car. The equations for these predictions depend on the U.S. price index for the transportation sector, an exogenous variable.

Following the transportation charge equations are the equations for domestic base prices by size class (prices without any options) and for installed options expenditures on domestic cars by size class. Predictions of base price are calculated in two steps. The first step involves estimating an average domestic base price by regressing an average domestic base price on a production cost index. The average domestic base price is computed by subtracting the value of installed options from the base sticker price as reported in

FIGURE 2-3

FLOW DIAGRAM OF BLOCK B
NEW CAR SALES EQUATIONS



various issues of Wards Yearbook and Automotive News Almanac. The production index that is developed by Wharton EFA is a weighted index of automobile industry costs of factory production. It should be noted that the production index variable is exogenous. However, production costs can be changed significantly by regulations, and there is some justification for handling the production index as an endogenous variable. As long as it remains an exogenous variable, it is not possible to forecast the cost-related policy impact or the production index, and this could lead to misleading model results.

The second step involves multiplying the average domestic base price by an exogenously specified ratio of the domestic base price for each size class to the average domestic base price for all vehicles. This produces estimates of domestic base prices by size class.

This process for predicting domestic base prices by size class, therefore, relies heavily on the user of the model or analyst operating the model. Although the model is capable of predicting an average domestic base price, it is not capable of predicting the base price by size class: the ratio of the base price for each size class to the average base price must be determined before exercising the model.

This is important because the base price is a large portion of the purchase price, and the purchase price is the major portion of the capitalized cost per mile variable. The relative value of this cost by size class determines to a large extent the desired stock share and new car market share for each type of vehicle. Therefore, the determination of the ratios of base price by size class to average base price for all cars is critical. This matter is made more complex according to the basic economic theory, because these ratios depend on the demand for new cars by market share, which is not known until after the model is run. Thus, these ratios should be determined endogenously.

The estimation of expenditures on options installed on domestic cars is a three-step process that is similar to the estimation process for domestic base prices. The first step involves predicting the average price for the maximum installed options on domestic cars. This prediction is based also on the production cost index. The second step involves multiplying this maximum average price by a ratio of domestic price options installed for each size class to the average domestic price of options installed. These ratios are also specified exogenously.

In the third step the predictions of expenditures for options by size class are calculated. The ratio of average domestic price of installed options to the maximum price of installed options for each size class is calculated, using a set of statistically derived equations. These equations depend on the consumer price index, real disposable income per family, and the percentage of families with income in excess of $15,000, in real dollars. These ratios are then multiplied by the maximum prices of installed options, determined in step two, to estimate the expenditures for options installed for each size class.

Foreign base prices are estimated as a function of a weighted average of a foreign car export price index that was developed by Wharton EFA. This index must be specified exogenously. The expenditures for options installed on foreign cars are set equal to those of the corresponding domestic cars by size class.

The last price component is the purchase tax. An average state and local tax rate is specified exogenously, and this tax rate is applied to the base price plus expenditures on installed options for each class. The total purchase price for a new car is the sum of the transportation charge, base price, expenditures on options installed, and purchase tax.

Details of the specification of the statistically derived equations in Block B are presented in Section 3.2.3.

2.3.5 Block C - Capitalized Cost Per Mile Equations. Block C contains the equations for capitalized cost per mile (CPM) for each class of car. The Wharton EFA authors do not compute CPM in the usual way (i.e., a miles-weighted average discounted yearly cost per mile). Instead the authors compute a ratio of capitalized costs of owning and operating a "typical" car for its entire lifetime (the present value of the sum of vehicle costs over its lifetime) divided by the capitalized miles driven over the lifetime of this "typical" car (a discounted sum of miles driven yearly). A "typical" car, according the the schedule in Table 2-2, is one that was owned for ten years and was driven 100,000 miles. A capitalization concept is used to discount the costs of owning and operating a car to present value terms. Separately, the stream of services over time--i.e., miles driven--is discounted using the same discount factors. The Wharton EFA authors argue that the streams of costs and services must be placed on the same scale, and they further argue unconvincingly that their discounting of these two streams separately but at the same rate achieves this.

A better explanation of the CPM equation than the one given by the Wharton EFA model authors is to consider CPM as a cost per mile that, if applied to the series of "typical" miles driven and discounted to the present, would equal the present value of the cost components. Thus

$$\sum_{i=1}^{10} d_i \times Cost_i = \sum_{i=1}^{10} d_i \times (CPM \times Miles_i)$$

can be rewritten as

$$CPM = \frac{\sum_{i=1}^{10} d_i \times Cost_i}{\sum_{i=1}^{10} d_i \times Miles_i}$$

where d_i = discount factor in year i

$Cost_i$ = total cost of owning and operating a car in year i

$Miles_i$ = typical miles driven in year i

In this derivation, the discount rate is applied to financial factors only, eliminating the somewhat bewildering explanation of discounting miles. Thus with this explanation it can be argued that the stream of costs and services should be discounted at the same rate.

Table 2-2

WHARTON EFA'S ESTIMATES OF MILES DRIVEN IN A "TYPICAL" CAR'S Ith YEAR

Age in Years	0	1	2	3	4	5	6	7	8	9
Thousands of Miles	14.5	13.0	11.5	10.0	9.5	9.5	9.0	8.3	7.6	7.1

Source: (Schink and Loxley 1977, vol. III, p. A1-23).

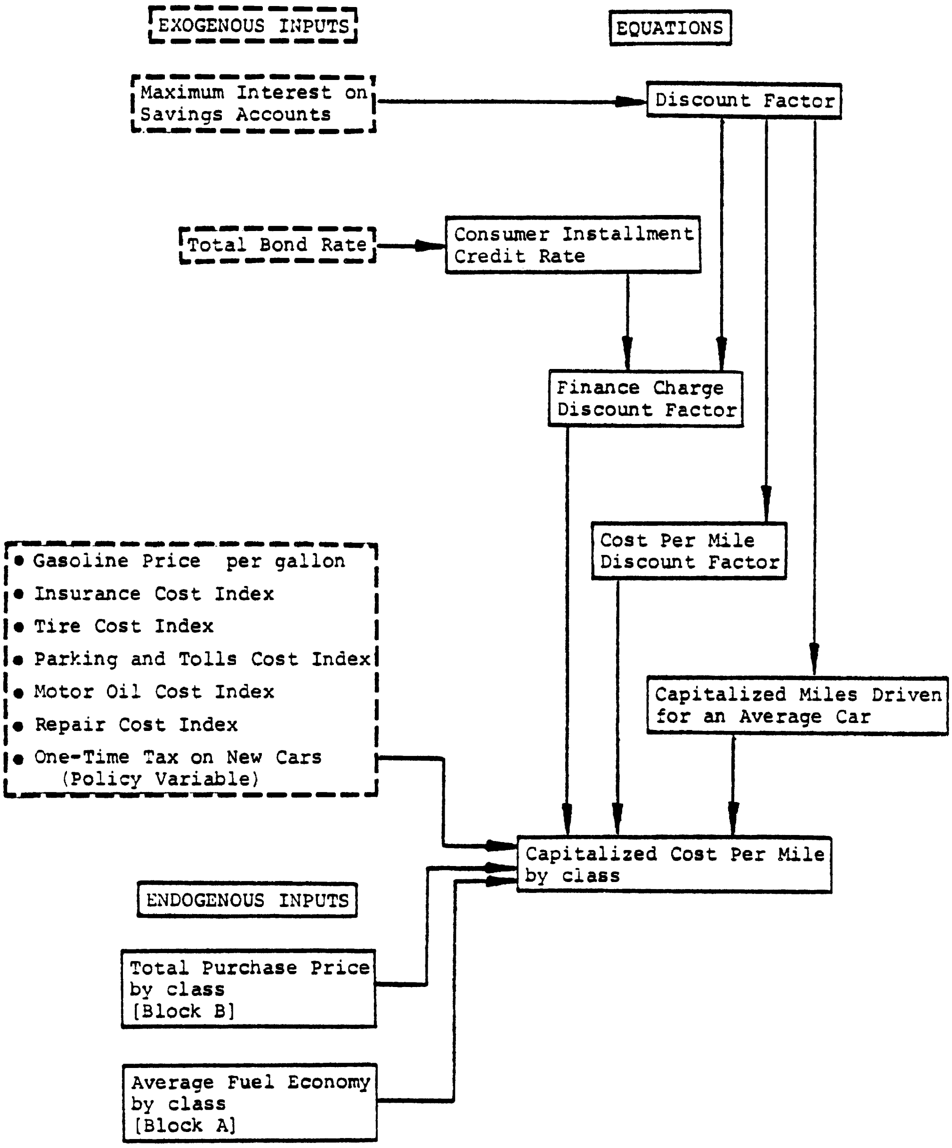
Following are discussions of the equations for the CPM variables by class and the data used to generate these variables in the Wharton EFA auto model.

2.3.5.1 Discount Factors. Capitalized cost per mile variables are estimated in a process of several steps, illustrated in the flow diagram of Figure 2-4. The first step is to calculate the discount factor (R1) used in discounting costs per miles. This discount factor is the maximum nominal interest rate payable on U.S. passbook savings accounts. The next calculation determines the consumer installment interest rate (R2) used in financing the purchase of a new car. This installment rate is estimated from Moody's total corporate bond rate.

2.3.5.2 Finance Charges. The installment rate and discount factor are used to calculate capitalized finance charges for a "typical" car over its lifetime. To calculate the finance charges, a car is assumed to be resold, that is, refinanced, each year. For this calculation, estimates are needed of: (1) the average price of

FIGURE 2-4

FLOW DIAGRAM OF BLOCK C
CAPITALIZED COST PER MILE EQUATIONS



a used car of age i relative to its original purchase price (PR_i), (2) an average fraction financed of the purchase price of a car of age i (FR_i), and (3) the installment credit rate for a car of age i (CR_i). Wharton EFA estimates these data series based on a variety of sources and reports the values of PR_i and FR_i (Schink and Loxley 1977, vol. III, p. A1-92).

CR_i is calculated from the new car installment rate as follows:

$$CR_i = R2 + .01\,(i) \quad \text{for } i = 0 \text{ to } 6$$
$$= .20 \quad \text{for } i = 7 \text{ to } 9$$

The finance charges are discounted each year at the annual rate, R1, which is given in fractional form. The formula for capitalized finance charge is thus

$$CFC = (\text{New Car Price}) \sum_{i=0}^{9} \frac{FR_i\, PR_i\, CR_i}{(1.0 + R1)^i} \tag{2.4}$$

where the new car price is determined endogenously from Block B.

The assumption that a car is resold each year may tend to inflate the total discounted finance charges of a car over its lifetime. This would be true if, on the average, a car were owned by an individual for more than a one-year period--i.e., if a car is resold, on the average, less often than every year. To illustrate this, HSRI staff constructed an example in which a 1972 vintage car is assumed to be resold every other year. In this example, it is assumed that a three-year loan is taken out on a new car, and a two-year loan at each succeeding resale. Using the 1972 Wharton EFA estimates of R1 and R2 (5% and 11%, respectively), the Wharton EFA estimates of PR_i, FR_i, and CR_i (see Table 2-3), and equation 2.4, the HSRI staff calculated the capitalized finance charge to be .298 times the new car price. This discounted charge is roughly 10% lower than the discounted finance charge of .332 times the new car price that Wharton EFA estimates, assuming a car was resold each year. However, this difference is minor compared to the other costs included in the CPM variables.

TABLE 2-3

VALUES OF PRICE RELATIVES (PR_i), FRACTION FINANCED (FR_i), AND CREDIT RATE (CR_i) USED BY HSRI IN CALCULATING FINANCE CHARGES OF A CAR FINANCED EVERY OTHER YEAR

AGE(i)	PR_i	FR_i	CR_i
0	1.0	.75	.11
1	1.0	.53	.11
2	.65625	.70	.13
3	.65625	.37	.13
4	.42183	.60	.15
5	.42183	.32	.15
6	.26640	.40	.17
7	.26640	.22	.17
8	.17580	.30	.20
9	.17580	.16	.20

2.3.5.3 Capitalized Miles. The next calculation in Block C is the one for capitalized miles driven for a "typical" car. The following formula is used:

$$\text{Capitalized Miles (CM)} = \sum_{i=0}^{9} \frac{\text{Miles}_i}{(1 + R1/100)^i}$$

where

R1 = the discount factor

Miles_i = miles driven per year for a "typical" car of age i (see Table 2-2)

Wharton EFA does not document the source of their series of miles driven per year (Miles_i). However, the series seems to be a variation of the series used by Liston and Gauthier (1972) in their paper, Cost of Operating an Automobile (see Table 2-4). The Wharton EFA and the Liston and Gauthier series are identical for the first four years of vehicle life, and differ for the remaining years. However, when each series is discounted, the capitalized miles calculated are extremely close. At a 5% discount rate, the capitalized miles calculation for the Wharton EFA series is 83,545, and for the Liston and Gauthier series, 83,732.

TABLE 2-4

LISTON AND GAUTHIER'S ESTIMATES OF MILES DRIVEN IN A "TYPICAL" CAR'S Ith YEAR

Age in Years	0	1	2	3	4	5	6	7	8	9
Thousands of Miles	14.5	13.0	11.5	10.0	9.9	9.9	9.5	8.5	7.5	5.7

A problem with the capitalized miles calculation is the assumption of a fixed ten-year driving schedule over time. As the equation is presently formulated, the 1955 value of capitalized miles was 91,084, and the 1974 value was 82,178. The difference in these two values is due to the difference in the discount rates for the two years. However, a larger capitalized miles value for 1955 than for 1974 is somewhat misleading in that certain factors, such as the availability of roads, and the movement of the population from urban to suburban areas, have certainly increased the "ten-year lifetime" mileage of cars. Obviously, the perceived ten-year lifetime driving schedule at the time of new purchase for a 1955 car was different from that for a 1974 car. To adjust for yearly differences in the capitalized miles variable, perhaps Wharton EFA authors should have used the annual vehicle miles traveled (VMT) per car variable, predicted in Block E, and the scrappage probabilities by age, predicted in Block F, as weighting factors to the $Miles_i$ series.

2.3.5.4 Operating Costs. The last set of components necessary to calculate the CPM for each class are the operating cost components for fuel, repairs, insurance, tires, motor oil, and parking and tolls. Wharton EFA calculates a car's fuel cost per mile by simply dividing the price of gasoline, specified exogenously, by the fuel economy estimate determined endogenously in Block A. This calculation assumes that the fuel economy of a car remains constant over its lifetime.

The other operating costs are based on a set of estimated annual costs of vehicle operation for the year 1972 reported by Liston and Gauthier (1972). These estimated costs are only for subcompacts, compacts, and standard (full-size) cars. Thus, Wharton EFA authors needed to generate operating cost estimates for intermediate and luxury cars. The derivation of these cost estimates is not explained in the Wharton EFA auto model documentation. The costs for intermediate cars are estimated by averaging the yearly costs for compacts and full-size cars. For luxury cars, operating costs are generated as follows:

1) Repair Costs--10% higher than full-size cars.
2) Insurance Costs--full-size costs plus the difference

between full-size and compact costs.

3) Other Costs--set to the same value as full-size costs.

The methods outlined for estimating these costs seem reasonable.

To translate these 1972 operating costs to other years, the costs are multiplied by an appropriate consumer product index (i.e., indices for repair costs, insurance costs, etc.). These indices, which are all equal to 1.0 in 1972, must be exogenously specified.

2.3.5.5 Capitalized Cost Per Mile. The equation for capitalized cost per mile is calculated using three sets of variables: the new car purchase price, financing and operating costs per year, and miles driven. A discounted yearly value of each of these components is calculated, and these yearly values are aggregated over the ten-year life of the vehicle to estimate CPM by class. The yearly values for financing and operating costs and for miles driven were discussed in the previous sections. In this section, the apportionment of new car purchase price over the life of a "typical" car is discussed.

The cost schedule per year for new car purchase price can be generated in many different ways. One procedure assumes that a new car owner perceives the entire burden of the purchase price as falling in the first year. Another procedure is to calculate the depreciation of the car for each year using the price relatives (PR_i), and to add the interest foregone on the money used to buy a car to the depreciation. The Wharton EFA authors (in collaboration with Transportation Systems Center staff) decided to implement the first procedure--that is, to place the purchase cost completely in the first year. Clearly, this procedure gives a heavy weight to new car purchase price in the CPM variables. This is defensable given existing market research.

The three components were combined for each class of car by adding the new car price and the sum of discounted yearly operating costs, and dividing this total by capitalized miles.

The CPM variables, in a sense, are indices of vehicle costs. These indices are generated because, as the Wharton EFA authors hypothesized, they have a major influence both on the total demand for automobiles and on the distribution of demand by class. However, because the CPM variables are composed of many factors, the computed index is rather insensitive to changes in any one of the factors. For example, the elasticity of car sales with respect to insurance, maintenance and repair, or parking and tolls is quite small. Confounding the situation, the purchase price variable is such a dominant component in the CPM variables that it further reduces the contribution of the other components.

To illustrate these points, the 1972 value of the CPM for a full-size car is examined here. Table 2-5 lists the aggregated sums over the ten-year life of the discounted cost components for full-size cars. The purchase price and the financing cost that is directly related to purchase price together account for over over 45% of the total discounted sum of costs. Thus, a change of 1% in the purchase price of full-size cars will generate a change of about .5% in the CPM for that size class. Such a change would have some effect on the predictions concerning automobile demand and HSRI staff experimented with changing the purchase price and the financing cost in the submodel and full-model evaluations in Sections 4.0 and 5.0. However, similar percentage changes in the other cost components would have negligible impact on the model.

The insensitivity of the model to the various operating cost components may be a shortcoming of the model. Previous studies have shown that automobile demand is related to credit conditions, and that scrappage is related to repair costs (4). It is conceivable that similar relationships may exist between insurance costs and new car sales and/or scrappage. As the Wharton EFA auto model is presently constructed, it does not fully represent these relationships.

2.3.6 Block D - Desired Shares and Desired Stock Equations. Block D contains the equations for the "desired" variables. The desired variables include the desired domestic shares of stock by size class,

TABLE 2-5

COST COMPONENT VALUES OF THE 1972 CAPITALIZED
COST PER MILE FOR FULL-SIZE CARS

Cost Component	Discounted Sum of Costs Over 10-Year Life of Car	Percentage of Total Costs
Purchase Price	$ 4,753.00	34.1
Financing Costs	1,575.00	11.3
Repair Costs	1,727.00	12.4
Parking and Toll Costs	1,483.00	10.7
Insurance Costs	1,115.00	8.0
Tire Costs	333.00	2.4
Motor Oil Costs	97.00	.7
Gasoline Costs	2,834.00	20.4
	$13,907.00	100.0

Source: Wharton EFA model time series data bank.

desired shares of stock by size class, and the desired stock per family. These variables are used in the stock adjustment framework to calculate the shares of new car sales by class, total new car sales, and annual scrappage in Blocks E and F.

The computations in Block D are complex because two groups of variables in the block are simultaneous. In a group of simultaneous equations, the predicted value of each of the variables is dependent on the predicted value of the other variables. Procedures for handling simultaneity of the variables in the block are discussed in this section. A flow diagram of Block D is presented in Figure 2-5.

The computations in the block can be divided into five sections: (1) computations of ratios capitalized cost per mile (CPM) of each class of vehicle to the average CPM of the other classes and to family income; (2) estimation of the desired domestic stock shares by size class; (3) estimation of the desired stock shares by size class; (4) computation of the desired share weighted CPM; and (5) estimation of desired stock per family and total desired stock.

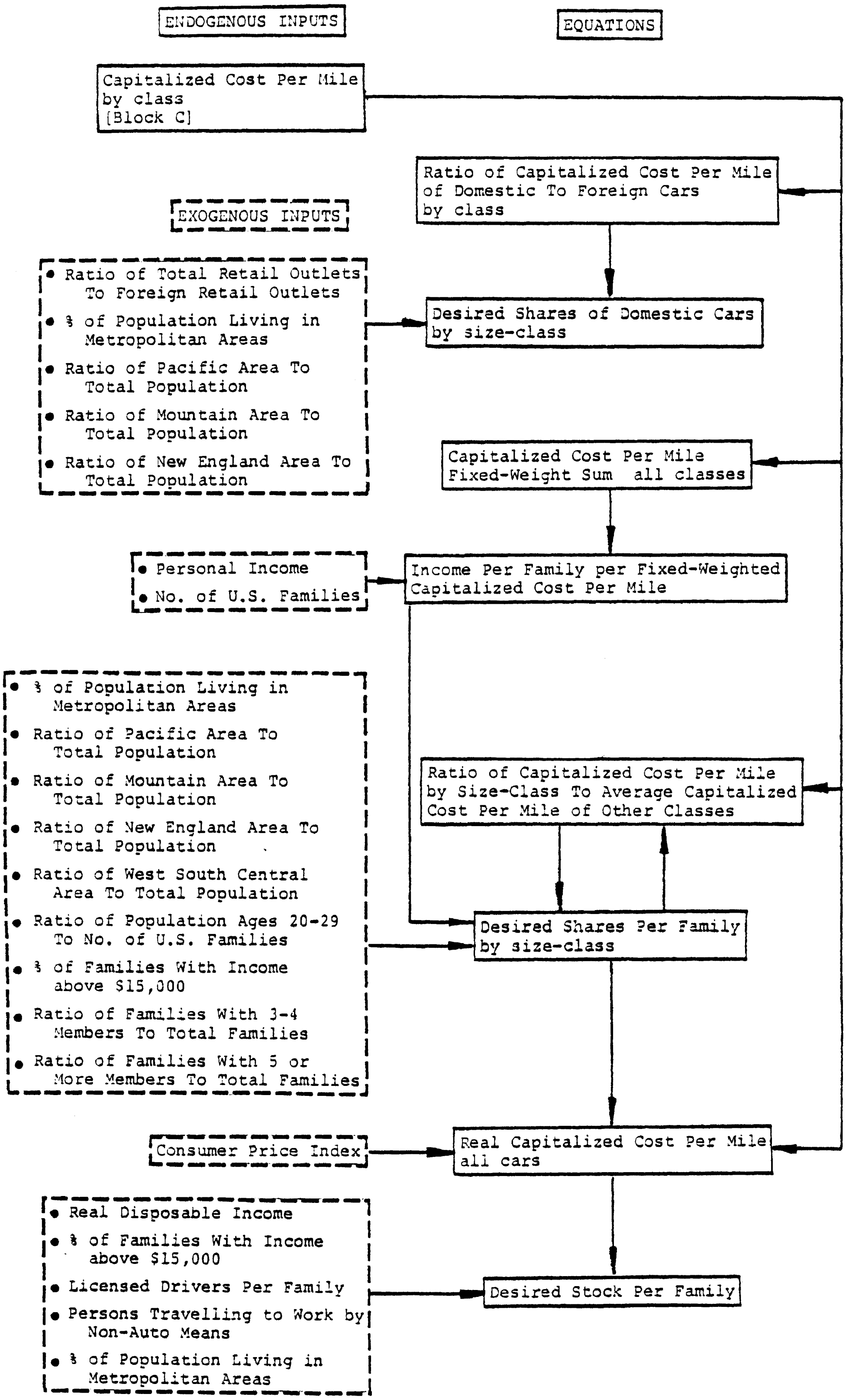
The calculations in the first section include five sets of ratios: (1) the ratios of the CPM for each size class to the average desired share-weighted CPM of the other size classes; (2) the ratio of CPM for subcompacts to the desired share-weighted CPM for subcompacts and compacts combined; (3) the ratio of family income to a fixed weighted average CPM of the size classes; (4) the ratio of family income to a fixed weighted average CPM for subcompacts and compacts; and (5) the ratio of CPM for a domestic car to a CPM for a foreign car in each size class.

These ratios play an important role in determining the desired stock shares, and, in turn, the desired stock shares estimated later in the block play an important role in determining these ratios. Thus, this first set of calculations is simultaneous with the second and third set in which the desired stock shares are estimated. Their solutions must be derived in the iterative procedure that was outlined in Section 2.3.2.

The ratios of the CPM for a domestic car to a foreign car for each

FIGURE 2-5

FLOW DIAGRAM OF BLOCK D
DESIRED STOCK AND DESIRED STOCK SHARE EQUATIONS



size class are used in the desired domestic share predictions. Essentially, as these ratios increase, the desired domestic share of the corresponding size class of car decreases, and vice versa. In addition, the predictions of desired domestic shares depend on an income distribution variable and several demographic variables.

The Wharton EFA model authors report that the simulated results of the desired domestic share equations were poor. In fact, in the version of the model program that HSRI received from the Transportation Systems Center, the equations for the desired domestic shares are not calculated; that is, these equations are skipped when the model is exercised. The same is true for the equations of actual domestic shares that depend on the desired shares. Instead, no predictions are made of the desired domestic shares, and the predictions of the actual domestic shares must be specified exogenously. **This means that forecasts of the foreign-domestic split must be taken from a model other than the Wharton EFA auto model, or derived from the subjective assessments of the analysts who run the model or of the users of the model.**

The inability of the model to forecast the foreign-domestic split casts serious doubts on Wharton EFA's treatment of the composition of sales. The stock adjustment approach does not work in the modeling of the foreign-domestic split, and, as will be shown in later sections of this report, it does not work in the modeling of the new car market classes by size class. The primary cause of this problem is the Wharton EFA authors' poor assumption that the demand for a particular class of car is dependent on the actual and "desired" stock of that class of car, as if the most distinguishing attributes of a car are its size class and origin of manufacture. One of the primary attributes of a car is its age, and the model probably would be improved greatly if the authors had realized this.

The remaining ratios generated in the first set of calculations are required for the estimation of the desired stock shares by size class. These ratios interact with the desired stock shares in a very reasonable manner. As the CPM of one size class increases relative to the average CPM of the other size classes, the desired stock share of the first size class decreases. Decreases in the ratios of family income to fixed weighted average CPM tend to produce downshifting in the desired stock shares from full-size to mid-size to compacts to subcompacts. The results in this case are a lowering of the desired share of full-size cars and a rise in the desired share of subcompacts, with minor effects on desired compacts and mid-size shares and no effect on luxury shares. On the other hand, upshifting to larger size classes occurs as these ratios increase.

The computations involved in estimating the desired stock shares are complicated because these variables must sum to one. The Wharton EFA auto model program uses a three-step process to make these predictions. In the first step, equations are solved for the combined desired shares of subcompacts and compacts, and for the desired shares of mid-size, full-size, and luxury cars. (The equations are presented in Section 3.3.2) In the second step, these four solutions are normalized so that they sum to one, as follows:

1. The solutions of the equations for desired combined shares of subcompacts and compacts, and the desired shares of mid-size and full-size cars are added together.
2. This sum is divided into one minus the equation solution for the desired luxury share to produce a normalization factor.
3. The normalization factor is multiplied with the solutions of the equations for the desired combined share of subcompacts and compacts and for the desired shares of mid-size and full-size cars.

In the third step, the equation for the desired subcompact share of the desired combined share of subcompacts and compacts is solved. This result is used to predict the desired share of subcompacts and compacts separately.

The Wharton EFA model authors indicate two reasons for using such a complicated procedure. First, because the luxury market share has been so stable over time, the authors feel that the estimates produced by the desired luxury share equation are accurate. This adjustment may be spurious since quite often the stability of a dependent variable makes it difficult to determine accurately the factors that influence it. Thus, their procedure preserves the solution value of the desired luxury share equation and normalizes the other desired stock share estimates with respect to it. This procedure implies that the authors had more confidence in the desired luxury share equation than in the other desired stock share equations.

The other reason behind the complicated calculations is that the Wharton EFA model authors had great difficulty in modeling small car shares. They point out in their report that they experimented with several procedures and found that the one adopted produced the best simulations over time. However, it is unclear in the report why this procedure is better than the other procedures that they tested, and there is no clear indication of a theoretical justification for it.

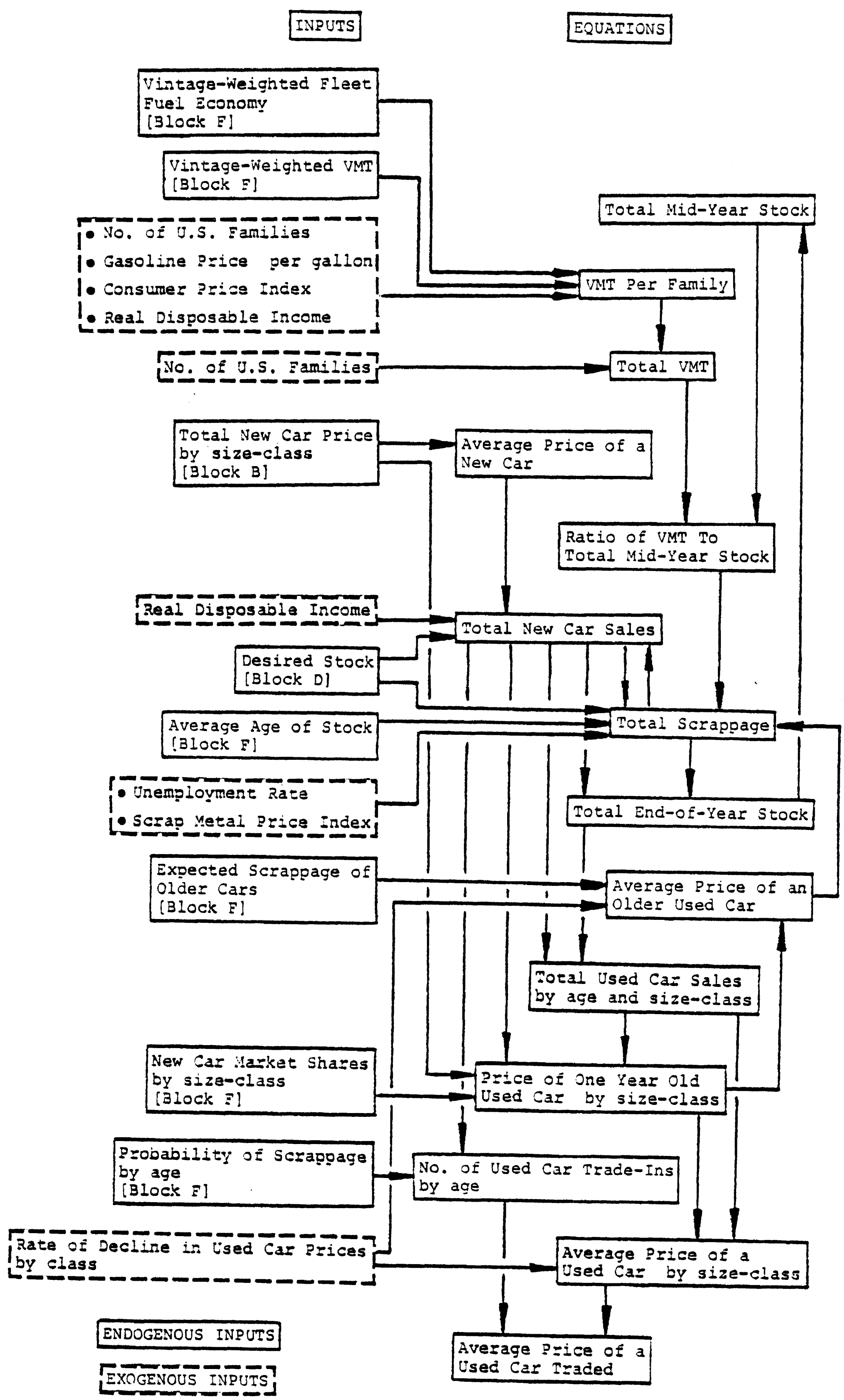
The fourth set of computations in the block is comprised of the single equation for computing the desired share weighted CPM. This result feeds into the fifth set of calculations to predict desired stock per family. In addition, desired stock per family depends on permanent family income, an income distribution variable, and several demographic variables. Desired stock per family is multiplied by the number of U.S. families to obtain total desired stock.

2.3.7 Block E - Actual Demand Equations. Block E contains three of the key equations in the model: new car sales or actual demand (from which the name of the block is derived), total scrappage, and vehicle miles traveled (VMT). These variables are important not only because they are inherently interesting, but because the predictions of many of the variables in Blocks E and F depend upon the predictions of these key variables, especially new car sales and scrappage.

As can be seen in Figure 2-6, the computations in Block E revolve around the predictions for new car sales and scrappage. Most of the

FIGURE 2-6

FLOW DIAGRAM OF BLOCK E
ACTUAL DEMAND EQUATIONS



variables in the block, in fact, are simultaneous with new car sales and scrappage, and the equations for new car sales and scrappage are themselves highly simultaneous--that is, the predicted value of scrappage is strongly related to the predicted value of new car sales, and vice versa. In addition, the endogenous inputs from Block F--vintage-weighted fleet fuel economy, vintage-weighted VMT, average age of stock, and expected scrappage of older cars--are also simultaneous with new car sales and scrappage.

The calculations in Block E can be divided into three groups. The first group contains the VMT equations; the second group contains the new car sales, total scrappage, and end-of-year stock equations; and the third group contains the used car market equations.

2.3.7.1 VMT Equations. The VMT calculations are based on a behavioral equation for VMT per family. This equation expresses a strong relation between the VMT per family and the age distribution of vehicles on the road. (See Section 3.4.1 for a full discussion of the VMT equation.) The age distribution of vehicles on the road works itself into the equation through the vintage-weighted VMT and vintage-weighted fleet fuel economy variables derived in Block F. The vintage-weighted VMT variable, which is discussed in greater detail in Section 2.3.8, is a function of the number of cars on the road of given ages and the number of miles those cars are driven. The mileage a car is driven is assumed to decrease for increasing vehicle age. This reflects the hypothesis that newer cars are driven more than older ones.

The vintage-weighted fleet fuel economy figure, which is the harmonic average of the average fuel economy over age and size classes weighted by the age distribution of stock, is then divided into the price of gasoline to measure a real gasoline cost per mile. This measure of real gasoline cost per mile is strongly and negatively related to VMT per family; in other words, higher real costs of gasoline per mile lead to lower VMT per family. The equation for the vintage-weighted fleet fuel economy is also discussed in Section 2.3.8.

The VMT per family prediction is used to calculate the ratio of VMT to total midyear stocks, which is a measure of the average miles driven per vehicle in a year. This ratio is fed into the second group of equations in Block E, which predict total scrappage. Therefore, VMT is related to scrappage and also to the new car sales prediction that is simultaneous with scrappage. Interestingly, the age distribution of stock, derived in Block F and used to predict the endogenous inputs for the VMT per family equation, is itself a function of new car sales and scrappage. Therefore, VMT is simultaneous with new car sales and scrappage.

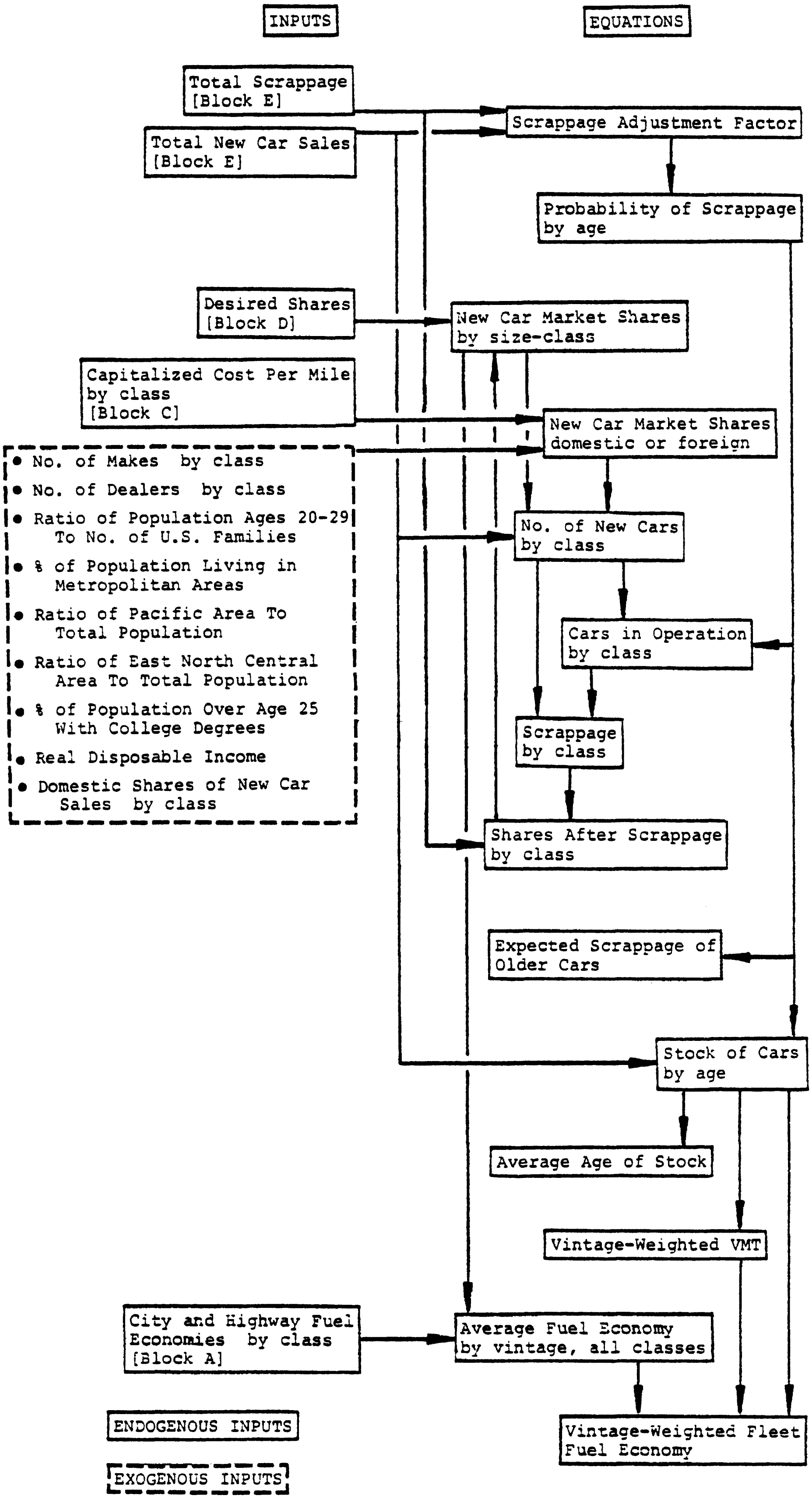
2.3.7.2 <u>Scrappage, New Car Sales, and End-of-Year Stock Equations</u>. The second group of equations of Block E is comprised of three very important equations in the model. These are the scrappage, new car sales, and end-of-year stock equations. Besides being related to VMT, the scrappage equation depends upon 1) desired stock predicted in Block D, 2) the exogenous inputs--unemployment rate and scrap metal price index, and 3) endogenous variables predicted in Block E and F--total new car sales, average age of stock, and the average price of an older car. (See Section 3.3 for a detailed discussion of the scrappage equation.) The desired stock variable is included in the equation within a stock adjustment framework. As the desired stock increases relative to actual stock (actual stock is approximated by the beginning-of-the-year stock plus new car sales), scrappage decreases and causes actual stock to increase. The reverse process occurs if desired stock decreases.

The scrappage equation is simultaneous with all the equations of the endogenous inputs from Blocks E and F. This can easily be observed in Figures 2-6 and 2-7. The simultaneity with new car sales is especially strong since, as has been true throughout recent history, scrappage and new car sales are correlated.

New car sales depend upon the annual change in the average price of a new car, the relation of disposable income to permanent income,

FIGURE 2-7

FLOW DIAGRAM OF BLOCK F
ACTUAL STOCK EQUATIONS



and desired stock--in addition to scrappage. (See Section 3.2 for a detailed discussion of the new car sales equation.) New car sales and scrappage respond in opposite directions as the difference between desired stock and actual stock changes. (In this equation, actual stock is approximated by beginning-of-the-year stock minus scrappage.) Thus, as the gap between desired stock and actual stock increases (decreases), new car sales increase (decrease) which causes actual stock to increase (decrease).

The last equation in the second group computes the total end-of-year stock. This is calculated by adding new car sales to last year's end-of-year stock and then subtracting total scrappage.

2.3.7.3 Used Car Market Equations. The third set of equations in Block E is used to predict the characteristics of the used car market. These predictions include used car prices by size class, used car sales by size class and age, number of used car trade-ins by age, and the average price of a used car trade-in.

The data that the Wharton EFA model authors use to build the used-car market equation are limited, and therefore the equations in this group are based on strong, possibly arbitrary assumptions.

For used car prices, data were collected from the 1958 to 1974 National Automobile Dealers Association Used Car Prices for a sample of cars within each size class. The used car prices reported are for cars from one to seven years of age. From these data, a model of used car prices was constructed that does the following:

1. Predicts total used car transactions from total end-of-year stock and changes in new car sales. This prediction is made with a behavioral equation for total used car sales.
2. Predicts the relative price of a one-year-old car to a new car for each size class, based on the ratio of used car transactions to total end-of-year stock and the annual change in the price of the car, excluding taxes.

3. Predicts the relative price of two- through twenty-year-old cars to new car price by size class, assuming that the price declines exponentially with age. The exponential rate used to calculate the prices of two- through twenty-year-old cars must be specified exogenously.

In Wharton EFA's historical analysis, the exponential rate is estimated on the basis of the data for one- to seven-year-old used cars. The very strong assumption is made that this same exponential decay in prices is valid for eight- to twenty-year-old used cars.

Used car transactions by age of car are based on the vehicle survival probabilities calculated in Block F and on the proportions of used cars (by age) traded in for new cars; the latter data were provided to Wharton EFA by General Motors Corporation (GM). The model authors first calculate the number of used car transactions involved in the purchase of new cars, using the GM estimates and the assumption that 50% of new car sales involve trade-ins. The age distribution of the remainder of the transactions in the used car market is predicted by subtracting the sum of trade-ins from the predicted figure for total used car transactions used in calculating used car prices. This result is then classified by age by arbitrarily assuming that the number of transactions for used cars of a given age is proportional to the surviving number of used cars of that age that were ever traded in for new cars.

The Wharton EFA model of the used car market is not reasonable. Its most serious shortcoming is its failure to incorporate the interaction among the demand, supply, and prices of used cars. The prices of individual makes and ages of cars are determined by supply and demand. Thus, the existing supply (stock) and the desired stock of used cars for sale are brought into equilibrium by the pricing process. The result is a system of used car prices. In the Wharton EFA auto model, the prices of used cars do not depend on the supply and demand for used cars. Instead, it is assumed that used car prices decline exponentially with age at some exogenously specified rate. It is also assumed that the number of used car transactions by age is in no way affected by the price of these used cars though clearly price should be considered.

The used car price and transactions by age predictions are used to estimate the average used car price and the average price of an older used car, which is an independent variable of minor importance in the scrappage equation.

Because of the data limitations, the group of used car market equations is a weak part of the model. However, it has little influence on other predictions in the model. Only the variable for the average price of older used cars feeds back into any other part of the model, specifically through its somewhat weak relationship with scrappage.

2.3.8 Block F - Actual Stock Equations. Block F, which is shown in Figure 2-7, contains two sets of important equations. The first set includes the equations to predict the stock of cars by class and age. This block is named for these sets of equations. The second set includes the equations to predict the new car market shares and the number of new cars by class.

2.3.8.1 Wharton EFA Vehicle Survival Model. To predict the stock of cars by class and age, the authors of the Wharton EFA auto model developed a vehicle survival model. The vehicle survival model predicts the probability that cars of each age from 0 years (new car) to 20 years will survive to the end of the year. It is assumed in this model that all cars surviving to their 20th year are scrapped at the end of that year. Because disaggregated data are not available, the Wharton EFA model authors make the assumption that the survival probabilities for all cars of a given age are the same, regardless of their size class.

Documentation of the Wharton EFA vehicle survival model is confusing. Therefore, an expanded HSRI interpretation of it is presented here. The vehicle survival model operates as follows:

1. "Normal" scrappage is estimated initially. The normal total scrappage is defined as the number of cars that would be scrapped if the "average" scrappage probabilities, q_i, alone determined total scrappage. The quantity q_i is formally defined as the "normal" probability that a car of age i will be scrapped by the end of the current year, given that it has survived to the end of the previous year. The q_i's are estimated using the R.L. Polk and Co. table of cars still in operation by model year, published in the <u>1975 Automotive News Almanac</u>. These tables provide the number of cars by model year registered in the U.S. on July 1 for the 1959 to 1974 calendar years (Schink and Loxley 1977, p. A1-36).

From these data, Wharton EFA authors estimate the fraction of cars of a given age that were not registered since the previous year for five sets of calendar years (not specified in the documentation). These five sets of data are averaged for each age of car to derive a midyear scrappage probability. The end-of-year scrappage probabilities, q_i, are estimated by the simple moving average:

$$q_i = (q_{i-1/2} + q_{i+1/2})/2 \text{ for } i = \text{integers} > 0$$

$$q_0 = .002$$

where $q_{i+1/2}$ represents the midyear scrappage probabilities.

Since, in general, R.L. Polk compiles registrations for the most recent sixteen model years, scrappage probabilities could only be generated for cars up to fourteen-years-old. To estimate q_i's for fifteen to twenty-year-old cars, the model authors assume that these probabilities as well as q_{12} to q_{14}, are equal to the rounded average of q_{12} to q_{14}, or .3. (5) In addition, q_0 is arbitrarily set to .002, and q_{21} was set to 1.0, guaranteeing that no cars more than twenty years old are on the road. The equation for "normal" scrappage is

$$\text{Normal Scrappage} = \sum_{i=0}^{20} q_i \times PSE_i \times (\text{New Car Sales})_{-i} \qquad (2.5)$$

where

PSE_i	=	probability a car survives to age i
PSE_0	=	1.0
New Car $Sales_i$	=	new car sales i years before the current year--i.e., new car sales lagged i

2. Since, in general, "normal" scrappage will not equal the predicted value of the total scrappage calculated in Block E, an adjustment to the q_i's is required. A simple adjustment factor is calculated as follows:

$$\text{Adjustment Factor} = \frac{(\text{Scrappage - Given Scrappage})}{\text{Normal Scrappage}} \qquad (2.6)$$

where

Scrappage	=	Total scrappage predicted in Block E
Given Scrappage	=	the number of cars that have survived to their 20th year by the beginning of the current year. This equals: PSE_{21} x (new car sales) $_{-21}$

Each q_i is multiplied by the adjustment factor to derive an adjusted scrappage probability, aq_i.

3. The last step in the vehicle survival model is to update the probability that a car survives to age i, PSE_i. This formula is simply

$$PSE_i = PSE_{i-1} \times (1 - aq_i) \quad \text{for } i = 1 \text{ to } 20 \text{ and } PSE_0 = 1.0. \qquad (2.7)$$

In words, the formula says that the probability that a car survives to age i (PSE_i), is equal to the probability that a car survives to age i-1 (PSE_{i-1}), times the adjusted probability that a car is not scrapped when it is i-1 years old ($1 - aq_i$).

Therefore, in order to forecast with the model, the PSE_i (i equal to values between 1 and 20) must be known for the year previous to the first forecast year. The Wharton EFA auto model has generated a set of PSE_i's for 1953 through 1974 for this purpose by assuming the scrappage probabilities by age are constant at the average levels (q_i) for the twenty years prior to 1953. Then the PSE_i's for 1953 can be computed by

$$PSE_i = \prod_{i=0}^{j} (1 - q_i)^i$$

where $q_0 = 0$.

The PSE_i values are used in equation 2.5 to estimate a "normal" total scrappage for 1953, and this result plus the known historical value of total scrappage are used in equation 2.6 to derive the adjustment factor for 1953. The adjustment factor is used in equation 2.7 to update PSE_i for the 1954 calculations. This process is repeated to generate PSE_i values for 1955 through 1974.

The application of the adjustment factor is somewhat arbitrary, and it is not justified empirically in the Wharton EFA auto model documentation. It seems more likely that the scrappage rates would vary more due to economic conditions in the case of older cars than for younger cars. The vehicle survival model uses the same adjustment factor for all ages of cars. This assumption may generate errors in the prediction of the stock of cars by age, and of those variables which depend on the age distribution of existing stock.

2.3.8.2 Age Distribution of Stock and Related Equations. The scrappage probabilities generated by the vehicle survival model are used to calculate the end-of-year age distibution of stock by class and the midyear age distribution of total stock. The end-of-year age distribution of stock by class is an intermediate calculation used to predict the total end-of-year stock and scrappage by class. The predicted midyear age distribution of stock is used to calculate the average age of stock, the vintage-weighted VMT, and the vintage-weighted fleet fuel economy.

The end-of-year age distribution by class is calculated by the following formula:

$$\text{No. of Cars of Class j and Age i} = (1-aq_i) \times PSE_i \times (\text{New Car Sales of Class j, i Years Ago}) \quad (2.8)$$

where

Age i ranges from 0 to 20

aq_i = adjusted scrappage probability for a car of age i

PSE_i = probability a car survives to age i

The total cars in operation by class is simply the sum over age of the stock of cars by class computed in equation 2.8. Scrappage by class is computed by adding the end-of-year total of cars in operation for the previous year to new car sales for the current year then subtracting the end-of-year total of cars in operation for the current year in each class.

The midyear total stock of cars by age is calculated with a simple moving average of the current and previous years' values of the end-of-year stock by age, as follows:

$$\text{Midyear Stock of Age i} = .5[(PSE_i)_{-1} \cdot (\text{New Car Sales i Years Ago}) - PSE_i\,(1-aq_i)\,(\text{New Car Sales i Years Ago})]$$

for i = 1 to 20, and

$$\text{Midyear Stock of Cars} = .5(1-aq_0)(\text{New Car Sales in Current Year}).$$

The midyear age distribution of stock is used to calculate the average age of stock, as follows:

$$\text{Average Age of Stock} = \sum_{i=0}^{20} \frac{\text{i x Midyear Stock of Age i}}{\text{Total Midyear Stock}}$$

Also, weights used in calculating the vintage-weighted VMT are from the midyear distribution of stock. This variable is calculated by summing over age the results of the multiplications of stock by age and "average" miles for that age of vehicle. The "average" miles by age, listed in Table 2-6, are based on the somewhat arbitrary values listed in Liston and Gauthier's paper (1972) and used in the capitalized cost per mile calculations. They are adjusted so that the 1972 value of vintage-weighted VMT approximates the 1972 value of total VMT.

The vintage-weighted VMT variable is then used to predict the average vintage-weighted fleet fuel economy, as follows:

$$\text{Average vintage-weighted fleet fuel economy} =$$

$$(\text{Vintage-Weighted VMT})/\left(\sum_{j=0}^{20} \frac{\text{Miles}_j \times \text{Midyear Stock of Age } j}{\text{Average Fuel Economy of Cars of Age } j}\right)$$

where

Miles_j = the "average" mile values in Table 2-6.

Average Fuel Economy of Cars of Age j = harmonic average over size class of the fuel economy of the stock of cars of age j when those cars were new, calculated by Wharton EFA

The average age of stock, the vintage-weighted VMT, and the vintage-weighted fleet fuel economy predictions are fed back into Block E to predict scrappage and VMT.

2.3.8.3 New Car Market Equations. The second set of equations in Block F are used to predict new car market shares and sales by class. These include equations for the new car market shares by size class (i.e., percentage of new car market for each size class), new car market shares of domestic and foreign cars by size class, and the number of new cars by class.

Predictions of new car market shares by size class are functions of the desired shares of total desired stock estimated in Block D and the actual shares of total stock estimated within Block F. For the estimation of these equations the Wharton EFA auto model authors

TABLE 2-6

MILEAGE WEIGHTS FOR VINTAGE-WEIGHTED VMT EQUATION

Car Age	0	1	2	3	4	5	6	7	8	9	10	11-20
"Average" Vehicle Mileage per year (July 1 to July 1) (in thousands)	7.5	15	15	14	13.5	12.5	11.5	10	9	8	7	6

assumed that for each size class the difference between the new car market share and desired stock share is proportional to the difference between the desired stock share and actual stock share. A detailed discussion of the specification of these new car size class shares equations is presented in Section 3.5.3.

Predictions of new car shares by class are generated by the computer program in a three-step process similar to the process used in generating the desired stock share predictions. In the first step, the equations are solved for the combined market shares of new subcompacts and compacts, and for the new car market shares of mid-size, full-size, and luxury cars. The four equations are logically constrained in that their solutions must sum to one. However, as with the desired stock share equations, the equations are not mathematically constrained in the model to sum to one. Therefore, in the second step, the share predictions are normalized to one by summing the results of the four equations and dividing this sum into each of the equation solutions. In the last step, the new car subcompact and compact shares predictions are separated by solving an equation for the market share of new subcompacts.

After the new car market share predictions by size class are generated, these predictions are separated into domestic and foreign shares. Although equations are included in the computer program for determining the domestic-foreign split, the model authors found that these equations produced poor simulations. **Therefore, these equations are bypassed in the operation of the computer program, and the domestic-foreign split by size class must be specified exogenously.** These exogenous values are multiplied with the new car size class share predictions to obtain the new car market share predictions by class. These market share predictions by class of new cars are multiplied with the total new car sales prediction from Block E to predict the number of new car sales by class.

2.4 Summary

The model structure analysis presented in this paper examines the overall theory and operation of the Wharton EFA Automobile Demand Model and provides a detailed look into the complex interrelatonships of the equations of the model. At its most basic level, the Wharton EFA auto model is a stock adjustment model of automobile demand. However, the model is very complex, since it is designed to forecast the size and composition of long-run automobile demand and total stock, vehicle fuel efficiencies, new car prices, used car prices, used car market transactions, as well as many other variables.

Five major original concepts are identified in the analysis:

1. The development of a desired stock equation based on cross-sectional data by state.
2. The construction of the new car sales equation to express new car sales as a rate relative to existing stock.
3. The construction of the scrappage equation so that scrappage is affected by the stock adjustment process.
4. The development of the new car market share equations so that the new car market shares are determined in a stock adjustment framework.
5. The development of the capitalized cost per mile concept.

In order to facilitate the discussion and analysis of the model, the model is divided into the following six sets of equations referred to as computational blocks:

1. Miles per gallon.
2. New car price.
3. Capitalized costs per mile.
4. Desired shares and desired stock.
5. Actual demand, including the equations for new car sales, scrappage, vehicle miles travelled, used car prices, and used car market transactions.
6. Actual stock, including equations for new car market shares, actual stock and stock by class shares.

In the examinations of the sets of equations, several important results are obtained. These results, which are summarized below, serve as notes of caution in applications of the model.

The model is not completely capable of predicting the domestic base price of each class of new cars, whereas it is capable of predicting an average base price for all new cars. The ratio of the base price for each size class to the average base price must be determined exogenously before using the model.

The capitalized cost per mile variables are comprehensive indices of the cost of purchasing, owning, and operating cars. However, because these variables are composed of many factors, the computed indices are very insensitive to changes in any one of their components, with the exception of the purchase cost. This may be a shortcoming of the model since previous studies have shown that the owning and operating costs do have a relationship to new car sales, scrappage, and possibly other variables in the model.

The logic used in the development of the new car market share equations in the model is deficient since the age distribution of each class of car, a very important attribute, has been neglected. This deficiency could lead to poor model forecasts.

The same flaw that undermines the model's ability to forecast new car market shares is probably the major cause of the failure of the model to predict the foreign-domestic split of the new car market. Thus the model should not be used to model or forecast the penetration of imported cars in the U.S. new car market.

The model of the used car market included in the Wharton EFA auto model is not reasonable. Its most serious shortcoming is its failure to incorporate the interactions among the demand, supply, and price of new cars.

3.0 EQUATION RECONSTRUCTION

3.1 Introduction

In this section the results of the attempt to reconstruct the time series equations of the model are presented. The majority of the time series equations of the model were reconstructed using multiple regression analysis. An effort was also made to reproduce the cross-section equations of the model. However, this latter task could not be completed because the documentation for the Wharton EFA auto model cross-section data tape is limited, and it would have been a difficult and time-consuming task to determine exactly which variables were on the tape.

The three basic purposes of equation reconstruction in this study are:

1. To check the equation specifications, the data, and the techniques used in estimating equations in the model.
2. To check the accuracy of the estimated equations of the model as reported by the model authors.
3. To allow for an evaluation of the statistical information that is generated in the course of building the model.

To meet these objectives, an attempt was first made to reproduce the equations. If an equation could not be reproduced, the data used in estimating the equation, the fit period of the equation, and the estimation technique were examined to determine possible causes of the problem. After an equation was reconstructed, the specification of that equation was analyzed. This analysis involved examining the independent variables to determine the justification, or lack of justification, for their inclusion in the equation, and examining the coefficients of the independent variables that are estimated by Wharton EFA and HSRI to determine if their size and sign (positive or negative) make sense. Also, the statistics generated in the course of estimating the equation were examined to test the statistical significance of the parameter estimates (e.g., to test if a coefficient is different from zero) and to test the overall goodness of fit of the equation.

There are many equations presented in this section that the HSRI staff were unable to reproduce (6). For these equations, the computer output results (including HSRI's estimated coefficients, the data, fit period, and generated statistics) were sent to the Wharton EFA model authors for their review and comment. A personal visit to Wharton EFA was made to follow up on this matter. In general, the model authors could not detect any mistakes in the HSRI analysis. They did suggest that some of the problems may have occurred because a few of the data timeseries were modified between the times that the equations were modified and the data were sent to TSC. HSRI received these data from TSC. However, the Wharton EFA authors lacked documentation on the nature and existence of these modifications. Another explanation offered was that the fit periods of some of the equations were improperly documented in the model report. However, whenever a reestimation problem arose, the HSRI staff experimented with different fit periods. This experimentation usually led to larger discrepencies between the HSRI and Wharton EFA results.

The equations discussed in this section are grouped according to the computational blocks in which they are contained. Only the equations contained in Blocks B, E, and F are reproduced. The fuel economy equations of Block A were not reconstructed because they require Wharton EFA's automotive characteristics data base that was not available from TSC. Block C, which contains the capitalized cost per mile equations, is discussed in full in Section 2.3.5. Block D contains the cross-sectional equations that HSRI was unsuccessful in reconstructing. However, since these equations are important in the model, they are also discussed here.

Specific information pertaining to many of the equations of the Wharton EFA auto model is presented here, organized in the following way. First, the general specification of the equation is indicated. Second, for the time series equations, the estimated coefficients and summary statistics prepared by HSRI are presented and compared with the Wharton EFA estimates in tabular form. The statistics presented are: the adjusted R-square ($\overline{R}^2$), the standard error of the estimated equation (SEE), the fit period (FP), and the Durbin-Watson statistic (DW). Third, the specification of the equation is discussed.

The principal results of the equation reconstruction task are summarized at the end of this section.

3.2 New Car Price Equations - Block B

In this section the statistically derived equations of the model concerning new car prices are discussed. The equations, based on time series data, are as follows:

- Average domestic base price
- Average domestic price for all options
- Expenditures for options installed by size class

3.2.1 Average Domestic Base Purchase Price, Excluding Options, All Classes

The equation for the average domestic base price is specified as follows:

$$\ln(\text{USTDPUBASEFW}) = A + B_1\,[\ln(\text{PINPUTA})] + B_2\,(\text{DUM58.63}) + B_3\,[\Delta\ln(\text{PINPUTA})]$$

where

USTDPUBASEFW	=	fixed-weighted average domestic new car price
PINPUTA	=	fixed-weighted index of input costs, automobiles
DUM58.63	=	dummy variable equal to 4.0 in 1958, -3.0 in 1962, -2.0 in 1963, zero otherwise

Table 3-1 presents a comparison of the Wharton EFA and HSRI coefficient estimates, standard errors, and summary statistics.

TABLE 3-1

Estimated Coefficients and Summary Statistics
Average Domestic Base Purchase Price, Excluding Options, All Classes

(Standard errors of coefficient estimates in parentheses)

	$\hat{A}$	$\hat{B}_1$	$\hat{B}_2$	$\hat{B}_3$	$\bar{R}^2$	SEE	FP
WHARTON EFA	3.5893 (.268)	.9788 (.060)	.0153 (.003)	.4253 (.224)	.964	.016174	58-74
HSRI	3.704 (.274)	.9535 (.0612)	.0153 (.0032)	.3042 (.207)	.965	.016175	58-74

Wharton EFA reported t-statistics; HSRI staff changed these to standard errors for comparison purposes. In general there are nontrivial differences between the two sets of coefficient estimates, with differences occurring in the first and second decimal places. Although the differences between the Wharton EFA and HSRI estimates are not statistically meaningful, they are large enough that their cause must be questioned. A likely explanation offered by one of the model authors is that the input costs variable was changed between the time the equation was estimated by Wharton EFA and the time the computer tape, containing the Wharton EFA model time series data bank, was delivered to TSC. Unfortunately, the input costs time series is not reported in the Wharton EFA model report, and it is not possible to verify this.

The summary statistics, which appear in the Wharton EFA report, indicate that the Wharton EFA version of the equation fits the data reasonably well, with over 96% of the variance in the dependent variable being explained by the equation. Also, the standard errors reported indicate that all of the estimated coefficients are statistically significant at the ten percent level or lower.

The specification of the average domestic base price equation is based on the simple hypothesis that price is a markup over an adjusted cost:

$$\text{Price} = A\ (\text{Cost})^B$$

"A" is viewed as the markup coefficient, which represents the percentage pass through of input cost to retail price. "B" is the cost adjustment factor, which is a percentage pass through factor of input cost changes to retail price changes. Wharton EFA's estimate of B equal to .979 is not statistically different from 1.0. Thus, domestic base purchase prices are estimated as a full markup over input costs, and these prices are estimated such that changes in them are directly proportional to changes in input costs in the long run.

In the short run, new car prices are also assumed to be affected by the change in costs. Wharton EFA includes the change in cost variable as an "expectations effect." If costs increase today, prices are increased slightly more in anticipation of additional cost increases in the future. Of course, in steady state, this "expectations effect" has no effect, as one would expect.

One can also make the point that the equation is limited by the fact that it only considers retail price to be a function of cost elements, i.e., price is only determined by supply conditions. In fact, price is very likely to be also determined by demand conditions, that is, by the strength of demand for new cars relative to inventories.

3.2.2 Average Domestic Price for All Options, All Classes. The average domestic options price equation is as follows:

$$\ln(\text{USTDPOPTMFW}) = A + B_1 [\ln(\text{PINPUTA})] + B_2 (\text{DUM58.59})$$

where

USTDPOPTMFW	=	fixed-weighted average price of maximum installed options
PINPUTA	=	fixed-weighted index of input costs, autos
DUM58.59	=	dummy variable equal to 1.0 in 1958-59, zero otherwise

Table 3-2 contains a comparison of the Wharton EFA and HSRI coefficient estimates and summary statistics. Substantial differences exist between the two sets of coefficient estimates, with the differences generally being in the second decimal place. When asked about this, Wharton EFA's response was that the input costs variable had been revised and was probably the cause of the discrepancies. This same variable, input costs, was offered as the source of the differences in the average domestic base purchase price equation (See Section 3.2.1).

The summary statistics indicate no problems with overall goodness of fit or statistical significance of individual coefficients.

The specification of the options-price equation is very similar to

TABLE 3-2

Estimated Coefficients and Summary Statistics
Average Domestic Price For All Options, All Classes

(standard errors in parentheses)

	$\hat{A}$	$\hat{B}_1$	$\hat{B}_2$	$\bar{R}^2$	SEE	FP
WHARTON EFA	3.5347 (.269)	.7572 (.059)	.1326 (.0145)	.919	.017197	58-74
HSRI	3.6733 (.272)	.7263 (.060)	.1301 (.015)	.908	.018008	58-74

that of the average base purchase price equation. The average domestic price for all options is assumed to be a markup over an adjusted cost; i.e., Options Price = A $(\text{Cost})^B$. For this equation, Wharton EFA's estimate of the markup coefficient "A" is, not surprisingly, the same as the markup coefficient for the average domestic base price equation. However, the estimate for the adjustment factor "B" of .757 is significantly different from 1.0--in fact, it is four standard errors from one. Thus, domestic price of options is estimated as less than a full markup over cost, and the equation implies that automobile manufacturers pass through to their options price less than full percentage increases in input costs. Specifically, for a given percentage increase in input costs, the options price is estimated to increase by only 76% of that percentage.

The equation also contains a dummy variable to account for irregular variations in options prices and costs in 1958 and 1959.

This equation does not contain a "price expectations effect"--that is, a change in the input costs term--as does the average base purchase price equation. This is not surprising, given the weak statistical power of the term in the average base price equation.

3.2.3 <u>Expenditures For Options Installed - Subcompacts</u>. The equation for expenditures on options installed in subcompacts is as follows:

$$\ln\left(\frac{\text{USSDPUOPT-2/USSDPOPTM}}{1.0 - (\text{USSDPUOPT-2/USSDPOPTM})}\right) = A + B_1\,[\ln(\text{USTDPOPTMFW/PC})] + B_2\,[\ln(\text{PER15+})] + B_3\,(\text{DUM58}) + B_4\,(\text{DUM59.61}) + B_5\,[\ln(\text{RDIP4/FM})]$$

where

USSDPUOPT-2	=	cost of options purchases, subcompact
USSDPOPTM	=	maximum cost of options, subcompact
USTDPOPTMFW	=	fixed-weighted average maximum cost of options

PC	=	consumer price index, all items, 1972 = 1.0
PER15+	=	percentage of families with real incomes of $15,000 or more
DUM58	=	dummy variable, equal to 1.0 in 1958, zero otherwise
DUM59.61	=	dummy variable, equal to 1.0 in 1959-61, zero otherwise
RDIP4/FM	=	real permanent disposable income per family unit

Table 3-3 contains a comparison of the Wharton EFA and HSRI results. There is good agreement between the two sets of results, with differences only in the third and fourth decimal places.

The specification of consumer expenditures for options on subcompacts follows the classical demand approach of assuming expenditures to be a function of income and relative prices. For the income variable, permanent income per family is used and appears with the expected positive sign. In addition, an income distribution variable was found to be significant with a negative sign. This implies a bewildering relationship--more affluence implies fewer expenditures on options in subcompacts.

The fixed-weighted average maximum price (assumes cars purchased with all available options) relative to the all-items-Consumer Price Index is used as the relative price variable and has the expected negative sign.

Finally, two dummy variables are included to account for unusual observations in several years. However, the use of the dummy variable for 1958 by the Wharton EFA model authors tends to distort the statistics of the equation in an unjustified manner. This dummy variable forces the regression line through the 1958 value of the dependent variable, in effect eliminating the year 1958 from the estimation. However, the 1958 data point, which is predicted by the regression line with zero error, is used in calculating the $\bar{R}^2$ and SEE. Thus, these statistics, as they appear in the Wharton EFA model

TABLE 3-3

Expenditures for Options Installed - Subcompacts
Estimated Coefficients and Summary Statistics

(standard errors in parentheses)

	$\hat{A}$	$\hat{B}_1$	$\hat{B}_2$	$\hat{B}_3$	$\hat{B}_4$	$\hat{B}_5$	$\bar{R}^2$	SEE	FP	DW
WHARTON EFA	27.4189 (3.840)	-4.6334 (.627)	-.8539 (.368)	.3354 (.1185)	.2888 (.084)	2.9271 (1.219)	.950	.0823	58-74	2.21
HSRI	27.418 (3.845)	-4.6331 (.628)	-.8534 (.368)	.3356 (.119)	.2888 (.084)	2.9259 (1.218)	.9504	.0823	58-74	

documentation, appear to indicate a very good fit. If the regression line is estimated without the dummy variable that applies only to the year 1958, the SEE rises by about twenty percent and the $\bar{R}^2$ falls to .92.

The dependent variable in the equation is the ratio of options expenditure for subcompacts relative to the maximum cost of options in subcompacts. These "shares" are then formulated in "odds" (logit) form so that actual expenditures on options may never exceed the maximum cost of options.

3.2.4 Expenditures for Options Installed - Compacts, Mid-Size, Full-Size, and Luxury. The general form of the equation for options installed in compact, mid-size, full-size, and luxury cars is as follows:

$$\ln\left(\frac{\text{USXXPUOPT-2/USXXPOPTM}}{\text{1.0 - USXXPUOPT-2/USXXPOPTM}}\right) = A + B_1\ [\ln(\text{USTDPOPTMFW/PC})] + B_2\ (\text{DUM58}) + B_3\ (\text{DUM59}) + B_4\ [\ln(\text{RDIP4/FM})]$$

where

USXXPUOPT-2	=	cost of options purchased by class (compact, mid-size, full-size, and luxury)
USXXPOPTM	=	maximum cost of options by class (compact, mid-size, full-size, and luxury)
USTDPOPTMFW	=	fixed-weighted average maximum cost of options
PC	=	consumer price index, all items, 1972 = 1.0
DUM58	=	dummy variable, equal to 1.0 in 1958, zero otherwise
DUM59	=	dummy variable, equal to 1.0 in 1959, zero otherwise

RDIP4/FM = real permanent disposable income per family unit

Tables 3-4 to 3-7 contain comparisons of the Wharton EFA and HSRI coefficient estimates and summary statistics for each of the four market segments considered in this section. There is excellent agreement between the two sets of results, with only trivial differences existing in the third and fourth decimal places.

The summary statistics for all four market classes are biased because of the use of the dummy variables for 1958 and 1959. If these dummy variables are eliminated from the time series used in the estimation, the following results are produced:

a) Compact equation--the SEE more than doubles to .263 and the $\bar{R}^2$ falls sharply to .80.

b) Mid-size equation--the SEE increases by a third and the $\bar{R}^2$ falls to .88.

c) Full-size equation--the SEE increases by about fifty percent and the $\bar{R}^2$ falls to .81.

d) Luxury equation--the SEE increases by about fifty percent and the $\bar{R}^2$ falls slightly to .95.

Since the years 1958 and 1959 have such a negative effect on the goodness of fit of the expenditures for installed options equations for all five classes, it may be more logical to have simply eliminated these years from the fit period of the regression rather than eliminating their effects with dummy variables, as is done by Wharton EFA. Removing the problem years and their corresponding dummies would not change the standard error because the resulting degrees of freedom are the same and there is no change in the size of the total error (since no error is associated with the dummied years); but the $\bar{R}^2$ will be reduced if the dummy variables are removed, although not as much as is indicated above.

The specification of these four equations is very similar to the equation previously discussed for options expenditures on subcompacts. The principal difference between the two is that the income distribution variable is not included in these four equations,

TABLE 3-4

Expenditures for Options Installed - Compacts
Estimated Coefficients and Summary Statistics

(standard errors in parentheses)

	$\hat{A}$	$\hat{B}_1$	$\hat{B}_2$	$\hat{B}_3$	$\hat{B}_4$	$\bar{R}^2$	SEE	FP	DW
WHARTON EFA	28.919 (3.493)	-4.7463 (.365)	1.0807 (.125)	.6722 (.122)	1.7941 (.526)	.970	.1014	58-74	1.22
HSRI	28.921 (3.492)	-4.7465 (.365)	1.0807 (.125)	.6722 (.122)	1.7939 (.526)	.970	.10138	58-74	-

TABLE 3-5

Expenditures for Options Installed - Mid-Size
Estimated Coefficients and Summary Statistics

(standard errors in parentheses)

	$\hat{A}$	$\hat{B}_1$	$\hat{B}_2$	$\hat{B}_3$	$\hat{B}_4$	$\bar{R}^2$	SEE	FP	DW
WHARTON EFA	38.557 (5.637)	-5.9699 (.589)	.7158 (.202)	.8024 (.198)	1.6801 (.849)	.951	.1636	58-74	1.04
HSRI	38.558 (5.636)	-5.97 (.589)	.7159 (.202)	.8024 (.198)	1.68 (.848)	.952	.16365	58-74	-

TABLE 3-6

Expenditures for Options Installed - Full-Size
Estimated Coefficients and Summary Statistics

(standard errors in parentheses)

	$\hat{A}$	$\hat{B}_1$	$\hat{B}_2$	$\hat{B}_3$	$\hat{B}_4$	$\bar{R}^2$	SEE	FP	DW
WHARTON EFA	37.6617 (6.654)	-5.8634 (.696)	1.0364 (.239)	.9064 (.234)	2.0004 (1.000)	.930	.1933	58-74	.91
HSRI	37.664 (6.656)	-5.8636 (.696)	1.0365 (.239)	.9064 (.234)	2.0002 (1.002)	.930	.19335	58-74	-

TABLE 3-7

Expenditures for Options Installed - Luxury
Estimated Coefficients and Summary Statistics

(standard errors in parentheses)

	$\hat{A}$	$\hat{B}_1$	$\hat{B}_2$	$\hat{B}_3$	$\hat{B}_4$	$\bar{R}^2$	SEE	FP	DW
WHARTON EFA	31.034 (3.592)	-4.8621 (.375)	.4434 (.129)	.4560 (.126)	2.1775 (.540)	.977	.10431	58-74	1.14
HSRI	31.035 (3.592)	-4.8623 (.375)	.4436 (.129)	.4560 (.126)	2.1775 (.540)	.977	.10431	58-74	-

while it is included in the subcompact equation.

Permanent income is again the income variable in each equation. It appears with the expected positive sign and is statistically significant in each case. The fixed-weighted average maximum options price relative to the all-items-CPI is used as the relative price variable in each equation. It has a negative sign in all four equations, as economic theory would predict.

3.3 Desired Stock and Desired Stock Share Equations - Block D

This section discusses the six equations that explain desired stock per family and desired stock shares by size class. These equations, which are in Block D of the model, are estimated using cross-section data by state for the year 1972. Due to inadequate documentation of the cross-section data, the HSRI study team was unable to reproduce these equations. However, they are of central importance in the structure and operation of the model, and hence their specifications are analyzed in some detail.

3.3.1 Desired Stock Per Family. The equation for the desired stock per family is as follows:

$$
\begin{aligned}
\ln(KEND/FM) = & -1.90959 + 0.563344\,[\ln(RDIP4/FM)] \\
& \quad\ (.796) \qquad\ (.180) \\
& - 0.100994\,[\ln(PER15+(100 - PER15+))] \\
& \quad\ (.052) \\
& - 0.199527\,[\ln(CMTTCAP/PC)] \\
& \quad\ (.238) \\
& + 0.421187\,[\ln(LD/FM)] \\
& \quad\ (.137) \\
& - 0.0536642\,[\ln(MTWNA/FM)] \\
& \quad\ (.036) \\
& + 0.0990056\,(NPMET/100) \\
& \quad\ (.062)
\end{aligned}
$$

$\bar{R}^2 = 0.461$, SEE = .0596

where standard errors are in parentheses, and

KEND/FM	=	number of cars in operation at year-end over number of family units
RDIP4/FM	=	real permanent income per family
PER15+	=	percentage of families (excluding unrelated individuals) earning $15,000 or more (in 1970 dollars)
CPMTTCAP	=	desired share weighted cost per mile (including all classes: domestic and foreign)
LD/FM	=	number of licensed drivers over number of family units
PC	=	consumer price index, all items
MTWNA/FM	=	number of persons not using an automobile to travel to work over number of family units
NPMET	=	percentage of population living in Standard Metropolitan Statistical Areas (SMSAs)

The estimated coefficients and summary statistics discussed here are those reported by Wharton EFA. The overall goodness of fit of the equation, as indicated by the $\bar{R}^2$ value of .461, seems to indicate a poor fit. However, one must remember that the equation was fitted over cross-section data that typically have considerably more variation about the mean and are not trend-dominated as are many economic time series. Therefore, explaining 46.1% of the variance in desired stock per family is reasonable and is within the range of typical $\bar{R}^2$ (about .40 to .80) for cross-section data.

What is disappointing about this equation is the lack of strength of the individual coefficient estimates. Only three coefficients (permanent income, income distribution, and licensed drivers per family) are significantly different from zero at the 5% significance level. Indeed, the coefficient of the average capitalized-cost-per-mile variable, one of the central concepts of the entire model, is smaller in value than its standard error. The data appear to indicate that average capitalized cost per mile, as defined in the model, has no significant influence on the stock of cars in operation by state for the year 1972. A possible explanation of this is the fact that the cost per mile variable probably has very little variation across states. This means that state cross-section data is poorly suited to estimating price effects.

The coefficients of the variables that measure the number of persons using nonauto transportation to work and the percentage of the population living in SMSAs are also statistically weak, although these two variables are of minor importance in the model.

Finally, it should be noted that the equation was estimated over forty-seven states, excluding Oklahoma, Alaska, Hawaii, and the District of Columbia, for the year 1972.

The first explanatory variable in the equation is real permanent income, which has the expected positive sign. An increase in income, ceteris paribus, should increase the desired stock of cars.

An income "saturation effect" is represented by the percentage of families with real incomes greater than $15,000 in 1970 dollars. As the percentage of families with real incomes greater than $15,000 increases, the desired stock tends to decrease. In other words, there is a nonlinear relationship between desired stock and income, and at higher income levels, increases in income imply smaller and smaller increases in the desired stock of cars per family.

The interaction of these two income variables (permanent income and percent of families with income greater than $15,000) is of interest. For example, consider the long-run effect on the desired stock of a one percent increase in real disposable income. In the long run, permanent income also increases by one percent, and therefore the desired stock would rise by 0.563% if permanent income were the only income effect on desired stock. However, the income distribution variable will offset some or perhaps all of this permanent-income-induced increase in desired stock. To calculate the magnitude of the decrease in desired stock implied by the income distribution variable, the equation that explains the percent of families with income greater than $15,000 must be understood. This equation expresses the income distribution variable as a distributed lag function of real disposable income. The equation is as follows:

$$\ln[(PER15+/(100 - PER15+)] = \underset{(1.023)}{12.9870} + \underset{(.520)}{1.15395}\,[\ln(RDI/RM)]$$
$$+ \underset{(.128)}{1.25588}\,[(\ln(RDI/FM)_{-1}]$$
$$+ \underset{(.144)}{1.19145}\,[\ln(RDI/FM_{-2})]$$
$$+ \underset{(.243)}{0.960663}\,[\ln(RDI/FM)_{-3}]$$
$$+ \underset{(.195)}{0.563511}\,[\ln(RDI/FM)_{-4}]$$

$\bar{R}^2 = 0.967$, SEE = 0.1124, DW = 0.749, FP = 1954-74

where standard errors are in parentheses, and

PER15+ = percentage of family units with real disposable incomes of $15,000 or more

RDI/FM = real disposable income per family unit

Thus, the long-run increase in the dependent variable, (percent of families with real income of $15,000 or more, over 100 minus the percent of families with real income of $15,000 or more) due to a 1% percent increase in real disposable income is 5.1% (the sum of the coefficients of RDI/FM variables). The variable, percent of families with income of $15,000 or more, conveniently appears in the same logit form in the desired stock per family equation, so multiplying 5.1% by .100994 produces an estimate of the percentage decline in desired stock per family caused by the income saturation effect. The result is a 0.517% reduction. Therefore, the net effect on the desired stock of a 1% increase in real disposable income, taking into account the 0.563% increase stimulated by the rise in general income and the 0.517% decrease that occurs because of the shift in the income distribution at the $15,000 level, is a very modest 0.05% increase (7). One very important implication of this result is that, given the structure of the rest of the model, the long-run income elasticity with respect to new car sales volume is essentially zero. In other words, greater long-term affluence has no impact on new car sales. This is a very questionable result and one that will be discussed in more detail in Section 5.3, Full Model Dynamic Properties.

The next regressor in the desired stock equation is the average real capitalized cost per mile. It enters the equation with the expected negative sign and, as noted previously, is statistically very weak, being not significantly different from zero at any reasonable significance level. This raises the obvious question of why the variable is included in the equation. The answer probably is that the Wharton EFA authors were committed to the concept of capitalized cost per mile playing a central role in the model and therefore could not exclude it from the desired stock equation (as long as it at least had a negative sign).

The number of licensed drivers per family is estimated to have a positive impact on desired stock per family, as one would expect.

The number of persons using nonauto transportation to commute to work is meant to act as a proxy for the availability of public transit. A negative sign is found on this variable as expected.

Finally, the metropolitan population is estimated to have a slight positive impact on the desired stock. It is believed the metropolitan population variable reflects large suburban populations that tend to have above-average numbers of cars per family.

3.3.2 Desired Stock Share. The estimated equations for the desired stock shares are as follows:

(i) Combined Subcompact and Compact Stock Share

$$\ln\left(\frac{SHRSC}{1 - SHRSC}\right) = \underset{(1.629)}{2.63851} - \underset{(1.814)}{2.75703}\,[\ln(CPMSC/T\text{-}SC)]$$

$$- \underset{(.402)}{1.16875}\,[\ln(YDI/FM/CT^{*}Q)] + \underset{(.131)}{0.378345}\,[\ln(PER15+)]$$

$$+ \underset{(.32)}{0.540311}\,[\ln(NP20.29/FM)] + \underset{(.073)}{0.445103}\,(DUMNEW)$$

$$- \underset{(.110)}{0.228363}\,(DUMWSC) + \underset{(.082)}{0.321488}\,(DUMMTN)$$

$$+ \underset{(.125)}{0.559391}\,(DUMPAC)$$

$\bar{R}^2 = 0.755$, SEE = 0.1591

where standard errors are in parentheses, and

SHRSC	=	desired stock share of subcompact and compact cars
CPMSC/T-SC	=	capitalized cost per mile of subcompact and compact cars over capitalized cost per mile of all cars other than subcompact and compact
YDI	=	current dollar disposable income
FM	=	number of family units
CT*Q	=	fixed-weighted average cost per mile of passenger cars
PER15+	=	percentage of families with real income in excess of $15,000 (in 1970 dollars)
NP20.29	=	number of people aged 20-29 years old
DUMNEW	=	dummy variable for New England States
DUMWSC	=	dummy variable for West-South-Central States
DUMMTN	=	dummy variable for Mountain States
DUMPAC	=	dummy variable for Pacific States

(ii) Subcompact Share of Combined Subcompact and Compact Stock Share

$$\ln\left(\frac{SHRS/SC}{1 - SHRS/SC}\right) = \underset{(.937)}{0.665464} - \underset{(2.146)}{11.9101}\,[\ln(CPMS/C)]$$

$$- \underset{(.22)}{0.599591}\,[\ln(YDI/FM/SC{*}Q)] + \underset{(.262)}{0.225044}\,[\ln(NP20.29/FM)]$$

$$+ \underset{(.263)}{0.702456}\,[\ln(LD/FM)] + \underset{(.057)}{0.321199}\,(DUMMTN)$$

$$+ \underset{(.093)}{0.494263}\,(DUMPAC)$$

$\bar{R}^2$ = 0.792, SEE = 0.1315

where standard errors are in parentheses, and

SHRS/SC	=	desired stock share of subcompacts in total subcompact and compact
CPMS/C	=	capitalized cost per mile of subcompacts over capitalized cost per mile of compacts
YDI/FM/SC*Q	=	dollars of disposable income over number of family units over fixed-weighted average cost per mile for subcompacts and compacts
LD/FM	=	number of licensed drivers over number of families

Note: Variables that have appeared in prior desired stock share equations (e.g., NP20.29) are not redefined here. This practice is followed throughout this section.

(iii) Desired Mid-Size Stock Share

$$\ln\left(\frac{SHRM}{1 - SHRM}\right) = \underset{(.541)}{0.211089} - \underset{(.433)}{1.98095}\,[\ln(CPMM/T\text{-}M)]$$

$$- \underset{(.123)}{.161133}\,[\ln(YDI/FM/CT*Q)] + \underset{(.166)}{0.785861}\,[\ln(FM3{+}4/FM)]$$

$$+ \underset{(.041)}{0.162809}\,(DUMNEW) - \underset{(.035)}{0.125991}\,(DUMMTN)$$

$\bar{R}^2$ = 0.683, SEE = 0.0779

where standard errors are in parentheses, and

SHRM	=	desired stock share for mid-size cars
CPMM/T-M	=	capitalized cost per mile for mid-size cars over desired share weighted capitalized cost per mile for all cars other than mid-size

CT*Q	=	fixed weighted cost per mile
FM3+4	=	number of families with 3 or 4 members

(iv) Desired Full-Size Share

$$\ln\left(\frac{SHRF}{1 - SHRF}\right) = \underset{(1.133)}{-1.84714} - \underset{(.691)}{8.84702} \left[\ln(CPMF/T\text{-}F)\right]$$
$$+ \underset{(.276)}{0.831944} \left[\ln(YDI/FM/CT^*Q)\right] - \underset{(.083)}{0.506012} \left[\ln(PER15+)\right]$$
$$- \underset{(.219)}{0.771159} \left[\ln(FM3+4/FM)\right] + \underset{(.143)}{0.158820} \left[\ln(FM5+/FM)\right]$$

$\bar{R}^2 = 0.865$, SEE = 0.1070

where standard errors are in parentheses, and

SHRF	=	desired full-size car stock share
CPMF/T-F	=	capitalized cost per mile of full-size cars over desired share weighted capitalized cost per mile for all cars other than full-size
FM5+	=	number of families with 5 or more members

(v) Desired Luxury Stock Share

$$\ln\left(\frac{SHRL}{1 - SHRL}\right) = \underset{(.312)}{-2.88455} - \underset{(.650)}{0.467677} \left[\ln(CPML/T\text{-}L)\right]$$
$$+ \underset{(.099)}{0.209938} \left[\ln(PER15+)\right] + \underset{(.0012)}{0.00183016} \,(NPMET)$$
$$- \underset{(.064)}{0.298623} \,(DUMNEW) + \underset{(.092)}{0.203160} \,(DUMWSC)$$

$\bar{R}^2 = 0.519$, SEE = 0.1388

where standard errors are in parentheses, and

SHRL	=	desired stock share for luxury cars

CPML/T-L = capitalized cost per mile for luxury cars over desired share weighted, capitalized cost per mile for all cars other than luxury

NPMET = percentage of population living in SMSAs

In terms of overall goodness of fit, the desired stock share equations fit the cross-section data very well; the adjusted coefficients of determination ($\bar{R}^2$) range from 0.519 to 0.865, which is quite respectable for cross-section data. Most of the estimated coefficients are significantly different from zero at the 20% level or lower and are of the correct sign. There are three exceptions to this, however. The variables NP20.29/FM in the subcompact share of combined subcompact and compact share equation, FM5+/FM in the full-size share equation and CPML/T-L in the luxury share equation are all very weak statistically.

Since the specification of the desired stock share equations has several common elements, it is convenient to analyze the equations together as a group rather than separately.

Relative cost per mile, that is, cost per mile of the i^{th} share divided by the average cost per mile of all other shares, is the most important factor in all the share equations except the luxury car equation. As would be expected, this cost has a negative effect throughout--higher relative cost leads to lower relative share. In three of the share equations (subcompact share of combined subcompact and compact share, mid-size, and full-size) the relative capitalized cost per mile variable is highly significant while in the other two equations (combined subcompact and compact share, and luxury share) the variable is fairly weak statistically.

The next most important variable in the share equations is income relative to average costs per mile of auto travel. This variable is supposed to represent a "trading up or down" phenomenon. If income increases relative to the costs of owning and operating a new automobile, it is hypothesized that this will result in an upgrading of new car purchases, with more expensive cars gaining at the expense of more economical ones. Conversely, if automobile costs increase relative to income, it is asserted that this will result in a downgrading of new car purchases, with less expensive cars being bought more readily than more expensive ones. In terms of the estimated share equations, full-size cars, for example, suffer the most from "trading down," with small cars (subcompact and compact) gaining and mid-size having a weak tendency for a small net loss in share. As one might expect, luxury cars are not affected by this type of behavior.

Income distribution also plays a significant role in the desired share equations. Increasing affluence implies gains in the luxury and small car shares at the expense of the full-size share. The gain in the luxury share is certainly to be expected, given a higher percentage of families with real incomes greater than $15,000 (in 1970 dollars). The gain in small car share is less obvious and presumably reflects additions to the household stock of cars (second and third cars) in response to greater wealth. Why these gains in desired share for luxury and small cars come only at the expense of full-size cars is puzzling. One might expect mid-size to also lose some share to luxury and small.

Next in general significance are various demographic factors. Increasing numbers of three- and four-member families increase the mid-size share, and the percent of families with five or more members has a small positive impact on full-size share. People between the ages of 20-29 years display a minor preference for small cars (subcompact and compact), according to the model. The number of licensed drivers per family is assumed to increase the subcompact share, probably reflecting more second and third cars in the family. Finally, the share equations indicate that the metropolitan population tends to buy more luxury cars, other things being equal.

The share equations also include regional dummy variables to account for differences in buying behavior that are not captured by income, cost, and demographic variables. The regional dummies suggest the following:

- New England new car buyers demonstrate a stronger preference for small cars and a weaker desire for luxury cars than would be expected given income, costs, and demographhic factors.

- Mountain and Pacific region new car buyers purchase more small cars in general and more subcompacts in particular than would be expected given income, costs, and demographics. The Mountain region also buys fewer mid-size cars, other things being equal.
- West, South, and Central region new car buyers purchase fewer small cars and more luxury cars than would be expected given income, costs, and demographics.

One major criticism of the desired stock share equations is that they do not consider the issue of potential substitution between the low-priced end of the new car market and the used car market. Used car prices may have a significant impact on subcompact and compact new car sales. For example, a large family with limited financial resources may decide to purchase a large used car rather than "trade down" to a smaller new car that does not fit their needs for space and comfort. This limitation of the model contributes to its inability to predict new car sales and stock accurately by type of car.

3.4 Actual Demand Equations - Block E

In this section, each of the statistically derived equations of Block E are discussed. These equations, which are all based on time series data, are:

- VMT per family equation
- New car sales equation
- Scrappage equation
- Used car price equations

3.4.1 Vehicle Miles Traveled (VMT) Per Family Equation.

The equation for VMT per family is as follows:

$$\ln(VMT/FM) = \ln(WTDMVINT/FM) + A + B_1 [\ln(PRGAS/AVMPGVINT/PC)] + B_2 \{\ln[PER15+/(100 - PER15+)]\} + B_3 [\ln(RDIP4/FM)]$$

where

VMT/FM	=	vehicle miles traveled, passenger car, per family unit
WTDMVINT/FM	=	constant (1972) mileage weighted sum of vehicle miles by vintage per family unit
PRGAS	=	constant dollar (1972) retail gasoline price per gallon including taxes
AVMPGVINT	=	vintage weighted average fleet miles per gallon
PC	=	consumer price index, total, 1972 = 1.0
PER15+	=	percent of families with real incomes of $15,000 or more (in 1970 dollars)
RDIP4/FM	=	real disposable permanent income per family unit

Table 3-8 contains the comparison of the Wharton EFA and HSRI coefficient estimates and summary statistics. There is excellent agreement between the two sets of results, with only minor differences existing in the third and fourth decimal place (less than one percent difference).

The summary statistics indicate that the equation fits the sample data reasonably well with the $\overline{R}^2$ showing that 85% of the variation in the dependent variable is explained by the equation. The standard error of estimate of the equation implies a 1.4% within-sample prediction error. The standard errors indicate all the estimated coefficients (except for the constant term) are statistically significant at the 5% level or lower.

The specification of the VMT-per-family equation essentially follows the conventional format of assuming VMT to be basically a function of the real gasoline cost per mile of auto travel and of

TABLE 3-8

Estimated Coefficients and Summary Statistics

VMT Per Family Unit

(standard errors in parentheses)

	$\hat{A}$	$\hat{B}_1$	$\hat{B}_2$	$\hat{B}_3$	$\bar{R}^2$	SEE	FP	DW
WHARTON EFA	.418327 (.352)	-.20601 (.067)	.11899 (.021)	-.46754 (.137)	.852	.014	54-74	1.66
HSRI	.41805 (.351)	-.20444 (.067)	.11862 (.021)	-.46517 (.137)	.851	.014	54-74	-

real income. A survey of VMT models was recently reported by Mellman (1976). In terms of the available literature on VMT models, several new concepts are introduced in the Wharton EFA auto model. First, VMT is estimated in terms of the utilization of the auto stock. To allow for the impact of a changing age distribution of the stock, an index of VMT was constructed, called vintage-weighted VMT, that reflects variations in mileage due to fluctuations in the age composition of the stock. The value of the index, which is discussed in Section 2.3.8.2, is equal to actual 1972 mileage and rises above or below actual VMT in other years, depending on the age distribution of the stock. This effect is represented in the equation by the constant (1972) mileage-weighted VMT variable.

The real gasoline cost per mile of auto travel has the expected negative sign in the equation. The elasticity of VMT with respect to real gasoline cost per mile is calculated to be approximately -.20.

The equation contains an interesting and unusual interaction between real income and income distribution. The estimated coefficients indicate a positive relationship between VMT per family and the income distribution variable and a negative association between VMT per family and real permanent income. This specification is quite unusual in terms of the other models of VMT in economic literature. The negative sign on real permanent disposable income is peculiar at best and is totally inconsistent with previous work on VMT. However, the Wharton EFA authors justify this strange result by noting that the income distribution variable will normally respond more rapidly to a change in current income than permanent income, thus yielding a positive impact on VMT in response to, say, an increase in real disposable income.

One could argue, apart from the above, that the pattern of signs on the income variable is the opposite of what one would expect. The income distribution is meant to account for an income saturation effect, which implies that at relatively high levels of income, additional income may result in very small increases in automobile travel. Then one would expect a negative sign on the coefficient of the income distribution variable, not a positive sign. Presumably VMT is a normal good--that is, a good whose consumption increases in response to an increase in income. Thus, the coefficient of the permanent income variable should have a positive sign, not a negative one. It is not clear why the model authors selected this specification in view of the perverse signs on the income variables. Because of this, **the HSRI project staff have reservations about the structural content of the VMT per family equation.**

3.4.2 New Car Sales. The Wharton EFA equation for new car sales is as follows:

$$\ln\left(\frac{OMVUANR}{OPMVUAYEND_{-1} - SCMVUA}\right) = A + B_1 \left[\ln\left(\frac{KEND*AY}{OPMVUAYEND_{-1} - SCMVUA}\right)\right.$$

$$+ B_2 \, (DUMAUTOS) + B_3 \left[\ln\left(\frac{RDI/FM}{RDIP4/FM}\right)\right]$$

$$+ B_4 \left[\ln\left(\frac{PUTOTNRL}{PUTOTNR_{-1}}\right)\right]$$

OMVUANR	=	new car registrations
OPMVUAYEND	=	year-end stock of cars in operation
SCMVUA	=	total auto scrappage
KEND*AY	=	desired stock
DUMAUTOS	=	dummy variable for strikes
RDI/FM	=	real disposable income per family
RDIP4/FM	=	permanent family income
PUTOTNRL	=	previous year average new car price, sales weighted
PUTOTNR	=	new car price, average, weighted by previous year sales

Table 3-9 contains a comparison of the Wharton EFA and HSRI coefficient estimates and summary statistics. There is excellent agreement between the two sets of results, with only minor differences existing in the third or fourth decimal place (less than one percent). $\bar{R}^2$, the adjusted coefficient of determination

TABLE 3-9

Total New Car Registrations
Estimated Coefficients and Summary Statistics

(standard errors in parentheses)

	$\hat{A}$	$\hat{B}_1$	$\hat{B}_2$	$\hat{B}_3$	$\hat{B}_4$	$\bar{R}^2$	SEE	FP
WHARTON EFA	-2.9151	3.7929	-.25519	6.0391	-1.2668	.864	.0473	1954-74
	(.083)	(.383)	(.103)	(.728)	(.367)			
HSRI	-2.9161	3.7974	-.25455	6.0426	-1.2682	.864	.0473	1954-74
	(.083)	(.383)	(.103)	(.728)	(.367)			

indicates a good fit, with approximately 86% of the variance in the dependent variable being explained by the equation. Since the equation is log-linear, the standard error of estimate of the equation (SEE), implies an average percentage error of 4.84% in predicting the dependent variable over the same period. The t-ratios indicated all the estimated coefficients are statistically significant at the 5% level or lower.

In the specification of this equation, the dependent variable, new car registrations, is expressed relative to the stock of cars that would exist at the end of the year if no new cars were sold during the year. Thus, the sale of new cars is formulated as a "rate" relative to the stock that it is augmenting.

The first explanatory variable encountered in the equation is the desired stock relative to the actual stock, less scrappage. Since the variable is formulated in natural logarithms, this specification assumes the new car sales rate to be a function of the difference between the desired and actual stock. This is consistent with the conventional stock adjustment approach, as discussed in Section 2.2.

The second explanatory variable is real disposable income divided by real permanent income. This variable represents the logarithmic measure of transitory income. If permanent income is interpreted as average or "expected" income, then transitory income represents above- or below-average income. It can be likened to an unforeseen windfall gain or loss. Empirically, durable goods in general and new car sales in particular tend to be quite responsive to changes in transitory income, and the strong positive coefficient (6.04) on transitory income reflects this relationship.

The last behavioral variable in the equation is a new car price change variable. This variable enters the equation with the expected negative sign and implies a large impact elasticity of approximately -1.30. The interpretation of this result is that when faced with increases in new car prices, consumers will postpone buying in the short term. In steady-state the price change variable as well as the transitory income variable have no impact on auto sales. Thus, new car sales in the long run are essentially determined by movements in the desired stock.

The equation also contains a dummy variable to account for the auto strikes in 1964, 1967, and 1970.

3.4.3 Total Automobile Scrappage. Automobile scrappage is specified as follows:

$$\ln\left(\frac{SCMVUA - SCMVAGIV}{OPMVUAYEND_{-1} + OMVUANR}\right) = A + B_1 \left[\ln\left(\frac{KEND*AY}{OPMVUAYEND_{-1} + OMVUANR}\right)\right]$$

$$+ B_2 \left[\ln(AVAGE0\text{-}20)\right] + B_3 \left[\ln\left(\frac{PUOLD}{PSCRAPAV}\right)\right]$$

$$+ B_4 \left[\ln(NRUT)\right] + \sum_{i=0}^{2} c_i \left[\ln\left(\frac{VMT/K}{(VMT/K)_{-1}}\right)_{-i}\right]$$

where

SCMVUA	=	total auto scrappage
SCMVAGIV	=	given scrappage for cars over 20 years old
OPMVUAYEND	=	year-end stock of cars in operation
OMVUANR	=	new car registations
KEND*AY	=	desired stock
AVAGE0-20	=	average age of stock, vintages 0 through 20
PUOLD	=	average price of old cars
PSCRAPAV	=	scrap metal price
NRUT	=	unemployment rate
VMT/K	=	ratio of vehicle miles traveled to cars in operation at midyear

Table 3-10 contains a comparison of the Wharton EFA and HSRI coefficient estimates and summary statistics. For this equation, differences exist between the two sets of estimates. The differences generally occur in the second decimal place and correspond to variations of 1%-3%. Wharton EFA staff members were consulted in an attempt to understand the cause of these differences, and they

TABLE 3-10

Total Auto Scrappage
Estimated Coefficients and Summary Statistics

(standard errors in parentheses)

	$\hat{A}$	$\hat{B}_1$	$\hat{B}_2$	$\hat{B}_3$	$\hat{B}_4$	$\hat{C}_0$	$\hat{C}_1$	$\hat{C}_2$	$\bar{R}^2$	SEE	FP
WHARTON EFA	-6.9829 (.874)	-3.8276 (.851)	2.9108 (.547)	-.14509 (.066)	-.33815 (.078)	2.2340 (.923)	4.1954 (1.165)	3.4507 (1.207)	.923	.0462	1958-74
HSRI	-6.9548 (.880)	-3.7990 .862)	2.8998 (.552)	-.14370 (.065)	-.34441 (.079)	2.198 (.927)	4.140 (1.167)	3.407 (1.212)	.9221	.04657	1958-74

offered the following two explanations as the likely causes of the differences:

1. The average age of stock data had probably been revised between the time of model estimation and delivery of the data tape to TSC.
2. The Almon lag procedure used in estimating the scrappage equation was revised slightly by Wharton EFA in the course of the model building activity (8).

Both sets of summary statistics indicate that the equation fits the data with reasonable precision, with the standard error of estimate (SEE) implying a 4.72% within-sample prediction error. The standard errors of the estimated coefficients show that all estimated coefficients are statistically significant at the 5% level or lower.

The scrappage equation was reconstructed by HSRI staff using the Almon lag procedure, with three coefficients of the VMT/K variable specified to lie on a second degree polynomial and with a zero restriction on the far end point.

The specification of the scrappage equation is as follows. The dependent variable, scrappage less given scrappage (cars twenty years of age and older--see Section 2.3.8.1 for a discussion of the calculation of given scrappage), is expressed as a rate relative to the stock of cars that would exist at the end of the year if no cars were scrapped during the year. Scrappage is thus formulated relative to the stock it is decreasing.

The rationale behind the explanatory variables in the equation is as follows. First, scrappage is estimated to depend inversely on the desired stock, which is what one would expect a priori. An increase in the desired stock, other things being equal, reduces scrappage since consumers want to hold more cars in the stock.

The average age of the stock has a positive influence on scrappage as it should; that is, as cars become older there is a greater tendency for them to be retired from the fleet.

The price of old cars relative to the scrap metal price reduces scrappage. As the price of used cars increases, holding scrap metal prices constant, it becomes financially more attractive to repair and then sell an older used car rather than scrap it. Hence the negative sign on the coefficient (B_3) in the equation.

The unemployment rate has the expected negative impact on scrappage. As unemployment increases it creates financial uncertainty among consumers (e.g., losing a job or fear of losing a job) and lowers scrappage, since people will generally maintain and repair their older used cars rather than trade them in to be scrapped when buying a "newer" used car.

Changes in vehicle miles traveled per auto are estimated to strongly affect scrappage. Increasing utilization of the stock, holding durability constant, implies increased scrappage as cars "wear out" faster than normal. The Almon lag structure indicates the effects are largest with a one- and two-year lag.

3.4.4 Average Wholesale Price For Used Cars. The equation for the average wholesale price of used cars is

$$\ln(PUSEDW) = A + B\,[\ln(PUSEDR)]$$

where

PUSEDW = Automotive News average wholesale used car price

PUSEDR = age and class-weighted average used car price, computed by Wharton EFA

Table 3-11 contains a comparison of the Wharton EFA and HSRI results. Excellent agreement exists between the two sets of results with only minor differences in the third or fourth decimal place.

The summary statistics are reasonable with the standard error of estimate indicating an average percentage error of 3.74%

The basic purpose of this simple equation is to relate the Automotive News average wholesale used car price to Wharton EFA's vintage-weighted average used car price series. The estimate of B_1, 1.047, is not significantly different from one that indicates an exact proportional relationship between the two measures of average used car price. Wharton EFA authors note that this close

TABLE 3-11

Estimated Coefficients and Summary Statistics
Average Wholesale Price for Used Cars

(standard errors in parentheses)

	$\hat{A}$	$\hat{B}_1$	$\bar{R}^2$	SEE	FP	DW
WHARTON EFA	-.0180 (.36)	1.04679 (.057)	.960	.0368	60-74	1.52
HSRI	-.0180 (.39)	1.0468 (.057)	.9599	.0368	60-74	-

relationship is an encouraging result for the methodology they employed in constructing their average traded used car price series.

3.4.5 Used Car Price Relative to New Car Price by Market Class.

Subcompact. The equation for the price of a one-year-old subcompact relative to a new subcompact is

$$\ln\left(\frac{PU/NST}{1 - PU/NST}\right) = A + B_1 \text{ (DUM63.65)} + B_2 \text{ (DUM67.68)} + B_3 \text{ (DUM69.74)}$$
$$+ B_4 \left[\ln\left(\frac{PURMVUA}{OMVUANR}\right)\right] + B_5 \left[\Delta\ln(PNEWST)\right] \text{ (DUM69.74)}$$

where

PU/NST	=	price of a one-year-old subcompact over new car price of a subcompact
DUM63.65	=	dummy variable, equal to 1 in 1963-65, zero otherwise
DUM67.68	=	dummy variable, equal to 1 in 1967-68, zero otherwise
DUM69.74	=	dummy variable, equal to 1 in 1969-74, zero otherwise
PURMVUA	=	number of used car purchases
OMVUANR	=	number of new car registrations
Δ	=	the first difference of the variable
PNEWST	=	purchase price of a new subcompact

Compact. The equation for the price of a one-year-old compact car relative to a new compact car is

$$\ln\left(\frac{PU/NCT}{1 - PU/NCT}\right) = A + B_1 \text{ (DUM67.68)} + B_2 \left[\ln\left(\frac{PURMVUA}{OMVUANR}\right)\right]$$
$$+ B_3 \left[\Delta\ln(PNEWCT)\right] + B_4 \left[\ln\left(\frac{SHRCTNR}{SHRCTNR_{-1}}\right)\right]$$

where

PU/NCT	=	price of a one-year-old compact over price of a new compact
SHRCTNR	=	share of new car registrations for compacts
PNEWCT	=	new compact purchase price

Mid-Size. The equation for the price of a one-year-old mid-size car relative to a new mid-size car is

$$\ln\left(\frac{PU/NMD}{1 - PU/NMD}\right) = A + B_1 \ (DUM61) + B_2 \ (DUM68) + B_3 \ [\ln\left(\frac{PURMVUA}{OMVUANR}\right)]$$

$$+ B_4 \ [\Delta\ln(PNEWMD)] + B_5 \ [\ln\left(\frac{SHRMDNR}{SHRMDNR_{-1}}\right)]$$

where

PU/NMD	=	price of a one-year-old mid-size car over price of a new mid-size car
DUM61	=	dummy variable, equal to 1 in 1961, zero otherwise
DUM68	=	dummy variable, equal to 1 in 1968, zero otherwise
SHRMDNR	=	share of new car registrations for mid-size cars
PNEWMD	=	new mid-size car purchase price

Full-Size. The equation for the price of a one-year-old full-size car relative to a new full-size car is

$$\ln\left(\frac{PU/NFD}{1 - PU/NFD}\right) = A + B_1 \ (DUM59) + (DUM64) + B_3 \ (DUM65.66)$$

$$+ B_4 \ (DUM70) + B_5 \ [\ln\left(\frac{PURMVUA}{OMVUANR}\right)] + B_6 \ [\Delta\ln(PNEWFD)]$$

where

PU/NFD	=	price of a one-year-old full-size car over price of a new full-size car
DUM59	=	dummy variable, equal to 1 in 1959, zero otherwise
DUM64	=	dummy variable, equal to 1 in 1964, zero otherwise
DUM65.66	=	dummy variable, equal to 1 in 1965-1966, zero otherwise
DUM70	=	dummy variable, equal to 1 in 1970, zero otherwise
PNEWFD	=	purchase price of a new full-size car

Luxury. The equation for the price of a one-year-old luxury car relative to a new luxury car is

$$\ln\left(\frac{PU/NLT}{1 - PU/NLT}\right) = A + B_1\ (DUM67) + B_2\ (DUM72) + B_3\ \left[\ln\left(\frac{PURMVUA}{OMVUANR}\right)\right]$$

$$+ B_4\ [\Delta \ln(PNEWLT)]$$

PU/NLT	=	price of a one-year-old luxury car over price of a new luxury car
DUM67	=	dummy variable, equal to 1 in 1967, zero otherwise
DUM72	=	dummy variable, equal to 1 in 1972, zero otherwise
PNEWLT	=	purchase price of a new luxury car

Tables 3-12 to 3-16 contain the Wharton EFA and HSRI coefficient estimates and summary statistics. In all cases there is excellent agreement between the two sets of estimates. The summary statistics all appear to be reasonable, with each equation fitting the data well.

The specification of all five used car price-relative equations is similar, and therefore the equations can be considered together as a

TABLE 3-12

Estimated Coefficients and Summary Statistics
Price of One-Year-Old Subcompact Relative to New Subcompact

(standard errors in parentheses)

	$\hat{A}$	$\hat{B}_1$	$\hat{B}_2$	$\hat{B}_3$	$\hat{B}_4$	$\hat{B}_5$	$\bar{R}^2$	SEE	FP	DW
WHARTON EFA	.7801 (.150)	.5591 (.125)	-.4365 (.126)	-.2466 (.118)	1.6235 (.331)	2.3857 (1.075)	.800	.1515	58-74	1.97
HSRI	.7776 (.150)	.5618 (.125)	-.4367 (.127)	-.2460 (.119)	1.630 (.332)	2.3928 (1.081)	.7996	.15216	58-74	-

TABLE 3-13

Estimated Coefficients and Summary Statistics
Price of One-Year-Old Compact Relative to New Compact

(standard errors in parentheses)

	$\hat{A}$	$\hat{B}_1$	$\hat{B}_2$	$\hat{B}_3$	$\hat{B}_4$	$\bar{R}^2$	SEE	FP	DW
WHARTON EFA	.3861	-.4624	.9289	3.5193	.3658	.783	.1361	58-74	2.08
	(.099)	(.105)	(.310)	(.856)	(.139)				
HSRI	.3841	-.4637	.9352	3.5132	.3667	.7832	.1358	58-74	-
	(.099)	(.105)	(.308)	(.857)	(.139)				

TABLE 3-14

Estimated Coefficients and Summary Statistics
Price of One-Year-Old Mid-Size Relative to New Mid-Size

(standard errors in parentheses)

	$\hat{A}$	$\hat{B}_1$	$\hat{B}_2$	$\hat{B}_3$	$\hat{B}_4$	$\hat{B}_5$	$\bar{R}^2$	SEE	FP	DW
WHARTON EFA	.5599 (.067)	-.2129 (.104)	-.1764 (.112)	.3370 (.205)	-1.238 (.746)	.5439 (.235)	.309	.0984	58-74	2.14
HSRI	.5588 (.067)	-.2112 (.104)	-.1734 (.113)	.3383 (.206)	-1.239 (.747)	.5377 (.236)	.3031	.0985	58-74	-

TABLE 3-15

Estimated Coefficients and Summary Statistics
Price of One-Year-Old Full-Size Relative to New Full-Size

(standard errors in parentheses)

	$\hat{A}$	$\hat{B}_1$	$\hat{B}_2$	$\hat{B}_3$	$\hat{B}_4$	$\hat{B}_5$	$\hat{B}_6$	$\bar{R}^2$	SEE	FP	DW
WHARTON EFA	.1464 (.077)	-.3040 (.107)	.3707 (.089)	.3095 (.075)	-.2217 (.086)	1.3043 (.219)	-3.4195 (.723)	.802	.0813	58-74	2.14
HSRI	.1477 (.077)	-.3033 (.106)	.3687 (.089)	.3081 (.073)	-.2211 (.086)	1.3017 (.218)	-3.4271 (.718)	.8034	.0808	58-74	-

TABLE 3-16

Estimated Coefficients and Summary Statistics
Price of One-Year-Old Luxury Relative to New Luxury

(standard errors in parentheses)

	$\hat{A}$	$\hat{B}_1$	$\hat{B}_2$	$\hat{B}_3$	$\hat{B}_4$	$\bar{R}^2$	SEE	FP	DW
WHARTON EFA	.6555 (.047)	-.2043 (.069)	.2122 (.070)	.7853 (.126)	-2.0766 (.578)	.786	.0663	58-74	2.24
HSRI	.6561 (.048)	-.2058 (.069)	.2127 (.070)	.7837 (.126)	-2.085 (.581)	.7851	.0665	58-74	-

complete unit.

Used car sales relative to new car sales enter each equation with a positive sign. This indicates that if the demand for used cars relative to new cars increases, used car prices have a tendency to increase relative to new car prices. This result is sensible and is consistent with conventional economic theory. However, the equations neglect to include one aspect of supply--that is, the availability of one-year-old cars. A supply variable seems essential in determining used car prices.

A second influence comes from the new car price for each market class. Increasing new car prices would lower the used car/new car price ratio unless sufficient new car purchasers were driven into the used car market to induce a larger percentage change in used-car prices. In the case of subcompacts and compacts, the positive sign of the new car price variable in each equation indicates that some potential new car buyers turned to the used car market. This implies buyers of large cars are less sensitive to price increases than small cars buyers, a reasonable result.

Finally, a third effect is estimated for the compact and mid-size car equations. If the share of new car sales increases in the market class of compacts, or mid-size cars, the used car price for that class also tends to rise.

There are also numerous dummy variables in the equations. These variables are included to account for unusual relationships in the data for selected years. The dummy variables for single years (DUM64, DUM65, etc.) serve to delete those years from the time series. These dummy variables bias the statistics generated in the regression. If these dummy variables are removed from the regression, the following results are produced:

a) In the price of one-year-old compact to a new compact equation, the $\bar{R}^2$ statistics drops to .47 and the SEE almost doubles to .21.

b) In the price of a one-year-old mid-size car to a new mid-size car equation, the $\bar{R}^2$ statistic falls to .06.

This implies that the equation is a very poor fit for the 1958-1974 period.

c) In the price of a one-year-old luxury car to a new luxury car equation, $\bar{R}^2$ drops to .52 and the SEE increases by a third to 1.070.

These revised results indicate that the price-relative equations fit the data over the chosen fit period rather poorly, and they are likely to be poor as predictors of used car prices.

The comments made previously with regard to dummy variables that isolate one year (in the section on the expenditures for options installed equations) also apply here. Eliminating the problem years as well as their corresponding dummies from the equation results in the same coefficients but reduced $\bar{R}^2$.

3.5 Actual Stock Equations - Block F

The only statistically derived equations in Block F are the five new car market share equations by size class that are discussed here.

The Wharton EFA auto model contains five equations that explain new car registrations shares by market class. The five market classes are: combined subcompact and compact, subcompact share of combined subcompact and compact, mid-size, full-size, and luxury. The general form of each equation is as follows:

$$\ln\left(\frac{SHRXXNR}{1 - SHRXXNR}\right) = [\ln\left(\frac{SHRX*A}{1 - SHRX*A}\right)] + A + B\,[\ln\left(\frac{TMXXK\text{-}SC}{1 - TMXXK\text{-}SC}\right) - \ln\left(\frac{SHRX*A}{1 - SHRX*A}\right)]$$

where

SHRXXNR	=	share of new car registrations, by market class XX
SHRX*A	=	desired stock share, by market class X
TMXXK-SC	=	share (fraction) of stock after scrappage, by market class; shares adjusted to sum to one

Tables 3-17 to 3-21 contain comparisons of the Wharton EFA and HSRI

TABLE 3-17

Estimated Coefficients and Summary Statistics
Combined Subcompact and Compact New Registration Share

(standard errors in parentheses)

	$\hat{A}$	$\hat{B}_1$	$\bar{R}^2$	SEE	FP	DW
WHARTON EFA	.05988 (.015)	-.40055 (.024)	.932	.0483	54-74	.83
HSRI	.05840 (.016)	-.40288 (.025)	.9269	.05065	54-74	-

TABLE 3-18

Estimated Coefficients and Summary Statistics
Mid-Size New Registration Share

(standard errors in parentheses)

	$\hat{A}$	$\hat{B}_1$	$\bar{R}^2$	SEE	FP	DW
WHARTON EFA	-.00199 (.003)	-.87308 (.011)	.997	.0101	54-74	1.26
HSRI	-.00179 (.004)	-.87469 (.012)	.9961	.0118	54-74	-

TABLE 3-19

Estimated Coefficients and Summary Statistics
Full-Size New Registration Share

(standard errors in parentheses)

	$\hat{A}$	$\hat{B}_1$	$\bar{R}^2$	SEE	FP	DW
WHARTON EFA	-.01158 (.004)	-.8269 (.018)	.991	.0168	54-74	1.05
HSRI	-.01163 (.004)	-.82781 (.018)	.99048	.0174	54-74	-

TABLE 3-20

Estimated Coefficients and Summary Statistics
Luxury New Registration Share

(standard errors in parentheses)

	$\hat{A}$	$\hat{B}_1$	$\bar{R}^2$	SEE	FP	DW
WHARTON EFA	.00026 (.001)	-.71306 (.007)	.998	.0021	54-74	1.33
HSRI	-.00002 (.005)	-.75483 (.037)	.9545	.0115	54-74	-

TABLE 3-21

Estimated Coefficients and Summary Statistics
Subcompact Share of Combined Subcompact and Compact New Registrations

(standard errors in parentheses)

	$\hat{A}$	$\hat{B}_1$	$\bar{R}^2$	SEE	FP	DW
WHARTON EFA	.00275 (.010)	-.6995 (.033)	.958	.0453	54-74	1.39
HSRI	.00231 (.011)	-.69784 (.033)	.9569	.0459	54-74	-

estimates of the coefficients and summary statistics of the market segment equations. In all five equations differences exist between the two sets of estimates. In four of the segments (combined subcompact and compact, mid-size, and full-size) the differences are relatively minor, generally occurring in the third decimal place. However, in the luxury share equation, the differences are substantial. For example, HSRI staff estimate a standard error of estimate for the equation that is approximately five times greater than the Wharton EFA estimate of the standard error. In the same light, the HSRI value of $\bar{R}^2$ is essentially four percentage points lower than the Wharton EFA value of $\bar{R}^2$. When asked about these discrepancies, the Wharton EFA authors' only response was that perhaps the equation was fitted over a different time period from that reported in the text (1954-1974). However, HSRI staff have tried various other plausible fit periods (e.g., 1958-1974) and have not been able to replicate the Wharton EFA results for the luxury share equation.

In general, both sets of summary statistics show that all five market share equations fit the sample data quite well with between 93% and 99% of the variance in the dependent variable being explained in any given equation. The t-ratios indicate that the estimated coefficients on all of the actual-stock-minus-desired-stock variables are highly significant, which indicates that the stock adjustment approach employed is successful in terms of fitting the historical data.

The rationale behind the new car registrations shares equations is quite simple. As the model authors note, sales by market class are assumed to respond directly to changes in desired stock shares at a rate proportional to the divergence between actual and desired stock.

The market share equations are formulated using the logit model. Each market share variable is expressed in "odds" form. For example, the full-size market share variable actually appears in the equation as:

$$\ln\left(\frac{\text{Full-Size Market Share}}{1 - \text{Full-Size Market Share}}\right)$$

The logit model approach has the advantage of constraining each predicted market share to lie between zero and one, as of course it logically should. However, the logit model does not eliminate the problem of the shares adding up to more than one. In fact with five market classes, the logit model only constrains the five shares to add up to less than 5.0. Thus, ex post normalization of the shares is required in the model program, and the procedure for doing this has been discussed in Section 2.3.8.3.

The dependent variable in each equation is the difference between the new car sales share and the desired stock share. This approach constrains the coefficient of the desired stock share variable to be one, since in equilibrium the new car sales share equals the desired stock share.

Each market share equation contains the conventional stock adjustment expression of desired-stock-minus-actual-stock, although the variables are actually expressed in the logit format (i.e., "odds" form) and the order is reversed. Therefore, a negative sign on this variable (the estimate of B) is expected in each equation, as indeed the estimate results indicate.

As the Wharton EFA model authors state, if the shares of stock less scrappage are held constant, the initial (first year) response to a change in the desired share is greater than one for each market class. A 1% increase in the desired share of each class is estimated to increase the small new car sales share by 1.4%, the subcompact share of small new car sales by 1.7%, the mid-size share by 1.9%, the full-size share by 1.8%, and the luxury share by 1.7%. Note that for the small increase considered, the model authors assume that the elasticities are equal to the coefficients. In general this is not the case, since the equations are specified in the logit format. The dynamic properties of the market share equations will be analyzed in detail in the submodel and full model evaluation sections of this report.

3.6 Summary of Equation Reconstruction

In terms of replicating the key time series equations of the model, the results were mixed. Some equations were exactly reproduced, some were closely reproduced, and some were poorly reproduced. "Closely reproduced" means that the HSRI-estimated coefficients are no more than 2% or 3% different from the Wharton EFA coefficients. "Poorly reproduced" means that there is a greater than 3% difference or a difference in signs.

Some of the exactly reproduced equations include those predicting new car registrations, vehicle miles traveled, foreign car base purchase price excluding options for subcompact, compact, and luxury classes, expenditures for options installed for all size classes, and relative price of one-year-old cars to new cars for all classes.

Those equations that were closely reproduced include total auto scrappage, and new car market shares for all but the luxury size class.

Some of the poorly reproduced equations are the new car market share for the luxury size class, the domestic new car market shares for subcompact, compact, and luxury classes, the average domestic base purchase price excluding options for all classes, and the average domestic price for all options, for all classes.

With respect to the cross-section equations, it was found that the cross-section data tape was very difficult to work with. After an attempt was made to replicate these equations, it was found that this was impossible to do within the constraints of the project.

These general results of equation reconstruction suggest the following summary points:

1. **The documentation concerning the data used in estimating the equations is often quite limited and difficult to understand.** This is particularly true for the cross-section data.
2. **There appears to be carelessness on Wharton EFA's part in maintaining a one-to-one correspondence between the data series on the**

data tape delivered to TSC and the data series used in actually estimating the time series equations of the model. Indeed, the HSRI results suggest that it is highly likely that several of the series on the data tape are not the ones used in the actual estimation of the model. Given the fact that data series are often revised as a matter of routine, the question arises as to what version of these series was used in estimating the model. If it was an out-of-date or preliminary version of the data series, then the appropriate equation clearly should be refitted with the more recent version of the data series. This is a fairly simple task to perform and it definitely should have been done by Wharton EFA if the series had been revised.

3. **Errors may have been made on the part of Wharton EFA in the estimation of several time series equations of the model** (primarily those in the poorly reproduced category).

The specification of the individual equations of the model was also discussed in this section. The following are summary points on the specification of the model:

1. The model covers a substantial amount of new territory compared to previous work on automobile demand modeling. **The model represents the highest state of the art from the perspective of degree of coverage of the automobile market.** In fact, there are only two equations in the model, new car sales and VMT, for which there is any significant amount of prior published work. The specification of new car sales as a stock adjustment process is consistent with previous studies of auto demand. However, the VMT equation is quite peculiar in that permanent income appears as an independent variable

with a negative sign, and an income distribution variable appears with a positive sign in the equation. If one were to argue that the income distribution variable belongs in the equation to capture an income saturation effect on auto travel, then one would expect a positive sign on permanent income and a negative sign on the income distribution variable, the opposite of what occurs. Because of this perverse sign pattern, **the HSRI authors have serious doubts as to the validity of the specification of the VMT equation.**

2. The rest of the equations of the model have little or no precedent on which to base an evaluation of their specification. Very little econometric work in the public domain has been done on scrappage, new car demand by market segment, desired stocks and shares, new car prices (base price, options price, and transportation charges), and the used car market.

Therefore, it is the view of the HSRI authors that the appropriate interpretation of the structure of the model is simply that Wharton EFA has "discovered" a number of hypotheses that are at least broadly consistent with the data. **In no case is an equation derived a priori from the theory, and most are justified after the fact.** Therefore, one can only surmise that the equations were specified using hypothesis-searching techniques (i.e., data mining). This indeed is quite conventional in terms of the methodology employed in building econometric models that are used for forecasting and policy analysis. However, it does have several extremely important implications in terms of the "validity" of the model.

It is important to realize that Wharton EFA has not "proved" anything in the deductive sense of the word. Rather, they have offered one interpretation of the structure of the automobile market for which there is classical statistical support (ignoring the issue of preliminary test estimation), and in which the signs of the estimated coefficients are generally consistent with economic theory and other institutional knowledge. However, in many cases the data may be consistent with more than one hypothesis. In this case, choosing among various experimental specifications often comes down to a variety of personal biases and subjective criteria--best fit, elasticities "look right," agrees with prior expectations and beliefs, agrees with previous work or other evidence (perhaps survey data), postsample forecasting accuracy is good, within-sample simulation results (dynamics and forecasting) are adequate, and so on. Therefore, it is the view of the HSRI authors that the results implied by the structure of this model (particularly the dynamic properties and forecasting behavior) must be interpreted with these limitations in mind.

4.0 SUBMODEL EVALUATION

4.1 Introduction

The purpose of submodel evaluation is to analyze the forecasting behavior and dynamic properties of submodels--that is, individual equation or groups of interrelated equations--within the full model. This analysis provides insights into the operation of key aspects of the model. An interrelated group of equations is one where the solution of at least one of the equations influences the solution of the other equations. An example is the group comprised of the new car sales and scrappage equations. For this submodel, the solution of the new car sales equation depends on the solution of the scrappage equation and vice versa; i.e., the two equations are highly simultaneous.

Analyzing the forecasting behavior of submodels involves examining simulations generated by the submodel over a period in which the actual values of the submodel variables are known, i.e., a historical period. The examination essentially involves looking at the difference between the simulated values and the actual values. Based on these differences, various statistics are calculated to measure forecast errors. Also, since this analysis is performed over a period in which the model was calibrated, the forecast errors are expected to be smaller than if the model were tested outside of the fit period. Thus, the model is analyzed under its "best" performance conditions. The version of the model used in this analysis is the Wharton EFA auto model that HSRI obtained from TSC. The coefficients estimated by HSRI are not used here. Use of the HSRI coefficients, however, would make little difference in the simulation results.

The analysis of the dynamic properties of the submodels involves examining the response of the submodel simulations to specified changes in the independent variables and estimated parameters. Since values are needed for independent variables of the submodel that normally would be predicted in the full model, the dynamic analysis is also conducted over a historical period when the values of all independent variables are known.

The submodel evaluation of the Wharton EFA auto model focuses on three sets of submodels in the model comprised of the following equations:

Set 1 - new car sales, scrappage, VMT per family (from Block E), and desired stock per family (from Block D)

Set 2 - new car market shares by size class (from Block F) and desired shares by size class (from Block D)

Set 3 - capitalized cost per miles variables (from Block C)

The first two sets of submodels were chosen because they contain the key equations of the model. In the first set, the relationships of the important model outputs--automobile demand, scrappage, and travel demand--are examined. Also examined is the manner in which the estimate for desired stock affects the forecasting accuracy and dynamic properties of these model outputs. Through the stock adjustment process, desired stock influences new car sales and scrappage, which in turn influence VMT.

The second set of submodels examines the new car market segment equations and how the desired stock share equations influence the forecasting behavior and dynamic properties of the new car share equations.

For the third set of submodels, the dynamic properties of the capitalized cost per mile (CPM) equations are examined in terms of how each of the components of these equations--purchase price, financing and operating costs, and discount factor--influence the value of the CPM variables over time.

Note on Computer Operation in Submodel Evaluation

In this section, a brief explanation is presented on how the HSRI version of the computer program generates output for the submodel evaluations. A two-step process is necessary to generate submodel evaluations. The first step involves identifying the equations to be included in a submodel. This is achieved by flagging, as exogenous or endogenous, those equations in the computer program to be included in the submodel. If the equation is flagged as exogenous, then the equation is ignored in a simulation of the model; instead the dependent variable is set to an exogenous value, a value specified before the model simulation is run. For a simulation run over a historical period, the program automatically sets the value of the dependent variable to its historical value if no value is explicitly specified. If an equation is flagged as endogenous, the equation is solved in the simulation--that is, the model generates a prediction for the dependent variable.

Once the behavioral equations in the submodel are identified, the second step in generating the submodel simulations is to run the model as outlined in Section 2.3.2.

4.2 Forecasting Behavior of Submodels

This section presents an analysis of the forecasting behavior of the first two sets of submodels. The analysis involves generating simulations of the submodels over a historical period when the actual values of the submodel variables are known, and comparing the simulated values to the actual values.

The comparison is examined in three different ways. The first method is to plot the simulated and actual values of a variable of the submodel over time on a graph. The second method is to list the simulation and actual results in a table. Each table has four headings labeled ACTUAL, SIMULATION, ERROR, and % DIFF. ERROR refers to the difference between the simulated and actual values (SIMULATION minus ACTUAL), and % DIFF refers to the precentage error with respect to the actual value.

The third method is to examine the error statistics associated with the submodel simulation. Three error statistics are included.

The first is the root mean squared error (RMSE), which is equal to the square root of the average of the squared forecasting errors and is a measure of the average yearly errors of the simulated values. The second is the root mean squared error as a percentage of the average actual values of the variable over the simulation period (100*RMSE/MEAN ACTUAL). It is a measure of the average yearly percentage errors with respect to the actual values of the simulated variables. The third is a simulated R^2 statistic (SIML R-SQ), a measure of the predictive accuracy of the equation as solved in the model simulation. Its interpretation is similar to that of the R^2 statistic--with the exception that the simulated R^2 can have negative values that indicate that the underlying equation is very unreliable. A unit value of SIML R-SQ indicates that the simulation experiment generated exact values of the historical data. Negative values of SIML R-SQ indicate that the underlying equation is very unreliable (9).

Each of the submodel forecasting experiments is run over the historical period 1960 to 1974. This permits comparisons among various simulations. This historical period was chosen because it is the largest time period within which most of the model equations were estimated. Since it is likely that the economic and demographic conditions under which the model was estimated are different outside of the fit period for the model and will change in the future, these simulations may be assumed to represent the "best" performance of the model.

4.2.1 Forecasting Behavior of Submodel Set 1 - New Car Sales, Scrappage, VMT per Family, and Desired Stock. Submodel set 1 contains three important behavioral equations of the model--new car sales, scrappage, and VMT per family. The predictions produced by these equations influence many other predictions of the model (see Section 2.3.7 and 2.3.8). Therefore, the forecasting accuracy of these equations is crucial to the forecasting accuracy of a major part of the model and of the model as a whole.

To examine the forecasting behavior of the new car sales, scrappage, and VMT per family equations, the following five submodel experiments have been formulated.

1. In the first experiment, the submodel consisting of the new car sales and scrappage equations is examined over the historical period 1960 to 1974. It was decided to examine new car sales and scrappage together in the first simulations because these two variables are so closely tied together--although each variable could have been simulated separately. New car sales is an important variable in the scrappage equation, and scrappage is an important variable in the new car sales equation.

2. In the second experiment, the submodel consisting of the single equation for VMT per family equation is examined.

3. In the third experiment, a submodel that consists of the combination of the first two submodels plus all the identities that link these two submodels is examined. Since the first and second submodels are related to one another, forecasting errors generated in one may influence the forecasting errors generated in the other. The analysis of the forecasting behavior of the third submodel will indicate the degree of this influence. The identities that link the second submodel to the first one are the total VMT and the ratio of VMT to total midyear stock equations. The identities that link the first submodel to the second submodel are the scrappage adjustment factor and probability of scrappage by age equations that comprise Wharton EFA's vehicle survival model, plus the stock of cars by age, vintage-weighted VMT, and vintage-weighted fleet fuel economy equations. The relationship of these identities to the new car sales, scrappage, and VMT per family equations is discussed in Sections 2.3.6 and 2.3.7.

4. The fourth experiment involves an analysis of the submodel consisting of the desired stock per family, new car sales, and scrappage equations. Since the new car sales and scrappage equations are essentially stock adjustment equations, the desired stock variable is an important determinant in these equations. This

experiment examines how the estimates for desired stock influence the forecasting accuracy of new car sales and scrappage.

It would be expected that the desired stock per family equation should not influence the errors generated by the new-car sales and scrappage equations. This expectation, turns out to be false, due to the method used in generating the desired stock series.

The desired stock per family equation was estimated based on 1972 cross-section data by state. To estimate the new car sales and scrappage equations, estimates are needed of the values of desired stock for each historical year on which the new car sales and scrappage equations are fitted. However, there is no historical series because desired stock is not a measurable variable. These historical values are generated by solving the desired stock per family equation for the historical values of its independent variables and multiplying this result times the historical values of the number of United States families. For example, the 1970 estimate of desired stock is equal to the solution of the desired stock per family equation with the independent variables set to their 1970 values times the number of United States families in 1970. Since desired stock per family is not influenced in any manner by new car sales and scrappage--i.e., there is no feedback from the new car sales and scrappage predictions to the desired stock per family equations--the independent variables of the desired stock per family equation are set to their actual historical values in the submodel simulation. Therefore, this submodel simulation should produce the "historical" time series for desired stock per family. This same time series was presumably used in the first submodel experiment described above.

However, the Wharton EFA model authors found that the translation of desired stock to a time series produced what they consider to be misleading values, especially during the 1950s and early 1960s. The model authors argue that this problem is due to the low values of the income distribution variable (percentage of families earning in excess of $15,000 in 1970 dollars) during this period. The income distribution variable is included in the desired stock per family equation to model the income saturation effect. (The income saturation effect assumes that the rate at which families increase their stock of cars decreases as families become wealthier.)

For a historical period in which the income distribution variable was at a low level, a misleading reverse income saturation effect is produced by the desired stock per family equation that leads to too high values of desired stock. To correct this problem, the Wharton EFA model authors adjusted the desired stock series to "more reasonable" values, although they never state in their report the methodology used in the adjustment process. They then used the adjusted series to estimate the new car sales and scrappage equations.

The adjusted desired stock series is used in the first experiment, and the unadjusted series is used in the fourth experiment. Comparing these two experiments will indicate what role of the adjustment to desired stock has on the forecasting behavior of the new car sales and scrappage equations.

5. In the fifth experiment, the VMT per family equation is added to the submodel of the fourth experiment. Comparing this experiment to the third experiment, the effect of the adjustment to desired stock on the forecasting behavior of the VMT per family equation can be observed.

In summary, the five experiments performed on submodel set 1 involving historical simulations of submodels for the years 1960 to 1974, consist of the following behavioral equations:

1. New-car sales and scrappage
2. VMT per family
3. New car sales, scrappage, and VMT per family
4. New car sales, scrappage, and desired stock per family
5. New car sales, scrappage, VMT per family, and desired stock per family

4.2.1.1 <u>Results for Submodel Set 1</u>. The results of the experiments to examine the forecasting behavior of submodels one to five of set 1 are presented in this section. Tables A-1 to A-11, in Appendix A, show the yearly errors of the predictions of the behavioral equations in each experiment. Figures 4-1 to 4-11 are graphs of the actual and simulated values of important variables in each experiment. Tables 4-1 to 4-5 display the error statistics associated with each experiment.

1. Looking at the first experiment, one can see that the forecasting errors of the new car sales and scrappage equations are generally modest. Figures 4-1 and 4-2 show that the simulated values for both new-car sales and scrappage follow trends in the actual values. The average yearly forecasting error (RMSE) over the forecasting period 1960 to 1974 is roughly 400,000 units, or 6.4% per year, for scrappage. The high values of SIML R-SQ also confirm the accuracy of this simulation.

2. The second submodel experiment, the simulation of the VMT per family equation, generates much smaller errors than the first submodel. Predictions of this submodel are very close to the actual values over the entire experimental period, with an average error of 1.3% per year.

3. Combining the first two submodels, the third submodel experiment indicates that the new car sales and scrappage predictions have almost no effect on the VMT per family predictions. This result is expected because the new car sales and scrappage predictions affect VMT through their impact on the distribution of stock by age that has remained fairly stable over time.

On the other hand, the VMT per family predictions affect the new car sales and scrappage predictions. There is a sizable increase in the scrappage simulation errors for the period 1971 to 1974 over the errors produced in the first experiment. During this period, the VMT per family predictions are about 2% lower than the actual values, and this causes the average error in the scrappage predictions to rise during this same period from about 3.5% per year in the first experiment to over 12% per year in the third experiment. Over the entire experimental period, the average error in the scrappage

FIGURE 4-1

NEW CAR SALES AND SCRAPPAGE SUBMODEL
DYNAMIC SIMULATION OF
NEW CAR SALES

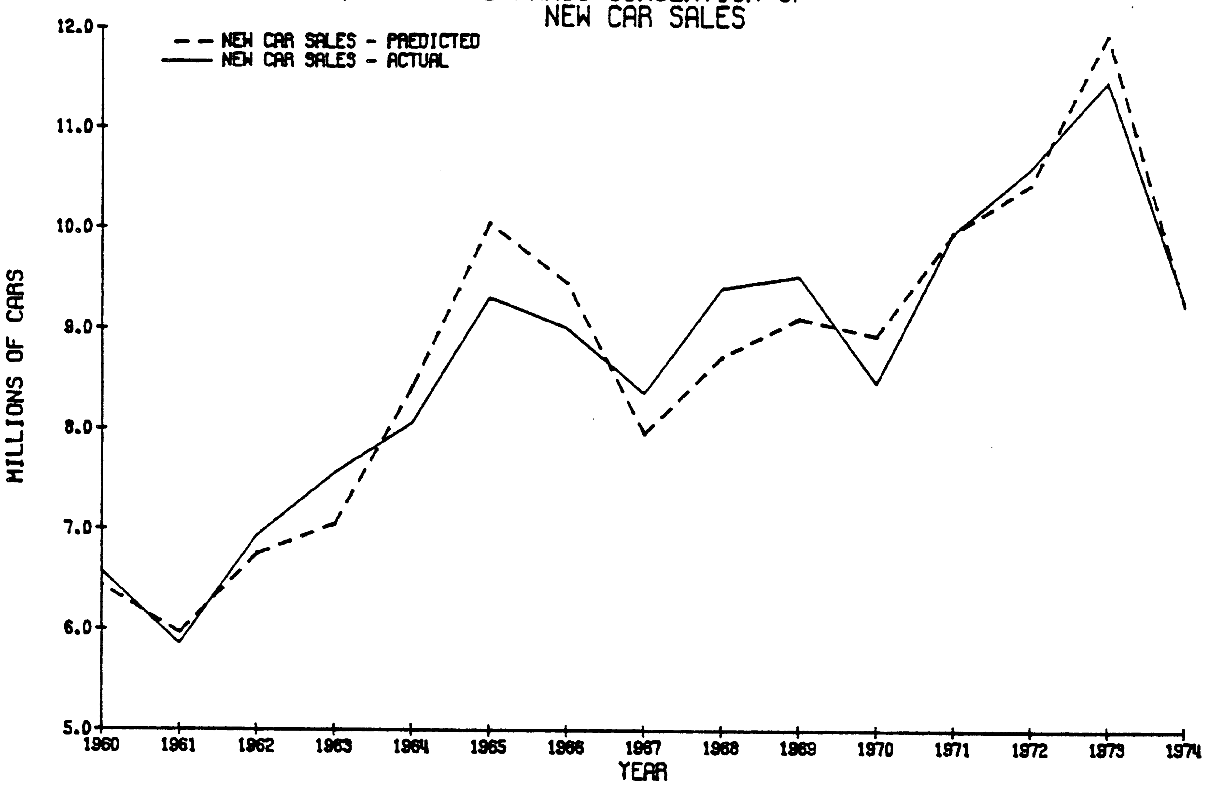


FIGURE 4-2

NEW CAR SALES AND SCRAPPAGE SUBMODEL
DYNAMIC SIMULATION OF
SCRAPPAGE

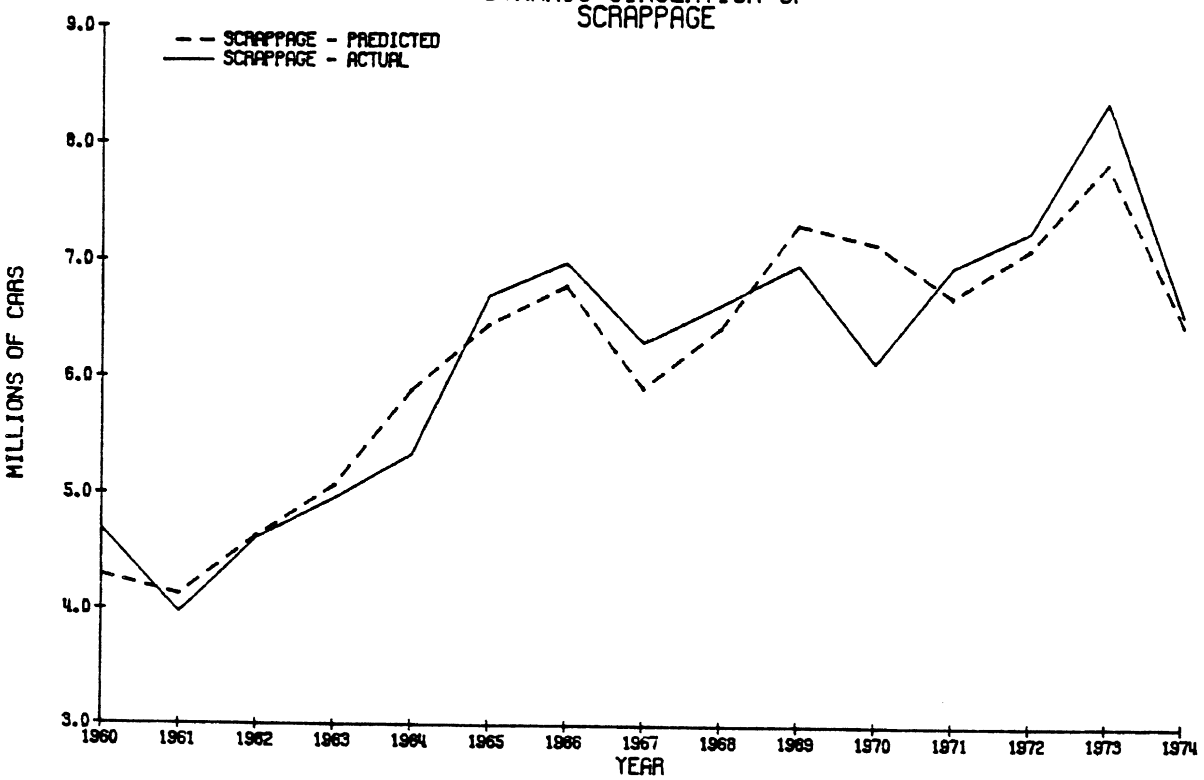


FIGURE 4-3

NEW CAR SALES, SCRAPPAGE, AND VMT PER FAMILY SUBMODEL
DYNAMIC SIMULATION OF
NEW CAR SALES

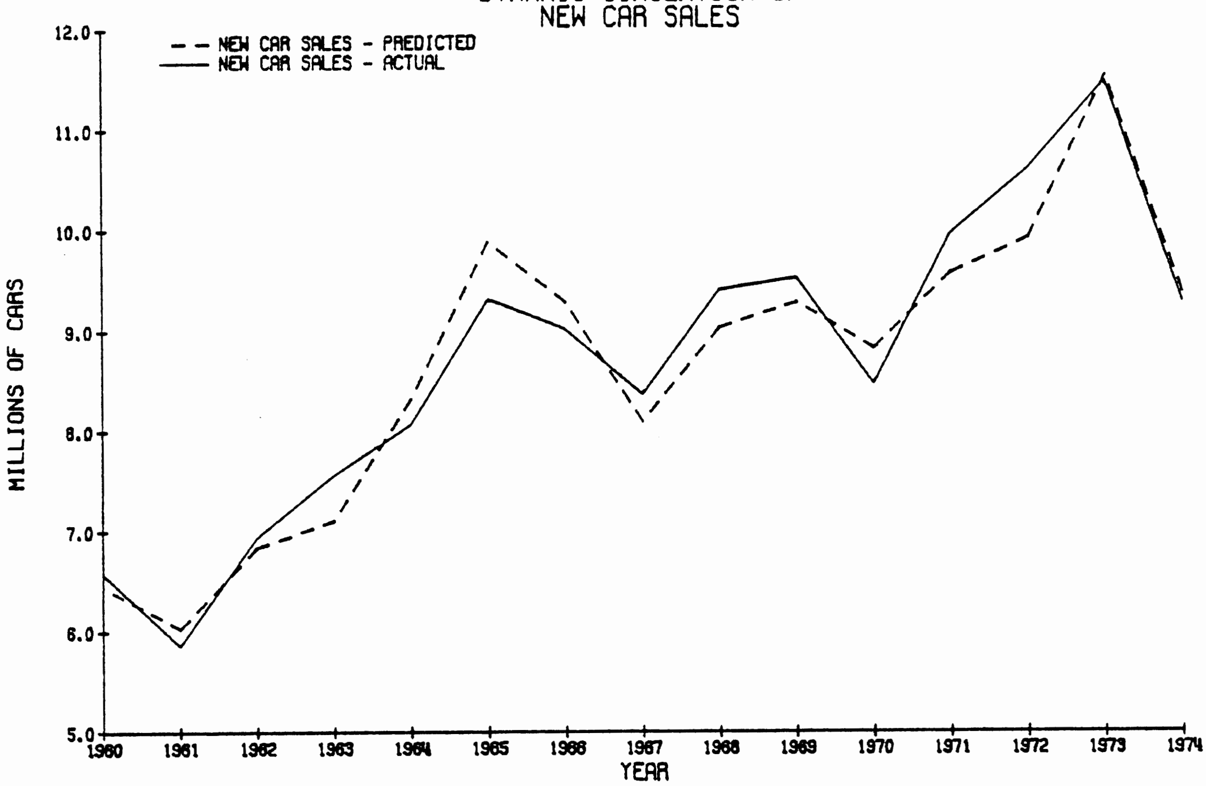


FIGURE 4-4

NEW CAR SALES, SCRAPPAGE, AND VMT PER FAMILY SUBMODEL
DYNAMIC SIMULATION OF
SCRAPPAGE

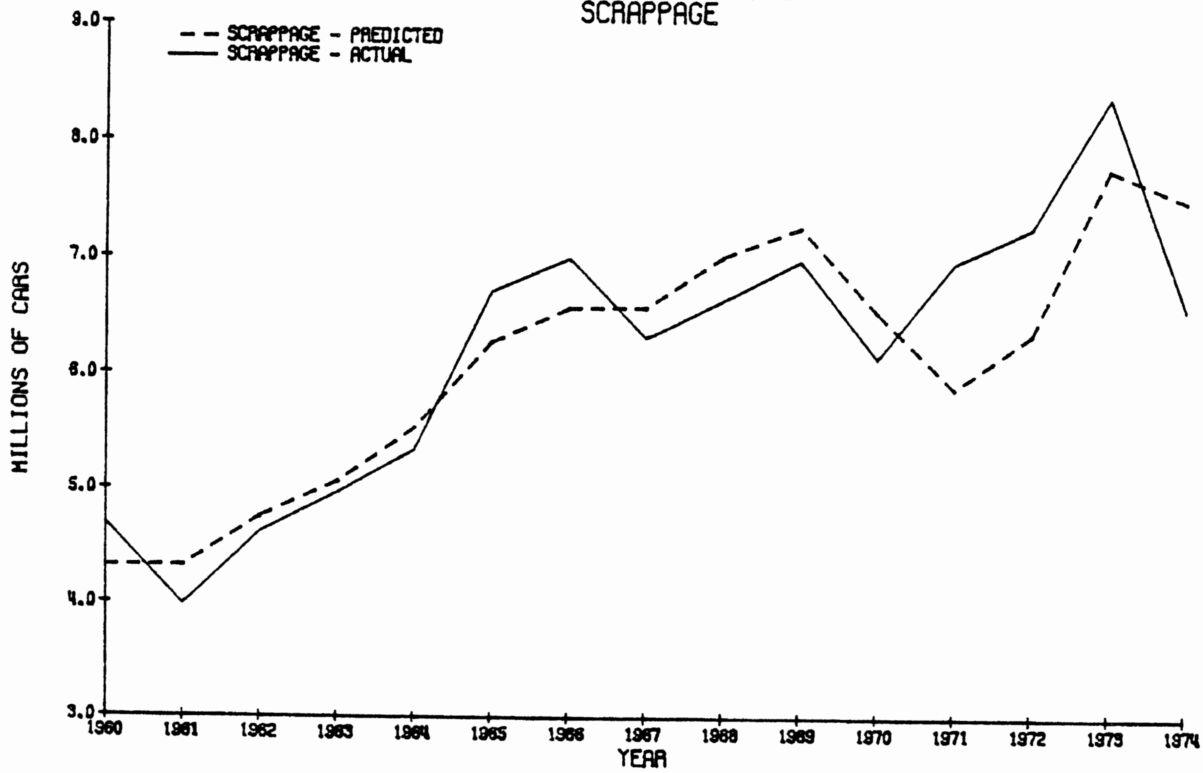


FIGURE 4-5

VMT PER FAMILY SUBMODEL
DYNAMIC SIMULATION OF
VEHICLE MILES TRAVELED PER FAMILY

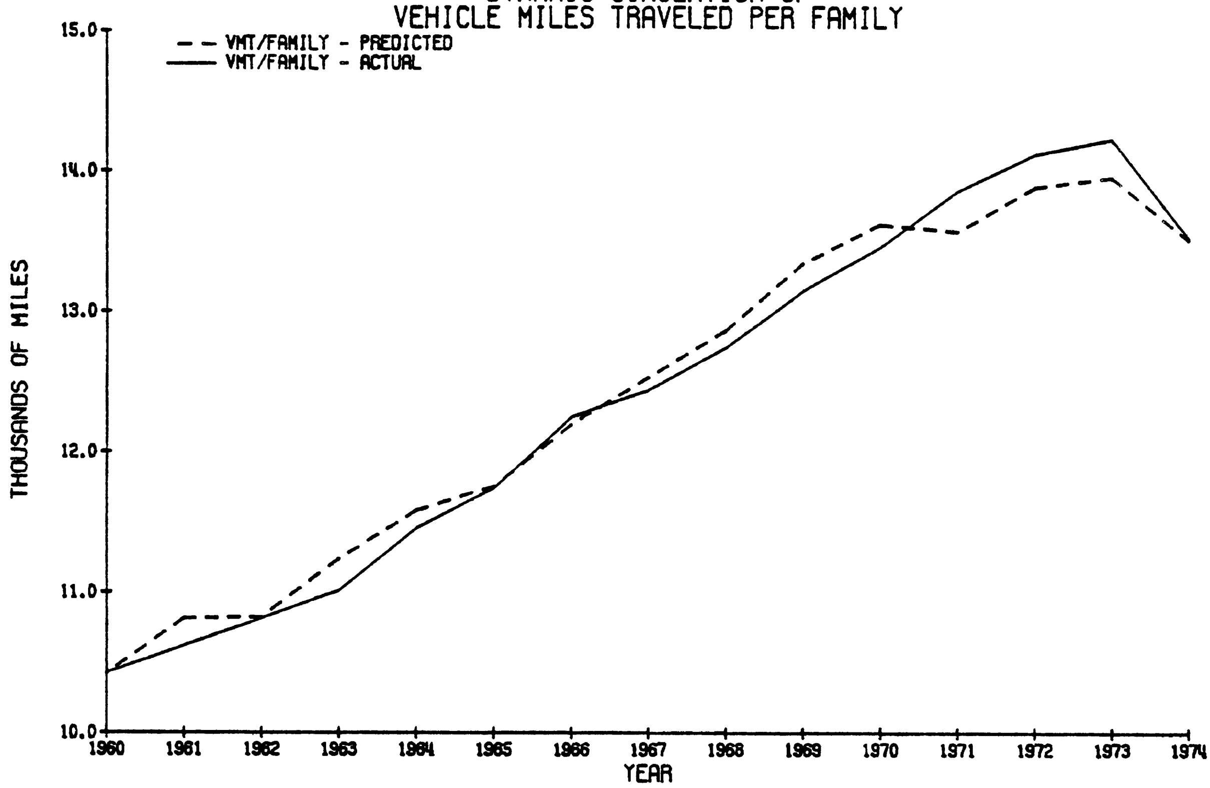


FIGURE 4-6

NEW CAR SALES, SCRAPPAGE, AND VMT PER FAMILY SUBMODEL
DYNAMIC SIMULATION OF
VEHICLE MILES TRAVELED PER FAMILY

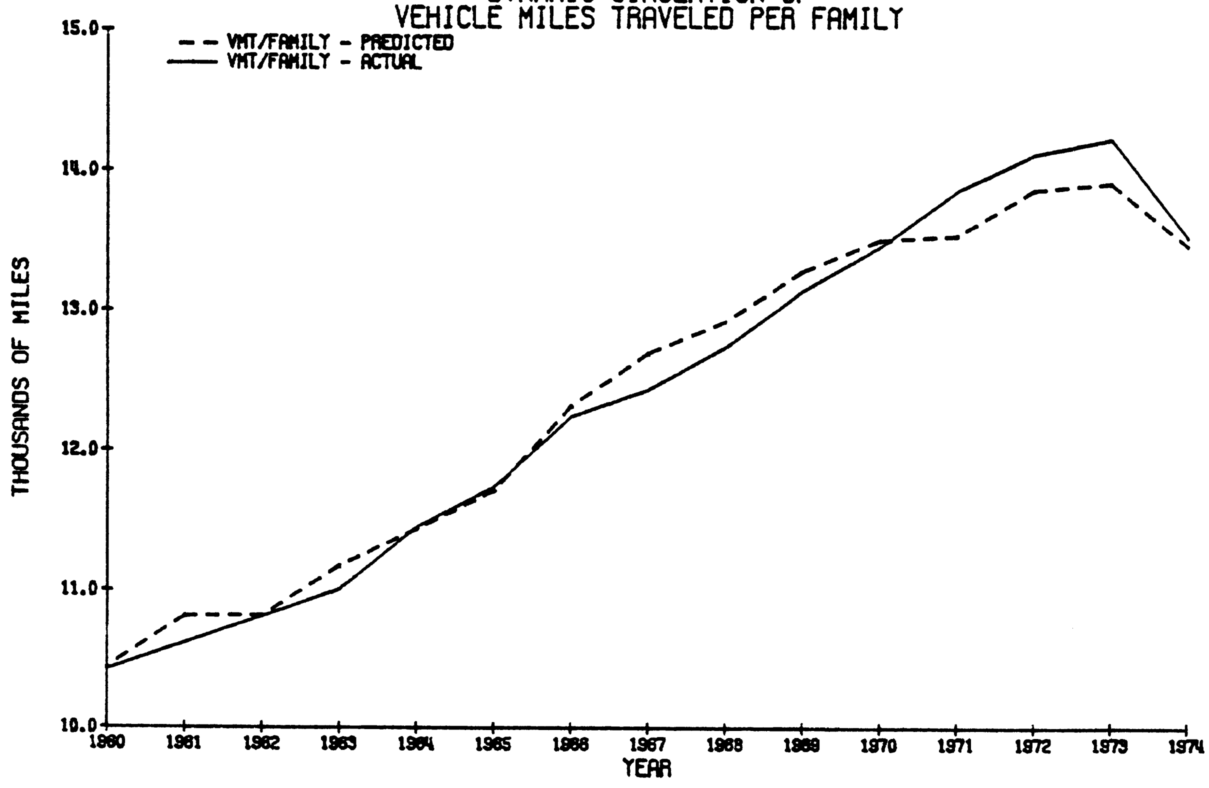


FIGURE 4-7

NEW CAR SALES, SCRAPPAGE, AND DESIRED STOCK/FAMILY SUBMODEL
DYNAMIC SIMULATION OF
NEW CAR SALES

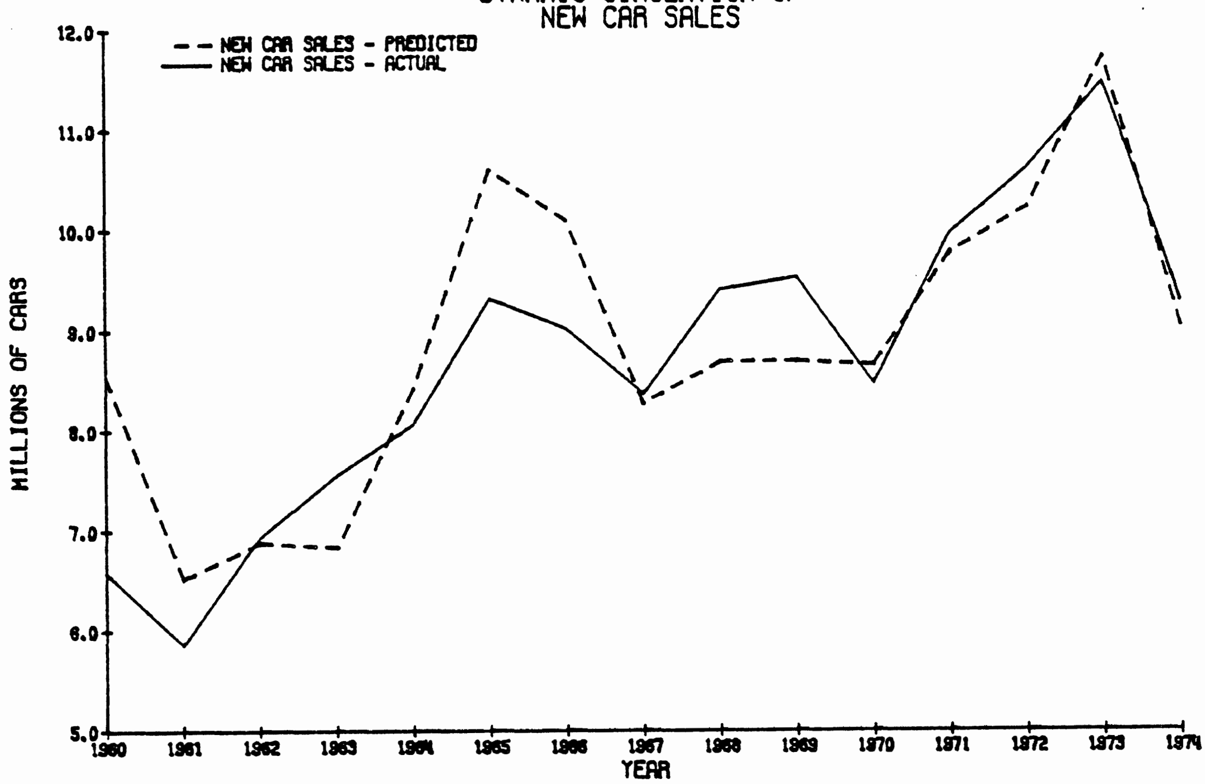


FIGURE 4-8

NEW CAR SALES, SCRAPPAGE, AND DESIRED STOCK/FAMILY SUBMODEL
DYNAMIC SIMULATION OF
SCRAPPAGE

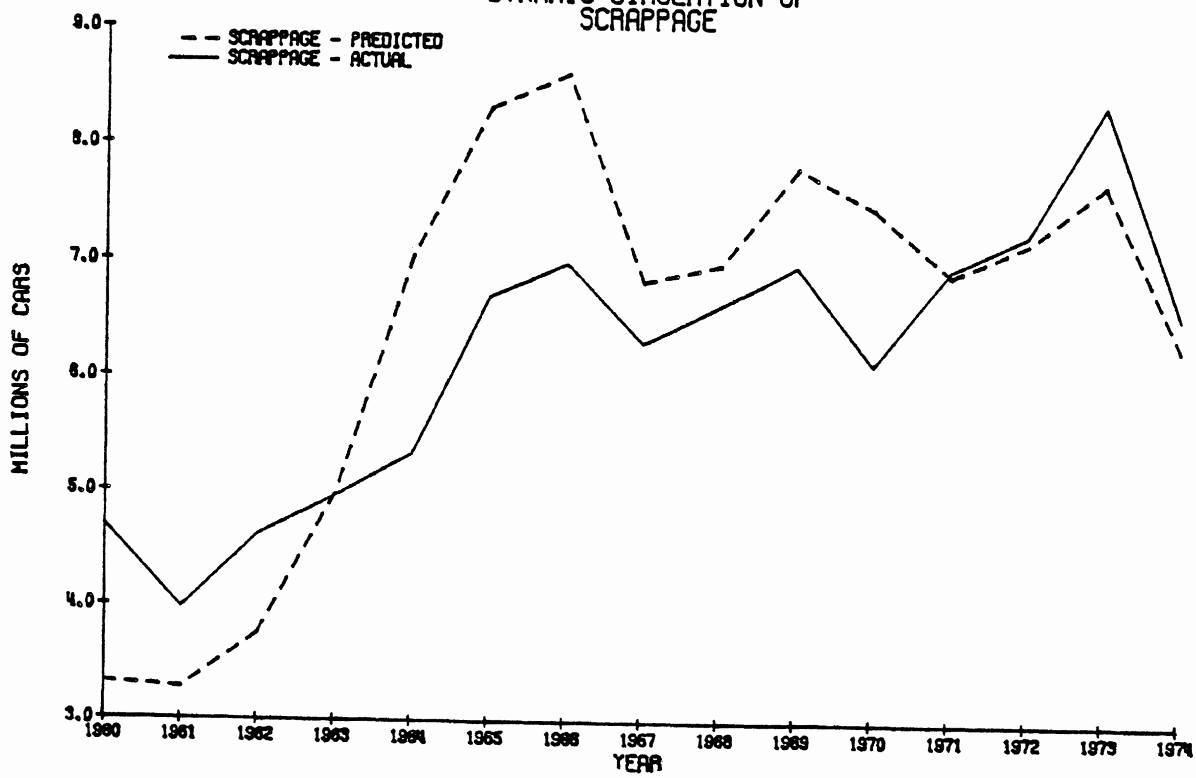


FIGURE 4-9

NEW CAR SALES, SCRAPPAGE, DESIRED STOCK/FAMILY, AND VMT/FAMILY SUBMODEL - DYNAMIC SIMULATION OF NEW CAR SALES

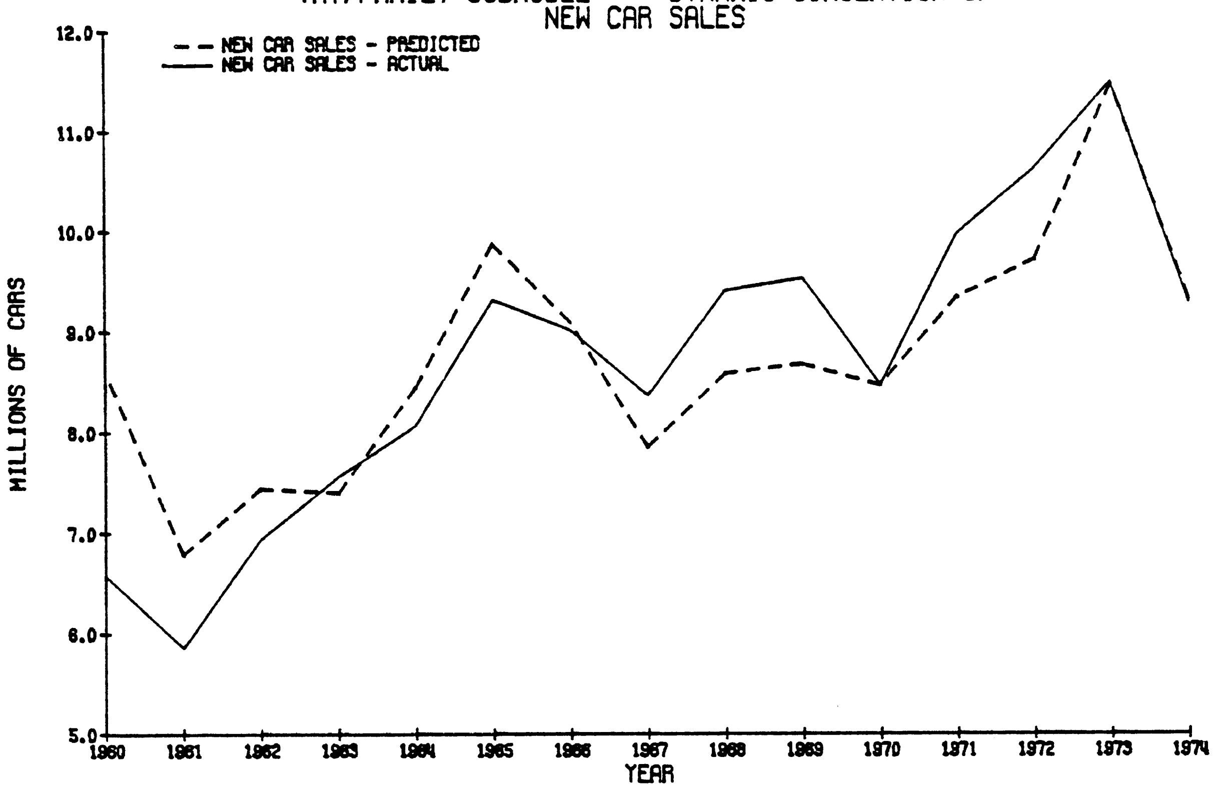


FIGURE 4-10

NEW CAR SALES, SCRAPPAGE, DESIRED STOCK/FAMILY, AND VMT/FAMILY SUBMODEL - DYNAMIC SIMULATION OF SCRAPPAGE

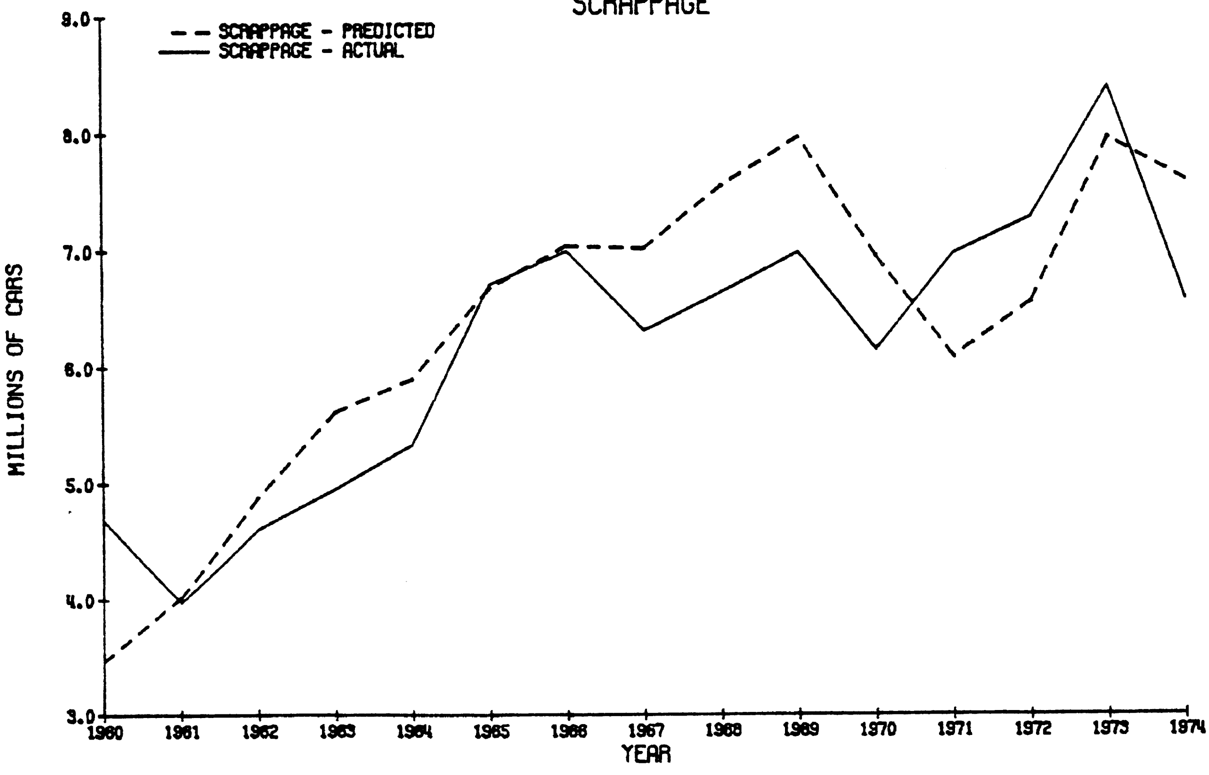


FIGURE 4-11

NEW CAR SALES, SCRAPPAGE, DESIRED STOCK/FAMILY, AND VMT/FAMILY SUBMODEL - DYNAMIC SIMULATION OF VEHICLE MILES TRAVELED PER FAMILY

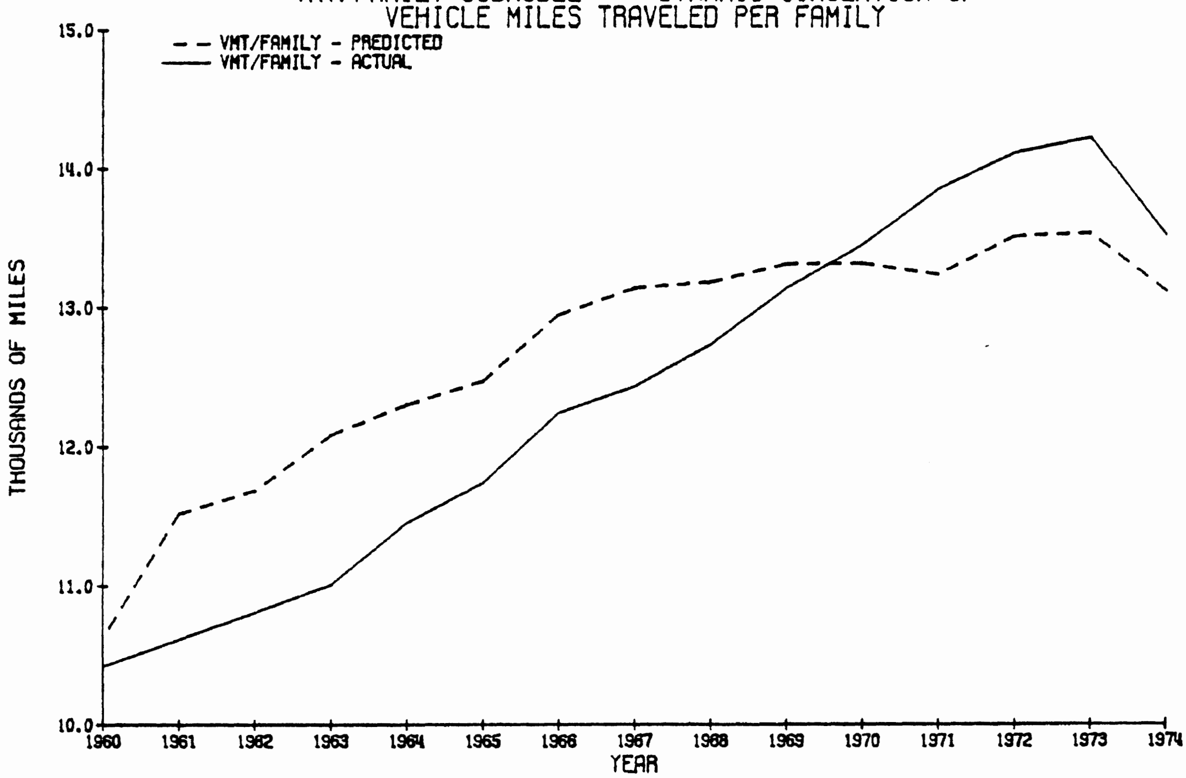


TABLE 4-1

ERROR STATISTICS
NEW CAR SALES AND SCRAPPAGE SUBMODEL

	Mean Actual	RMSE	100* RMSE/Mean	SIML R-SQ
New Car Sales	8.693	0.4047	4.656	.925
Scrappage	6.171	0.3954	6.407	.885

TABLE 4-2

ERROR STATISTICS
VEHICLE MILES TRAVELED PER FAMILY SUBMODEL

	Mean Actual	RMSE	100* RMSE/Mean	SIML R-SQ
VMT per Family	12.38	0.1647	1.330	.983

TABLE 4-3

ERROR STATISTICS
NEW CAR SALES, SCRAPPAGE, AND VMT PER FAMILY SUBMODEL

	Mean Actual	RMSE	100* RMSE/Mean	SIML R-SQ
New Car Sales	8.693	0.3427	3.942	.946
Scrappage	6.171	0.5432	8.802	.783
VMT per Family	12.38	0.1765	1.426	.981

TABLE 4-4

ERROR STATISTICS
NEW CAR SALES, SCRAPPAGE, AND DESIRED STOCK PER FAMILY SUBMODEL

	Mean Actual	RMSE	100* RMSE/Mean	SIML R-SQ
New Car Sales	8.693	0.7888	9.074	.713
Scrappage	6.171	0.9905	16.05	.278
Desired Stock per Family	1.199	0.05158	4.303	.424

TABLE 4-5

ERROR STATISTICS
NEW CAR SALES, SCRAPPAGE, DESIRED STOCK PER FAMILY,
AND VMT PER FAMILY SUBMODEL

	Mean Actual	RMSE	100* RMSE/Mean	SIML R-SQ
New Car Sales	8.693	0.7572	8.710	.736
Scrappage	6.171	0.7208	11.68	.618
VMT per Family	12.38	0.6646	5.366	.728
Desired Stock per Family	1.199	0.05158	4.303	.424

predictions rises to 8.8% per year.

The new car sales predictions are affected to a much lesser extent. The average error in these predictions actually falls to 3.9% per year over the experimental period. As in the two previous experiments, the trends in the actual data are well represented in the simulations.

4. The fourth experiment is designed to examine the effect of Wharton EFA authors' adjustment to the desired stock series. In Table A-8, the ACTUAL column of the desired stock table lists the Wharton EFA adjusted desired stock series, and the SIMULATION column lists the unadjusted results that are produced by the desired stock per family equation. The largest adjustments are made during the early 1960s, when low values of the income distribution variable produce misleading high values of desired stock. During this period, the desired stock series are adjusted downward. However, Wharton EFA model authors also made adjustments to the series over the remainder of the period including 1972, the year for which the desired stock per family equation was estimated. No explanation is provided in the Wharton EFA report about the adjustments over the recent years.

The unadjusted desired stock series has a substantial influence on the new car sales and scrappage predictions. As expected, the influence is greatest over the early part of the experimental period. The average yearly errors for 1960 to 1966 are nearly 10% for new car sales and over 20% for scrappage. The large overpredictions of new car sales in these years are due to the fact that the unadjusted value of desired stock is high. During these years new car sales must be large enough to adjust the total stock to approach desired stock. (This is the stock adjustment process discussed in Section 2.2.1.) Similarly, scrappage is underpredicted due to the stock adjustment process during the first several years. Over the entire experimental period, 1960 to 1974, the average yearly error in the new car sales predictions is almost 800,000 cars, or 9%, and the average yearly error in the scrappage predictions is almost one million cars, or 16%.

Although this submodel does produce large errors, the trends in the actual data are fairly well predicted.

5. The adjustment made by the model authors to the desired stock series also has a sizable influence on the forecasting behavior of the VMT per family equation. The results of the fifth experiment, indicate that the average yearly error in the VMT per family predictions are almost four times as large as those errors generated in the third experiment that used the adjusted desired stock series. In addition, the VMT per family equation has produced severe overpredictions in each of the first ten years of the experimental period, 1960 to 1969. The high, unadjusted desired stock values lead to overestimating sales and underestimating scrappage, and result in overpredictions in the total stock values. Since VMT per family is a function of total stock, the overprediction in total stock values also causes overpredictions in VMT per family. During the last five years of the experimental period, 1970 to 1974, the unadjusted desired stock series is lower than the adjusted desired stock series. This causes a lower prediction of total stock as compared to the third experiment, and therefore underpredictions in VMT per family result.

The forecasting behavior of the VMT per family equation has actually reduced the errors in scrappage predictions of the fourth experiment. Because VMT per family is overpredicted during the early years of the experimental period, this represents an increase in driving as compared to the actual values used in the fourth experiment. The increase in VMT per family produces a greater increase in scrappage than the results in the fourth experiment. This interaction between the VMT per family and scrappage equations reduced the average yearly forecast error of scrappage to about 11.5%.

4.2.1.2 <u>Discussion of Results</u>. It is clear from the previous section that the Wharton EFA model authors' adjustment to the desired stock series greatly influences the forecasting accuracy of the new car sales, scrappage, and VMT per family predictions. It also can be concluded that since many of the predictions in Blocks E and F depend on the new car sales, scrappage, and VMT per family predictions, the forecasting accuracy of these predictions is influenced also. In this section, the implications of the adjustment to the desired stock series are examined in terms of its validity and how it affects the use of the Wharton EFA auto model for forecasting purposes.

First, for explaining accurately the behavior of new car sales and scrappage in the past, the adjustments to desired stock seem reasonable. Over the historical period, the problems in the desired stock series may be explored by comparing the unadjusted series to total stock and other variables, and based on this comparison, it is possible to formulate arguments for adjusting the series.

On the other hand, to produce forecasts into the future, the model relies upon the desired stock per family equation to generate future values of desired stock. Because the future is not known, there is no basis for making extensive adjustments to the future values of the desired stock series. Nevertheless, Wharton EFA authors did make a modest adjustment to this series to produce the baseline forecasts in the Wharton EFA report. This adjustment was based on their adjustment of the 1974 desired stock value. The reason for adjusting both the 1974 value and future values is not explained in the Wharton EFA report, and it is totally unclear to the authors of this report.

Of course, it might be argued that if the assumptions based on 1972 data and built into the equation for desired stock per family hold true for the future, and if the 1974 adjustment to the desired stock value increases the accuracy of future predictions of desired stock, then the results of HSRI's first and third experiments (when adjusted values of desired stock were used) are a good indicator of the forecasting accuracy of set 1 submodels. Under these conditions, it could be concluded that the adjustment is valid.

However, these assumptions seem unlikely. The Wharton EFA model authors made these adjustments because the low values of the income distribution variable during the 1950s and early 1960s created forecasting errors. It has been mentioned that the income distribution variable (the percentage of U.S. families earning more than $15,000) is used to measure an income saturation effect--i.e., families above a certain income level increase their stock of cars at a lower rate relative to increases in income than families below this level do. Apparently, the estimated coefficient in the desired stock per family equation is not valid when the percentage of families earning over $15,000 is outside the range of values for 1972 by state. Otherwise, as the model authors argue, adjustments would not be needed. There is no reason to believe that the income distribution variable will not fall outside this range in the future. In fact, in Wharton EFA's baseline forecast, this variable almost triples from 1975 to 2000, and by 1985 the forecast value of this variable is higher than all but four 1972 state values of this variable used to estimate the coefficient. Therefore, it seems very likely that this variable will cause problems similar to those displayed in the fourth and fifth experiments.

The income distribution variable has been highlighted in this discussion because the Wharton EFA model authors chose to discuss only this variable in explanation of the adjustment made to the desired stock series. However, similar problems may exist with each of the independent variables in the desired stock per family equation.

This discussion leads to the conclusion that **the forecasting accuracy of the new car sales, scrappage, and VMT per family equations is severely limited by the desired stock per family equation.** Forecasting errors of over 10% in new car sales, 15% in scrappage, and 5% in VMT per family are likely in the short term (five years) even if the values of the baseline scenario are assumed to be known with certainty. Therefore, the model must be used cautiously in predicting absolute levels of these or related variables.

However, even with the problems of the desired stock per family equation, trends in the variables are predicted in the fourth and fifth experiment. Therefore, relative changes in the future in new car sales, scrappage, and VMT per family under various altered assumptions can be measured to some extent. In fact, the stated purpose of the Wharton EFA model authors in their final report is to measure relative changes in the long-run size and composition of U.S. automobile stock under altered assumptions about the characteristics of future cars, gasoline prices, and automobile-related tax laws. Their objective was not to measure the absolute levels. However, the forecasting accuracy of the equations in the first set of submodels may affect the extent to which these relative changes may be measured.

4.2.2 Forecasting Behavior of Submodel Set 2 - New Car Market Shares by Size Class and Desired Shares by Size Class. Submodel set 2 contains the new car market segment equations. These equations, which predict the new car market shares by size class, are important in predicting the average new car fuel efficiency, vintage-weighted fleet fuel efficiency, cars in operation by size class, and scrappage by size class. In fact, the combination of predictions of the set 1 submodels with set 2 influences every prediction generated in Blocks E and F. Therefore, the forecasting accuracy of the submodel set 2 equations is important to the forecasting accuracy of the model.

To examine the forecasting behavior of the new car market by size class, four experiments have been formulated. The first experiment involves a simulation of the submodel, consisting of the five new car market shares by size class equations, over the period 1960 to 1974. In the second experiment, the five desired stock shares by size class equations are added to the first submodel, and a simulation of this new submodel is examined over the 1960 to 1974 period. The desired stock share equations were estimated based on 1972 cross-section data by state. As in the case of desired stock equations, problems arose when Wharton EFA attempted to generate a "historical" time series of desired stock shares by size class. The "historical" series is necessary for estimating the new car market shares by size class equations (see Section 3.5). The primary reason for the problems in generating the desired stock shares series, as Wharton EFA model authors point out, is that the 1972 model offerings were substantially different from the model offerings over most of the historical period. The most notable difference was in the greater number of subcompacts available in 1972 in contrast to years prior to 1970 or thereabout.

The Wharton EFA report presents other reasons for the particular adjustments made to each desired stock share time series. These adjustments are outlined in (Schink and Loxley 1972, pp. 3-22). However, the Wharton EFA authors describe neither the methodology nor the details of the adjustment process. Therefore, HSRI's second experiment displays the details of the adjustment process.

The third experiment is a variation of the second experiment. Wharton EFA authors point out in their report that they had trouble modeling the small car desired stock shares--that is, subcompacts and compacts. Since the desired share equations are constrained in that they must sum to one, a problem with the small car desired stock share predictions may cause significant problems in the other desired stock share predictions. This problem could certainly cripple the forecasting accuracy of the new car market share predictions. To investigate the extent of this problem, the small car desired stock shares are constrained to their adjusted values in the third experiment. Otherwise, the third experiment is the same as the second experiment. The comparison of the second and third experiments indicates the extent of the problem.

In the fourth experiment, the influence the desired stock share predictions on the predictions generated by the equations of submodel set 1 is examined. The desired stock share predictions are used in predicting capitalized cost per mile, which affects the total desired stock. This total desired stock is used in turn to predict new car sales and scrappage.

In summary, the four forecasting experiments on submodel set 2 involve historical simulations (1960 to 1974) of submodels consisting of the following behavioral equations:

1. New car market shares by size class
2. New car market shares and desired stock shares by

size class

3. New car market shares by size class and desired stock shares of mid-size, full-size, and luxury cars
4. Desired stock shares by size class, desired stock per family, new car sales, scrappage, and VMT per family

4.2.2.1 Results for Submodel Set 2. Four experiments to examine the forecasting behavior of the submodel set 2 were conducted. Appendix tables A-13 to A-26 display the yearly errors of the predictions of the equations in each experiment. Figures 4-12 to 4-18 are graphs of the actual and simulated values of a sample of variables in the four experiments. Tables 4-6 to 4-8 display the error statistics associated with each experiment.

The first experiment's results show that the equations for new car market shares by size class simulate extremely well, using the adjusted desired stock share values. The differences between the actual and simulated results for the small car shares, subcompacts, and compacts, is for the most part less than 3%; for mid-size and full-size shares, the difference generally is less than 1%; and for luxury shares, the difference is generally less than 2%. Figures 4-12 and 4-13 show clearly how close the simulations are to the actual values, and, in fact, in Figure 4-13 the actual and predicted values of full-size new-car shares are almost indistinguishable.

In the second experiment, the desired stock shares are simulated with the new car market shares. The results of this experiment indicate the extent to which the desired stock shares were adjusted by Wharton EFA, and what effect this adjustment has on the new car market share predictions.

The desired small car shares were adjusted downwards for years prior to 1973 on the average of eight percentage points per year; the desired mid-size shares were adjusted upwards from about four percentage points around 1972 to nine percentage points in 1965; the desired full-size shares were adjusted extensively both upwards and downwards over the historical period; and desired luxury shares were

FIGURE 4-12

NEW CAR SHARES BY SIZE CLASS SUBMODEL
DYNAMIC SIMULATION OF
SUBCOMPACT CLASS NEW CAR MARKET SHARE

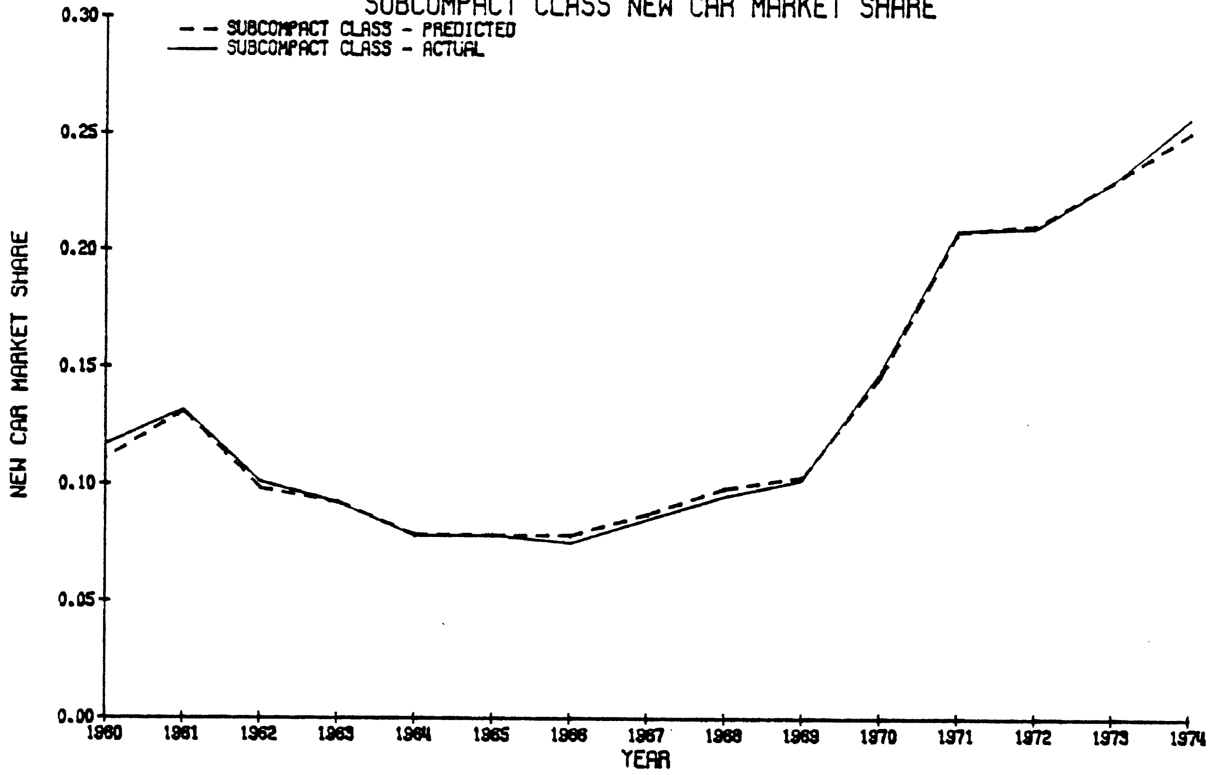


FIGURE 4-13

NEW CAR SHARES BY SIZE CLASS SUBMODEL
DYNAMIC SIMULATION OF
FULL-SIZE CLASS NEW CAR MARKET SHARE

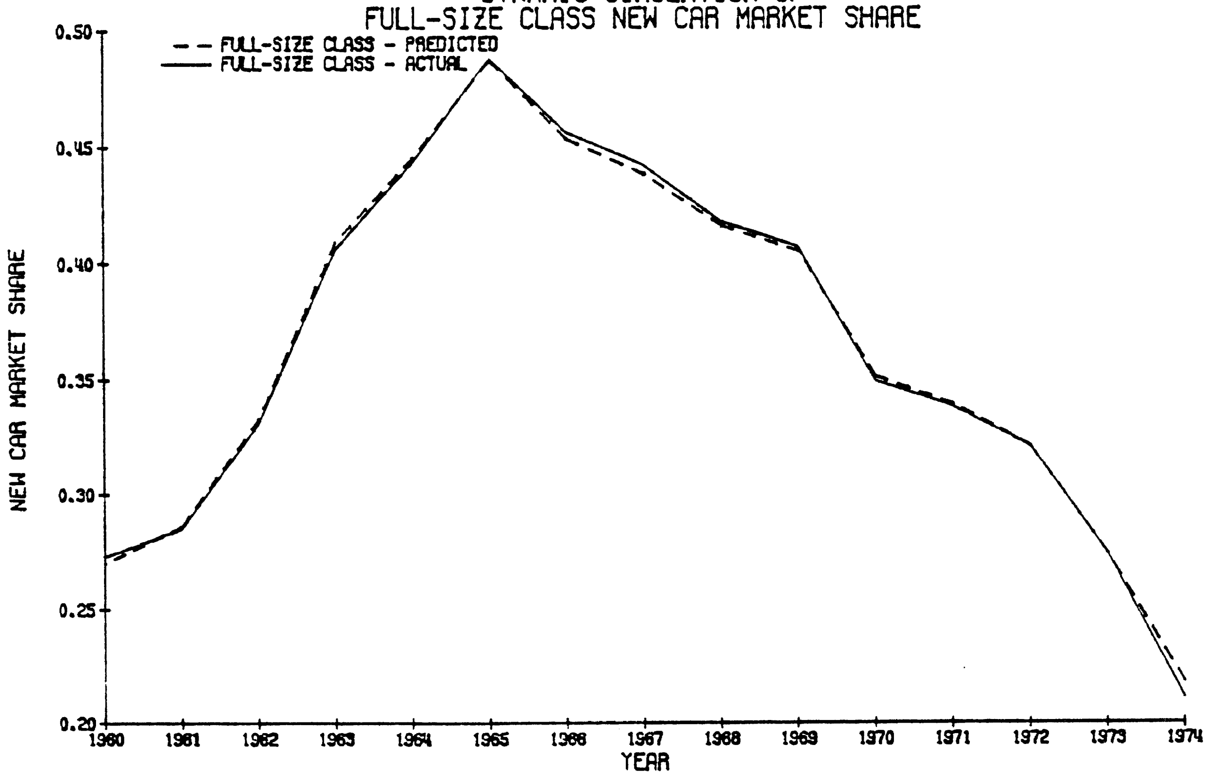


FIGURE 4-14

NEW CAR SHARES AND DESIRED SHARES BY SIZE-CLASS SUBMODEL
DYNAMIC SIMULATION OF
SUBCOMPACT CLASS NEW CAR MARKET SHARE

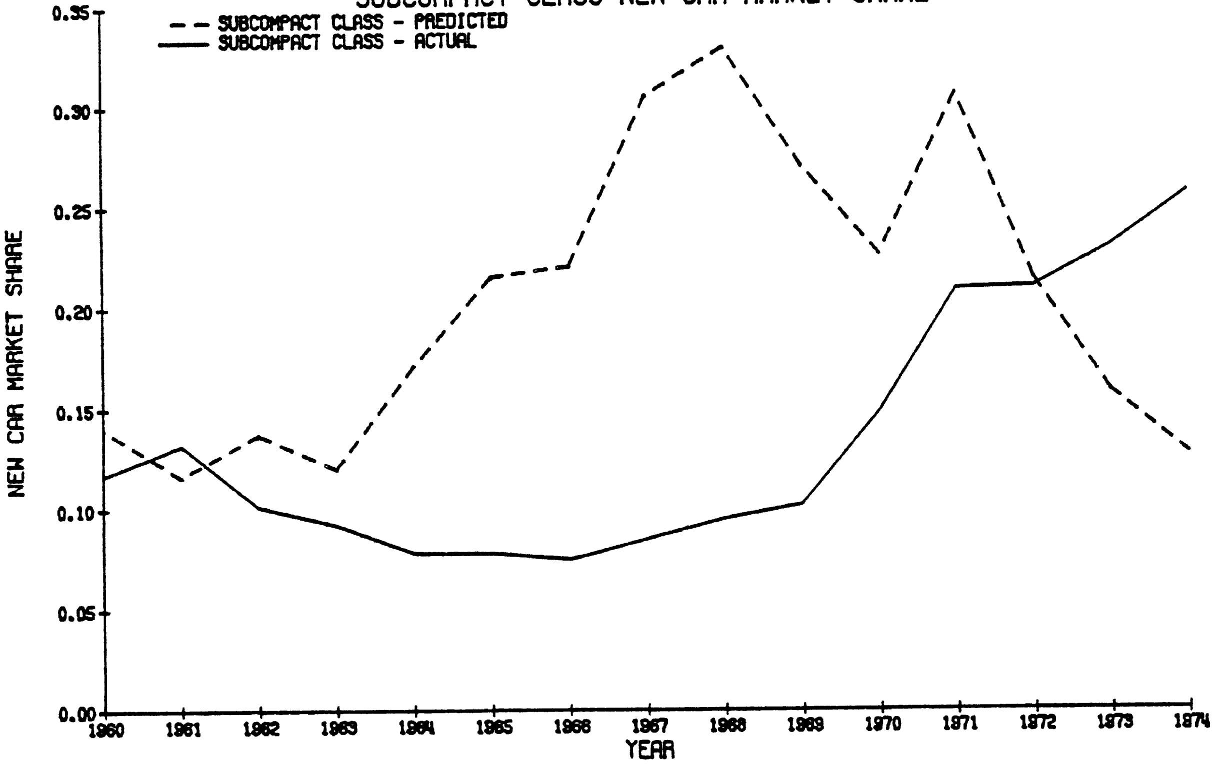


FIGURE 4-15

NEW CAR SHARES AND DESIRED SHARES BY SIZE CLASS SUBMODEL
DYNAMIC SIMULATION OF
COMPACT CLASS NEW CAR MARKET SHARE

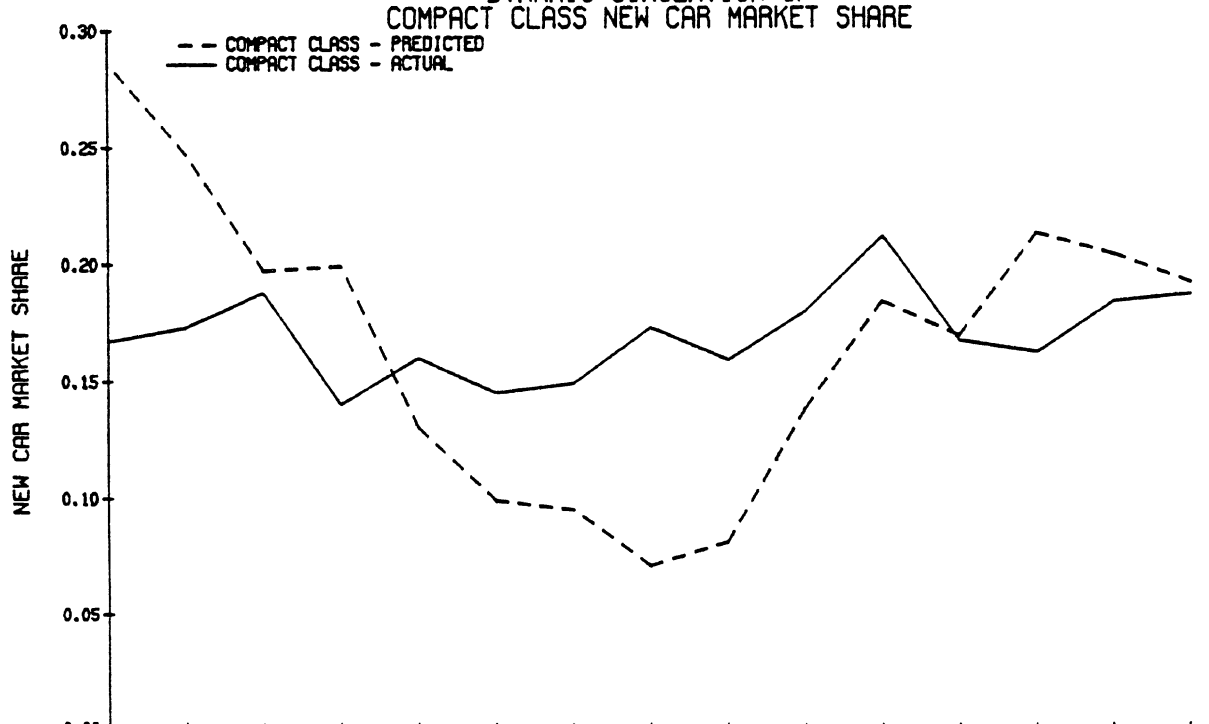


FIGURE 4-16

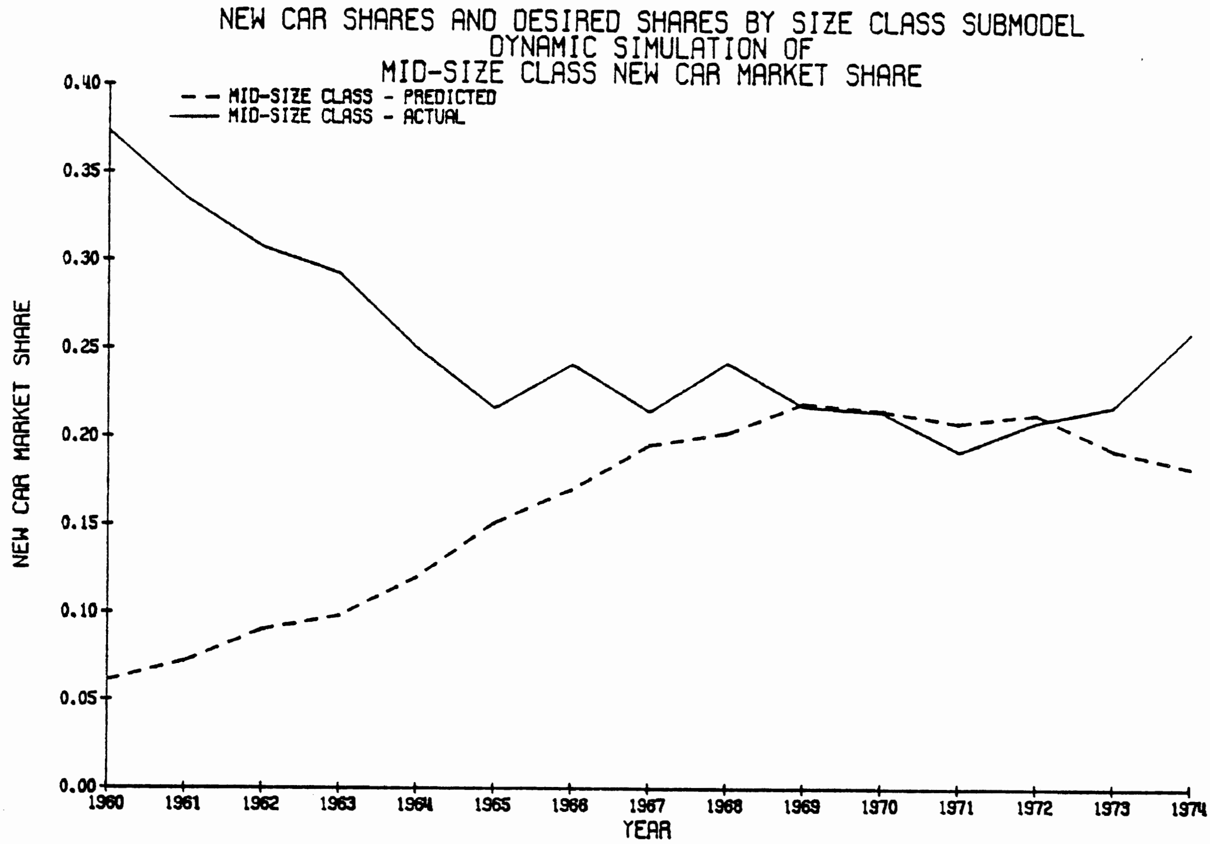


FIGURE 4-17

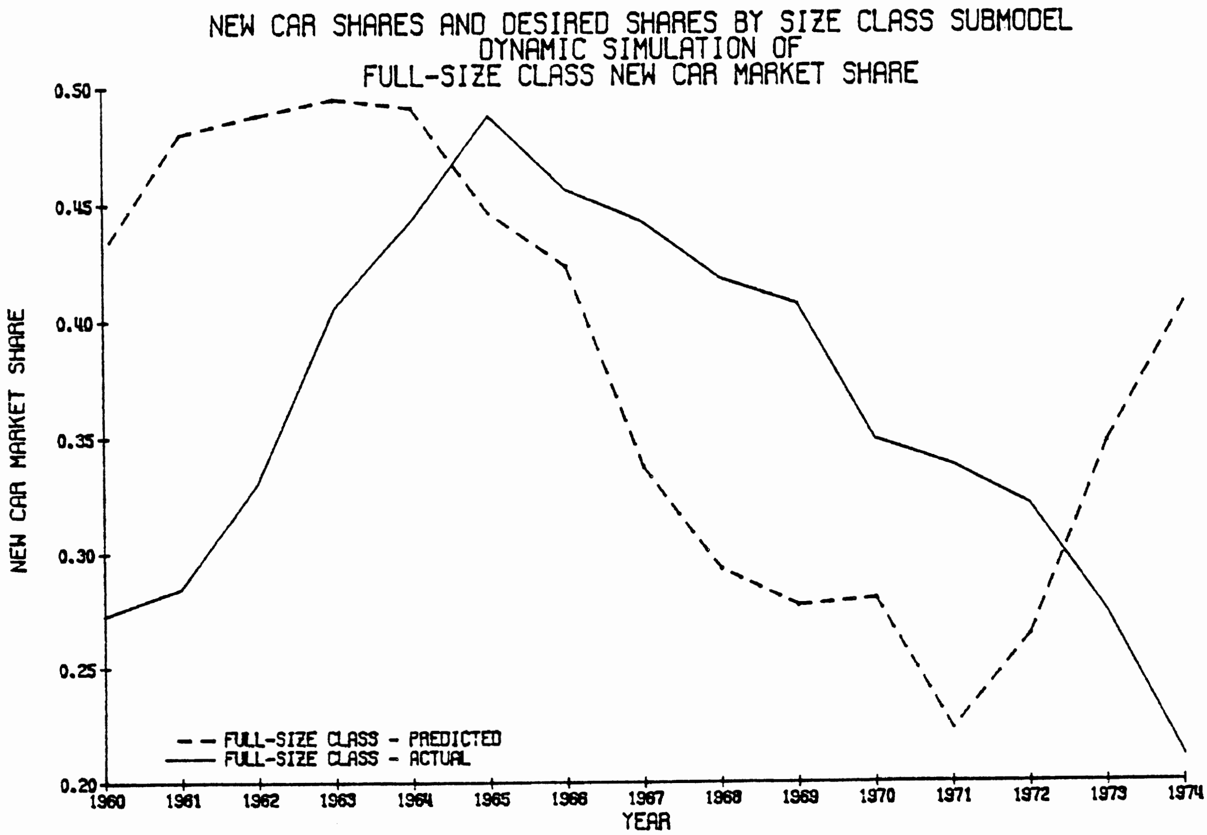


FIGURE 4-18

NEW CAR SHARES AND DESIRED SHARES BY SIZE CLASS SUBMODEL
DYNAMIC SIMULATION OF
LUXURY CLASS NEW CAR MARKET SHARE

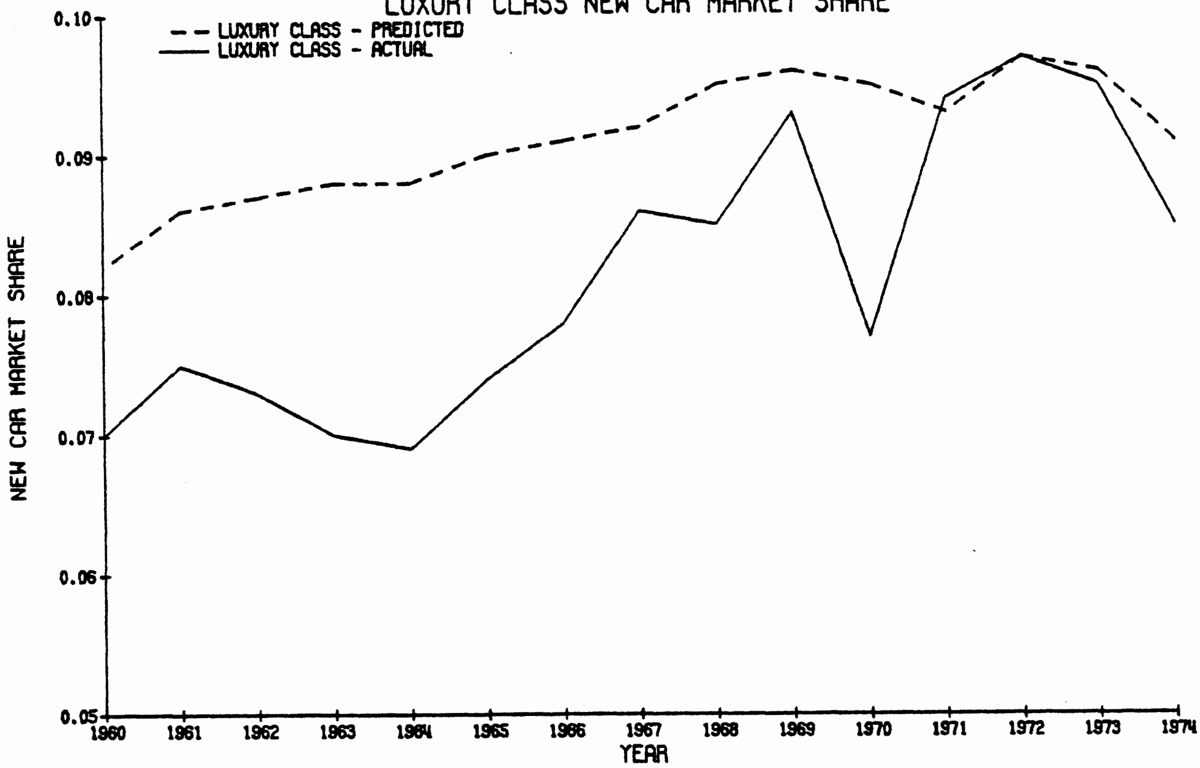


TABLE 4-6

ERROR STATISTICS
NEW CAR MARKET SHARES BY SIZE CLASS SUBMODEL

	Mean Actual	RMSE	100* RMSE/Mean	SIML R-SQ
New Subcompact Share	.134	.003	2.030	.999
New Compact Share	.170	.005	2.687	.937
New Mid-Size Share	.252	.002	.968	.998
New Full-Size Share	.363	.003	.756	.999
New Luxury Share	.081	.001	1.104	.991

TABLE 4-7
ERROR STATISTICS
NEW CAR MARKET SHARES AND DESIRED STOCK SHARES OF
MID-SIZE, FULL-SIZE, AND LUXURY CLASS SUBMODEL

	Mean Actual	RMSE	100* RMSE/Mean	SIML R-SQ
Desired Mid-Size Share	.304	.109	36.00	-1.173
Desired Full-Size Share	.363	.102	28.26	-4.307
Desired Luxury Share	.078	.094	12.18	-.296
New Subcompact Share	.134	.006	4.74	.989
New Compact Share	.170	.006	3.68	.882
New Mid-Size Share	.252	.131	51.80	-5.645
New Full-Size Share	.363	.135	37.22	-1.955
New Luxury Share	.081	.106	13.07	-.231

TABLE 4-8
ERROR STATISTICS
DESIRED SHARES, DESIRED STOCK PER FAMILY, NEW CAR SALES,
SCRAPPAGE, AND VMT PER FAMILY SUBMODEL

	Mean Actual	RMSE	100* RMSE/Mean	SIML R-SQ
New Car Sales	8.69	.747	8.59	.743
Scrappage	6.17	.728	11.81	.609
VMT per Family	12.38	.667	5.39	.725
Desired Stock per Family	1.20	.052	4.37	.405

Note: Desired Share Statistics are the same as those in Table 4-7.

adjusted downwards roughly one percentage point per year.

Adjustment to the desired stock shares series has a severe effect on the new car market share predictions. Figures 4-14 to 4-18 illustrate that many of the new car market share predictions diverge greatly from the actual values. The subcompact new car share is grossly overpredicted during the mid-1960s, and only for the first few years of the experimental period do these predictions even follow the trends in the actual data. The average yearly forecast error for the experimental period is over 90%. The predicted values of the compact new car shares are not nearly as poor as the predictions of the new subcompact. These predictions generally follow the trends in the actual data. However, as indicated by the negative SIML R-SQ statistic, the compact share equations are poor predictors of new compact market shares. In fact, the higher negative value of SIML R-SQ for compact shares indicate that the compact share equations account for less variance in the historical data then do the subcompact share equations.

The new mid-size share predictions also generally follow the actual trends from 1965 to 1972. However, the submodel fails to predict the upturn in mid-size shares in 1973 and 1974. Similarly, although the submodel results indicate the downward trend in new full-size shares from 1965 to 1970, the submodel fails to continue this trend through 1974. The new luxury share predictions are generally good compared to the other new car share predictions. The luxury new car share predictions exhibit a fairly random error over the 1960 to 1974 period of about one percentage point in about fourteen percent per year. However, the SIML R-SQ statistic for the new luxury share simulations also has a negative value that indicates that the luxury share equations also produce a poor fit to the historical data.

A possible reason for these results in the second experiment is that the poor predictions of the new small car shares, particularly the subcompact shares, is causing errors in the other new car share predictions. This is due to the strong simultaneity of the new car share equations. Therefore, to investigate this, a third experiment was run in which the desired small car stock shares are constrained to their adjusted levels and in which the desired share equations for the mid-size, full-size, and luxury classes only were used. This constraint produced fairly good predictions of the new small car market shares (see Tables 4-18 to 4-22 and 4-7). However, the new mid-size and full-size share predictions exhibit forecasting problems similar to those in the second experiment.

In the fourth experiment, the effect of the adjustment to the desired stock shares on the equations of submodel set 1 is tested. As explained in Section 2.3.6, the desired stock shares are used as weights to determine the average capitalized cost per mile. This average is used in determining desired stock. Comparing Tables A-23 through A-26 with A-9 through A-12 and Tables 4-8 with 4-5, one can see that predicting the desired stock shares instead of using the adjusted values has little impact on the equations of submodel set 1. The largest impacts are in the 1966-1967 and in the 1973-1974 time periods. During the 1966-1967 period, the results of the fourth experiment tend to predict sales 1.5% higher than in the fifth experiment in submodel set 1. This is due to the overprediction of desired subcompact shares that tends to lower the average capitalized cost per mile. The opposite impact is observed in the 1973 to 1974 period when the desired shares of full-size cars are overpredicted.

4.2.2.2 Discussion of Results of Experiments on Submodel Set 2. The results of the previous sections display severe problems in the forecasting behavior of the new car market segment equations. The large forecasting errors generated are due to the inability of the desired stock share equations to predict reasonable results over the experimental period. The results of the second experiment show that when the desired stock share equations are included in the submodel experiment, the submodel is unable to predict the recent trends (1973 and 1974) in the new mid-size and full-size shares; and it is unable to predict new subcompact shares at all.

Luxury shares are predicted with reasonable accuracy. But, as can be seen in Figure 4-18 (keeping in mind the large scale of this graph), new luxury shares have increased linearly with almost no variation over the experimental period. Such a smooth series is usually easy to estimate. The new compact shares are also somewhat reasonably estimated. However, as Figure 4-15 illustrates, this series is fairly flat, and thus the forecasting accuracy of these predictions is not surprising.

HSRI staff hypothesized, based on the Wharton EFA final report and on a discussion with one of the model authors, that the poor results of the second experiment may be due to the very poor desired subcompact share predictions. Since subcompacts had only recently penetrated the market on a sizable scale by 1972, the year from which the desired stock share equations were estimated, it is not surprising that the equations for the desired subcompact shares are unable to predict low levels for the years prior to 1972. Also because the desired stock share equations are highly simultaneous and the new car market share equations are highly simultaneous, severe forecasting errors in one share estimate could affect the others. However, the third experiment indicates that even if the desired stock shares of subcompacts and compacts are constrained to their adjusted levels, the submodel is still unable to predict the recent trends in new mid-size and full-size shares.

Based on the first, second, and third experiments, it can be concluded that the desired stock share equations are the cause of the forecasting problems in the new car share equations. The Wharton EFA model authors recognized this problem, and they made the necessary extensive adjustments to the "historical" desired stock share series to estimate the new car market share equations. The extent of the adjustments indicates the severe shortcomings of these equations.

To forecast into the future, users of the Wharton EFA auto model must rely on the predictions of the desired stock share equations. Since the predictions of the levels and trends in new car market shares for the years around 1972 are poor, the predictions into the future would almost certainly have similar or more severe problems. Thus, **the predictions into the future for the new car market shares by size class cannot be relied upon for forecasting the composition of new car sales or trends in the new car market shares.**

4.3 Dynamic Behavior of Submodels

This section presents an analysis of the dynamic behavior of the three sets of submodels. The analysis involves examining the response of the submodel simulations to changes in the independent variables. These analyses are important because they provide insights into the complex dynamic behavior of the full model.

Several experiments are conducted for each set of submodels. These experiments are called multiplier experiments because, in most of the experiments, the change of the independent variable involves multiplying that variable by some factor. For example, to examine the response of the predictions of a submodel to a 1% increase in nominal personal income, a submodel simulation is run with the values of nominal personal income multiplied by 1.01. The results of this simulation are then compared to the results of the simulation without any change in the independent variable. The simulation with no change in the independent variable is called a control simulation, and the simulation with the change is called a shock simulation.

The results of each experiment are shown in the tables of Appendix A. Each table contains four columns of output labeled CONTROL, SHOCK, DIFFERENCE, and % DIFFERENCE. CONTROL refers to the control solution of the submodel, and SHOCK refers to the perturbed solution of the submodel. The DIFFERENCE column contains the difference between the control and shock predictions, and the % DIFFERENCE column contains the percentage difference with respect to the control value.

Each of the multiplier experiments is run over the historical period 1960 to 1974.

4.3.1 Dynamic Behavior of Submodel Set 1 - New Car Sales, Scrappage, VMT per Family, and Desired Stock. The purpose of this section is to examine the dynamic properties of the new car sales, scrappage, VMT per family, and desired stock per family equations. Multiplier experiments are run on the submodel that consists of the new car sales and scrappage equations. The following changes (or shocks) are made in the first four experiments:

1. One percent increase in desired stock per family
2. One percent increase in VMT per family
3. One percentage point increase in unemployment
4. One percent increase in new car price for all classes of vehicles

The results of the first experiment (see Tables A-27 and A-28) show that when desired stock per family increases by 1% new car sales increase and scrappage decreases substantially in the first year, both by about 3%. This response is due to the stock adjustment process that causes actual stock, a function of sales and scrappage, to tend toward the raised level of desired stock. After about ten years, both new car sales and scrappage increase to about 1% over the control simulation.

In the second multiplier experiment (see Table A-29), the 1% increase in VMT per family over the experimental period causes scrappage to increase by about 2.3% in the first year, 3.6% in the second year, and 2.0% in the third year. Since scrappage is a function of the change in VMT per year for the current year and previous two years, the increase in VMT per family has no direct influence on the submodel after the third year of the shock simulation; thus, the shock simulations eventually return to the control simulation values after ten years.

In the third multiplier experiment, (see Tables A-30 and A-31), scrappage decreases substantially by 5.5% in the first year in response to the one percentage point increase in unemployment. The long-term response seems to fluctuate around a 1% decrease in scrappage. New car sales decrease by about 1% in the short term in response to the decrease in scrappage. In the long run, sales decrease by approximately .5%.

The fourth multiplier experiment (see Tables A-32 and A-33) shows the strong short-term downward impact on new car sales in response to an increase in all new car prices. This result was also predicted in the discussion of the new car sales equation in Section 3.4.3. Since new car sales in the model are a function of the change in average purchase price from the previous to the current year, the increase in price has no direct influence on sales for the remaining years of the experiment. Thus, new car sales in the shock simulation quickly converges to the control simulation values by the fourth year of the simulation. In other words, after four years there is essentially no impact on sales due to the price increase. The response of scrappage follows new car sales, but with a much smaller impact. The first-year impact is a reduction in scrappage of about .35%.

The following multiplier experiments examine the dynamic properties of the VMT per family and desired stock per family equations along with the new car sales and scrappage equations:

5. One percent increase in new car price for all classes of vehicles
6. One percent increase in nominal personal income
7. Ten percent increase in MPG for all classes
8. Ten percent increase in gasoline price

The results of the fifth multiplier experiment, a 1% increase in new car prices, are very similar to the results of the fourth multiplier experiment (see Tables A-34 through A-36). A slightly larger decline in sales is predicted for the first year. This is due to the very slight decline in desired stock per family as a result of the price increase. The drop in desired stock per family of less than .1% does cause a long-term drop in new car sales and a drop in scrappage of about .1% compared to the control simulation.

The impacts on VMT are negligible in the short and long run. The small changes in the second through eighth year are due to the minor perturbations to the age distribution of stock that are caused by the decline in sales and scrappage.

The sixth multiplier experiment examines the impacts of a 1% increase in nominal personal income on the predictions of the submodel. In this experiment, each variable that depends on nominal personal income is predicted so that their adjustment to the 1% increase in income can be seen. These variables include permanent real disposable income, real disposable income, and percentage of families earning over $15,000 per year in real dollars (income distribution variable). Each of these variables increases with the increase in nominal personal income.

The impact on new car sales in the first year is substantial (see Table A-37). New car sales are predicted to increase by about 5.3% in the first year. The impacts diminish rapidly, and in the long run sales increase by only .3% per year over the control simulation. These increases are caused by the direct impact on the sales equation through the income variable in that equation, and by the minor increase in desired stock per family.

As predicted in the discussion of the desired stock per family equation in Section 3.3.1, the increase in desired stock per family is minor. The increase due to the rise in permanent family income is limited by the "income saturation effect" caused by the income distribution variable (see Table A-38). In the long term, the increase in the income distribution variable almost completely offsets the increase in desired stock per family caused by the rise in permanent family income variable.

The increase in sales causes scrappage to increase by 1.2% in the first year (see Table A-39). In the long run, the impact on scrappage matches that of new car sales.

A fairly strong impact of just less than a 1% increase is made on VMT per family (see Table A-40). The impacts on VMT also diminish in the long run to an increase in VMT per family of about .2% per year over the control simulation.

In the seventh multiplier experiment, the impacts of a 10% increase in MPG for all classes of vehicles are examined. The predicted values of MPG generated in Block A are used in the control simulation, and these predictions are increased by 10% for the shock simulation.

The increase in MPG causes desired stock per family to increase by about .4% per year. The impact on desired stock per family causes new car sales to increase also. The rise in sales tends to increase scrappage. However, increases in scrappage are offset somewhat by increases in VMT per family.

The increases of MPG has the largest impact on the VMT per family predictions. VMT per family increases in the long term by 2.3% over the control simulations (see Tables A-41 through A-44).

The impacts of the increase in gasoline price, tested in the eighth multiplier experiment, are similar in magnitude but the opposite in sign to the impacts of the increase in MPG in the seventh multiplier experiment. Desired stock per family decreases relative to the control simulation. This decrease in desired stock per family causes substantial decreases in new car sales and scrappage in the short term. VMT per family also decreases substantially by about 2.3% per year over the control simulation in both the short and long term (see Tables A-45 through A-48).

4.3.2 Dynamic Behavior of Submodel Set 2 - New Car Market Shares and Desired Stock Shares. The purpose of this section is to examine the dynamic properties of the new car market share and desired stock share equations.

The multiplier experiments run are:

1. One percent increase in new car price for all classes of vehicles
2. Ten percent increase in MPG for all classes of vehicles
3. One percent increase in nominal personal income
4. Ten percent increase in insurance cost
5. Ten percent increase in repair cost
6. One percent increase in the population aged twenty to

twenty-nine years old

Although the forecasting accuracy of the equations of submodel set 2 was shown to be very poor, the dynamic properties of the equations are interesting. Examining the impacts of the multiplier experiment is marginally useful in that the direction and relative magnitude of the responses of the submodel predictions are reasonable.

In each experiment, the market segments exhibit either a "trading up" or "trading down" response: either an increase in new full-size shares and decrease in new subcompact and compact shares (trading up), or the reverse (trading down). This movement from small to large cars, or vice versa, is not necessarily a direct one. What is more likely is that the trading is from small to mid-size and then from mid-size to large cars, or vice versa, resulting in no net impact in the mid-size new car segment.

Trading up (or down) occurs in the multiplier experiments (1) when family income rises (falls) relative to the average capitalized cost per mile; (2) when the capitalized cost per mile of a small car rises (falls) relative to the capitalized cost per mile of a larger car; and (3) when the percentage of families earning over $15,000 falls (rises). Also, demographics affect the new car market shares.

In the first experiment, trading down is observed as a result of a price increase for all new cars. This occurs because new car price is a larger component in the capitalized cost per mile (CPM) for a large car than a small car. Thus, the CPM increases by a greater amount for a large car than a small car after a price increase. The results show a substantial increase in new subcompact and compact shares, a minor increase in new mid-size shares, a moderate decrease in new full-size shares, and no impacts on new luxury shares.

In the second experiment, a 10% increase in MPG for all new cars generates a trading up response (see Tables A-49 through A-53). This occurs for the same reason that caused the trading down response to higher new car prices in the first multiplier experiment. Since gasoline cost, which is a function of fuel economy, is a smaller component of the CPM of small cars than of large cars, a rise in fuel economy in all new cars will produce greater savings in the overall costs of large cars.

The third multiplier experiment results (see Tables A-54 through A-58) show a short-run trading up response and a long-run trading down response. The short-run response is due to the increase in family income relative to the average CPM. The long-run response is due to the rise in the percentage of families earning over $15,000 per year that occurs because of the rise in family income. The increase in the percentage of families earning over $15,000 per year also causes new luxury shares to increase.

The next two multiplier experiments show that increases in insurance costs or repair costs have fairly minor impacts on the new car market segments. The last multiplier experiment indicates that the impact of a 1% increase in the twenty to twenty-nine-year-old population causes a moderate trading down response.

4.3.3 Dynamic Behavior of Submodel Set 3 - Capitalized Cost Per Mile. The CPM equations are each made up of many components--new car price, insurance costs, gasoline costs, and so on. This section examines the following questions: What is the impact of increases in the values of the major components of the CPM equations? What percentage of CPM does each component represent? And how much impact do changes in these components have on other parts of the model?

Six multiplier experiments examine the impacts of 10% increases in each of the six components of operating costs:

1. Ten percent increase in insurance cost
2. Ten percent increase in cost of tires
3. Ten percent increase in parking costs and tolls
4. Ten percent increase in motor oil costs
5. Ten percent increase in repair costs
6. Ten percent increase in gasoline costs

The seventh multiplier experiment examines the impact of an increase in new car purchase price; the eighth examines the impacts of an increase in finance charges; and the ninth experiment examines the impacts of increasing the discount factor used in capitalizing the costs in the CPM equations. These three experiments are:

7. One percent increase in new car price for all classes of cars
8. One percentage point increase in the consumer installment credit rate
9. One percentage point increase in the discount rate--the maximum U.S. savings and loans passbook interest rate

The results of the first six multiplier experiments show that operating costs, with the exception of gasoline costs, have only a minor influence on the CPM variables. This result was predicted in the discussion of the CPM equations, Section 2.3.5. An increase of 10% in repair costs raises the CPM for each class of vehicles less than 1.5%, and an increase of 10% in motor oil costs raises the CPM for each class of vehicle less than .1%. These minor impacts on the CPM variables imply that changes in these variables will also have minor impacts on all other variables.

The impact of a 10% increase in gasoline cost on the CPM variables is somewhat larger than the impacts of increasing the other operating cost components. A 10% increase in gasoline cost causes about a 2% increase in the CPM variables. The impacts are less for foreign-made cars as compared to domestic-made cars, because the higher fuel economies of foreign cars drive down the cost of gas relative to the cost of the other components of the CPM variables.

The new car price, on the other hand, is a major component of the CPM variables (see Tables A-59 through A-66). A 1% increase in new car price for all classes of vehicles causes the CPM for small cars to rise by about .4% and the CPM for large cars to rise about .45%.

The eighth experiment looks at the impact of an increase in the finance charges associated with the purchase of a car. A one percentage point increase in the consumer installment credit rate causes the CPM variables to increase substantially by about .8% (see Tables A-67 through A-74).

The ninth multiplier experiment examines the effect that the discount rate, used to discount costs and miles in the CPM variables, has on the CPM variables (see Tables A-75 through A-82). The results show that for a one percentage point increase in the discount factor, the CPM for all cars rises; the CPM rises by a greater percentage for luxury cars than for full-size cars, and it rises more for full-size cars than for smaller cars. These relationships imply that a trading down response should have resulted from such an increase in the discount factor.

4.4 Summary of Submodel Evaluation

The submodel evaluation presented in this section focuses on three sets of equations in the model, including the equations for new car demand (total and by size class), travel demand, scrappage, and vehicle costs. These are important equations because so many of the predictions generated in the model depend on them. Therefore, understanding the forecasting accuracy, interrelationships, and dynamic properties of these equations helps in understanding the complex behavior and properties of the full model.

The submodel evaluation is divided into two parts: forecasting behavior of the submodels and dynamic properties of the submodels. The forecasting behavior analyses uncovered some serious problems in the forecasting accuracy of a major part of the model. **The ability of the model to forecast new car sales, scrappage, and VMT is limited.** Forecasting errors in excess of 10% in new-car sales and scrappage, and errors more than 5% in VMT per family were generated over the historical period for which the model was calibrated. These errors would almost certainly be much larger if the model were used to forecast beyond the calibration period--that is, into the future. However, **the trends in new car sales, scrappage, and VMT are accurately predicted over the historical period, and thus, the model can be used to study the trends in these variables into the future with some accuracy.**

The forecasting behavior of the submodel of new car market shares is shown to have serious problems. This submodel analysis shows that **the model equations concerning market shares are not only unable to predict the level of new car shares, but are also unable to predict trends in new car shares.**

The analysis of the dynamic properties indicates the relationship between the submodel equations and the response of the submodel's predictions to changes in exogenous variables. This analysis of submodel set 1 examines the relationship of new car sales and scrappage. A change in one of these variables generally causes a similar but smaller change in the other. HSRI analysis also indicates that **changes in desired stock and unemployment tend to have long-term effects on new car sales and scrappage, while changes in new car price, income, VMT, and gas prices tend to have short-term impacts.**

The analysis of the dynamic properties of submodel set 2 reveals shifts in market shares due to changes in the vehicle cost of one type of car relative to the average cost of other cars and due to changes in vehicle cost relative to family income. Although the forecasting accuracy of this submodel is very poor, these results do seem reasonable.

The analyses of the dynamic properties of submodel set 3 show that **the Wharton EFA measure of vehicle costs--that is, the capitalized cost per mile variables--is insensitive to changes in vehicle operating costs.** On the other hand, **the CPM variables are shown to be very sensitive to changes in new car purchase price and credit rates for financing cars.**

This is important. Car prices are one of the major determinants of desired stock, and relative car prices are critically important in the desired stock shares. It is the desired stock and desired stock shares that drive sales in any long-run simulation. But the Wharton EFA stock equations were estimated with 1972 cross-section data, and car prices hardly vary at all from state to state (all the variance is due to freight charges and other minor components of price). Thus, the estimated price effects on stock and stock shares are not due to variation in the price of cars. **Any simulation of a policy scenario involving a change in the price of cars with the Wharton EFA auto model has to be viewed with extreme caution and skepticism.**

5.0 FULL MODEL EVALUATION

5.1 Introduction

This section presents an analysis of the forecasting behavior and dynamic properties of the complete Wharton EFA Automobile Demand Model. The Wharton EFA version of the model that was obtained from TSC is the version that is used in this analysis.

The analyses in this section are an extension of those performed in the submodel evaluation section. In the submodel evaluation, three groups of submodels containing key equations of the model were examined. Understanding the properties and interrelationships of these groups of equations provides a better understanding of the complex properties of the full model.

The analysis of the forecasting behavior of the full model is performed by generating a simulation over the same period, 1960 to 1974, used for analyzing submodels so that comparisons can be made. In addition, three other simulation experiments are conducted. In the first experiment, the predictive capability of the model is examined over the period 1960 to 1967. This experiment is compared to the results of a second simulation experiment conducted over the period 1968 to 1974 to indicate how economic and demographic differences that existed in these two periods affect the forecasting accuracy of the model. The last experiment involves an analysis of whether the model has a tendency to accumulate forecasting errors as the forecasting horizon increases.

The dynamic properties of the model are studied by conducting multiplier experiments. Most of the multiplier experiments involve testing the response of the model's predictions to the same exogenous variables that were tested in the submodel evaluation. This permits comparisons between the submodel and full model experiments.

Because the model is large, the discussion is focused on eight key endogenous variables that are also highlighted in the submodel evaluation. These are: new car sales, scrappage, VMT per family, new subcompact shares, new compact shares, new mid-size shares, new full-size shares, and new luxury shares.

5.2 Forecasting Behavior of Full Model

To analyze the forecasting accuracy of the full model, HSRI staff generated simulations over the historical period used for submodel evaluation. Simulated values of the variables are compared in tabular and graphical form with the known historical values of the variables and statistics concerning the accuracy of the model are calculated. Section 4.2 of the submodel evaluation section contains a full discussion of the analytic methods.

Four simulation experiments are performed to study the forecasting accuracy of the model:

1. Simulation experiment - 1960 to 1974
2. Simulation experiment - 1960 to 1967
3. Simulation experiment - 1968 to 1974
4. Simulation experiment on error accumulation

5.2.1 Simulation Experiment - 1960 to 1974. In this experiment the forecasting capability of the model is examined over the period 1960 to 1974. Figures 5-1 to 5-8 are graphs of the actual and simulated values of the key variables, and Table 5-1 displays the error statistics associated with these key variables.

The results are largely self-explanatory. New car sales are forecast with a root mean squared error (RMSE) of 820,000 units (a percentage error of 9.5%) while scrappage is predicted with an average error of 900,000 units (14.5% error). These errors are roughly the same as those in the fifth experiment of submodel set 1 (see Section 4.2.1), and thus it can be concluded that they are caused by the forecasting problems of the desired stock per family equation. **The predictions of new car sales by market segment share are very poor by any reasonable criteria for within-sample econometric forecasting.** The percentage errors

FIGURE 5-1

FULL MODEL
DYNAMIC SIMULATION OF
NEW CAR SALES

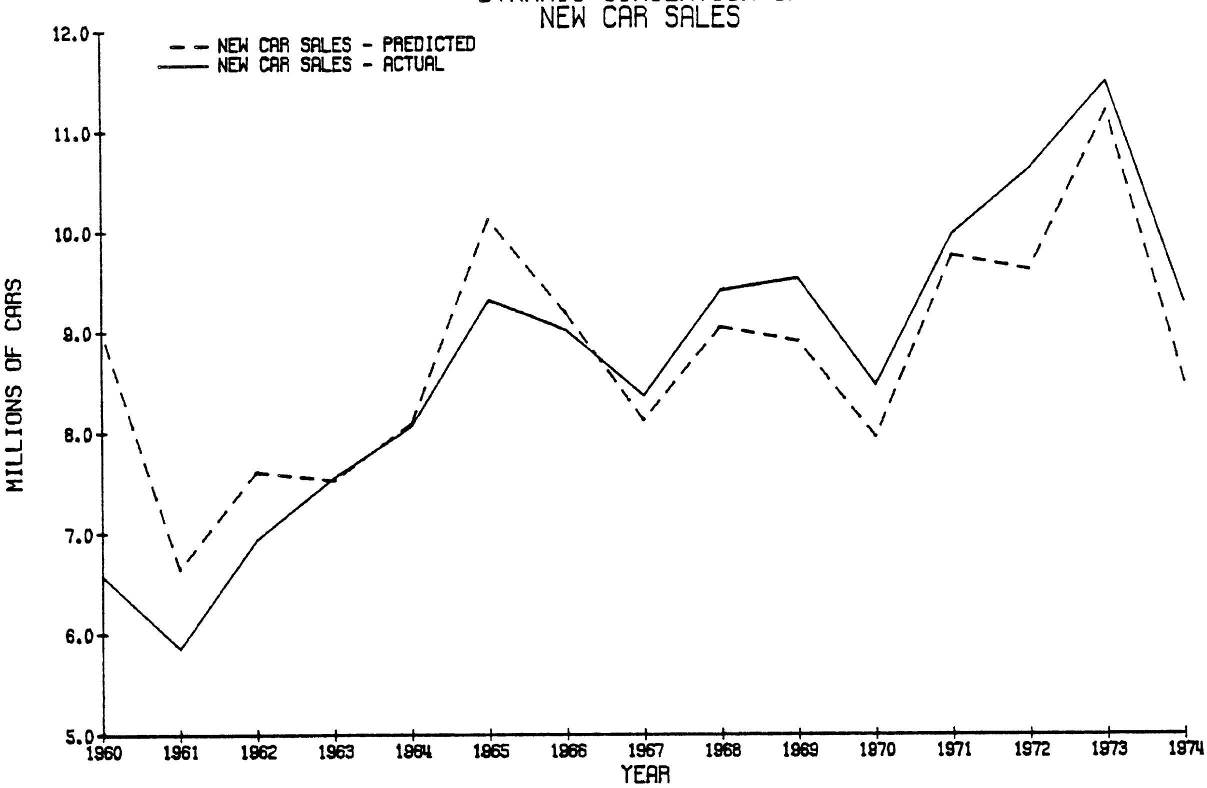


FIGURE 5-2

FULL MODEL
DYNAMIC SIMULATION OF
SCRAPPAGE

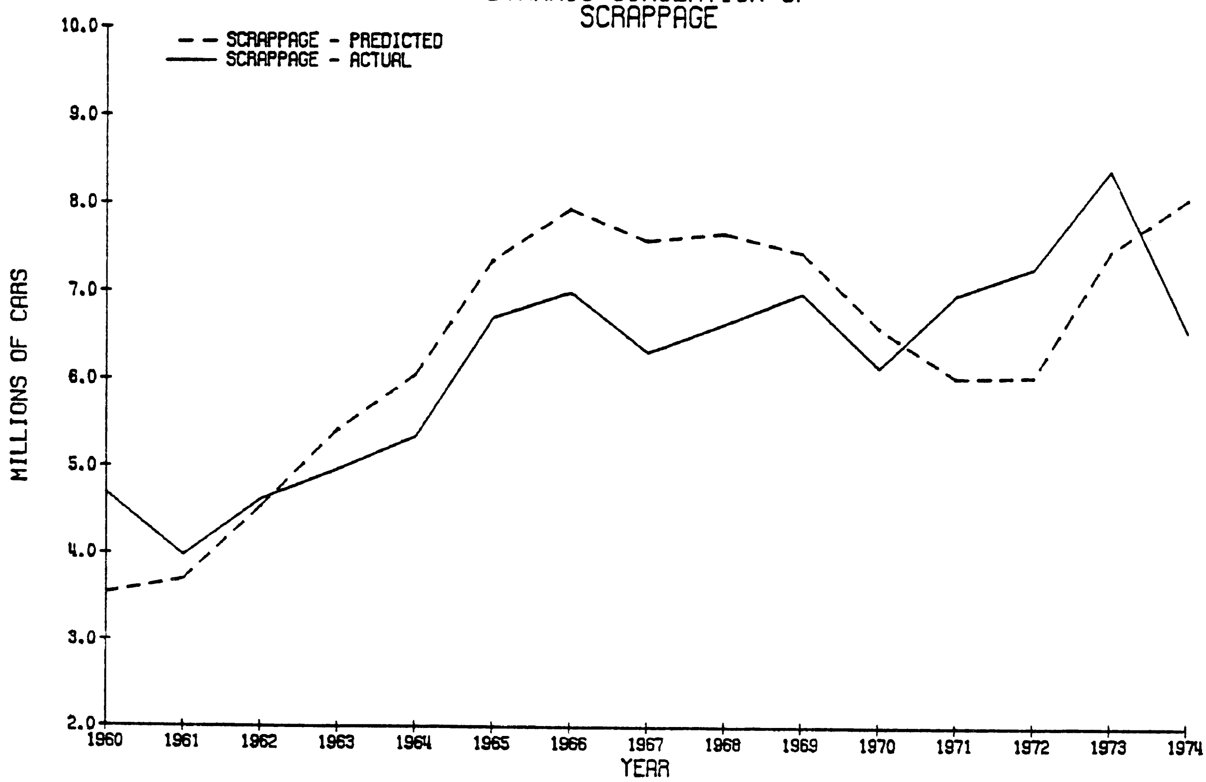


FIGURE 5-3

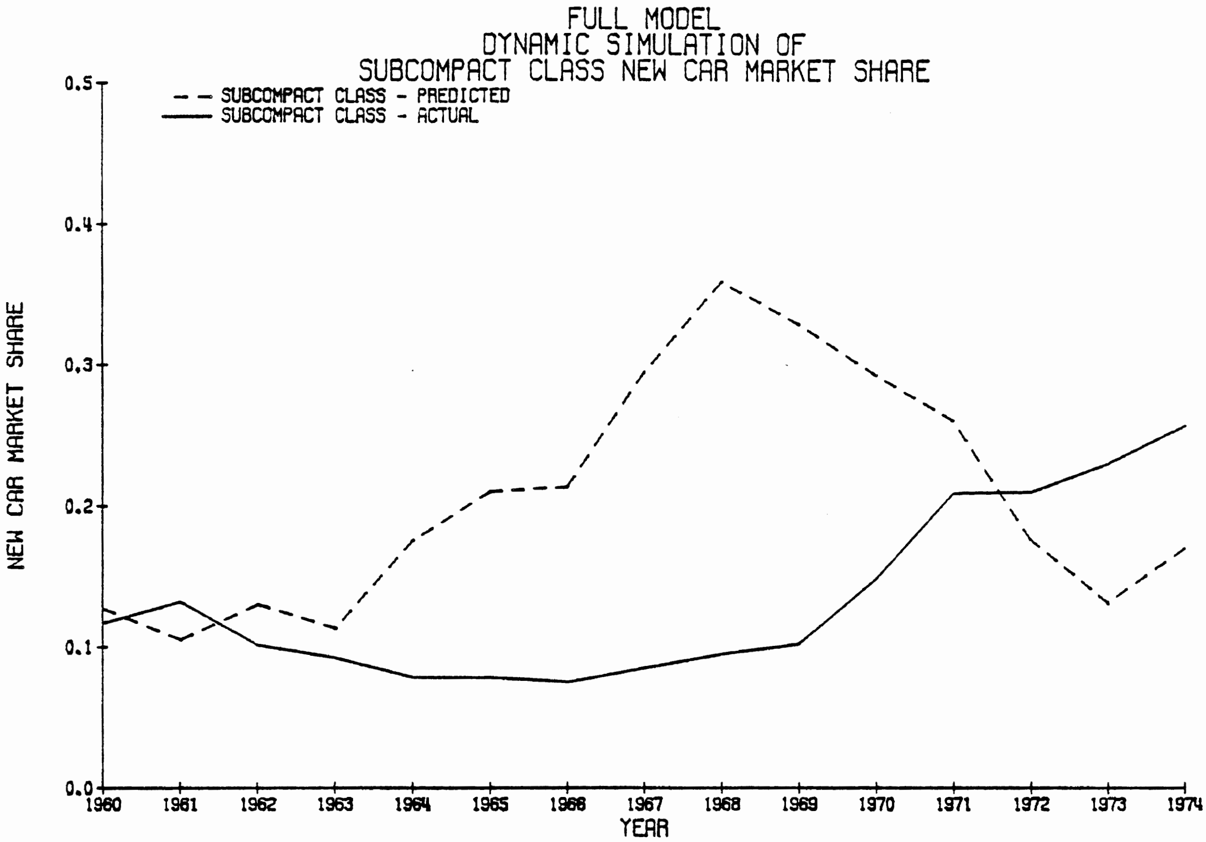


FIGURE 5-4

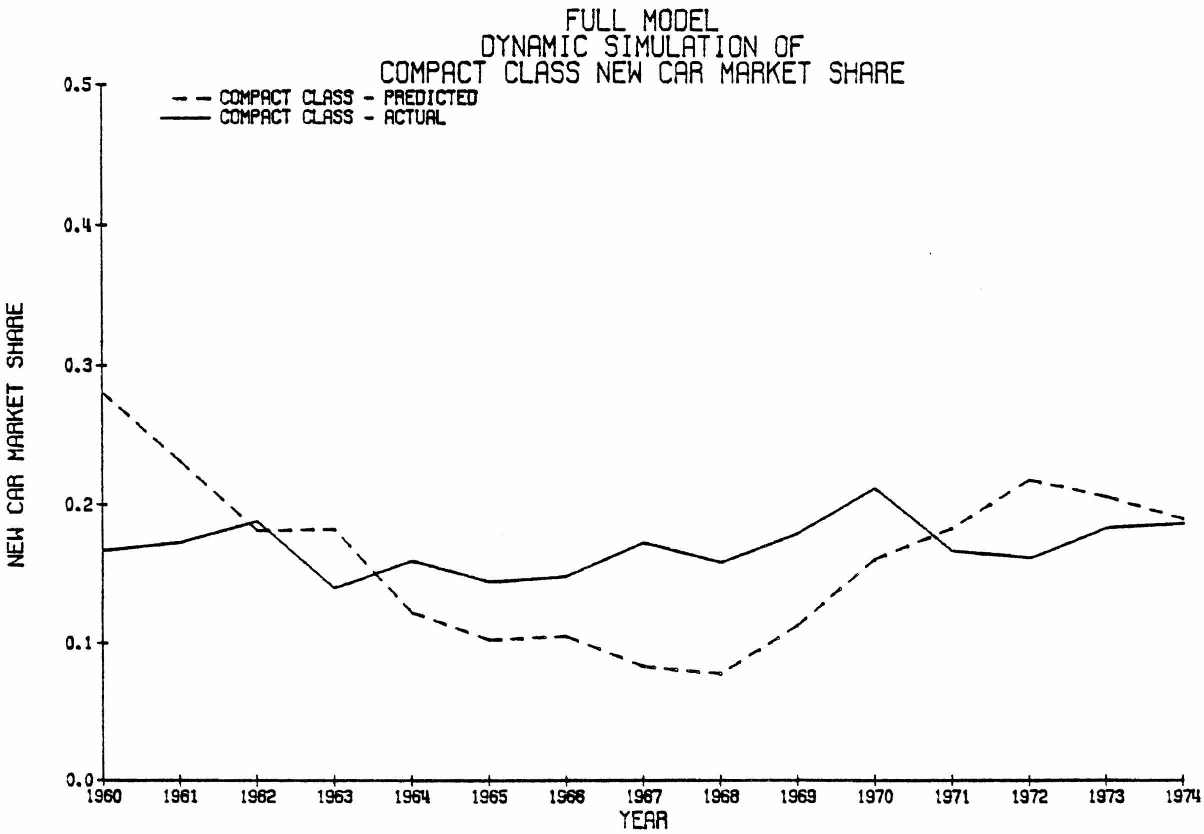


FIGURE 5-5

FULL MODEL
DYNAMIC SIMULATION OF
MID-SIZE CLASS NEW CAR MARKET SHARE

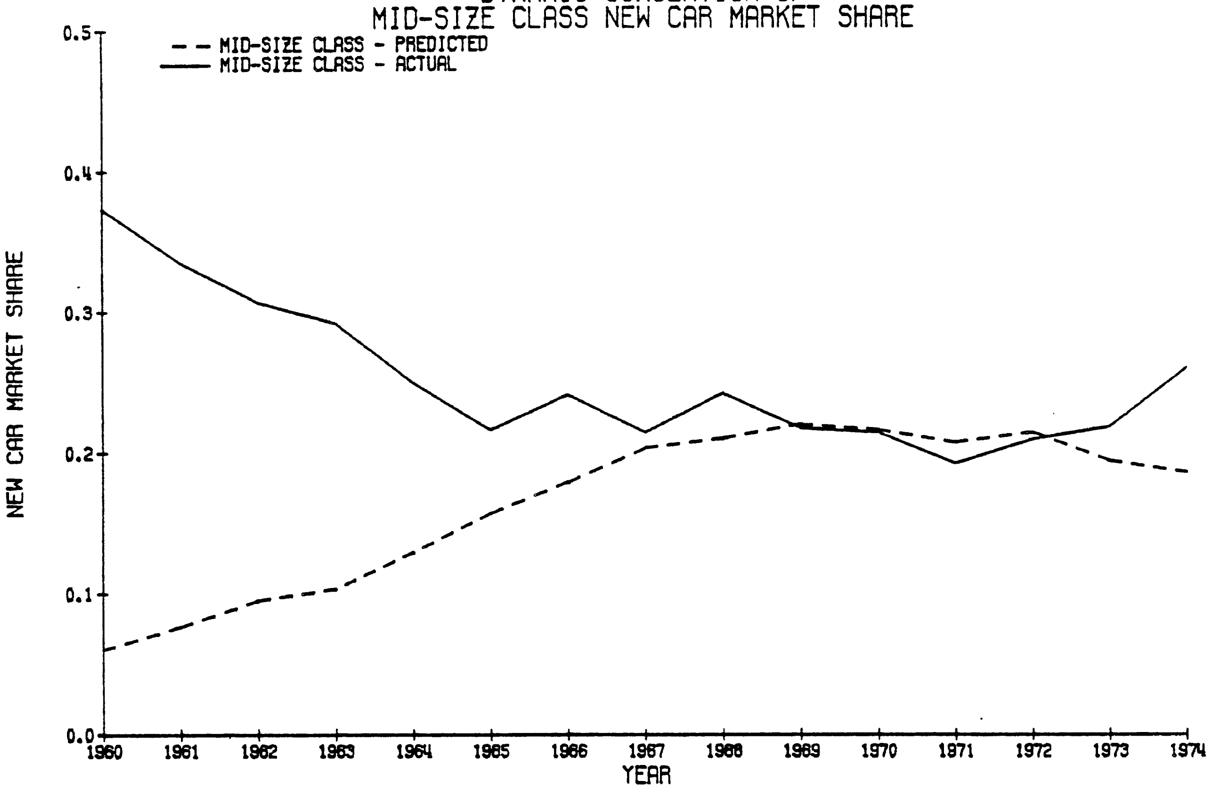


FIGURE 5-6

FULL MODEL
DYNAMIC SIMULATION OF
FULL-SIZE CLASS NEW CAR MARKET SHARE

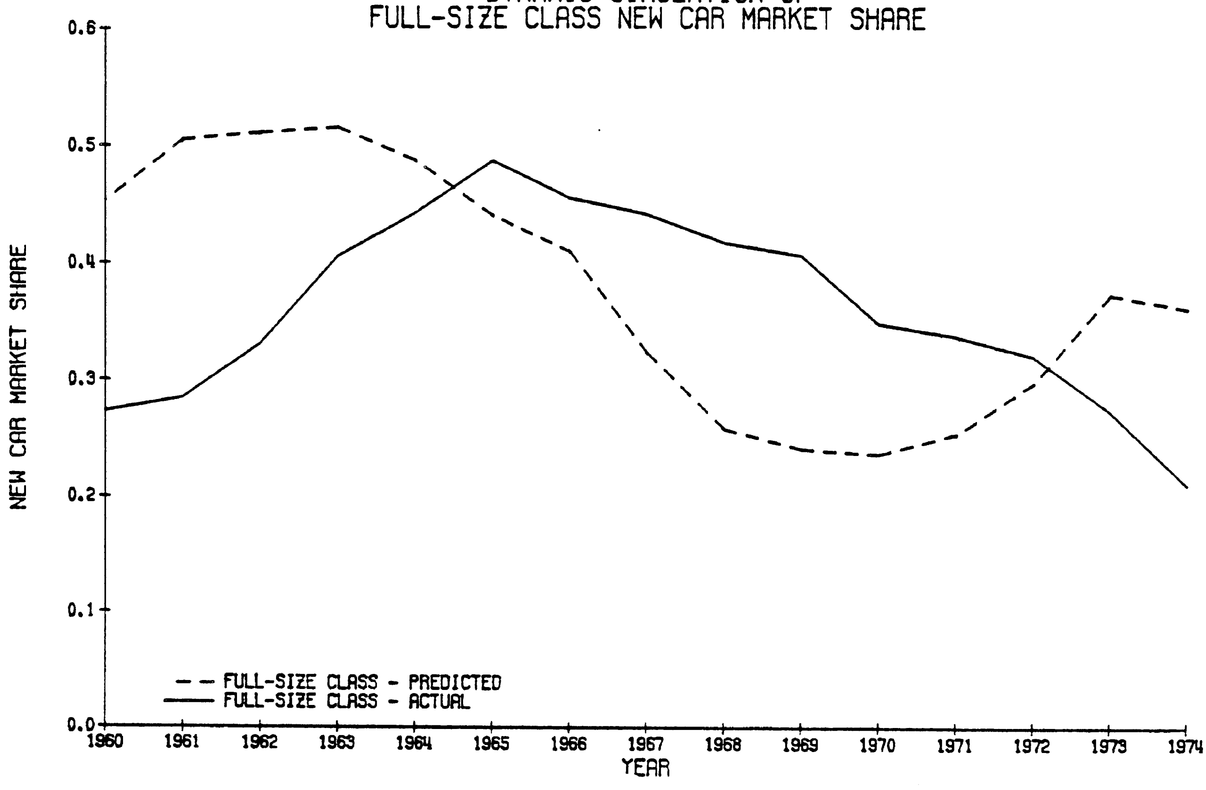


FIGURE 5-7

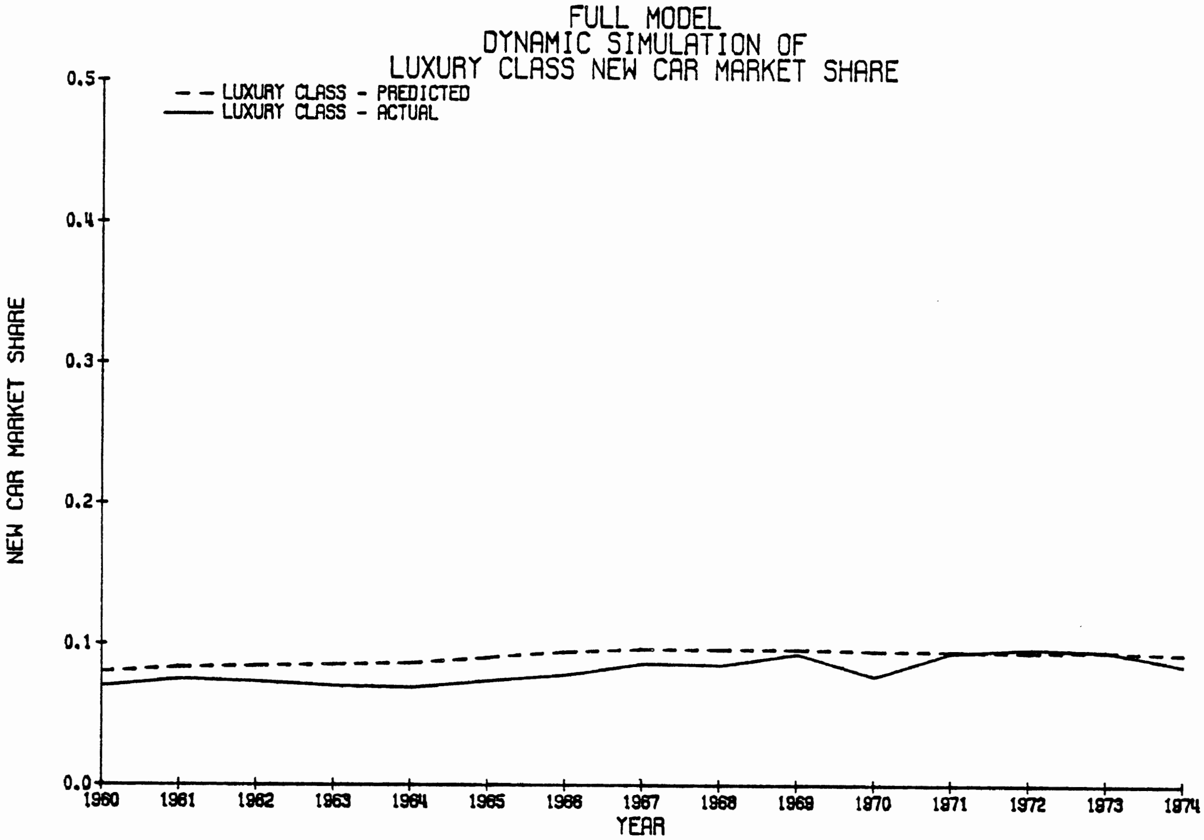


FIGURE 5-8

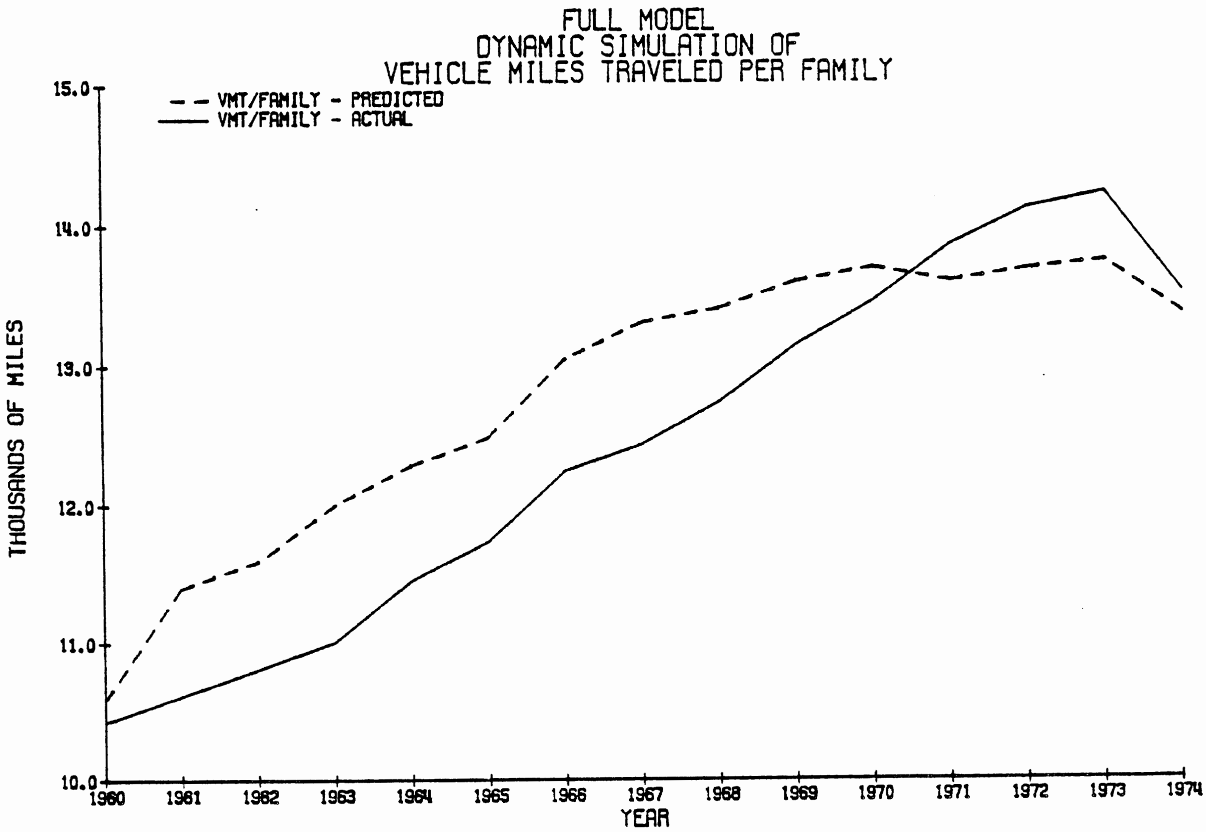


TABLE 5-1

ERROR STATISTICS FOR THE WITHIN-SAMPLE PERIOD 1960-1974
DYNAMIC SIMULATION

Variable	Mean	RMSE	100* RMSE/Mean	SIML R-SQ
Sales	8.693	.8234	9.47	.69
Scrappage	6.171	.8958	14.52	.41
VMT/FM	12.38	.6358	5.134	.75
Subcompact	.1339	.1300	97.08	-3.72
Compact	.1697	.0572	33.68	-8.88
Mid-Size	.2520	.1356	53.81	-6.17
Full-Size	.3628	.1294	35.66	-1.71
Luxury	.0814	.0113	13.90	-.39

range from 13.9% for the luxury new car market share to 97.1% in the subcompact new car market share. The SIML R-SQ statistics for all five new car market shares are negative, which also indicates very poor simulation results.

These inaccurate predictions for new car market shares are due to the severe problems in the market share equations that were pointed out in the previous sections. The main problem is probably in the method of dividing the overall stock of cars into market shares. The groupings are made by car size without any regard to car age, which is obviously one of the most distinguishing attributes of a vehicle. This gross oversight by the Wharton EFA model authors is evidently a contributing factor to the inability of the desired stock share equations to produce reasonable values over the historical period as indicated by the simulation experiments of Section 4.2.2. Since the desired stock share equations are incapable of generating realistic predictions, the new car market share equations, which depend on the desired stock share predictions through the stock adjustment process, are also unable to generate reasonable predictions.

The plots in Figures 5-1 through 5-8 present a clear picture of the performance of the model in tracking the historical record. The following points are illustrated:

1. **For new car sales, scrappage, and VMT per family, trends are predicted reasonably well but the levels of the variable are not forecast very accurately.** This indicates that the model is probably more useful in predicting changes (as opposed to levels) for variables such as new car sales, scrappage and VMT.
2. **The model exhibits several definite tendencies toward overprediction or underprediction.** For example, new car sales are underpredicted over the period 1967-1974 while VMT is persistently overpredicted from 1960-1969.
3. **The plots of new car sales by market segment**

share highlight the large errors indicated by the root mean squared error statistics. The subcompact share is grossly overpredicted throughout most of the period, with the errors in some years being on the order of twenty-five percentage points. The compact share fares somewhat better, with errors in the neighborhood of five to ten percentage points. New mid-size shares display an interesting pattern. The first half of the simulation period is characterized by gross underpredictions of the mid-size new car market share. In the second half of the period, the mid-size share is predicted fairly accurately, with errors of approximately one to five percentage points. The full-size market share suffers from large prediction errors throughout the entire period (ten to twenty percentage points). The luxury share is the only share that is simulated with any reasonable degree of accuracy, with the errors of about one to two percentage points. Of course, the luxury share remained very stable throughout the period 1960-1974, so perhaps it was not such a difficult task to predict it.

In fact, the sample mean of the luxury shares might be almost as good a predictor of the actual historical shares as the econometric model, using the root mean squared error as a basis of comparison.

This raises an interesting question about the forecasting accuracy of the model as compared to some naive alternative model. Consider the following naive alternative model for predicting new car sales by market share:

$Y_t^S = \bar{Y}^S$ S = Subcompact class

$Y_t^C = \bar{Y}^C$ C = Compact class

$Y_t^M = \bar{Y}^M$ M = Mid-size class

$Y_t^F = \bar{Y}^F$ F = Full-size class

$Y_t^L = \bar{Y}^L$ L = Luxury class

where

Y = market share of the particular class

t = time subscript (1960-1974)

$\bar{Y}$ = sample mean of the market share of the particular class

To predict the market share of a particular size class for any given year, the naive model says to use the sample mean of the actual market shares from 1960-1974 as the prediction. Thus, the naive uses the sample mean as a predictor of new car sales by market share rather than the complicated econometric model. In order to assess the forecasting accuracy of the naive model versus the Wharton EFA auto model over the sample period 1960-1974, root mean squared error statistics are calculated for the naive model and compared to the ones for the Wharton EFA auto model.

Table 5-2 contains such a comparison of root mean squared error statistics for the five new car market shares. The results are striking. In no case does the Wharton EFA model outperform the naive model in terms of forecasting accuracy. In all five market classes the naive model has a smaller root mean squared error than does the complete Wharton EFA model. Indeed in four of the market segments (subcompact, compact, mid-size, and full-size) the differences are quite substantial, with the RMSE of the naive model being on the order of four to eight percentage points lower. The difference is trivial for the luxury share (0.1 percentage points) (10).

TABLE 5-2

ROOT MEAN SQUARED ERROR
STATISTICS* OF WHARTON EFA MODEL
AND NAIVE ALTERNATIVE MODEL (1960-1974)

Market Class	Wharton EFA Model	Naive Model
Subcompact	.1300	.0598
Compact	.0572	.0181
Mid-Size	.1356	.0505
Full-Size	.1294	.0784
Luxury	.0113	.0103

*The root mean squared errors are measured in the same units as the actual market shares, i.e., fractions of the total market. For example, a root mean squared error of .1300 can be interpreted as an average forecasting error of 13 percentage points in market share.

For comparison purposes consider the same exercise for new car sales volume. The naive model simply forecasts the sample mean of new car sales for 1960-1974. Table 5-3 contains the RMSE statistics for the two models. In this case, the Wharton EFA auto model turns out to be a substantially more accurate predictor of total sales volume than the naive model. This is not surprising. **The graph of sales volume shows that the Wharton EFA model does a reasonably good job of tracking the trends in total sales volume.**

What are the implications of this analysis? First, from the point of view of pure forecasting, the Wharton EFA auto model has no advantage over the simple naive model in predicting new car sales by maket class. Indeed, the naive model has substantially smaller error statistics in four of the five market classes. Second, from the point of view of forecasting aggregate variables such as new car sales, scrappage, and VMT, the Wharton EFA model has an advantage over the naive model. Therefore, **the model may have some usefulness in forecasting new car sales, scrappage, and VMT (particularly for changes as opposed to levels) but it is inappropriate in its present state for forecasting new car sales by market class. This result can be taken one step further: forecasts of any variables that depend heavily on predictions for new car sales by market class (e.g., new car fleet average fuel economy) should be interpreted with a great deal of caution.**

Why spend the time and money to build a model to forecast new car sales by market segment when a naive model does much better over the historical period and may in fact do just as well in forecasting? The answer is two-fold. First, even though the current version of the Wharton EFA auto demand model is deficient in terms of forecasting market class new car sales, the knowledge gained to date from having built the model will presumably be of assistance in building a new version of the model that may turn out to be significantly better in predicting new car sales by size class. Second, it is important to remember that the naive model has no behavioral content and clearly

TABLE 5-3

ROOT MEAN SQUARED ERROR
STATISTICS* OF WHARTON EFA MODEL
AND NAIVE ALTERNATIVE MODEL (1960-1974)

Variable	Wharton EFA Model	Naive Model
New Car Sales	.8234	1.473

*The root mean squared errors are measured in the same units as new car sales: millions of passenger cars.

cannot be used as a tool in policy impact analysis (the "what if" game). However, if a model like the current version of the Wharton EFA auto model produced reasonable results, it could be used to estimate the effects of alternative policies on new car sales by market class.

5.2.2 Simulation Experiment 1960-1967. In this experiment the forecasting capability of the model over the first half (1960-1967) of the (1960-1974) period is studied. The error statistics for the eight key variables are listed in Table 5-4, and the actual and simulated values are displayed in Figures 5-9 to 5-16.

The error statistics are self-explanatory. For purposes of comparison, consider the error statistics in Table 5-1 that correspond to the complete sample period 1960-1974. The predictions of new car sales and VMT per family have larger overall errors (RMSE) in the 1960-1967 period than in the 1960-1974 period. This indicates that the model predicts more accurately these variables in the second half of the sample period (1968-1974) than in the first half. The results of new car sales forecasts were expected, given the problems identified in Section 4.2.1 concerning the desired stock per family equation on which new car sales predictions depend. However, the errors in the VMT per family predictions for the 1960-67 period are surprising. In fact, the negative value of the SIML R-SQ statistic for VMT per family indicates that the naive forecast of the mean actual value for the period would generate a smaller RMSE than the full model.

Although it is not possible to pinpoint the cause of this problem, the vintage-weighted VMT variable seems to be a major contributing factor. The vintage-weighted VMT variable is an index designed to measure variations in mileage traveled due to fluctuations in the age composition of stock. The index uses "average" miles driven per year for a given age of vehicle. These "average" miles by age are aligned so that the 1972 value of vintage-weighted VMT approximates the 1972 value of total VMT. (See Section 2.3.8.2 for a discussion of the

TABLE 5-4

ERROR STATISTICS 1960-1967
DYNAMIC SIMULATION

Variable	Mean	RMSE	100* RMSE/Mean	SIML R-SQ
Sales	7.709	.9764	12.67	.25
Scrappage	5.450	.7939	14.57	.40
VMT/FM	11.34	.7779	6.859	-.23
Subcompact	.0948	.1071	113.0	-29.82
Compact	.1619	.0627	38.71	-15.63
Mid-Size	.2785	.1832	65.77	-10.47
Full-Size	.3905	.1350	34.56	-2.04
Luxury	.0744	.0132	17.70	-5.36

TABLE 5-5

ERROR STATISTICS 1968-1974
DYNAMIC SIMULATION

Variable	Mean	RMSE	100* RMSE/Mean	SIML R-SQ
Sales	9.818	.5188	5.284	.67
Scrappage	6.995	1.004	14.35	-1.30
VMT/FM	13.58	.2730	2.011	.70
Subcompact	.1787	.1842	103.1	-8.70
Compact	.1787	.0595	33.31	-11.33
Mid-Size	.2217	.0611	27.55	-7.65
Full-Size	.3311	.1107	33.42	-1.73
Luxury	.0894	.0140	15.66	-3.35

FIGURE 5-9

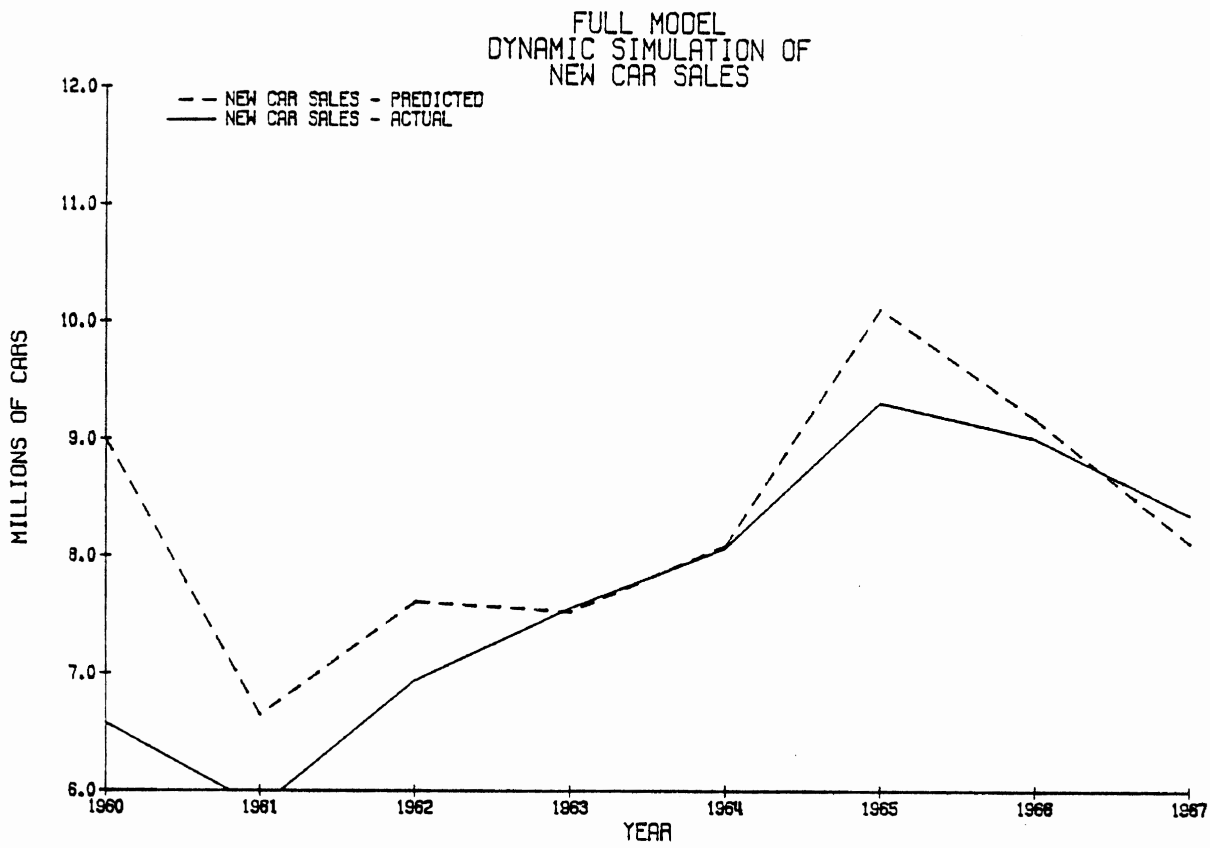


FIGURE 5-10

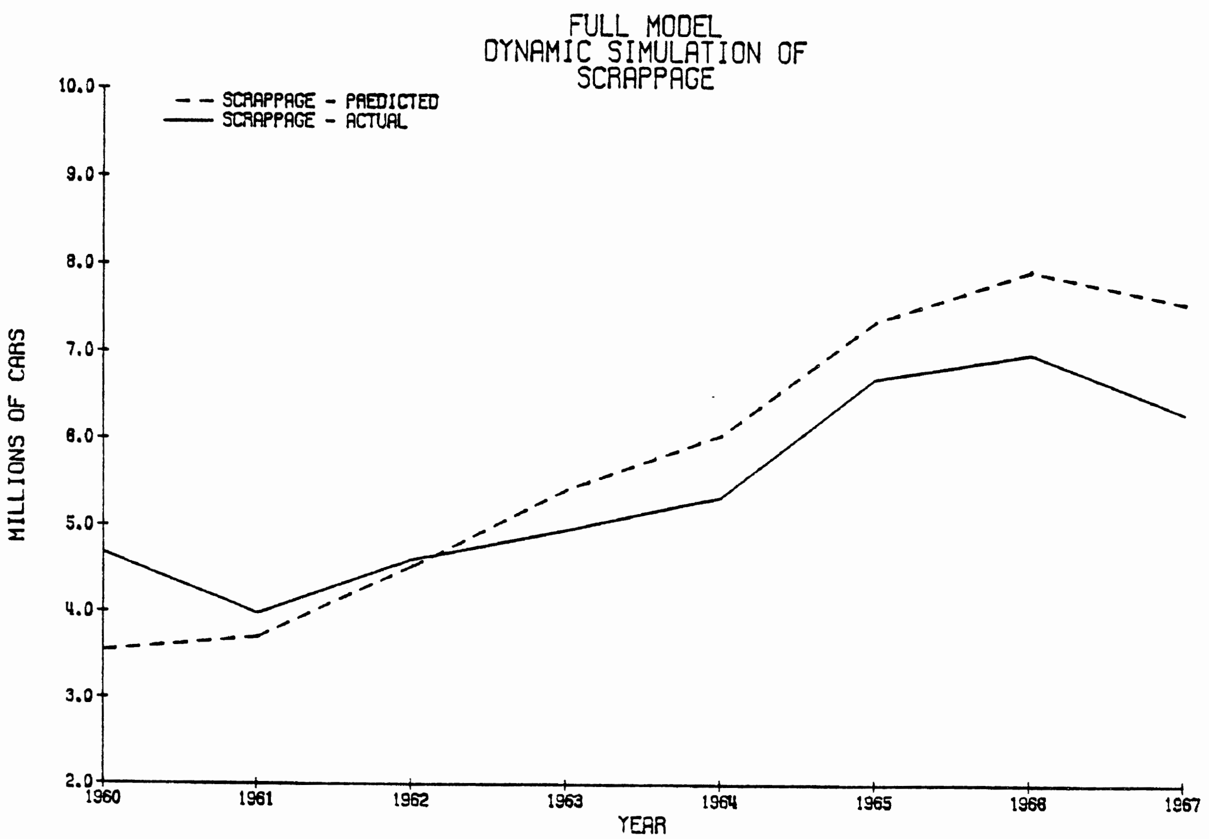


FIGURE 5-11

FULL MODEL
DYNAMIC SIMULATION OF
SUBCOMPACT CLASS NEW CAR MARKET SHARE

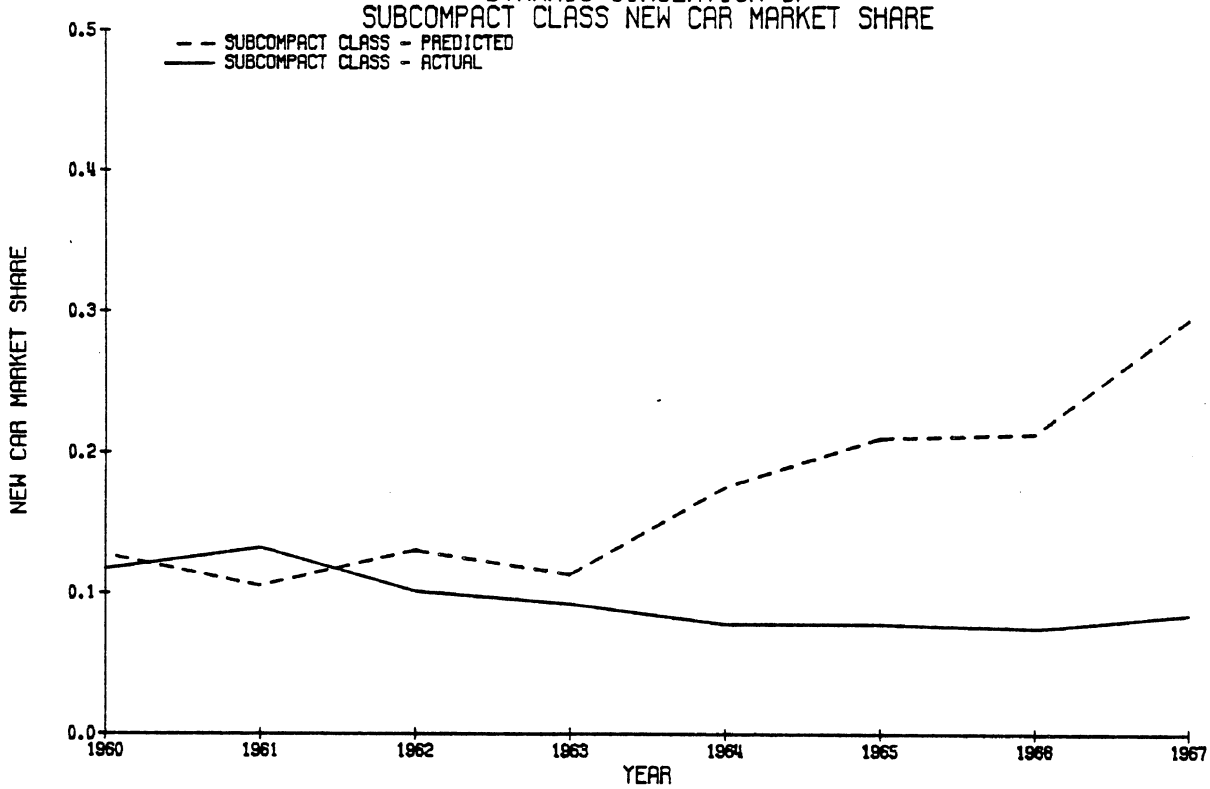


FIGURE 5-12

FULL MODEL
DYNAMIC SIMULATION OF
COMPACT CLASS NEW CAR MARKET SHARE

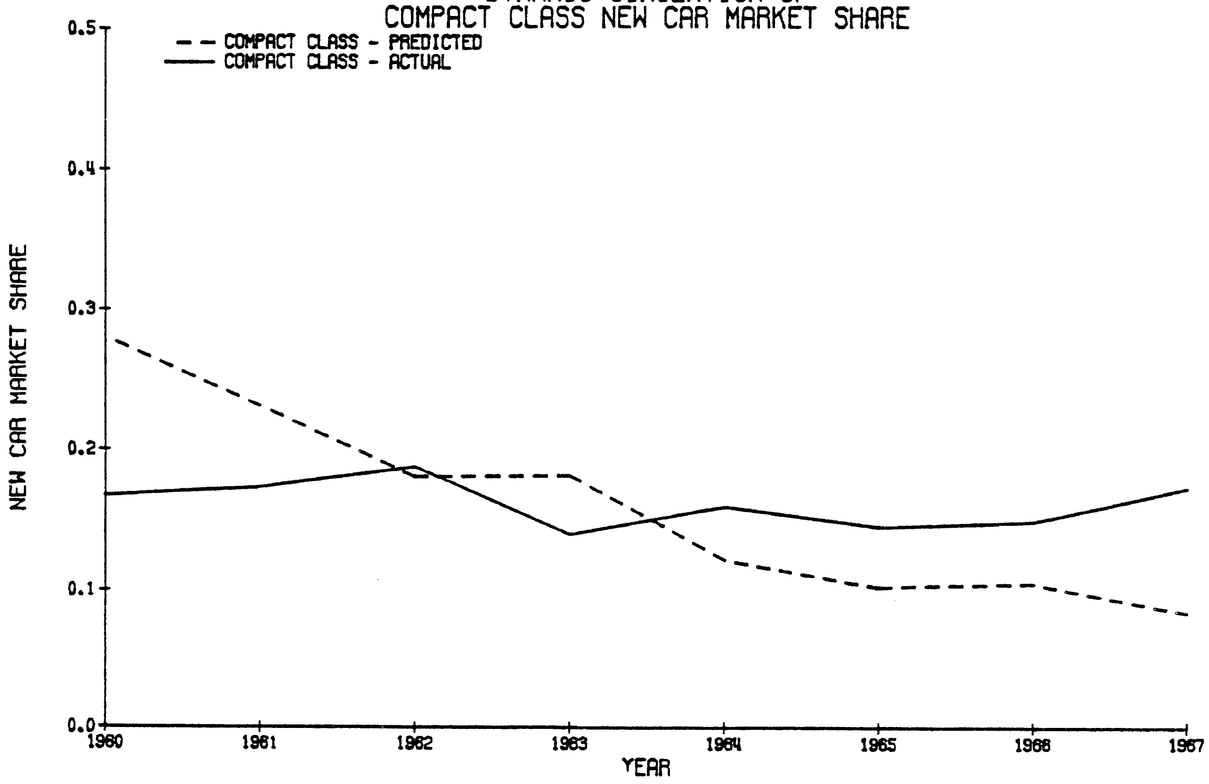


FIGURE 5-13

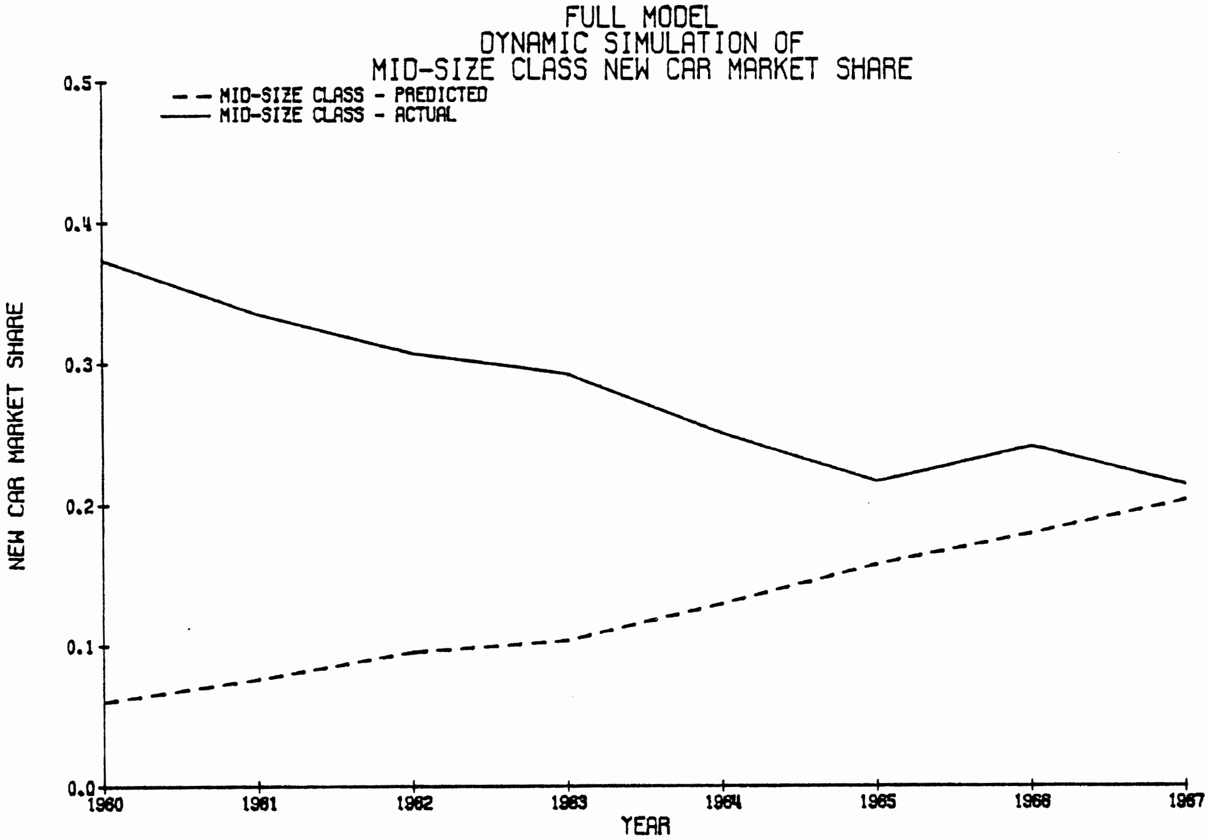


FIGURE 5-14

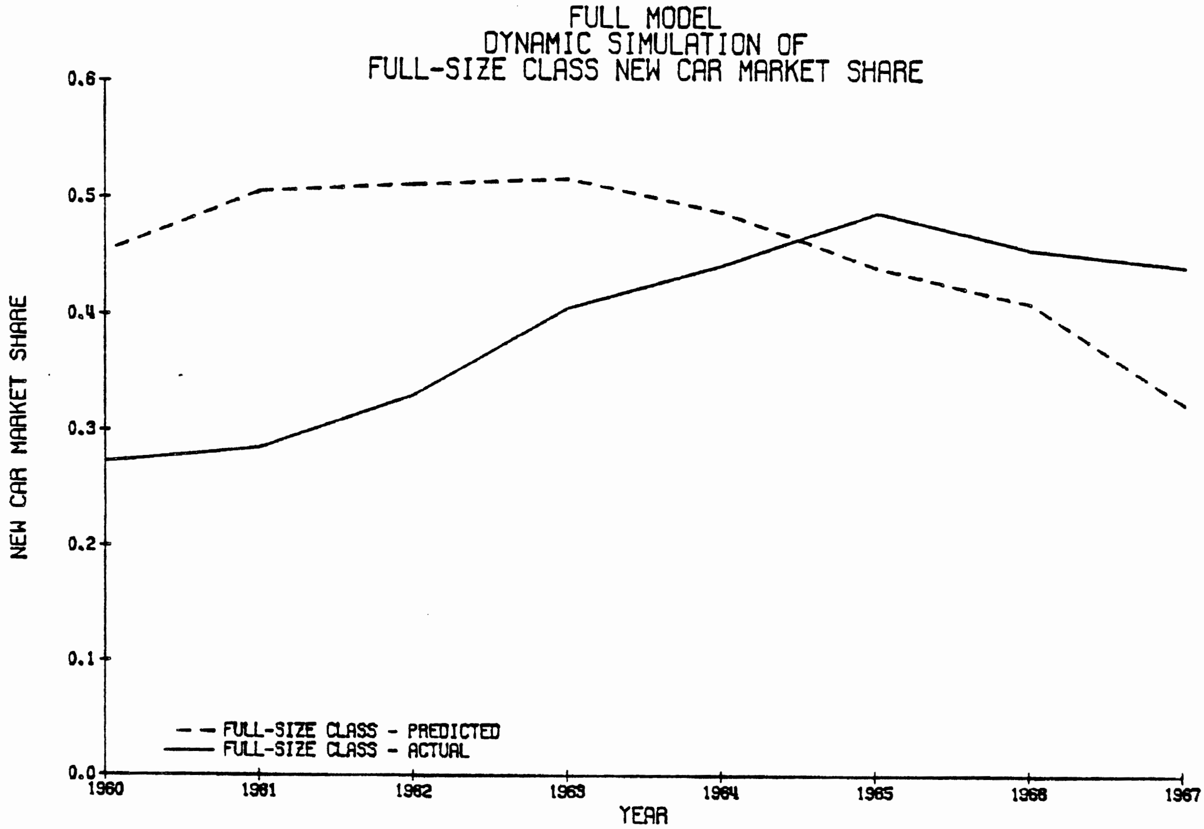


FIGURE 5-15

FULL MODEL
DYNAMIC SIMULATION OF
LUXURY CLASS NEW CAR MARKET SHARE

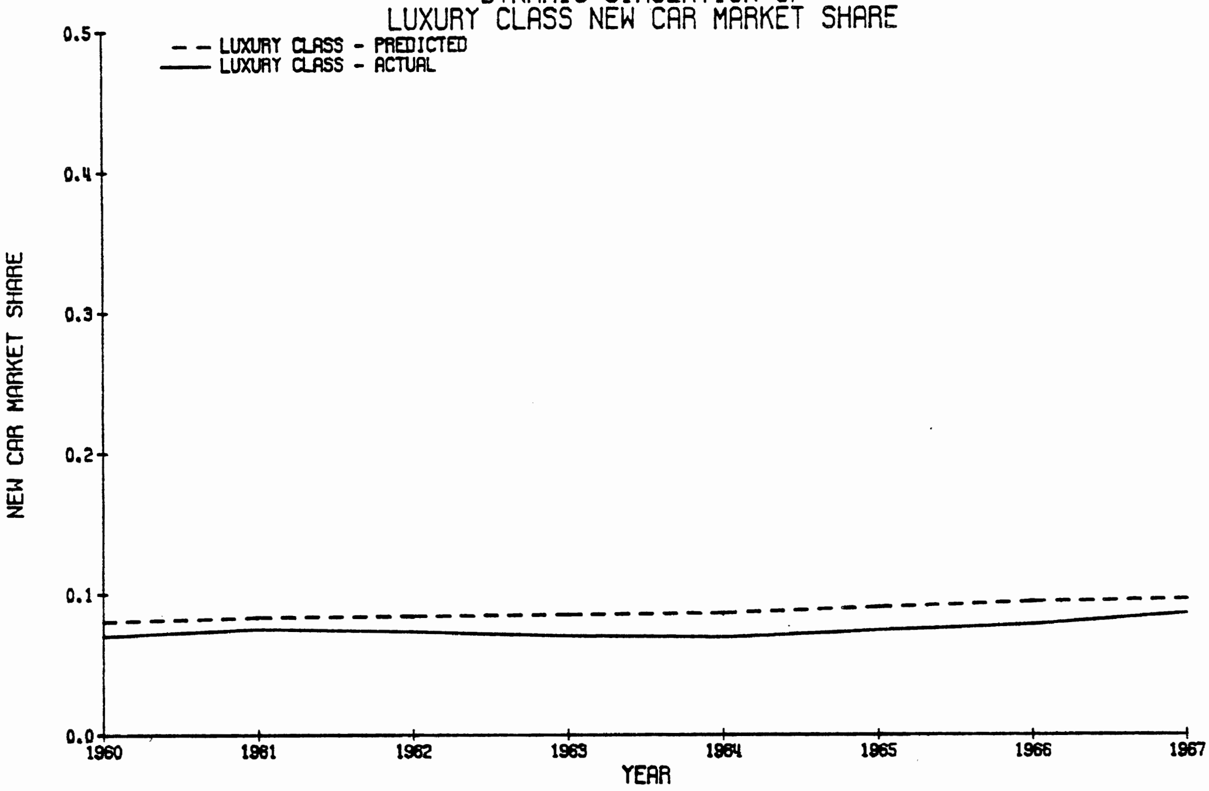
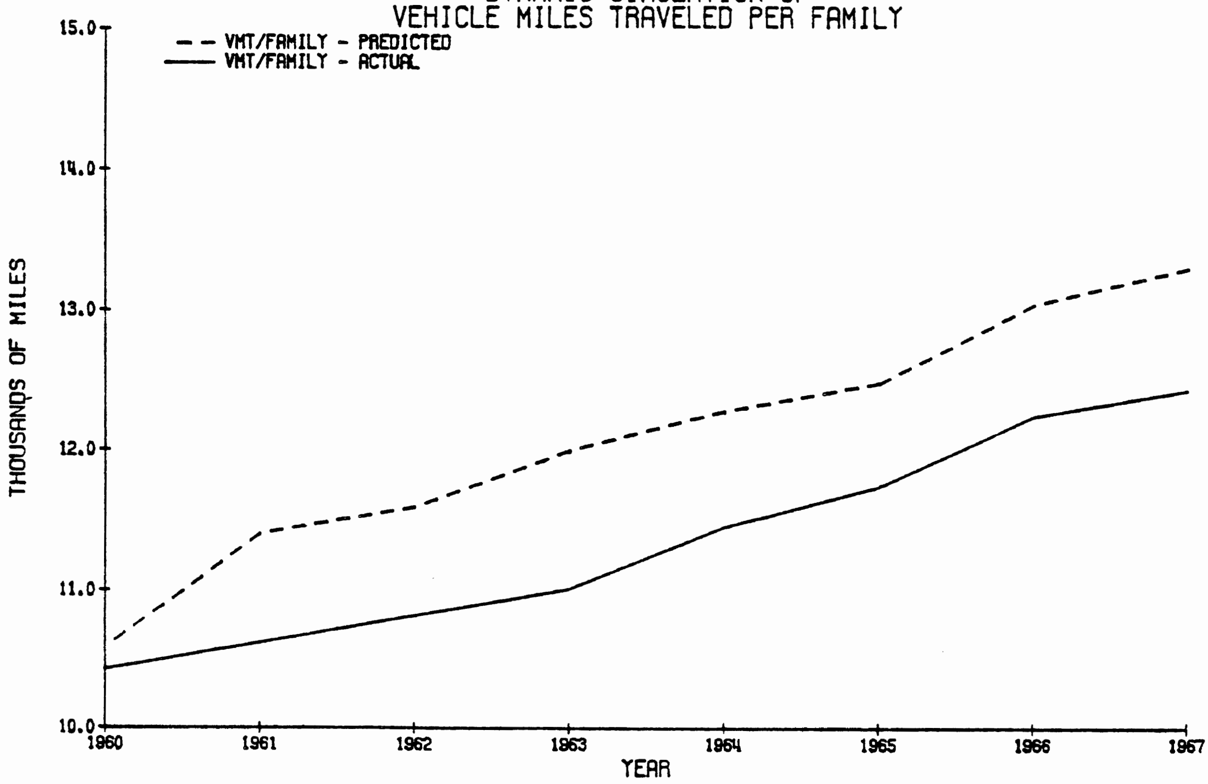


FIGURE 5-16

FULL MODEL
DYNAMIC SIMULATION OF
VEHICLE MILES TRAVELED PER FAMILY



formula.) The equation for VMT per family assumes that these "average" miles driven per year are equilibrium values, and thus represent vintage-weighted VMT over time. However, the vintage-weighted VMT is on the average 6% higher than total VMT for the years 1960 to 1967. This suggests that drivers drove fewer miles per year in the early to mid-1960s than in 1972. The high values of the vintage-weighted VMT variable cause the VMT per family equation to overpredict during the 1960 to 1967 period (see Figure 5-16). A similar difference in driving habits from those of 1972 would cause consistent overpredictions or underpredictions when this equation is used in forecasting.

This simulation is also noteworthy because scrappage has a smaller RMSE for 1960-1967 than for 1960-1974. This result is rather odd since scrappage is highly dependent on the desired stock per family predictions, which are problematic during the 1960-1967 period. Moreover, the scrappage predictions are highly dependent on the new car sales predictions which are also somewhat poor in this period.

The negative values of the SIML R-SQ statistics for the new car market shares point out the worthlessness of these predictions.

The graphs of the eight key variables in Figures 5-9 through 5-16 illustrate the following points:

1. **The trends in new car sales, scrappage, and VMT per family are predicted with reasonable accuracy, although the actual levels of the variables are off somewhat.** This is particularly true for VMT per family, which is overpredicted throughout the entire period.
2. **The market class shares are not simulated with any reasonable degree of accuracy.** Subcompacts are grossly overpredicted during the second half of the period (from 1964-1967) while mid-size and full-size cars suffer from similar problems of underprediction and overprediction, respectively, from 1960-1964. The compact and luxury market classes

are forecast with somewhat greater accuracy, although their average percentage errors of 38.7% and 17.7% respectively leave much to be desired.

5.2.3 Simulation Experiment 1968-1974. This experiment complements the 1960-1967 experiment in examining the forecasting capability of the model over the second half of the larger sample period 1960-1974. The error statistics for this experiment are displayed in Table 5-5, and the graphs of the key variables are in Figures 5-17 to 5-24.

For this experiment, new car sales, VMT per family, and mid-size new car market shares all experience substantial reductions in their root mean squared errors relative to the full period results (see Table 5-1 for 1960-1974 results). However, as indicated by the negative SIML R-SQ, the new car market share predictions are still extremely poor, and scrappage and subcompact new car market share are predicted with greater errors than in the full period. In fact, the SIML R-SQ statistic for scrappage is highly negative, indicating that the scrappage predictions in this experiment are very poor. This experiment points out a peculiar property of the scrappage equation--that is, even when its two major endogenous inputs, new car sales and desired stock, are predicted with reasonable accuracy, the scrappage predictions will probably be poor. This condition casts doubts on the specification of the scrappage equation.

The major points of this experiment are:

1. **The level of new car sales is now predicted quite accurately with the exception of one large error in 1972. The predictions for scrappage and VMT per family are still best viewed in terms of changes instead of absolute levels.**
2. **Considerable problems remain in forecasting new car sales by market share.** The subcompact share is greatly overpredicted for the years 1968-1971 and its trend is in the wrong direction (down instead of

FIGURE 5-17

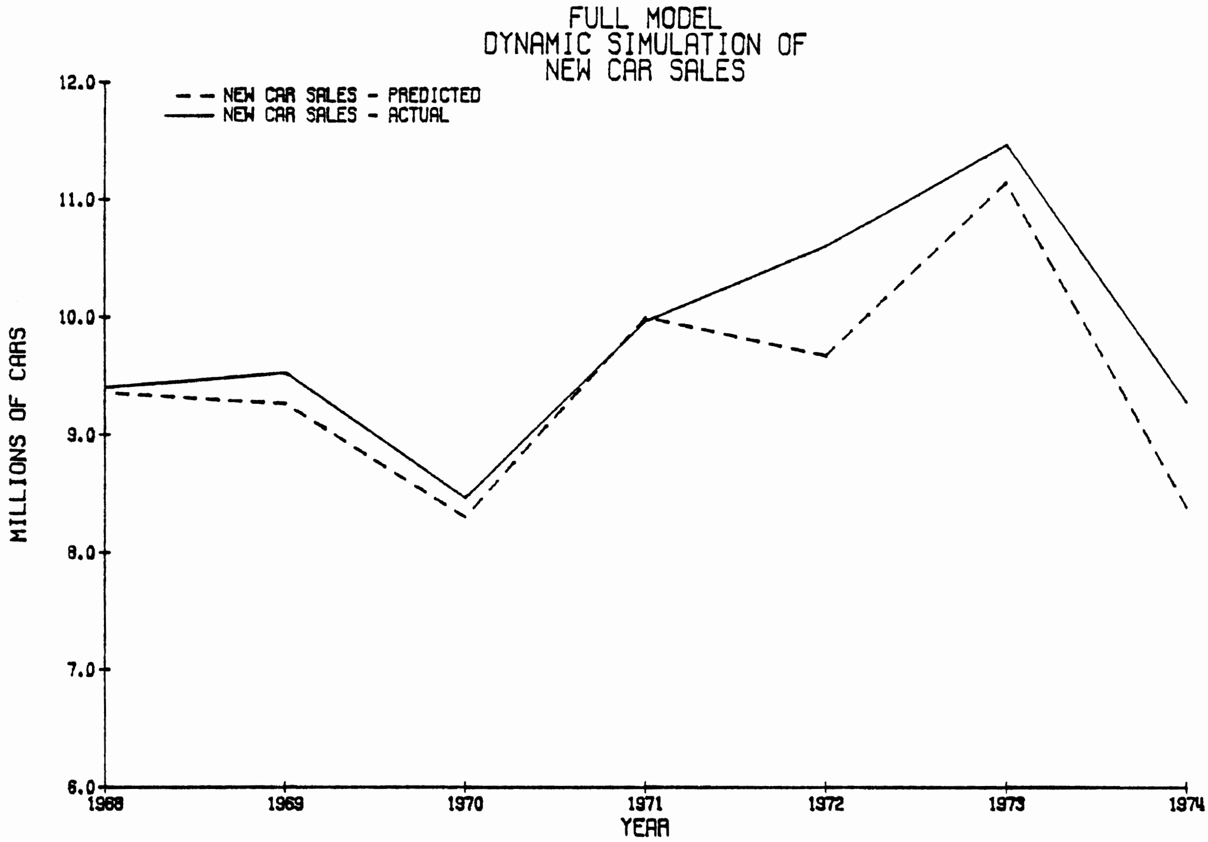


FIGURE 5-18

FIGURE 5-19

FULL MODEL
DYNAMIC SIMULATION OF
SUBCOMPACT CLASS NEW CAR MARKET SHARE

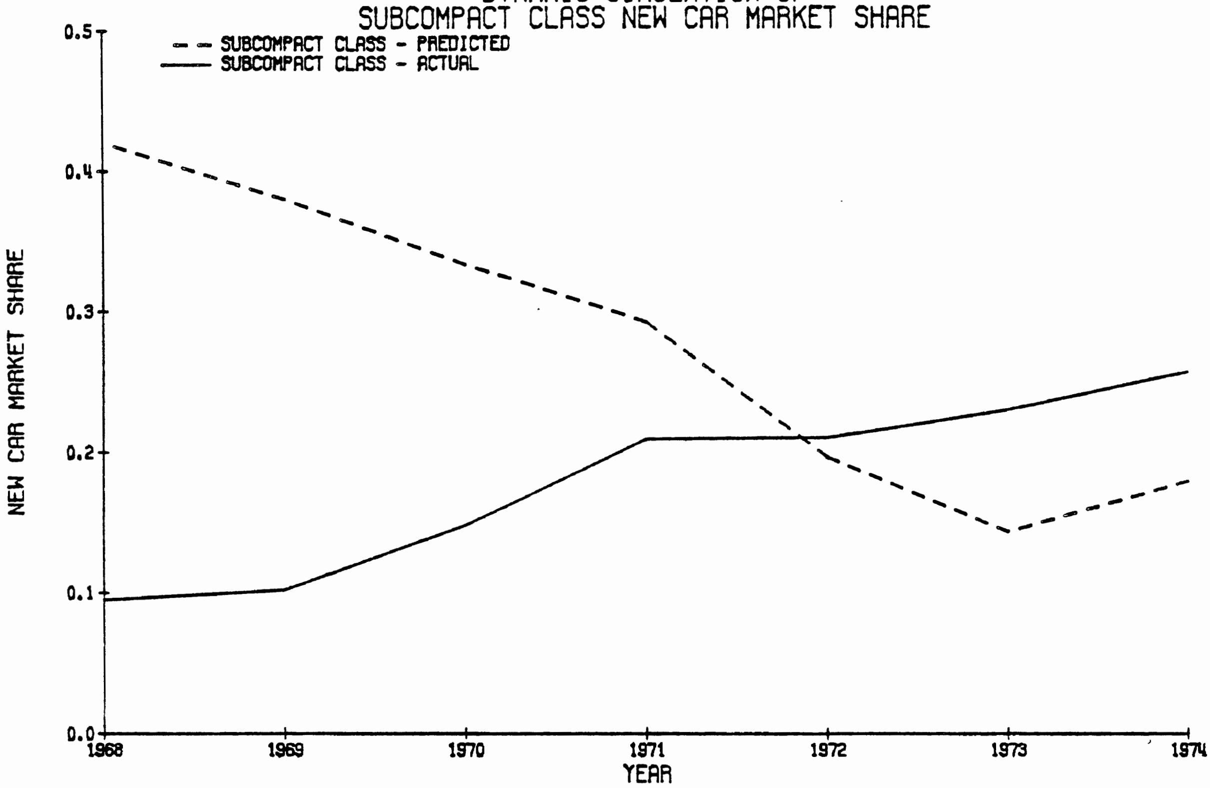


FIGURE 5-20

FULL MODEL
DYNAMIC SIMULATION OF
COMPACT CLASS NEW CAR MARKET SHARE

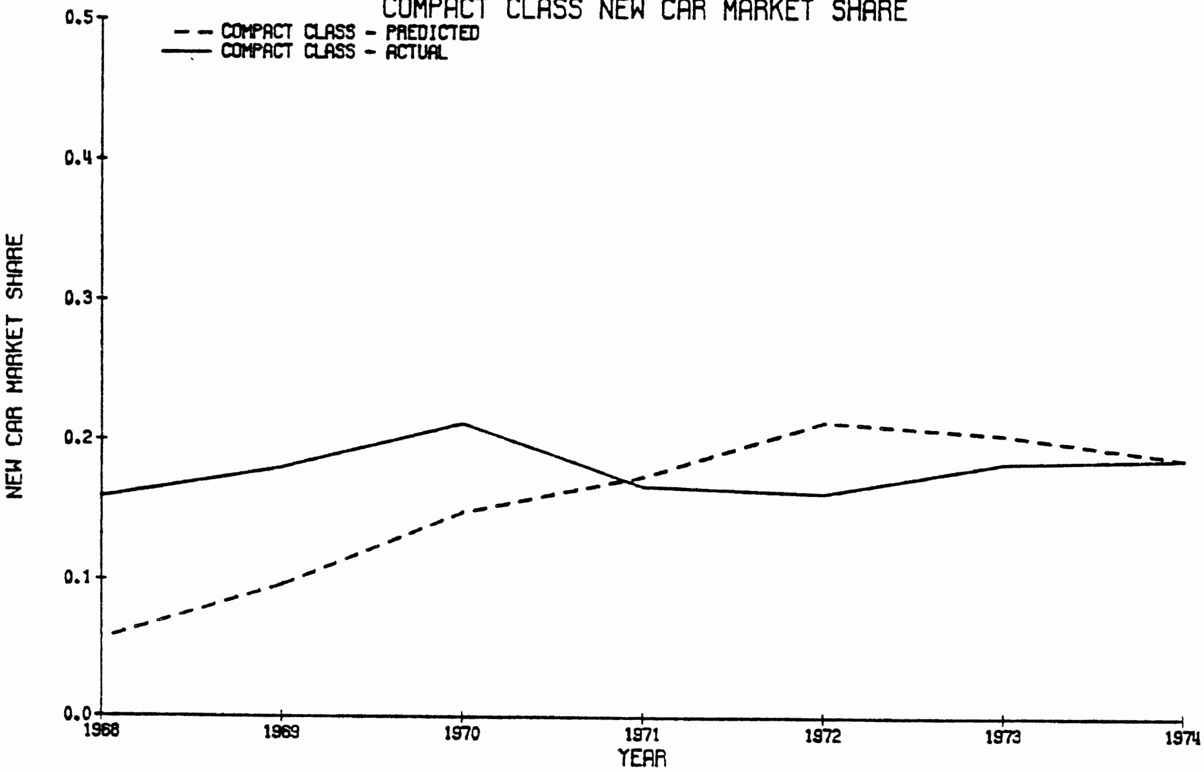


FIGURE 5-21

FULL MODEL
DYNAMIC SIMULATION OF
MID-SIZE CLASS NEW CAR MARKET SHARE

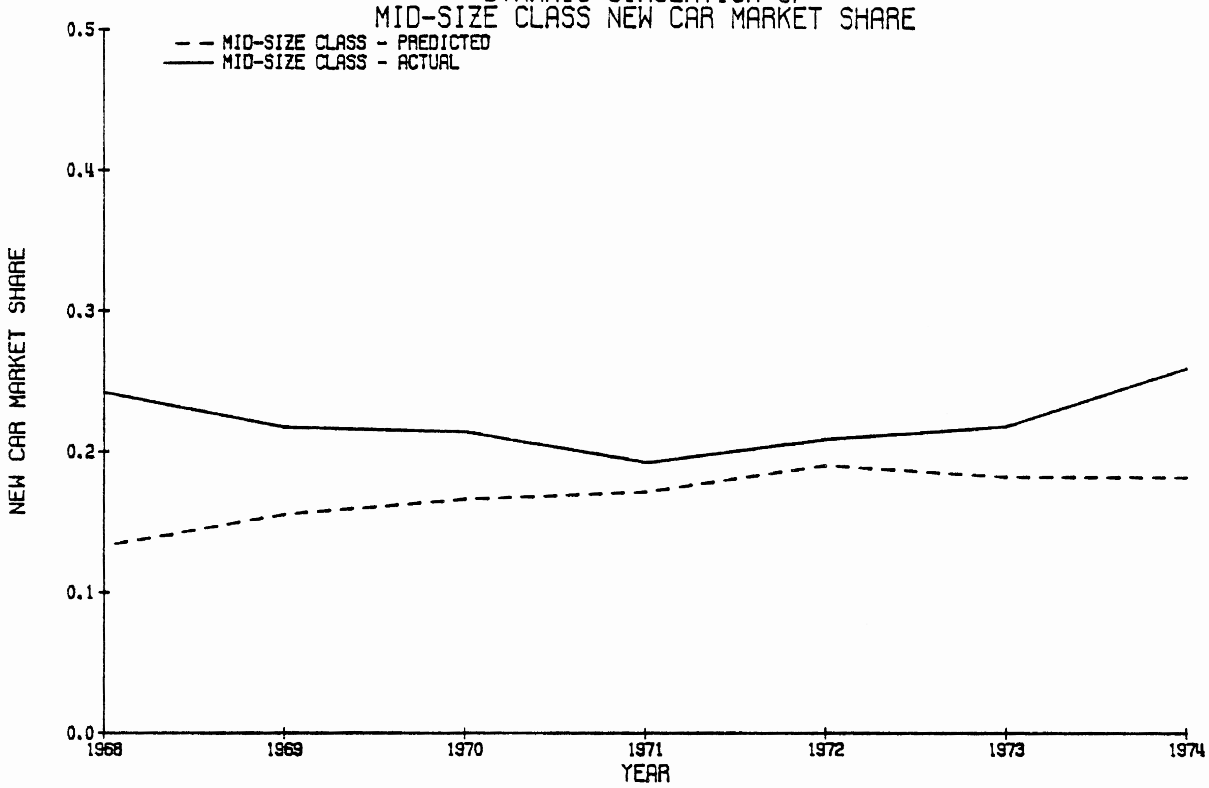


FIGURE 5-22

FULL MODEL
DYNAMIC SIMULATION OF
FULL-SIZE CLASS NEW CAR MARKET SHARE

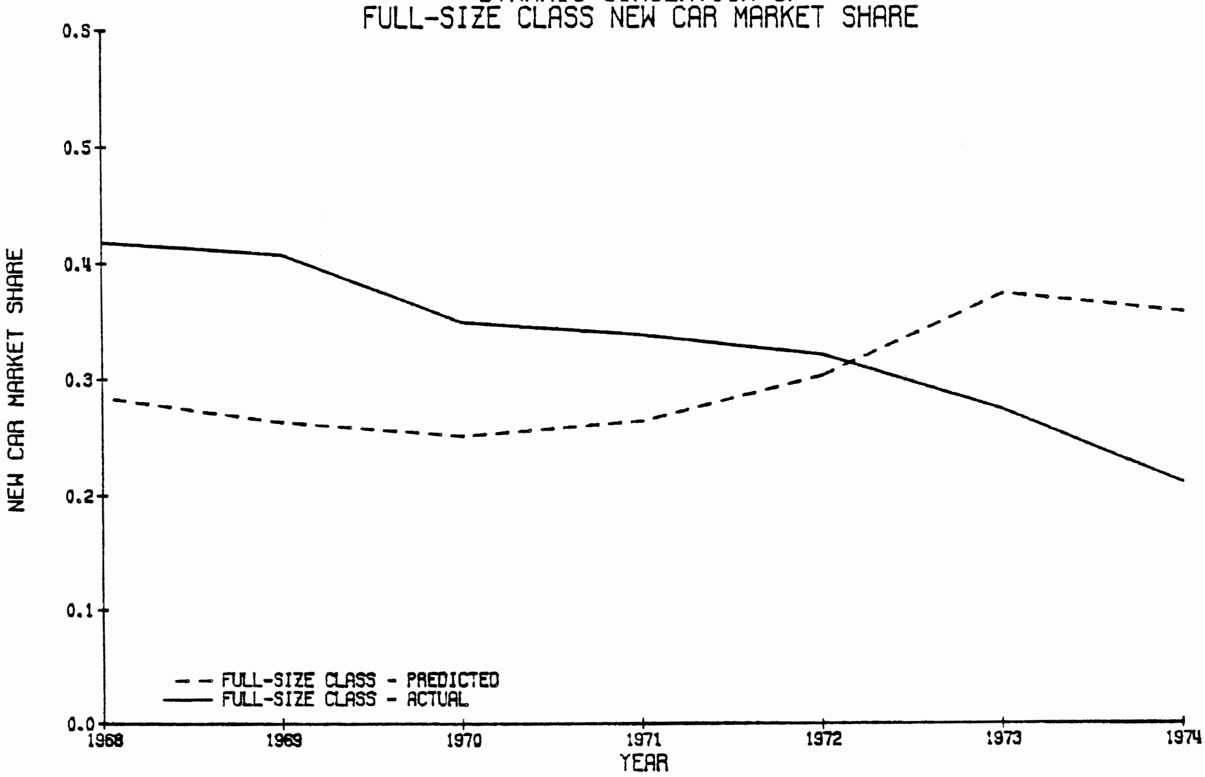


FIGURE 5-23

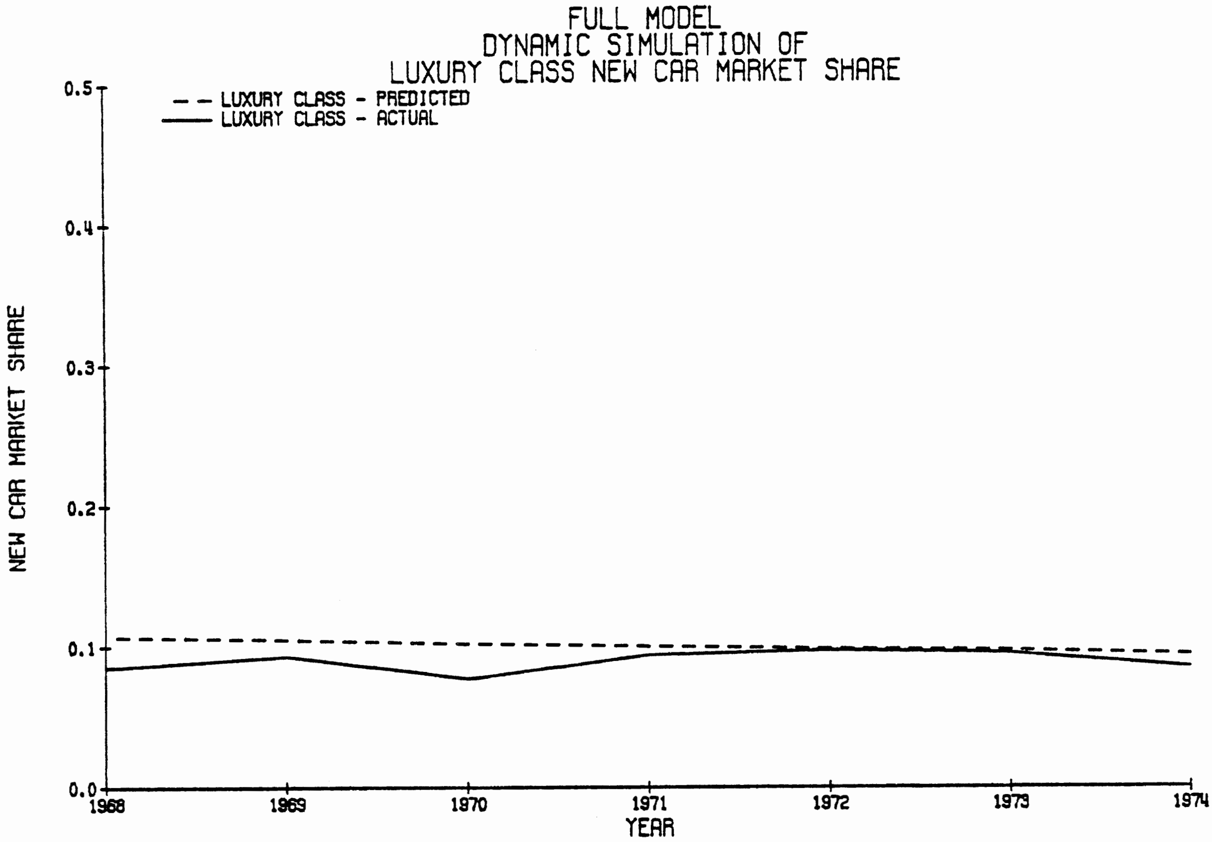
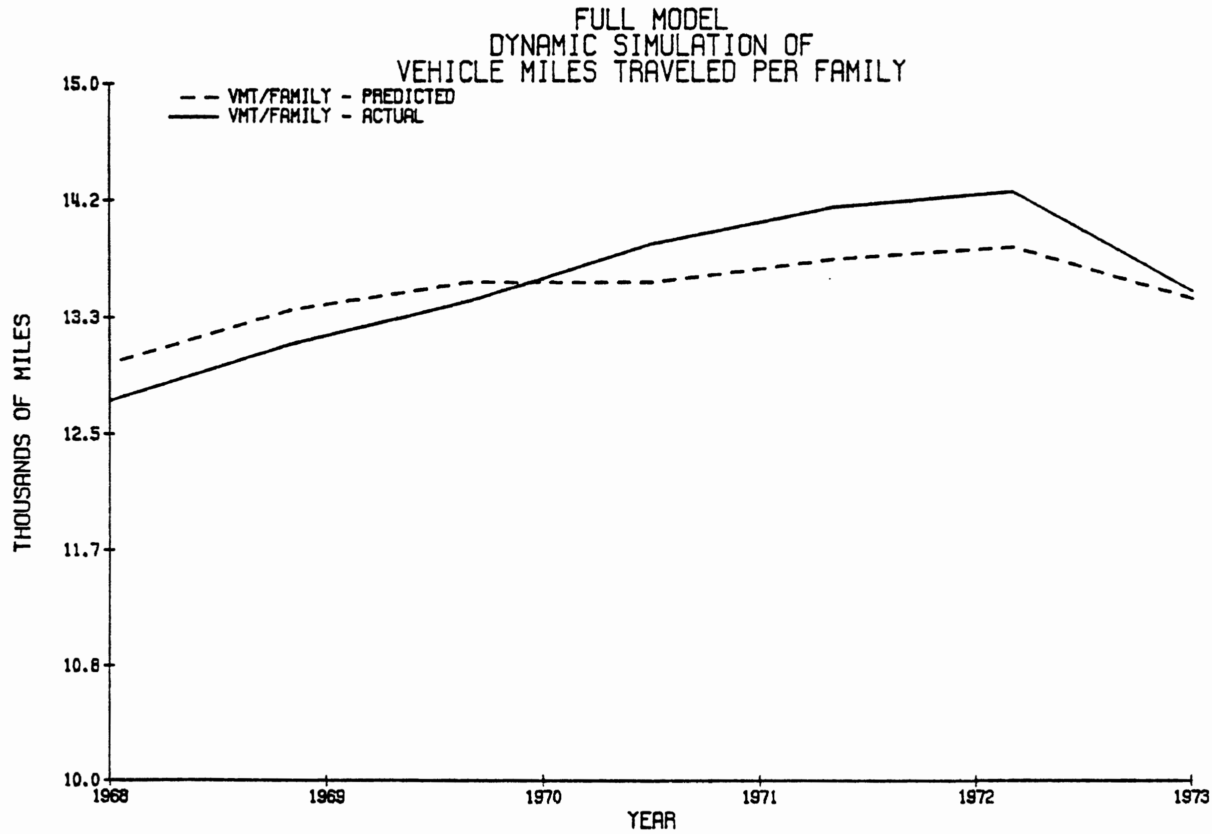


FIGURE 5-24



up). The full-size share suffers from similar overpredictions for the same years as well as tending downward after 1970 instead of up. The remaining three market classes (compact, mid-size, and luxury) generally follow the trends fairly well but make substantial errors in predicting the actual levels of market shares.

5.2.4 Simulation Experiment on Error Accumulation. This experiment is designed to study the forecasting accuracy of the model over different forecasting horizon lengths. The purpose of this analysis is to determine if the model displays a tendency to accumulate errors as the length of the forecasting horizon is increased. The simulations are run over the sample period 1960-1974.

Table 5-6 presents the simulation results related to ex post forecasting of the model over the period 1960-1974. The root mean squared error and SIML R-SQ statistics are presented for the eight key time series variables in the model (new car sales, scrappage, vehicle miles traveled, subcompact share, compact share, mid-size share, full-size share, and luxury share). The results were derived in the following manner.

The one-year forecasts are static simulations in which the model is reinitialized each year so that actual values of all lagged endogenous variables are always used in generating the one-period forecasts. In this framework, the model is not permitted to compound its own forecasting errors. This is clearly an artificial situation, but the results provide a useful reference point from which the results of dynamic simulations can be judged.

The one-year results in Table 5-6 indicate the model produces relatively large errors in one-period forecasts. New car sales are predicted with a root mean squared error (RMSE) of .8762 million units that corresponds to an average percentage error of 9.184%. Scrappage has a root mean squared error of 542,000 units or an average percentage error of 7.855%. For subcompact, compact,

TABLE 5-6

ERROR STATISTICS FOR 1960-1974
BY LENGTH OF FORECAST HORIZON

Variables	Mean Actuals	Root Mean Squared Error			
		1	2	4	6
Sales	9.541	.8762	.6319	.5527	.5899
Scrappage	6.897	.5418	.6046	1.098	.9905
Subcompact Share	.1489	.2045	.1815	.1593	.1559
Compact Share	.1718	.07162	.05825	.04939	.0514
Mid-Size Share	.2223	.08607	.07919	.06426	.0483
Full-Size Share	.3704	.09801	.09232	.09187	.1010
Luxury Share	.0864	.01818	.01625	.01346	.0118
VMT/Family	13.15	.2486	.4135	.5597	.5867

Variables	SIML R^2			
	1	2	4	6
Sales	.04759	.5046	.6211	.5683
Scrappage	.1689	.03508	-2.414	-1.778
Subcompact Share	-8.234	-6.273	-4.601	-4.368
Compact Share	-13.30	-8.460	-5.803	-6.354
Mid-Size Share	-20.29	-17.03	-10.87	-5.717
Full-Size Share	-.4014	-0.2435	-.2314	-0.4889
Luxury Share	-4.467	-3.371	-1.996	-1.284
VMT/Family	-.9019	.7287	.5027	.4536

mid-size, full-size, and luxury new car market shares, the average percentage errors are respectively 137.3%, 41.7%, 38.7%, 26.46%, and 21.0%. Only the VMT equation has a "reasonable" percentage error of 1.892%. These one-year results are quite disappointing in terms of forecasting accuracy.

These poor one-year results have at least two implications. First, they imply that the model is not capable of generating relatively accurate forecasts one year ahead. Second, the errors contained in the one-year forecasts may compound themselves over longer forecast horizon lengths, creating even more inaccurate forecasts. This second implication is examined in the remainder of this section by studying the forecasting accuracy of the model over larger forecasts horizon lengths.

Two-year forecasts are obtained by letting the model generate its own lagged endogenous variables for the second year of the forecast. The model first forecasts 1964 and then 1965, using its own forecast of 1964 as lagged data for the forecast of 1965. The model is then reinitialized as of 1964, and it forecasts 1965 and 1966 by using 1965 predictions as the basis of the 1966 forecasts. This process is repeated through 1973-1974. With this procedure a series of forecasts for 1965-1974 is obtained, with each being a two-year-ahead forecast. Table 5-6 contains the error statistics (RMSE) for these two-year dynamic simulations.

A similar procedure was followed with forecast horizons of four and six years. The results also shown in Table 5-6.

The results of these multiyear simulations are quite uneven. Simulation results for new car sales by market share (at least all shares except full-size) indicates that the six-period RMSEs are smaller than the static (one-period) ones. The full-size market share RMSE increases marginally from the static to six-year simulation. These results, then, indicate that there is no tendency toward error accumulation in the market shares; indeed the opposite takes place with the six-period RMSEs being generally smaller than the static RMSEs.

Scrappage and VMT do display a tendency to accumulate errors as the forecasting horizon is lengthened. The RMSE for scrappage increases from 542,000 units in the static simulation to 990,000 units in the six-year-ahead simulation. The SIML R-SQ statistics for scrappage indicate that the scrappage forecasts have a tendency to accumulate errors very rapidly. In fact, the error accumulation is so severe that the four- and six-year-ahead forecasts are extremely poor. This result casts doubts on the usefulness of the scrappage equation for forecasting purposes. VMT per family exhibits a similar pattern although the magnitude of the increase in the RMSE from the static to six-period dynamic simulation is much larger (an increase of over 100%). However, the VMT per family equation is still able to account for 45% of the variation in the actual values of VMT per family in the six-year-ahead forecasts.

The results for new car sales are rather peculiar in that the RMSE first decreases substantially from .8762 to .553 and then increases significantly to .59 in the six-year-ahead simulation. The results seem strange because the pattern of first a decrease and then an increase in the RMSE for new car sales is the exact opposite of that for scrappage, in which the RMSE increases and then decreases. Given the fact that new car sales and scrappage are highly simultaneous in the model and have tended to move together historically, one might expect a similar pattern of increases and decreases in their RMSEs. All that can be said here is that there does not appear to be any tendency for errors to accumulate for new car sales in the model.

To summarize, **the results of these simulation experiments indicate that VMT and scrappage do display a tendency to accumulate errors as the forecasting horizon lengthens, while new car sales and the five market share classes exhibit no tendency to accumulate errors.**

The lack of error accumulation in those two forecasts is interesting. In fact, forecasts of sales and shares get better as the horizon lengthens (aside from the jump from .55 to .59 in sales when the horizon goes from four to six years, but that hardly seems to be of major importance). This is symptomatic of a very poor model. The model does not really "understand" what is happening and is apt to make huge errors in short-term predictions. In longer-term predictions, the model is dominated by the underlying trends and wanders around the historical data almost randomly; being no worse, on the average, at predicting four years ahead than predicting only two years ahead.

These results are most damaging to the model as a forecasting tool, but not necessarily as a tool for policy scenario analyses.

5.3 Full Model Dynamic Properties

The purpose of this section is to present an analysis of the dynamic properties of the full model. As in the submodel evaluation in Section 4.3, the dynamic properties of the model are studied by conducting multiplier experiments. In general, a multiplier experiment involves changing the values of one or more exogenous variables to determine the resulting impacts on the endogenous or predicted variables of the model. A detailed discussion of how multiplier experiments are run and how to interpret the results of the experiments is provided in Section 4.3.

The following nine multiplier experiments are examined:

1. One percent increase in nominal personal income
2. One percentage point increase in the sales tax rate on new cars
3. Ten percent increase in gasoline price
4. One percentage point increase in the unemployment rate
5. Ten percent increase in the insurance cost index
6. Ten percent increase in the repair cost index
7. Ten percent increase in the production input cost index
8. One percent increase in the number of licensed drivers
9. One percent increase in the number of individuals aged twenty to twenty-nine years

A detailed discussion of each experiment follows. The discussion focuses on the effects of the increases on the eight key time series variables of the model: new car sales, scrappage, subcompact share, compact share, mid-size share, full-size share, luxury share, and VMT. The results of the multiplier runs are contained in Appendix B.

In the first multiplier experiment the path of nominal personal income is increased by one percent over the sample period 1960-1974 (see Tables B-1 through B-8). New car sales in the first year experience a substantial increase of approximately 5.2% (470,000 units). Over the longer term the effect of the increased income on new car sales fluctuates between very small positive and negative changes that, for practical purposes, imply a long run income elasticity of zero. This result also occurred in the similar experiment on submodel set 1, (Section 4.3.1), and it is caused by two factors in the model that work to offset the initial increase in sales volume. First, the income distribution variable in the total desired stock equation limits the increase in the desired stock (the so-called saturation effect). Second, the increase in income causes "trading up" to larger, more expensive cars; this increases the average capitalized cost per mile variable, which depresses the total desired stock.

It should be mentioned that this result of an essentially zero income elasticity in the long run is totally inconsistent with previous studies of automobile demand. For a survey of others' estimates of the income elasticity of new car demand, the interested reader is referred to studies on the automobile industry (White 1971, pp. 94-95) and on automobile demand (Mellman 1975). These two studies show that most auto demand models estimate the long-run income elasticity with respect to sales volume to be approximately 1.0.

Scrappage increases by 1.4% in the first year of the increase in income. In the long run the increase in scrappage is very minor, amounting to less than .5%.

In the market segments the initial response to the increase in income is one of "trading up." In the first year the subcompact share drops 0.2 percentage points, compacts fall by 0.1 percentage points, and full-size cars gain 0.3 percentage points. Several years later, however, these effects essentially reverse themselves. The increase in income has the effect of increasing the proportion of families with incomes at or above $15,000. This then implies an increase in the subcompact, compact, and luxury shares at the expense of full-size cars. For example, in the fifth year following the permanent 1% increase in income, the subcompact share has increased by 0.3 percentage points, compacts are up 0.1 percentage points, the mid-size share has increased 0.1 percentage points, and the luxury share has increased 0.1 percentage points. These increases all come at the expense of the full-size share that has decreased a substantial 0.6 percentage points. In the longer run (fifteenth year), the medium term results have diminished somewhat. Subcompacts, compacts, and luxury are each estimated to increase by 0.1 percentage points with full-size losing 0.3 percentage points.

The increase in income has a relatively strong impact on vehicle miles traveled. The largest impact--a 0.95% increase in VMT-- is experienced in the third year following the increase in income. The increase then declines to a long-run elasticity of approximately 0.2.

In summary, the increase in income has a substantial impact on new car sales in the first year but essentially a zero effect in the long run. Scrappage and VMT have similar response patterns, with the short-run elasticity being significantly greater than the long-run elasticity. The results indicate that the market segments go through at least two distinct phases. In the short run, the full-size share gains at the expense of small cars via the "trading up" effect. Over the longer term, luxury and small cars gain at expense of full-size cars due to the "income distribution" effect of the increase in nominal personal income (11).

In the second multiplier experiment, the sales tax rate on new cars is increased by one percentage point. This can be interpreted as a 1% increase in the average price of a new car. The multipliers are contained in Tables B-9 through B-16.

New car sales in the first year are reduced by 1.5%, which indicates a substantial impact elasticity of -1.5. In the long run the elasticity declines to a rather small value of -0.1.

Scrappage initially (in the first year) decreases about 0.34% in response to the lower new car sales caused by the increase in average new car price. In the long run scrappage is reduced by only 0.1 to 0.2%, which is consistent with the small decrease in total sales volume in the long run.

The market segments display a "trading down" response as a consequence of the increase in average new car price. Auto costs have risen but income is unchanged, which results in a decrease in the ratio of income to average capitalized cost per mile. In the model structure this variable accounts for the trading up and down that occurs when either income or auto costs change. In the first year of the one percentage point sales tax increase, subcompacts and compacts each gain 0.1 percentage points in market share while full-size cars lose 0.2 percentage points in market share. These results stay basically the same over the longer term, with small cars gaining a minor amount of market share at the expense of full-size share (12).

The impacts on VMT are essentially zero in both the short and long run, which is consistent with the structure of the model. The small changes shown in Table B-22 are due to a slightly different age distribution of the stock, which is caused by the reduction in total auto scrappage.

To summarize, the principal feature of this multiplier experiment is the response of total new car sales to the increase in average new car price. The impact elasticity is -1.5, and the long run elasticity is -0.1 (13).

In the third multiplier experiment, the real price of gasoline is increased 10% over the sample period 1969-1974. The results are contained in Tables B-17 through B-24.

New car sales in each of the first three years are reduced 2% as a consequence of the 10% increase in gasoline price. Over the long term, new car sales follow a cyclical pattern of slight divergences above and below the baseline path that indicates basically no impact in the long run.

The impact on scrappage in the first three years is quite substantial, with scrappage being reduced by 3.5% to 6.0%. This is caused by the reduction of VMT/stock variable in the equation. The stock is being utilized less, resulting in fewer miles driven by the average used car, thereby decreasing scrappage. In the long run, scrappage oscillates above and below the baseline solution, with a minor reduction occurring in the last few years.

The increase in gasoline price causes a substantial amount of trading down in the market segments. In the first year, subcompacts gain 0.9 percentage points in market share, with compacts increasing by 0.5 points. These initial gains come at the expense of the full-size share, which loses a very significant 1.5 percentage points in market share. Moreover, unlike most of the multipliers in the model, these initial impacts sustain themselves in the long run. In the last year of the simulation period, the subcompacts have increased 1.3 percentage points while compacts have fallen off somewhat with an increase of only 0.1 points. Full-size cars have experienced a 1.4 percentage point decline in market share.

Vehicle miles traveled per family decreases two percentage in the first year of the increase in gasoline price. This initial impact of a 2% reduction also sustains itself over the long term, with the impact in the fifteenth year estimated to be a 2.1% decline.

In summary, the 10% increase in gasoline price reduces total new car sales by 2% initially but has little long-run impact. Vehicle miles traveled per family unit decrease by approximately 2% in both the short run and long run. The market segments experience a significant amount of trading down, with subcompacts gaining 1.3 percentage points in the long run at the expense of the full-size market segment.

In the fourth multiplier experiment, the national unemployment rate is increased one percentage point. The multipliers are contained in Tables B-25 through B-32.

Scrappage decreases by 5.4% in the first year in response to the one percentage point increase in the unemployment rate. In the long run the decrease in scrappage is estimated to be only approximately 1%.

New car sales in the short run decrease slightly (1.0%) due to the concurrent decline in scrappage (recall that new car sales and scrappage are simultaneous and generally move in the same direction). In the long run sales volume declines by only approximately .5%.

The market segments, except for some very minor fluctuations, are not affected by the increase in the unemployment rate. This is not surprising since the unemployment rate only appears in the scrappage equation in the model (i.e., it does not appear as a right-hand variable in any of the desired stock share equations).

There is a marginal reduction in VMT per family in the long run due to the decrease in scrappage; as scrappage declines, more older cars stay on the road, but they tend to be driven less than newer cars, ceteris paribus.

In summary, the major impact of an increase in the unemployment rate is a substantial first-year decrease in automobile scrappage of 5.4%. All other effects on the eight key time series variables are quite small.

In the fifth multiplier experiment, the cost of automobile insurance is increased 10%. The results are reported in Tables B-33 through B-40.

The outstanding feature of this experiment is the insensitivity of the model to the increase in insurance costs. This model insensitivity was expected, based on the submodel results for the capitalized cost per mile (CPM) variables in Section 4.3.3. Increases in insurance costs in the submodel experiments cause only minor increases in the CPM variables. Since the CPM variables change very little, the impacts on sales volume, scrappage, market shares, and VMT are also quite small.

New car sales volume initially drops by 0.5%, with the long-run decline being something on the order of 0.1% to 0.2%.

Scrappage displays an interesting pattern. In the first two years scrappage actually increases slightly, which means that new car sales and scrappage are moving in opposite directions for these two years (14). In the long run, scrappage behaves in a manner similar to new car sales, with a decrease of about 0.2%.

The 10% increase in auto insurance has virtually no impact on market share new car sales. Depending on what year or years one looks at, there may be some very minor "trading down" taking place (gains and losses of 0.1 percentage points in market share), but these effects are very small and generally are not maintained for very long.

For VMT, there is a long-run decrease of approximately 0.2% that is caused by the decrease in scrappage; this implies an older stock of cars on the road, other things being equal.

In the sixth experiment automobile repair costs are increased 10%. The results are presented in Tables B-41 to B-48.

Again, the principal feature of the results is the relative insensitivity of the model to the increase in repair costs. The average capitalized cost per mile variable rises by 1.2% as a result of the 10% increase in repair costs. This rise in average capitalized cost per mile then implies the following changes for the eight time series variables of interest.

New car sales decrease 0.8% in the first year, with the long-run decline being only 0.1 to 0.2%.

As was the case with an increase in insurance costs, scrappage initially rises but then reverses itself and is reduced by a small amount over the long term.

The market segments again demonstrate a "trading down" response to the increase in repair costs. In both the short term and the long run, subcompact and compact cars each gain approximately 0.2 percentage points in market share, with full-size cars losing 0.4 percentage points in share.

The impacts on VMT are quite trivial. VMT declines by 0.2% in the long run due to the decrease in scrappage that implies an older average age of car stock.

In the seventh multiplier experiment, the costs of producing an automobile are increasing by 10%. The multipliers are contained in Tables B-49 to B-56.

Considering first the impact on average new car base purchase price, the first-year base purchase prices are estimated to increase by 14.3% as a result of the 10% rise in input costs. This nonproportional increase is the sum of two factors--a "normal" or proportional elasticity of approximately 1.0 and an "expectations effect" elasticity of 0.4. (The reader should recall the discussion of the specification of the average base purchase price equation in Section 3.2.1.) In the second and following years, the price expectations effect, of the increase in production costs has no effect and the long-run change in new car price is essentially proportional to the change in input costs.

Options prices increase by less than the 10% increase in input costs, with both the short- and long-run changes being identical at 7.5%.

New car sales are reduced sharply in the first year, with a 1.3 million drop in total unit volume that corresponds to a 14.6% decline. In the long run the large initial drop in sales volume is reduced considerably, and sales fall by only approximately 1.5%.

In the short run (first year) scrappage decreases by 3.3% due to the concurrent drop in sales volume. Scrappage over the long term shows a minor reduction of about 1% as a result of the 10% rise in auto production costs.

A substantial amount of "trading down" occurs in the market segments because of the increase in average new car price. Automobile ownership costs rise but income is unchanged, resulting in an increase in auto costs relative to income. In the first year, subcompacts are estimated to gain 7.5 percentage points in market share, compacts lose 3.0 percentage points, and full-size are off 4.5

percentage points. These are, quite obviously, very sizable redistribution effects in terms of the composition of new car sales volume. In the long run the principal gainers and losers of market share are again subcompact (up 1.5 percentage points), compact (up 0.5 percentage points), and full-size cars (down 2.0 percentage points). The reader should recall that these redistribution effects are caused primarily by the variable that measures income relative to average capitalized cost per mile of automobile travel. This variable appears in all the desired stock share equations except for the luxury segment.

VMT per family displays a rather unusual pattern. It decreases 1% to 2% in the short run. This is probably caused by the concurrent decrease in scrappage that increases the average age of the auto stock (15). Over the longer term, the decrease reverses itself and VMT per family actually increases by a small amount (less than 1%).

In summary, the main features of the 10% increase in auto production costs are: (1) the sharp drop in auto sales volume in the first year (14.6%); (2) the substantial amount of "trading down" in the market segments in both the short term and long run, with subcompacts generally gaining at the expense of full-size cars; and (3) the first-year increase in average base purchase price of 14.3% due to a cost-price expectations effect in the equation explaining average base purchase price.

In the eighth experiment, the number of licensed drivers in the United States is increased 1%. The results are contained in Tables B-57 to B-64.

In the first year, new car sales increase 1.4% as a result of the 1% rise in the number of licensed drivers. The total desired stock per family increases in response to the increase in licensed drivers, which then through the stock adjustment process implies a gain in new car sales. The short-run increase in sales volume quickly declines, and in the long run sales are up by only 0.5%.

The impact on scrappage is minimal, with scrappage estimated to rise by approximately 0.5% in the long term.

New car sales by market segment are virtually unchanged by the 1% increase in the number of licensed drivers.

Finally, VMT per family experiences a slight increase in the long run (0.4%), which is probably caused by the increase in scrappage that implies a "newer" auto stock on the road.

To summarize, the major impact on the model of a 1% increase in the number of licensed drivers is a fairly sharp (1.4%) rise in new car sales in the first year.

In the final experiment, the effects of a 1% increase in the number of individuals aged twenty to twenty-nine years are examined. The results are contained in Tables B-65 through B-72.

Examination of the multiplier results indicates the impacts on the eight time series variables are extremely minor. New car sales, scrappage, and VMT are virtually unaffected by the increase in the twenty to twenty-nine-year-old population. In the market segments there is a very small change in market shares, with subcompacts gaining 0.1% points at the expense of full-size cars.

This multiplier experiment clearly indicates that the model is highly insensitive to changes of this type in the age distribution of the population.

5.4 Summary - Full Model Evaluation

The behavior of the full model is studied by using simulation experiments over the period 1960-1974.

The first simulation experiment is intended to study the forecasting accuracy of the model over the sample period 1960-1974. On the basis of root mean squared error statistics and Calcomp plots, HSRI authors concluded that **the model predicts the trends in new car sales, scrappage, and vehicle miles traveled fairly accurately, but that the actual levels of these variables are not forecast with much precision. For new car sales by market class, the results clearly show that the model produces highly inaccurate forecasts of these variables.** In fact, the forecasting accuracy of the Wharton EFA auto model was compared to that of a naive alternative model using sample means, and, on a root mean squared error basis, the naive model outperforms the Wharton EFA model for all five market classes. Indeed, for four of the market classes (subcompact, compact, mid-size, and full-size) the differences are quite substantial, with the RMSE of the naive model being on the order of four to eight percentage points lower.

The second and third experiments study the forecasting behavior of the model over the first and second halves of the full sample period (1960-1967 and 1968-1974 respectively). In general, **the model, with the exception of scrappage, does a better job of tracking the historical record over the second half (1968-1974) of the full sample period than the first half.** This is to be expected, given the fact that the desired stock and desired share equations were estimated with cross-section data for the years 1971 and 1972. **It was also found that the model grossly overpredicts VMT per family during the first half of the full sample period, and it fails to predict scrappage with any reasonable accuracy during the second half.**

The final experiment was designed to study the tendency of the model, if any, to accumulate forecasting errors as the length of the forecasting horizon is increased. **It was found that vehicle miles of travel and scrappage display a tendency to accumulate errors as the length of the forecasting horizon is increased, while new car sales and the five market classes exhibit no tendency toward error accumulation.**

In general, of the eight key dependent variables of the model, **only new car sales is predicted with any reasonable accuracy** (SIML R-SQ of 25% or higher) in all the experiments performed. **In no experiment is any of the new car market shares predicted with any accuracy, and the scrappage predictions are very poor in several of the experiments.** In terms of predicting trends, **the model is able to track trends in new car sales, scrappage, and VMT per family, but it is unable to do the same for new car market shares.**

The dynamic properties of the full model are analyzed using multiplier experiments. A multiplier experiment involves changing one or more exogenous variables to determine the impact on the endogenous variables of the model. The following nine multiplier experiments were conducted:

1. One percent increase in nominal personal income
2. One percentage point increase in the sales tax rate on new cars
3. Ten percent increase in gasoline price
4. One percentage point increase in the unemployment rate
5. Ten percent increase in the insurance cost index
6. Ten percent increase in the repair cost index
7. Ten percent increase in the production input cost index
8. One percent increase in the number of licensed drivers
9. One percent increase in the number of individuals aged twenty to twenty-nine years

In general, the results indicate that the model is rather insensitive to changes in the exogenous variables listed above. This is particularly true in the long run, although in some cases there can be a substantial short-run impact that then quickly declines over the long term. The effect of a permanent 1% increase in current dollar income on new car sales provides a good example of this type of behavior. New car sales in the first year experience a substantial increase of approximately 5.2% (470,000 units) as a result of the 1% increase in income. Over the longer term, however, the change in new car sales fluctuates between very small positive and negative values; for practical purposes, this behavior implies a long-run income elasticity of zero. It was noted that this result is totally inconsistent with previous work on new car demand.

6.0 SUMMARY OF FINDINGS

The analysis of the Wharton EFA Automobile Demand Model produced the following major findings.

1. The model is large and complex and is designed to forecast the size and composition of long-run U.S. automobile demand (sales) and total stock. While the traditional stock adjustment approach is used, the model nevertheless includes several innovations in modeling automobile demand including, for example, separate equations for the desired shares of vehicles by size class, the use of a rate in the new car sales equation, and the inclusion of a desired stock variable as an influence on scrappage.
2. Using a conventional multiple linear regression package and the data supplied by Wharton EFA to the Transportation Systems Center (TSC), it was possible to reconstruct several equations of the model as reported in the model documentation. It was not possible, however, to reconstruct many of them because of poor documentation. The data series used in estimating the equation of the model may have been revised between the times the Wharton EFA authors wrote the model report and the tape of the model was prepared for delivery to TSC.
3. Over the historical period the model can track the trends in such variables as new car sales, scrappage, and vehicle miles of travel fairly well, but it calculates the levels of these variables poorly, with over 10% error in the levels of new car sales and scrappage, and over 5% error in vehicle miles of travel. Both the levels and trends of market shares of new car sales, however, are "forecast" poorly over the historical period. Because of the way in

which the model was constructed, the errors in forecasting will be even worse in using the model to forecast future year values of these variables.

4. The model does not tend to accumulate errors as it is run further into the future in the cases of new car sales and market shares. It does, however, accumulate errors in forecasting vehicle miles of travel and scrappage.
5. The model is insensitive in the long run to changes in income, sales tax rate on new cars, gasoline price, the unemployment rate, and several other economic and demographic variables.

7.0 CONCLUSIONS

Models such as the Wharton EFA Automobile Demand Model generally have two major uses: forecasting and policy analysis. The forecasting application is conceptually straightforward. It simply involves predicting the variables in question with as much accuracy as possible (either in levels or changes). The policy analysis application of the model is more complicated. It consists of using the model to predict the impacts of alternative policies relative either to each other or to some baseline or both. The principal conclusions of this study are organized around these two major uses of the model.

7.1 Forecasting Applications

The short-run forecasting use of the model can be dismissed rather easily. The model is based on annual data and therefore cannot forecast any time period shorter than one year. The structure of the model does not emphasize short-run type variables (e.g., unemployment rate, index of consumer sentiment, transitory income, etc.) and therefore the Wharton EFA Automobile Demand Model should not be used for short-term forecasting (0-2 years).

One of the stated purposes of the model is that of long-run forecasting. In long-run forecasting, one is interested in the ability of the model to track both the basic trends and the levels of the variables. In the Wharton EFA Automobile Demand Model the basic historical trends (1960-1974) in new car registrations, scrappage, and vehicle miles traveled are simulated fairly well. This suggests that if the basic structure of the automobile market remains the same, the model can be expected to forecast the future long-run trends for these three variables with a reasonable degree of accuracy. However, if the basic structure of consumer behavior with respect to automobile buying changes dramatically in the next ten years or so, then there would be no guarantee that the model would closely track the trends in these three variables. Another way of saying this is that, in the absence of a change in structure, the model is satisfactory for predicting changes in new car registrations, scrappage, and VMT, but not satisfactory at predicting their levels.

Critical here is the reliability of the estimated price elasticities in the stock and stock share equations. They are apt to be a weak link that could severely damage the model's credibility in forecasting future long-run trends in registrations, scrappage, VMT, and, of course, sales shares by class.

With respect to new car sales by size class, the model is clearly inadequate at predicting either the historical trends or levels of these five variables (subcompact, compact, mid-size, full-size, and luxury). The model does not understand the basic determinants of new car sales by size class. Thus, the Wharton EFA Automobile Demand Model should never be used to forecast new car sales by size class.

7.2 Policy Analysis Applications

The model is generally quite insensitive in the long run to changes in exogenous variables such as income, new car prices, and operating costs. These dynamic properties of the model have a rather straightforward implication for the use of the model in policy analysis. For example, consider the familiar case of federal regulators proposing policies that increase either the purchase price or the operating costs of a new car. In this example the problem of estimating the price effects on desired stock from cross-section data is directly relevant. The Wharton EFA Automobile Demand Model will reassure the policymaker that such policies will have little or no effect on the new car market in the long run (16).

This makes sense in some cases, but not in others. Small changes in variables such as insurance, maintenance and repair costs, and parking fees are not likely to generate significant long-run impacts on automobile demand since it is generally believed that first purchase price is the primary factor influencing new car sales from the cost side. However, one may reasonably assume that changes in real disposable income in the long run will affect new car sales, but the model predicts that the new car sales rate will remain essentially the same given an increase in income. Even if one were to assume a situation of saturation (i.e., zero growth in the auto fleet), an increase in real disposable income should presumably stimulate sales volume by increasing replacement demand by shortening the length of the average trading cycle. This would result in higher sales volumes throughout the relatively younger auto fleet. Therefore, it must be concluded that the model is not particularly useful in predicting the impact on car sales of public policies that would cause changes in real disposable income or other economic or demographic variables.

7.3 General Conclusions

The Wharton EFA Automobile Demand Model has some positive aspects in that it includes some new and interesting relationships. It is the end result of an extensive research process involving both theory and data analysis. As such, the HSRI authors believe this version of the model is best viewed as an interim product, subject to respecification and reestimation as both knowledge and data expand. In short, the model represents a tentative statement of the interactive logic of automobile demand.

As this report has shown, there are a number of serious problems with the model that may only be addressed by a considerable amount of work on the specification and estimation of the equations. A fundamental weakness of the model involves the price elasticities in the desired share stock and share equations. Desired stock and desired stock shares by vehicle class are critical to the operation of the model either in long-term forecasting or policy analysis. Yet these critical equations are estimated over a 1972 cross-section of state data. The cost of owning and operating a car will vary only minimally across states, and the variation that does exist will not be due to fundamental differences in the price of a car, the level of federal taxes, and so on. In these circumstances, one can have very little confidence in the estimated cost or price elasticities. They simply do not reflect responses to price variations that would be observed over time as the result of changes in policy. In effect, this rules out the possibility of using the model with any confidence in a number of interesting policy simulation experiments. In its present state the model should be used by policy analysts only with extreme caution.

APPENDIX B

TABLES FOR SECTION 5.0

TABLE A-1

NEW CAR SALES AND SCRAPPAGE SUBMODEL
DYNAMIC SIMULATION OF
NEW CAR SALES

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	6.577	6.437	0.140	2.122
1961	5.855	5.969	-0.114	1.946
1962	6.939	6.753	0.186	2.674
1963	7.557	7.053	0.504	6.664
1964	8.065	8.427	-0.362	4.492
1965	9.314	10.042	-0.728	7.819
1966	9.008	9.456	-0.448	4.971
1967	8.357	7.955	0.402	4.806
1968	9.404	8.719	0.685	7.279
1969	9.527	9.107	0.420	4.413
1970	8.460	8.935	-0.475	5.618
1971	9.964	9.961	0.003	0.026
1972	10.608	10.444	0.164	1.542
1973	11.478	11.940	-0.462	4.028
1974	9.286	9.250	0.036	0.382

TABLE A-2

NEW CAR SALES AND SCRAPPAGE SUBMODEL
DYNAMIC SIMULATION OF
SCRAPPAGE

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	4.693	4.303	0.390	8.311
1961	3.976	4.138	-0.162	4.086
1962	4.619	4.636	-0.017	0.359
1963	4.961	5.069	-0.108	2.173
1964	5.342	5.894	-0.552	10.337
1965	6.707	6.458	0.249	3.712
1966	6.994	6.790	0.204	2.912
1967	6.310	5.920	0.390	6.181
1968	6.640	6.437	0.203	3.059
1969	6.982	7.325	-0.343	4.906
1970	6.139	7.160	-1.021	16.631
1971	6.968	6.703	0.265	3.809
1972	7.274	7.118	0.156	2.143
1973	8.393	7.854	0.539	6.420
1974	6.568	6.480	0.088	1.346

TABLE A-3

VMT PER FAMILY SUBMODEL
DYNAMIC SIMULATION OF
VEHICLE MILES TRAVELED PER FAMILY

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	10.421	10.418	0.003	0.026
1961	10.616	10.809	-0.193	1.818
1962	10.810	10.818	-0.008	0.071
1963	11.009	11.232	-0.223	2.028
1964	11.453	11.576	-0.123	1.075
1965	11.740	11.750	-0.010	0.085
1966	12.243	12.187	0.056	0.460
1967	12.433	12.521	-0.088	0.710
1968	12.737	12.855	-0.118	0.925
1969	13.139	13.331	-0.192	1.461
1970	13.452	13.612	-0.160	1.191
1971	13.853	13.562	0.291	2.102
1972	14.113	13.876	0.237	1.681
1973	14.225	13.950	0.275	1.937
1974	13.519	13.504	0.015	0.114

TABLE A-4

NEW CAR SALES, SCRAPPAGE, AND VMT PER FAMILY SUBMODEL
DYNAMIC SIMULATION OF
NEW CAR SALES

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	6.577	6.442	0.135	2.050
1961	5.855	6.027	-0.172	2.943
1962	6.939	6.837	0.102	1.468
1963	7.557	7.104	0.453	5.996
1964	8.065	8.318	-0.253	3.135
1965	9.314	9.879	-0.565	6.063
1966	9.008	9.282	-0.274	3.043
1967	8.357	8.088	0.269	3.222
1968	9.404	9.024	0.380	4.044
1969	9.527	9.280	0.247	2.598
1970	8.460	8.821	-0.361	4.267
1971	9.964	9.581	0.383	3.846
1972	10.608	9.921	0.687	6.475
1973	11.478	11.535	-0.057	0.493
1974	9.286	9.383	-0.097	1.044

TABLE A-5

NEW CAR SALES, SCRAPPAGE, AND VMT PER FAMILY SUBMODEL
DYNAMIC SIMULATION OF
SCRAPPAGE

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	4.693	4.317	0.376	8.022
1961	3.976	4.318	-0.342	8.598
1962	4.619	4.750	-0.131	2.829
1963	4.961	5.054	-0.093	1.878
1964	5.342	5.526	-0.184	3.442
1965	6.707	6.267	0.440	6.560
1966	6.994	6.559	0.435	6.225
1967	6.310	6.565	-0.255	4.035
1968	6.640	7.011	-0.371	5.583
1969	6.982	7.262	-0.280	4.006
1970	6.139	6.531	-0.392	6.387
1971	6.968	5.880	1.088	15.620
1972	7.274	6.349	0.925	12.713
1973	8.393	7.770	0.623	7.429
1974	6.568	7.496	-0.928	14.130

TABLE A-6

NEW CAR SALES, SCRAPPAGE, AND VMT PER FAMILY SUBMODEL
DYNAMIC SIMULATION OF
VEHICLE MILES TRAVELED PER FAMILY

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	10.421	10.436	-0.015	0.140
1961	10.616	10.811	-0.195	1.839
1962	10.810	10.815	-0.005	0.049
1963	11.009	11.173	-0.164	1.491
1964	11.453	11.435	0.018	0.161
1965	11.740	11.709	0.031	0.266
1966	12.243	12.315	-0.072	0.589
1967	12.433	12.688	-0.255	2.053
1968	12.737	12.915	-0.178	1.396
1969	13.139	13.273	-0.134	1.020
1970	13.452	13.495	-0.043	0.318
1971	13.853	13.526	0.327	2.357
1972	14.113	13.855	0.258	1.825
1973	14.225	13.905	0.320	2.250
1974	13.519	13.458	0.061	0.454

TABLE A-7

NEW CAR SALES, SCRAPPAGE, AND DESIRED STOCK PER FAMILY SUBMODEL
DYNAMIC SIMULATION OF
NEW CAR SALES

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	6.577	8.536	-1.959	29.779
1961	5.855	6.518	-0.663	11.322
1962	6.939	6.876	0.063	0.902
1963	7.557	6.829	0.728	9.628
1964	8.065	8.418	-0.353	4.383
1965	9.314	10.594	-1.280	13.743
1966	9.008	10.089	-1.081	12.004
1967	8.357	8.265	0.092	1.095
1968	9.404	8.675	0.729	7.753
1969	9.527	8.685	0.842	8.836
1970	8.460	8.652	-0.192	2.265
1971	9.964	9.775	0.189	1.896
1972	10.608	10.225	0.383	3.611
1973	11.478	11.732	-0.254	2.214
1974	9.286	9.040	0.246	2.649

TABLE A-8

NEW CAR SALES, SCRAPPAGE, AND DESIRED STOCK PER FAMILY SUBMODEL
DYNAMIC SIMULATION OF
DESIRED STOCK PER FAMILY

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	1.071	1.170	-0.099	9.223
1961	1.090	1.175	-0.085	7.787
1962	1.098	1.181	-0.083	7.558
1963	1.129	1.199	-0.070	6.207
1964	1.163	1.224	-0.061	5.244
1965	1.188	1.239	-0.051	4.303
1966	1.220	1.256	-0.036	2.974
1967	1.238	1.261	-0.023	1.879
1968	1.238	1.244	-0.006	0.449
1969	1.245	1.230	0.015	1.234
1970	1.250	1.230	0.020	1.594
1971	1.260	1.238	0.022	1.714
1972	1.261	1.236	0.025	1.983
1973	1.273	1.249	0.024	1.908
1974	1.256	1.231	0.025	1.977

TABLE A-9

NEW CAR SALES, SCRAPPAGE, DESIRED STOCK PER FAMILY, AND VMT PER FAMILY SUBMODEL
DYNAMIC SIMULATION OF
NEW CAR SALES

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	6.577	8.602	-2.025	30.790
1961	5.855	6.784	-0.929	15.864
1962	6.939	7.439	-0.500	7.199
1963	7.557	7.398	0.159	2.107
1964	8.065	8.440	-0.375	4.647
1965	9.314	9.866	-0.552	5.929
1966	9.008	9.086	-0.078	0.866
1967	8.357	7.844	0.513	6.142
1968	9.404	8.571	0.833	8.863
1969	9.527	8.667	0.860	9.027
1970	8.460	8.460	0.000	0.004
1971	9.964	9.335	0.629	6.317
1972	10.608	9.706	0.902	8.507
1973	11.478	11.459	0.019	0.161
1974	9.286	9.320	-0.034	0.362

TABLE A-10

NEW CAR SALES, SCRAPPAGE, DESIRED STOCK PER FAMILY, AND VMT PER FAMILY SUBMODEL
DYNAMIC SIMULATION OF
SCRAPPAGE

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	4.693	3.466	1.227	26.140
1961	3.976	4.023	-0.047	1.189
1962	4.619	4.883	-0.264	5.714
1963	4.961	5.620	-0.659	13.285
1964	5.342	5.902	-0.560	10.482
1965	6.707	6.674	0.033	0.498
1966	6.994	7.037	-0.043	0.613
1967	6.310	7.014	-0.704	11.165
1968	6.640	7.545	-0.905	13.628
1969	6.982	7.961	-0.979	14.020
1970	6.139	6.940	-0.801	13.049
1971	6.968	6.082	0.886	12.720
1972	7.274	6.548	0.726	9.974
1973	8.393	7.948	0.445	5.298
1974	6.568	7.588	-1.020	15.532

TABLE A-11

NEW CAR SALES, SCRAPPAGE, DESIRED STOCK PER FAMILY AND VMT PER FAMILY SUBMODEL
DYNAMIC SIMULATION OF
VEHICLE MILES TRAVELED PER FAMILY

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	10.421	10.625	-0.204	1.962
1961	10.616	11.517	-0.901	8.488
1962	10.810	11.682	-0.872	8.063
1963	11.009	12.081	-1.072	9.737
1964	11.453	12.298	-0.845	7.377
1965	11.740	12.467	-0.727	6.197
1966	12.243	12.942	-0.699	5.708
1967	12.433	13.135	-0.702	5.644
1968	12.737	13.177	-0.440	3.456
1969	13.139	13.305	-0.166	1.267
1970	13.452	13.312	0.140	1.040
1971	13.853	13.232	0.621	4.483
1972	14.113	13.506	0.607	4.304
1973	14.225	13.533	0.692	4.865
1974	13.519	13.114	0.405	2.994

TABLE A-12

NEW CAR SALES, SCRAPPAGE, DESIRED STOCK PER FAMILY AND VMT PER FAMILY SUBMODEL
DYNAMIC SIMULATION OF
DESIRED STOCK PER FAMILY

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	1.071	1.170	-0.099	9.223
1961	1.090	1.175	-0.085	7.787
1962	1.098	1.181	-0.083	7.558
1963	1.129	1.199	-0.070	6.207
1964	1.163	1.224	-0.061	5.244
1965	1.188	1.239	-0.051	4.303
1966	1.220	1.256	-0.036	2.974
1967	1.238	1.261	-0.023	1.879
1968	1.238	1.244	-0.006	0.449
1969	1.245	1.230	0.015	1.234
1970	1.250	1.230	0.020	1.594
1971	1.260	1.238	0.022	1.714
1972	1.261	1.236	0.025	1.983
1973	1.273	1.249	0.024	1.908
1974	1.256	1.231	0.025	1.977

TABLE A-13

NEW CAR SHARES BY SIZE CLASS SUBMODEL
DYNAMIC SIMULATION OF
SUBCOMPACT CLASS NEW CAR MARKET SHARE

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	0.117	0.111	0.006	5.523
1961	0.132	0.131	0.001	0.905
1962	0.101	0.098	0.003	2.552
1963	0.092	0.092	0.000	0.443
1964	0.078	0.078	-0.000	0.509
1965	0.078	0.078	-0.000	0.236
1966	0.075	0.078	-0.003	4.342
1967	0.085	0.087	-0.002	2.213
1968	0.095	0.098	-0.003	3.091
1969	0.102	0.103	-0.001	1.246
1970	0.148	0.146	0.002	1.258
1971	0.209	0.208	0.001	0.576
1972	0.210	0.211	-0.001	0.428
1973	0.230	0.230	0.000	0.053
1974	0.257	0.251	0.006	2.153

TABLE A-14

NEW CAR SHARES BY SIZE CLASS SUBMODEL
DYNAMIC SIMULATION OF
COMPACT CLASS NEW CAR MARKET SHARE

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	0.167	0.181	-0.014	8.418
1961	0.173	0.169	0.004	2.451
1962	0.188	0.183	0.005	2.606
1963	0.140	0.136	0.004	2.586
1964	0.160	0.156	0.004	2.449
1965	0.145	0.147	-0.002	1.307
1966	0.149	0.152	-0.003	1.703
1967	0.173	0.173	-0.000	0.215
1968	0.159	0.163	-0.004	2.462
1969	0.180	0.182	-0.002	1.291
1970	0.212	0.209	0.003	1.238
1971	0.167	0.166	0.001	0.550
1972	0.162	0.163	-0.001	0.753
1973	0.184	0.183	0.001	0.489
1974	0.187	0.185	0.002	0.936

TABLE A-15

NEW CAR SHARES BY SIZE CLASS SUBMODEL
DYNAMIC SIMULATION OF
MID-SIZE CLASS NEW CAR MARKET SHARE

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	0.373	0.369	0.004	1.183
1961	0.335	0.339	-0.004	1.282
1962	0.307	0.312	-0.005	1.593
1963	0.292	0.292	0.000	0.003
1964	0.250	0.252	-0.002	0.938
1965	0.216	0.216	-0.000	0.126
1966	0.241	0.238	0.003	1.055
1967	0.214	0.216	-0.002	0.707
1968	0.242	0.239	0.003	1.167
1969	0.217	0.217	-0.000	0.011
1970	0.214	0.215	-0.001	0.547
1971	0.192	0.193	-0.001	0.665
1972	0.209	0.208	0.001	0.626
1973	0.218	0.218	-0.000	0.062
1974	0.260	0.259	0.001	0.229

TABLE A-16

NEW CAR SHARES BY SIZE CLASS SUBMODEL
DYNAMIC SIMULATION OF
FULL-SIZE CLASS NEW CAR MARKET SHARE

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	0.273	0.270	0.003	1.084
1961	0.285	0.286	-0.001	0.431
1962	0.331	0.333	-0.002	0.645
1963	0.406	0.409	-0.003	0.669
1964	0.443	0.445	-0.002	0.487
1965	0.488	0.487	0.001	0.234
1966	0.456	0.453	0.003	0.553
1967	0.442	0.438	0.004	0.893
1968	0.418	0.416	0.002	0.594
1969	0.407	0.405	0.002	0.439
1970	0.349	0.351	-0.002	0.504
1971	0.338	0.339	-0.001	0.233
1972	0.321	0.321	0.000	0.005
1973	0.274	0.274	0.000	0.061
1974	0.211	0.218	-0.007	3.340

TABLE A-17

NEW CAR SHARES BY SIZE CLASS SUBMODEL
DYNAMIC SIMULATIONS OF
LUXURY CLASS NEW CAR MARKET SHARE

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	0.070	0.070	0.000	0.321
1961	0.075	0.075	0.000	0.120
1962	0.073	0.073	-0.000	0.619
1963	0.070	0.071	-0.001	1.889
1964	0.069	0.068	0.001	1.422
1965	0.074	0.072	0.002	2.989
1966	0.078	0.078	-0.000	0.344
1967	0.086	0.086	-0.000	0.211
1968	0.085	0.084	0.001	0.640
1969	0.093	0.092	0.001	0.892
1970	0.077	0.079	-0.002	2.020
1971	0.094	0.094	-0.000	0.061
1972	0.097	0.097	-0.000	0.215
1973	0.095	0.095	-0.000	0.055
1974	0.085	0.086	-0.001	0.976

TABLE A-18

NEW CAR MARKET SHARES AND DESIRED STOCK SHARES OF MID-SIZE, FULL-SIZE
AND LUXURY CARS SUBMODEL
DYNAMIC SIMULATION OF
SUBCOMPACT CLASS NEW CAR MARKET SHARE

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	0.117	0.099	0.018	15.314
1961	0.132	0.120	0.012	9.251
1962	0.101	0.093	0.008	7.727
1963	0.092	0.089	0.003	2.978
1964	0.078	0.078	-0.000	0.217
1965	0.078	0.079	-0.001	1.867
1966	0.075	0.079	-0.004	5.802
1967	0.085	0.088	-0.003	3.842
1968	0.095	0.099	-0.004	3.841
1969	0.102	0.103	-0.001	1.349
1970	0.148	0.146	0.002	1.388
1971	0.209	0.207	0.002	0.909
1972	0.210	0.210	0.000	0.108
1973	0.230	0.230	-0.000	0.072
1974	0.257	0.254	0.003	1.356

TABLE A-19

NEW CAR MARKET SHARES AND DESIRED STOCK SHARES OF MID-SIZE, FULL-SIZE AND LUXURY CARS SUBMODEL
DYNAMIC SIMULATION OF
COMPACT CLASS NEW CAR MARKET SHARE

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	0.167	0.162	0.005	2.825
1961	0.173	0.157	0.016	9.243
1962	0.188	0.175	0.013	6.888
1963	0.140	0.134	0.006	4.583
1964	0.160	0.156	0.004	2.476
1965	0.145	0.149	-0.004	2.904
1966	0.149	0.153	-0.004	2.883
1967	0.173	0.176	-0.003	1.499
1968	0.159	0.164	-0.005	2.865
1969	0.180	0.182	-0.002	1.134
1970	0.212	0.209	0.003	1.549
1971	0.167	0.165	0.002	0.981
1972	0.162	0.162	-0.000	0.177
1973	0.184	0.183	0.001	0.398
1974	0.187	0.187	0.000	0.134

TABLE A-20

NEW CAR MARKET SHARES AND DESIRED STOCK SHARES OF MID-SIZE, FULL-SIZE AND LUXURY CLASS SUBMODEL
DYNAMIC SIMULATION OF
MID-SIZE CLASS NEW CAR MARKET SHARE

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	0.373	0.077	0.296	79.403
1961	0.335	0.084	0.251	74.856
1962	0.307	0.103	0.204	66.610
1963	0.292	0.114	0.178	60.922
1964	0.250	0.133	0.117	46.679
1965	0.216	0.163	0.053	24.533
1966	0.241	0.181	0.060	25.022
1967	0.214	0.201	0.013	6.272
1968	0.242	0.214	0.028	11.732
1969	0.217	0.236	-0.019	8.667
1970	0.214	0.224	-0.010	4.775
1971	0.192	0.225	-0.033	17.136
1972	0.209	0.227	-0.018	8.661
1973	0.218	0.190	0.028	12.832
1974	0.260	0.172	0.088	33.947

TABLE A-21

NEW CAR MARKET SHARES AND DESIRED STOCK SHARES OF MID-SIZE, FULL-SIZE AND LUXURY CARS SUBMODEL
FULL-SIZE CLASS NEW CAR MARKET SHARE

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	0.273	0.578	-0.305	111.585
1961	0.285	0.557	-0.272	95.524
1962	0.331	0.548	-0.217	65.506
1963	0.406	0.580	-0.174	42.889
1964	0.443	0.553	-0.110	24.721
1965	0.488	0.524	-0.036	7.342
1966	0.456	0.500	-0.044	9.706
1967	0.442	0.446	-0.004	1.010
1968	0.418	0.429	-0.011	2.608
1969	0.407	0.377	0.030	7.261
1970	0.349	0.321	0.028	7.944
1971	0.338	0.298	0.040	11.961
1972	0.321	0.296	0.025	7.943
1973	0.274	0.301	-0.027	9.917
1974	0.211	0.307	-0.096	45.415

TABLE A-22

NEW CAR MARKET SHARES AND DESIRED STOCK SHARES OF MID-SIZE, FULL-SIZE AND LUXURY CARS SUBMODEL
LUXURY CLASS NEW CAR MARKET SHARE

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	0.070	0.084	-0.014	20.261
1961	0.075	0.082	-0.007	8.970
1962	0.073	0.081	-0.008	11.534
1963	0.070	0.083	-0.013	18.456
1964	0.069	0.080	-0.011	15.912
1965	0.074	0.084	-0.010	14.184
1966	0.078	0.086	-0.008	10.763
1967	0.086	0.089	-0.003	3.601
1968	0.085	0.095	-0.010	12.100
1969	0.093	0.101	-0.008	8.956
1970	0.077	0.100	-0.023	29.668
1971	0.094	0.105	-0.011	11.773
1972	0.097	0.105	-0.008	8.594
1973	0.095	0.095	-0.000	0.387
1974	0.085	0.081	0.004	4.501

TABLE A-23

DESIRED SHARES, DESIRED STOCK PER FAMILY, NEW CAR SALES, SCRAPPAGE, AND VMT PER FAMILY SUBMODEL
DYNAMIC SIMULATION OF
DESIRED STOCK PER FAMILY

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	1.071	1.170	-0.099	9.209
1961	1.090	1.173	-0.083	7.588
1962	1.098	1.179	-0.081	7.335
1963	1.129	1.199	-0.070	6.157
1964	1.163	1.224	-0.061	5.209
1965	1.188	1.241	-0.053	4.501
1966	1.220	1.260	-0.040	3.243
1967	1.238	1.270	-0.032	2.549
1968	1.238	1.254	-0.016	1.277
1969	1.245	1.239	0.006	0.511
1970	1.250	1.235	0.015	1.191
1971	1.260	1.248	0.012	0.985
1972	1.261	1.241	0.020	1.597
1973	1.273	1.248	0.025	1.995
1974	1.256	1.226	0.030	2.415

TABLE A-24

DESIRED SHARES, DESIRED STOCK PER FAMILY, NEW CAR SALES, SCRAPPAGE, AND VMT PER FAMILY SUBMODEL
DYNAMIC SIMULATION OF
NEW CAR SALES

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	6.577	8.598	-2.021	30.733
1961	5.855	6.744	-0.889	15.186
1962	6.939	7.407	-0.468	6.745
1963	7.557	7.413	0.144	1.901
1964	8.065	8.448	-0.383	4.745
1965	9.314	9.936	-0.622	6.677
1966	9.008	9.139	-0.131	1.455
1967	8.357	7.969	0.388	4.649
1968	9.404	8.703	0.701	7.451
1969	9.527	8.737	0.790	8.293
1970	8.460	8.441	0.019	0.221
1971	9.964	9.445	0.519	5.212
1972	10.608	9.682	0.926	8.730
1973	11.478	11.298	0.180	1.570
1974	9.286	9.164	0.122	1.310

TABLE A-25

DESIRED SHARES, DESIRED STOCK PER FAMILY, NEW CAR SALES, SCRAPPAGE, AND VMT PER FAMILY SUBMODEL
DYNAMIC SIMULATION OF
SCRAPPAGE

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	4.693	3.467	1.226	26.118
1961	3.976	4.042	-0.066	1.661
1962	4.619	4.896	-0.277	6.007
1963	4.961	5.596	-0.635	12.809
1964	5.342	5.881	-0.539	10.097
1965	6.707	6.629	0.078	1.164
1966	6.994	7.013	-0.019	0.275
1967	6.310	6.940	-0.630	9.984
1968	6.640	7.501	-0.861	12.970
1969	6.982	7.993	-1.011	14.482
1970	6.139	7.050	-0.911	14.835
1971	6.968	6.084	0.884	12.682
1972	7.274	6.613	0.661	9.086
1973	8.393	8.098	0.295	3.517
1974	6.568	7.738	-1.170	17.813

TABLE A-26

DESIRED SHARES, DESIRED STOCK PER FAMILY, NEW CAR SALES, SCRAPPAGE, AND VMT PER FAMILY SUBMODEL
DYNAMIC SIMULATION OF
VEHICLE MILES TRAVELED PER FAMILY

YEAR	ACTUAL	SIMULATION	ERROR	% DIFF
1960	10.421	10.625	-0.204	1.959
1961	10.616	11.512	-0.896	8.443
1962	10.810	11.666	-0.856	7.918
1963	11.009	12.061	-1.052	9.560
1964	11.453	12.285	-0.832	7.267
1965	11.740	12.465	-0.725	6.179
1966	12.243	12.959	-0.716	5.849
1967	12.433	13.174	-0.741	5.961
1968	12.737	13.251	-0.514	4.034
1969	13.139	13.404	-0.265	2.019
1970	13.452	13.408	0.044	0.326
1971	13.853	13.318	0.535	3.863
1972	14.113	13.597	0.516	3.657
1973	14.225	13.592	0.633	4.449
1974	13.519	13.117	0.402	2.977

TABLE A-27

NEW CAR SALES AND SCRAPPAGE SUBMODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN DESIRED STOCK PER FAMILY
NEW CAR SALES

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	6.437	6.639	0.201	3.128
1961	5.969	6.057	0.088	1.470
1962	6.753	6.784	0.031	0.453
1963	7.053	7.065	0.011	0.158
1964	8.427	8.470	0.043	0.511
1965	10.042	10.152	0.110	1.092
1966	9.456	9.591	0.135	1.428
1967	7.955	8.064	0.109	1.369
1968	8.719	8.823	0.104	1.191
1969	9.107	9.194	0.087	0.958
1970	8.935	9.010	0.075	0.841
1971	9.961	10.046	0.084	0.847
1972	10.444	10.540	0.096	0.917
1973	11.940	12.060	0.119	0.998
1974	9.250	9.346	0.095	1.032

TABLE A-28

NEW CAR SALES AND SCRAPPAGE SUBMODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN DESIRED STOCK PER FAMILY
SCRAPPAGE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	4.303	4.174	-0.129	2.994
1961	4.138	4.018	-0.120	2.901
1962	4.636	4.510	-0.125	2.702
1963	5.069	5.018	-0.050	0.993
1964	5.894	5.965	0.070	1.195
1965	6.458	6.604	0.146	2.254
1966	6.790	6.945	0.154	2.274
1967	5.920	6.011	0.091	1.534
1968	6.437	6.489	0.052	0.813
1969	7.325	7.357	0.033	0.444
1970	7.160	7.197	0.037	0.521
1971	6.703	6.755	0.053	0.790
1972	7.118	7.192	0.074	1.040
1973	7.854	7.946	0.092	1.172
1974	6.480	6.554	0.075	1.152

TABLE A-29

NEW CAR SALES AND SCRAPPAGE SUBMODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN VMT PER FAMILY
SCRAPPAGE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	4.303	4.401	0.098	2.272
1961	4.138	4.287	0.148	3.580
1962	4.636	4.727	0.091	1.961
1963	5.069	4.950	-0.119	2.343
1964	5.894	5.764	-0.130	2.209
1965	6.458	6.349	-0.109	1.688
1966	6.790	6.769	-0.021	0.313
1967	5.920	5.962	0.042	0.711
1968	6.437	6.495	0.058	0.903
1969	7.325	7.370	0.046	0.626
1970	7.160	7.171	0.011	0.152
1971	6.703	6.692	-0.011	0.164
1972	7.118	7.098	-0.020	0.277
1973	7.854	7.837	-0.017	0.222
1974	6.480	6.474	-0.005	0.083

TABLE A-30

NEW CAR SALES AND SCRAPPAGE SUBMODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN UNEMPLOYMENT RATE
SCRAPPAGE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	4.303	4.065	-0.238	5.527
1961	4.138	4.011	-0.127	3.068
1962	4.636	4.479	-0.156	3.370
1963	5.069	4.975	-0.094	1.852
1964	5.894	5.824	-0.070	1.183
1965	6.458	6.372	-0.086	1.339
1966	6.790	6.661	-0.129	1.904
1967	5.920	5.830	-0.090	1.515
1968	6.437	6.299	-0.138	2.143
1969	7.325	7.159	-0.166	2.267
1970	7.160	7.183	0.023	0.319
1971	6.703	6.743	0.040	0.596
1972	7.118	7.080	-0.038	0.533
1973	7.854	7.689	-0.165	2.104
1974	6.480	6.379	-0.101	1.555

TABLE A-31

NEW CAR SALES AND SCRAPPAGE SUBMODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN UNEMPLOYMENT RATE
NEW CAR SALES

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	6.437	6.356	-0.082	1.271
1961	5.969	5.883	-0.086	1.447
1962	6.753	6.635	-0.119	1.757
1963	7.053	6.942	-0.112	1.586
1964	8.427	8.313	-0.114	1.359
1965	10.042	9.923	-0.119	1.188
1966	9.456	9.345	-0.111	1.169
1967	7.955	7.874	-0.081	1.024
1968	8.719	8.612	-0.107	1.227
1969	9.107	8.976	-0.131	1.435
1970	8.935	8.863	-0.072	0.808
1971	9.961	9.925	-0.036	0.365
1972	10.444	10.407	-0.037	0.358
1973	11.940	11.846	-0.094	0.791
1974	9.250	9.180	-0.070	0.761

TABLE A-32

NEW CAR SALES AND SCRAPPAGE SUBMODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN NEW CAR PRICE
NEW CAR SALES

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	6.437	6.364	-0.073	1.138
1961	5.969	5.988	0.019	0.323
1962	6.753	6.770	0.017	0.252
1963	7.053	7.060	0.007	0.099
1964	8.427	8.424	-0.003	0.038
1965	10.042	10.033	-0.010	0.096
1966	9.456	9.451	-0.004	0.047
1967	7.955	7.956	0.000	0.002
1968	8.719	8.722	0.002	0.025
1969	9.107	9.110	0.004	0.040
1970	8.935	8.936	0.001	0.007
1971	9.961	9.957	-0.004	0.041
1972	10.444	10.443	-0.002	0.015
1973	11.940	11.936	-0.004	0.035
1974	9.250	9.248	-0.002	0.025

TABLE A-33

NEW CAR SALES AND SCRAPPAGE SUBMODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN NEW CAR PRICE
SCRAPPAGE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	4.303	4.288	-0.015	0.347
1961	4.138	4.146	0.007	0.171
1962	4.636	4.639	0.004	0.078
1963	5.069	5.055	-0.014	0.280
1964	5.894	5.870	-0.024	0.402
1965	6.458	6.444	-0.014	0.222
1966	6.790	6.789	-0.002	0.024
1967	5.920	5.926	0.006	0.107
1968	6.437	6.446	0.009	0.136
1969	7.325	7.329	0.004	0.055
1970	7.160	7.157	-0.003	0.036
1971	6.703	6.697	-0.006	0.086
1972	7.118	7.113	-0.005	0.076
1973	7.854	7.850	-0.004	0.056
1974	6.480	6.478	-0.002	0.023

TABLE A-34

NEW CAR SALES, SCRAPPAGE, DESIRED STOCK PER FAMILY,
AND VMT PER FAMILY SUBMODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN NEW CAR PRICE
NEW CAR SALES

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	9.092	8.950	-0.143	1.567
1961	6.891	6.912	0.021	0.311
1962	7.447	7.456	0.008	0.113
1963	7.388	7.388	-0.000	0.000
1964	8.423	8.428	0.006	0.067
1965	9.870	9.876	0.006	0.057
1966	9.122	9.123	0.002	0.017
1967	7.890	7.889	-0.001	0.014
1968	8.633	8.629	-0.004	0.043
1969	8.745	8.736	-0.008	0.094
1970	8.536	8.525	-0.010	0.121
1971	9.421	9.408	-0.012	0.128
1972	9.808	9.794	-0.013	0.137
1973	11.567	11.551	-0.016	0.139
1974	9.410	9.400	-0.010	0.106

TABLE A-35

NEW CAR SALES, SCRAPPAGE, DESIRED STOCK PER FAMILY
AND VMT PER FAMILY SUBMODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN NEW CAR PRICE
DESIRED STOCK PER FAMILY

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	1.173	1.172	-0.001	0.086
1961	1.181	1.180	-0.001	0.086
1962	1.189	1.188	-0.001	0.087
1963	1.208	1.207	-0.001	0.087
1964	1.233	1.232	-0.001	0.086
1965	1.248	1.247	-0.001	0.085
1966	1.265	1.264	-0.001	0.085
1967	1.270	1.269	-0.001	0.084
1968	1.252	1.251	-0.001	0.086
1969	1.239	1.238	-0.001	0.085
1970	1.239	1.238	-0.001	0.084
1971	1.248	1.247	-0.001	0.084
1972	1.245	1.244	-0.001	0.082
1973	1.258	1.257	-0.001	0.082
1974	1.241	1.240	-0.001	0.079

TABLE A-36

NEW CAR SALES, SCRAPPAGE, DESIRED STOCK PER FAMILY
AND VMT PER FAMILY SUBMODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN NEW CAR PRICE
VEHICLE MILES TRAVELED PER FAMILY

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	10.629	10.621	-0.008	0.076
1961	11.597	11.564	-0.032	0.279
1962	11.768	11.742	-0.026	0.221
1963	12.150	12.129	-0.020	0.167
1964	12.354	12.335	-0.019	0.155
1965	12.507	12.490	-0.016	0.131
1966	12.966	12.952	-0.013	0.104
1967	13.146	13.136	-0.010	0.077
1968	13.183	13.174	-0.009	0.065
1969	13.308	13.300	-0.007	0.055
1970	13.314	13.307	-0.007	0.051
1971	13.236	13.229	-0.007	0.055
1972	13.515	13.506	-0.009	0.065
1973	13.549	13.539	-0.010	0.075
1974	13.134	13.123	-0.011	0.084

TABLE A-37

NEW CAR SALES, SCRAPPAGE, DESIRED STOCK PER FAMILY
AND VMT PER FAMILY SUBMODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN PERSONAL INCOME
NEW CAR SALES

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	8.733	9.192	0.459	5.257
1961	7.026	7.097	0.071	1.005
1962	7.484	7.452	-0.031	0.420
1963	7.486	7.439	-0.047	0.630
1964	8.481	8.421	-0.059	0.701
1965	9.848	9.800	-0.048	0.486
1966	9.162	9.129	-0.033	0.356
1967	7.877	7.855	-0.022	0.275
1968	8.621	8.610	-0.011	0.129
1969	8.691	8.699	0.008	0.089
1970	8.284	8.297	0.013	0.160
1971	9.083	9.104	0.021	0.235
1972	9.953	9.992	0.039	0.390
1973	11.317	11.351	0.034	0.301
1974	8.959	8.989	0.030	0.334

TABLE A-38

NEW CAR SALES, SCRAPPAGE, DESIRED STOCK PER FAMILY
AND VMT PER FAMILY SUBMODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN PERSONAL INCOME
DESIRED STOCK PER FAMILY

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	1.176	1.178	0.002	0.148
1961	1.194	1.196	0.002	0.200
1962	1.199	1.201	0.002	0.185
1963	1.221	1.223	0.002	0.129
1964	1.240	1.241	0.001	0.056
1965	1.244	1.245	0.001	0.055
1966	1.252	1.252	0.001	0.056
1967	1.249	1.249	0.001	0.060
1968	1.232	1.233	0.001	0.064
1969	1.225	1.226	0.001	0.067
1970	1.225	1.226	0.001	0.066
1971	1.232	1.233	0.001	0.064
1972	1.249	1.250	0.001	0.065
1973	1.258	1.259	0.001	0.064
1974	1.224	1.225	0.001	0.066

TABLE A-39

NEW CAR SALES, SCRAPPAGE, DESIRED STOCK PER FAMILY
AND VMT PER FAMILY SUBMODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN PERSONAL INCOME
SCRAPPAGE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	3.380	3.419	0.039	1.157
1961	3.702	3.725	0.023	0.615
1962	4.574	4.646	0.071	1.562
1963	5.502	5.612	0.110	2.004
1964	6.243	6.257	0.015	0.237
1965	7.313	7.291	-0.022	0.306
1966	7.952	7.915	-0.037	0.460
1967	7.589	7.558	-0.031	0.406
1968	7.565	7.566	0.001	0.013
1969	7.382	7.417	0.034	0.463
1970	6.410	6.455	0.045	0.707
1971	5.887	5.930	0.043	0.726
1972	6.043	6.085	0.041	0.685
1973	7.442	7.479	0.038	0.506
1974	8.081	8.102	0.021	0.264

TABLE A-40

NEW CAR SALES, SCRAPPAGE, DESIRED STOCK PER FAMILY
AND VMT PER FAMILY SUBMODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN PERSONAL INCOME
VEHICLE MILES TRAVELED PER FAMILY

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	10.575	10.592	0.018	0.167
1961	11.378	11.480	0.102	0.896
1962	11.636	11.748	0.112	0.961
1963	12.019	12.114	0.095	0.793
1964	12.299	12.380	0.082	0.663
1965	12.533	12.594	0.061	0.486
1966	13.026	13.073	0.047	0.362
1967	13.238	13.273	0.035	0.262
1968	13.239	13.265	0.026	0.199
1969	13.312	13.332	0.020	0.152
1970	13.380	13.398	0.018	0.131
1971	13.316	13.334	0.018	0.132
1972	13.342	13.364	0.022	0.167
1973	13.498	13.528	0.030	0.219
1974	13.242	13.277	0.034	0.260

TABLE A-41

NEW CAR SALES, SCRAPPAGE, DESIRED STOCK PER FAMILY
AND VMT PER FAMILY SUBMODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN MPG
DESIRED STOCK PER FAMILY

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	1.170	1.174	0.004	0.384
1961	1.175	1.179	0.004	0.372
1962	1.181	1.185	0.004	0.367
1963	1.199	1.203	0.004	0.360
1964	1.224	1.228	0.004	0.359
1965	1.239	1.244	0.005	0.367
1966	1.256	1.261	0.005	0.370
1967	1.261	1.266	0.005	0.392
1968	1.244	1.248	0.005	0.382
1969	1.230	1.234	0.005	0.377
1970	1.230	1.235	0.004	0.363
1971	1.238	1.243	0.004	0.352
1972	1.236	1.240	0.004	0.359
1973	1.249	1.253	0.005	0.372
1974	1.231	1.237	0.005	0.446

TABLE A-42

NEW CAR SALES, SCRAPPAGE, DESIRED STOCK PER FAMILY
AND VMT PER FAMILY SUBMODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN MPG
NEW CAR SALES

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	8.601	8.716	0.115	1.336
1961	6.784	6.841	0.057	0.841
1962	7.439	7.514	0.075	1.010
1963	7.398	7.487	0.089	1.207
1964	8.440	8.532	0.092	1.090
1965	9.867	9.959	0.092	0.936
1966	9.087	9.148	0.062	0.678
1967	7.843	7.884	0.041	0.520
1968	8.570	8.593	0.023	0.269
1969	8.666	8.678	0.011	0.128
1970	8.459	8.466	0.007	0.082
1971	9.333	9.342	0.009	0.093
1972	9.705	9.723	0.019	0.191
1973	11.459	11.493	0.035	0.303
1974	9.319	9.375	0.056	0.598

TABLE A-43

NEW CAR SALES, SCRAPPAGE, DESIRED STOCK PER FAMILY
AND VMT PER FAMILY SUBMODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN MPG
SCRAPPAGE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	3.466	3.442	-0.024	0.689
1961	4.023	4.045	0.022	0.547
1962	4.882	4.975	0.092	1.888
1963	5.620	5.741	0.121	2.152
1964	5.902	5.966	0.064	1.080
1965	6.674	6.722	0.048	0.720
1966	7.038	7.061	0.023	0.333
1967	7.016	7.012	-0.004	0.051
1968	7.545	7.532	-0.013	0.168
1969	7.959	7.948	-0.011	0.137
1970	6.938	6.944	0.006	0.082
1971	6.082	6.091	0.010	0.159
1972	6.548	6.564	0.016	0.242
1973	7.948	7.977	0.029	0.364
1974	7.588	7.611	0.023	0.306

TABLE A-44

NEW CAR SALES, SCRAPPAGE, DESIRED STOCK PER FAMILY
AND VMT PER FAMILY SUBMODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN MPG
VEHICLE MILES TRAVELED PER FAMILY

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	10.625	10.644	0.018	0.173
1961	11.517	11.597	0.080	0.698
1962	11.681	11.799	0.117	1.005
1963	12.081	12.233	0.153	1.263
1964	12.298	12.489	0.191	1.551
1965	12.468	12.697	0.229	1.840
1966	12.943	13.213	0.270	2.086
1967	13.135	13.430	0.295	2.244
1968	13.177	13.487	0.310	2.352
1969	13.305	13.625	0.320	2.402
1970	13.312	13.631	0.319	2.400
1971	13.231	13.544	0.313	2.363
1972	13.504	13.818	0.314	2.326
1973	13.531	13.843	0.312	2.303
1974	13.112	13.415	0.303	2.309

TABLE A-45

NEW CAR SALES, SCRAPPAGE, DESIRED STOCK PER FAMILY
AND VMT PER FAMILY SUBMODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN GAS PRICE
DESIRED STOCK PER FAMILY

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	1.173	1.168	-0.005	0.412
1961	1.181	1.176	-0.005	0.399
1962	1.189	1.184	-0.005	0.395
1963	1.208	1.203	-0.005	0.388
1964	1.233	1.228	-0.005	0.386
1965	1.248	1.243	-0.005	0.394
1966	1.265	1.260	-0.005	0.398
1967	1.270	1.265	-0.005	0.421
1968	1.252	1.247	-0.005	0.410
1969	1.239	1.234	-0.005	0.405
1970	1.239	1.234	-0.005	0.390
1971	1.248	1.243	-0.005	0.379
1972	1.245	1.240	-0.005	0.386
1973	1.258	1.253	-0.005	0.400
1974	1.241	1.235	-0.006	0.477

TABLE A-46

NEW CAR SALES, SCRAPPAGE, DESIRED STOCK PER FAMILY
AND VMT PER FAMILY SUBMODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN GAS PRICE
NEW CAR SALES

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	9.092	8.897	-0.195	2.145
1961	6.891	6.734	-0.157	2.275
1962	7.447	7.269	-0.178	2.389
1963	7.388	7.332	-0.056	0.758
1964	8.423	8.421	-0.002	0.020
1965	9.870	9.910	0.040	0.407
1966	9.122	9.166	0.044	0.486
1967	7.890	7.910	0.020	0.258
1968	8.633	8.644	0.011	0.127
1969	8.745	8.730	-0.015	0.168
1970	8.536	8.504	-0.031	0.367
1971	9.421	9.375	-0.046	0.488
1972	9.808	9.745	-0.063	0.637
1973	11.567	11.480	-0.086	0.747
1974	9.410	9.324	-0.086	0.911

TABLE A-47

NEW CAR SALES, SCRAPPAGE, DESIRED STOCK PER FAMILY
AND VMT PER FAMILY SUBMODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN GAS PRICE
SCRAPPAGE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	3.481	3.368	-0.113	3.257
1961	3.984	3.740	-0.244	6.115
1962	4.863	4.671	-0.192	3.943
1963	5.651	5.827	0.176	3.115
1964	5.884	5.997	0.113	1.922
1965	6.687	6.799	0.113	1.684
1966	7.084	7.166	0.081	1.146
1967	7.065	7.089	0.025	0.348
1968	7.606	7.585	-0.021	0.277
1969	8.044	7.980	-0.064	0.791
1970	7.020	6.947	-0.073	1.037
1971	6.151	6.086	-0.066	1.066
1972	6.621	6.551	-0.070	1.058
1973	8.025	7.951	-0.074	0.919
1974	7.648	7.611	-0.037	0.484

TABLE A-48

NEW CAR SALES, SCRAPPAGE, DESIRED STOCK PER FAMILY
AND VMT PER FAMILY SUBMODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN GAS PRICE
VEHICLE MILES TRAVELED PER FAMILY

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	10.629	10.418	-0.211	1.984
1961	11.597	11.345	-0.252	2.173
1962	11.768	11.500	-0.268	2.274
1963	12.150	11.842	-0.307	2.530
1964	12.354	12.020	-0.334	2.702
1965	12.507	12.169	-0.337	2.698
1966	12.966	12.628	-0.338	2.609
1967	13.146	12.819	-0.328	2.491
1968	13.183	12.868	-0.314	2.386
1969	13.308	13.005	-0.303	2.274
1970	13.314	13.021	-0.293	2.200
1971	13.236	12.949	-0.287	2.169
1972	13.515	13.221	-0.294	2.178
1973	13.549	13.249	-0.301	2.220
1974	13.134	12.832	-0.302	2.298

TABLE A-49

NEW CAR SHARES AND DESIRED SHARES SUBMODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN MPG
SUBCOMPACT CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.125	0.114	-0.010	8.333
1961	0.130	0.121	-0.008	6.522
1962	0.175	0.165	-0.010	5.881
1963	0.091	0.086	-0.005	5.562
1964	0.186	0.175	-0.011	6.009
1965	0.205	0.194	-0.012	5.711
1966	0.209	0.198	-0.011	5.403
1967	0.284	0.269	-0.015	5.258
1968	0.356	0.341	-0.015	4.126
1969	0.327	0.311	-0.015	4.732
1970	0.291	0.278	-0.013	4.313
1971	0.249	0.238	-0.011	4.504
1972	0.188	0.179	-0.009	4.928
1973	0.143	0.135	-0.008	5.479
1974	0.172	0.160	-0.013	7.272

TABLE A-50

NEW CAR SHARES AND DESIRED SHARES SUBMODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN MPG
COMPACT CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.281	0.278	-0.003	1.172
1961	0.217	0.214	-0.002	1.147
1962	0.157	0.156	-0.001	0.681
1963	0.196	0.193	-0.003	1.633
1964	0.118	0.118	0.000	0.342
1965	0.105	0.105	0.000	0.123
1966	0.107	0.107	0.000	0.038
1967	0.087	0.088	0.001	1.142
1968	0.079	0.080	0.001	0.986
1969	0.114	0.116	0.002	1.664
1970	0.162	0.163	0.002	1.001
1971	0.189	0.190	0.001	0.426
1972	0.212	0.212	0.001	0.242
1973	0.203	0.202	-0.000	0.114
1974	0.186	0.186	0.000	0.155

TABLE A-51

NEW CAR SHARES AND DESIRED SHARES SUBMODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN MPG
MID-SIZE CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.060	0.059	-0.001	1.036
1961	0.076	0.076	-0.001	0.786
1962	0.096	0.095	-0.001	0.833
1963	0.103	0.102	-0.001	0.645
1964	0.129	0.129	-0.000	0.250
1965	0.157	0.157	-0.000	0.073
1966	0.178	0.179	0.000	0.104
1967	0.203	0.203	0.000	0.199
1968	0.209	0.211	0.001	0.550
1969	0.220	0.221	0.001	0.466
1970	0.216	0.217	0.001	0.494
1971	0.207	0.208	0.001	0.247
1972	0.214	0.214	0.000	0.140
1973	0.194	0.194	-0.000	0.181
1974	0.186	0.185	-0.001	0.536

TABLE A-52

NEW CAR SHARES AND DESIRED SHARES SUBMODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN MPG
FULL-SIZE CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.454	0.468	0.014	3.179
1961	0.495	0.507	0.012	2.353
1962	0.489	0.502	0.012	2.507
1963	0.526	0.535	0.009	1.719
1964	0.481	0.492	0.011	2.330
1965	0.442	0.454	0.012	2.662
1966	0.411	0.422	0.011	2.701
1967	0.330	0.344	0.013	4.086
1968	0.260	0.272	0.013	4.843
1969	0.243	0.255	0.012	5.066
1970	0.237	0.247	0.010	4.077
1971	0.260	0.269	0.010	3.743
1972	0.292	0.301	0.008	2.855
1973	0.365	0.374	0.008	2.279
1974	0.363	0.376	0.013	3.662

TABLE A-53

NEW CAR SHARES AND DESIRED SHARES SUBMODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN MPG
LUXURY CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.081	0.080	-0.000	0.122
1961	0.082	0.082	-0.000	0.149
1962	0.083	0.083	-0.000	0.143
1963	0.085	0.085	-0.000	0.129
1964	0.086	0.086	-0.000	0.090
1965	0.090	0.090	-0.000	0.056
1966	0.093	0.093	-0.000	0.018
1967	0.096	0.096	0.000	0.047
1968	0.096	0.097	0.000	0.177
1969	0.096	0.096	0.000	0.227
1970	0.095	0.095	0.000	0.197
1971	0.095	0.095	0.000	0.180
1972	0.094	0.094	0.000	0.111
1973	0.095	0.095	0.000	0.087
1974	0.093	0.093	-0.000	0.044

TABLE A-54

NEW CAR SHARES AND DESIRED SHARES SUBMODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN PERSONAL INCOME
SUBCOMPACT CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.138	0.136	-0.002	1.687
1961	0.109	0.108	-0.001	0.962
1962	0.130	0.129	-0.000	0.213
1963	0.112	0.112	0.000	0.258
1964	0.164	0.165	0.001	0.647
1965	0.215	0.216	0.001	0.551
1966	0.226	0.227	0.001	0.366
1967	0.319	0.320	0.001	0.281
1968	0.339	0.340	0.001	0.153
1969	0.272	0.272	-0.000	0.016
1970	0.227	0.227	-0.000	0.076
1971	0.309	0.309	-0.000	0.020
1972	0.205	0.205	-0.000	0.095
1973	0.153	0.153	-0.000	0.098
1974	0.129	0.129	-0.000	0.155

TABLE A-55

NEW CAR SHARES AND DESIRED SHARES SUBMODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN PERSONAL INCOME
COMPACT CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.281	0.280	-0.001	0.437
1961	0.233	0.233	0.000	0.063
1962	0.188	0.189	0.001	0.686
1963	0.187	0.189	0.002	1.094
1964	0.125	0.126	0.002	1.414
1965	0.099	0.100	0.001	1.386
1966	0.099	0.100	0.001	1.272
1967	0.075	0.075	0.001	1.203
1968	0.085	0.086	0.001	1.088
1969	0.141	0.142	0.001	0.902
1970	0.188	0.189	0.001	0.790
1971	0.173	0.174	0.001	0.818
1972	0.206	0.207	0.002	0.742
1973	0.199	0.200	0.001	0.724
1974	0.197	0.198	0.001	0.695

TABLE A-56

NEW CAR SHARES AND DESIRED SHARES SUBMODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN PERSONAL INCOME
MID-SIZE CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.061	0.061	-0.000	0.272
1961	0.071	0.071	-0.000	0.191
1962	0.089	0.089	-0.000	0.072
1963	0.097	0.097	0.000	0.016
1964	0.119	0.120	0.000	0.048
1965	0.151	0.151	0.000	0.021
1966	0.172	0.171	-0.000	0.024
1967	0.196	0.196	-0.000	0.094
1968	0.202	0.202	-0.000	0.125
1969	0.219	0.219	-0.000	0.116
1970	0.215	0.215	-0.000	0.112
1971	0.207	0.207	-0.000	0.170
1972	0.213	0.213	-0.000	0.105
1973	0.193	0.193	-0.000	0.061
1974	0.184	0.184	-0.000	0.060

TABLE A-57

NEW CAR SHARES AND DESIRED SHARES SUBMODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN PERSONAL INCOME
FULL-SIZE CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.439	0.443	0.003	0.768
1961	0.505	0.506	0.000	0.069
1962	0.510	0.508	-0.002	0.384
1963	0.520	0.517	-0.004	0.687
1964	0.506	0.502	-0.004	0.825
1965	0.445	0.441	-0.004	0.846
1966	0.410	0.407	-0.003	0.755
1967	0.315	0.312	-0.003	0.811
1968	0.276	0.273	-0.002	0.753
1969	0.271	0.269	-0.002	0.675
1970	0.274	0.272	-0.002	0.701
1971	0.217	0.215	-0.002	0.853
1972	0.282	0.280	-0.002	0.703
1973	0.362	0.360	-0.002	0.567
1974	0.398	0.396	-0.002	0.490

TABLE A-58

NEW CAR SHARES AND DESIRED SHARES SUBMODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN PERSONAL INCOME
LUXURY CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.080	0.081	0.000	0.434
1961	0.082	0.083	0.001	0.837
1962	0.083	0.084	0.001	1.212
1963	0.085	0.086	0.001	1.452
1964	0.086	0.087	0.001	1.500
1965	0.090	0.091	0.001	1.309
1966	0.094	0.095	0.001	1.127
1967	0.096	0.097	0.001	0.988
1968	0.097	0.098	0.001	0.907
1969	0.097	0.098	0.001	0.882
1970	0.096	0.097	0.001	0.891
1971	0.094	0.095	0.001	0.901
1972	0.094	0.095	0.001	0.932
1973	0.094	0.095	0.001	0.934
1974	0.092	0.093	0.001	0.968

TABLE A-59

CAPITALIZED COST PER MILE SUBMODEL
MULTIPLIER ANALYSIS - 1% INCREASE
IN NEW CAR PRICE
SUBCOMPACT DOMESTIC CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.082	0.082	0.000	0.420
1961	0.082	0.083	0.000	0.422
1962	0.083	0.083	0.000	0.424
1963	0.084	0.084	0.000	0.422
1964	0.086	0.086	0.000	0.431
1965	0.089	0.089	0.000	0.427
1966	0.091	0.092	0.000	0.427
1967	0.096	0.096	0.000	0.420
1968	0.099	0.099	0.000	0.420
1969	0.104	0.104	0.000	0.415
1970	0.100	0.101	0.000	0.374
1971	0.105	0.106	0.000	0.368
1972	0.109	0.109	0.000	0.366
1973	0.116	0.117	0.000	0.374
1974	0.139	0.140	0.001	0.391

TABLE A-60

CAPITALIZED COST PER MILE SUBMODEL
MULTIPLIER ANALYSIS - 1% INCREASE
IN NEW CAR PRICE
COMPACT DOMESTIC CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.087	0.087	0.000	0.423
1961	0.086	0.086	0.000	0.418
1962	0.089	0.089	0.000	0.428
1963	0.088	0.088	0.000	0.420
1964	0.091	0.091	0.000	0.424
1965	0.095	0.096	0.000	0.428
1966	0.099	0.100	0.000	0.431
1967	0.106	0.107	0.000	0.426
1968	0.111	0.112	0.000	0.433
1969	0.115	0.116	0.000	0.420
1970	0.120	0.121	0.000	0.407
1971	0.128	0.128	0.001	0.407
1972	0.130	0.130	0.001	0.389
1973	0.138	0.138	0.001	0.394
1974	0.159	0.160	0.001	0.387

TABLE A-61

CAPITALIZED COST PER MILE SUBMODEL
MULTIPLIER ANALYSIS - 1% INCREASE
IN NEW CAR PRICE
MID-SIZE DOMESTIC CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.100	0.100	0.000	0.439
1961	0.099	0.100	0.000	0.441
1962	0.099	0.100	0.000	0.444
1963	0.101	0.101	0.000	0.450
1964	0.100	0.101	0.000	0.437
1965	0.102	0.103	0.000	0.426
1966	0.106	0.107	0.000	0.428
1967	0.113	0.113	0.000	0.423
1968	0.120	0.121	0.001	0.437
1969	0.126	0.127	0.001	0.434
1970	0.136	0.137	0.001	0.435
1971	0.147	0.148	0.001	0.440
1972	0.150	0.150	0.001	0.426
1973	0.159	0.160	0.001	0.431
1974	0.180	0.181	0.001	0.410

TABLE A-62

CAPITALIZED COST PER MILE SUBMODEL
MULTIPLIER ANALYSIS - 1% INCREASE
IN NEW CAR PRICE
FULL-SIZE DOMESTIC CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.111	0.111	0.001	0.460
1961	0.110	0.110	0.001	0.458
1962	0.111	0.112	0.001	0.463
1963	0.111	0.111	0.001	0.459
1964	0.112	0.112	0.001	0.458
1965	0.116	0.116	0.001	0.453
1966	0.120	0.120	0.001	0.455
1967	0.127	0.127	0.001	0.450
1968	0.134	0.134	0.001	0.460
1969	0.142	0.142	0.001	0.460
1970	0.152	0.152	0.001	0.461
1971	0.164	0.164	0.001	0.464
1972	0.167	0.167	0.001	0.454
1973	0.175	0.176	0.001	0.452
1974	0.197	0.198	0.001	0.426

TABLE A-63

CAPITALIZED COST PER MILE SUBMODEL
MULTIPLIER ANALYSIS - 1% INCREASE
IN NEW CAR PRICE
LUXURY DOMESTIC CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.140	0.141	0.001	0.548
1961	0.142	0.143	0.001	0.552
1962	0.145	0.145	0.001	0.558
1963	0.145	0.146	0.001	0.557
1964	0.149	0.150	0.001	0.563
1965	0.151	0.152	0.001	0.551
1966	0.155	0.156	0.001	0.549
1967	0.163	0.163	0.001	0.543
1968	0.169	0.170	0.001	0.545
1969	0.177	0.178	0.001	0.541
1970	0.189	0.190	0.001	0.541
1971	0.203	0.204	0.001	0.541
1972	0.206	0.207	0.001	0.534
1973	0.216	0.217	0.001	0.532
1974	0.248	0.249	0.001	0.518

TABLE A-64

CAPITALIZED COST PER MILE SUBMODEL
MULTIPLIER ANALYSIS - 1% INCREASE
IN NEW CAR PRICE
SUBCOMPACT FOREIGN CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.072	0.072	0.000	0.407
1961	0.071	0.072	0.000	0.398
1962	0.073	0.074	0.000	0.410
1963	0.074	0.074	0.000	0.410
1964	0.075	0.075	0.000	0.408
1965	0.076	0.077	0.000	0.398
1966	0.081	0.082	0.000	0.409
1967	0.085	0.085	0.000	0.402
1968	0.089	0.089	0.000	0.405
1969	0.095	0.095	0.000	0.412
1970	0.102	0.102	0.000	0.406
1971	0.107	0.107	0.000	0.391
1972	0.112	0.113	0.000	0.402
1973	0.122	0.123	0.001	0.423
1974	0.143	0.143	0.001	0.435

TABLE A-65

CAPITALIZED COST PER MILE SUBMODEL
MULTIPLIER ANALYSIS - 1% INCREASE
IN NEW CAR PRICE
COMPACT FOREIGN CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.084	0.084	0.000	0.454
1961	0.083	0.084	0.000	0.445
1962	0.087	0.087	0.000	0.462
1963	0.089	0.089	0.000	0.468
1964	0.091	0.091	0.000	0.463
1965	0.093	0.094	0.000	0.467
1966	0.098	0.099	0.000	0.479
1967	0.104	0.104	0.000	0.476
1968	0.109	0.109	0.001	0.479
1969	0.116	0.117	0.001	0.480
1970	0.127	0.128	0.001	0.487
1971	0.137	0.137	0.001	0.489
1972	0.144	0.145	0.001	0.500
1973	0.157	0.158	0.001	0.521
1974	0.182	0.183	0.001	0.527

TABLE A-66

CAPITALIZED COST PER MILE SUBMODEL
MULTIPLIER ANALYSIS - 1% INCREASE
IN NEW CAR PRICE
LUXURY FOREIGN CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.133	0.134	0.001	0.599
1961	0.134	0.135	0.001	0.600
1962	0.139	0.140	0.001	0.610
1963	0.141	0.142	0.001	0.609
1964	0.144	0.145	0.001	0.611
1965	0.148	0.149	0.001	0.608
1966	0.155	0.156	0.001	0.611
1967	0.160	0.161	0.001	0.602
1968	0.163	0.164	0.001	0.595
1969	0.171	0.172	0.001	0.592
1970	0.188	0.189	0.001	0.601
1971	0.197	0.198	0.001	0.592
1972	0.220	0.221	0.001	0.619
1973	0.250	0.252	0.002	0.650
1974	0.285	0.287	0.002	0.645

TABLE A-67

CAPITALIZED COST PER MILE SUBMODEL
MULTIPLIER ANALYSIS - 1% INCREASE
IN CONSUMER INSTALLMENT CREDIT RATE
SUBCOMPACT DOMESTIC CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.082	0.082	0.001	0.814
1961	0.082	0.083	0.001	0.818
1962	0.083	0.084	0.001	0.813
1963	0.084	0.084	0.001	0.811
1964	0.086	0.087	0.001	0.826
1965	0.089	0.089	0.001	0.819
1966	0.091	0.092	0.001	0.808
1967	0.096	0.096	0.001	0.791
1968	0.099	0.100	0.001	0.782
1969	0.104	0.104	0.001	0.763
1970	0.100	0.101	0.001	0.677
1971	0.105	0.106	0.001	0.671
1972	0.109	0.110	0.001	0.668
1973	0.116	0.117	0.001	0.679
1974	0.139	0.140	0.001	0.699

TABLE A-68

CAPITALIZED COST PER MILE SUBMODEL
MULTPILIER ANALYSIS - 1% INCREASE
IN CONSUMER INSTALLMENT CREDIT RATE
COMPACT DOMESTIC CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.087	0.087	0.001	0.820
1961	0.086	0.087	0.001	0.811
1962	0.089	0.089	0.001	0.821
1963	0.088	0.089	0.001	0.806
1964	0.091	0.092	0.001	0.814
1965	0.095	0.096	0.001	0.821
1966	0.099	0.100	0.001	0.816
1967	0.106	0.107	0.001	0.803
1968	0.111	0.112	0.001	0.807
1969	0.115	0.116	0.001	0.773
1970	0.120	0.121	0.001	0.737
1971	0.128	0.129	0.001	0.741
1972	0.130	0.131	0.001	0.711
1973	0.138	0.139	0.001	0.715
1974	0.159	0.161	0.001	0.692

TABLE A-69

CAPITALIZED COST PER MILE SUBMODEL
MULTIPLIER ANALYSIS - 1% INCREASE
IN CONSUMER INSTALLMENT CREDIT RATE
MID-SIZE DOMESTIC CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.100	0.101	0.001	0.850
1961	0.099	0.100	0.001	0.856
1962	0.099	0.100	0.001	0.851
1963	0.101	0.102	0.001	0.865
1964	0.100	0.101	0.001	0.838
1965	0.102	0.103	0.001	0.817
1966	0.106	0.107	0.001	0.811
1967	0.113	0.114	0.001	0.797
1968	0.120	0.121	0.001	0.813
1969	0.126	0.127	0.001	0.799
1970	0.136	0.137	0.001	0.786
1971	0.147	0.148	0.001	0.801
1972	0.150	0.151	0.001	0.779
1973	0.159	0.161	0.001	0.781
1974	0.180	0.181	0.001	0.734

TABLE A-70

CAPITALIZED COST PER MILE SUBMODEL
MULTIPLIER ANALYSIS - 1% INCREASE
IN CONSUMER INSTALLMENT CREDIT RATE
FULL-SIZE DOMESTIC CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.111	0.112	0.001	0.891
1961	0.110	0.110	0.001	0.889
1962	0.111	0.112	0.001	0.888
1963	0.111	0.112	0.001	0.882
1964	0.112	0.113	0.001	0.878
1965	0.116	0.117	0.001	0.869
1966	0.120	0.121	0.001	0.862
1967	0.127	0.128	0.001	0.846
1968	0.134	0.135	0.001	0.856
1969	0.142	0.143	0.001	0.847
1970	0.152	0.153	0.001	0.834
1971	0.164	0.165	0.001	0.845
1972	0.167	0.168	0.001	0.830
1973	0.175	0.176	0.001	0.821
1974	0.197	0.199	0.002	0.762

TABLE A-71

CAPITALIZED COST PER MILE SUBMODEL
MULTIPLIER ANALYSIS - 1% INCREASE
IN CONSUMER INSTALLMENT CREDIT RATE
LUXURY DOMESTIC CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.140	0.142	0.001	1.062
1961	0.142	0.143	0.002	1.070
1962	0.145	0.146	0.002	1.070
1963	0.145	0.147	0.002	1.070
1964	0.149	0.151	0.002	1.080
1965	0.151	0.153	0.002	1.057
1966	0.155	0.157	0.002	1.039
1967	0.163	0.164	0.002	1.021
1968	0.169	0.171	0.002	1.014
1969	0.177	0.179	0.002	0.996
1970	0.189	0.191	0.002	0.978
1971	0.203	0.205	0.002	0.986
1972	0.206	0.208	0.002	0.975
1973	0.216	0.218	0.002	0.965
1974	0.248	0.250	0.002	0.926

TABLE A-72

CAPITALIZED COST PER MILE SUBMODEL
MULTIPLIER ANALYSIS - 1% INCREASE
IN CONSUMER INSTALLMENT CREDIT RATE
SUBCOMPACT FOREIGN CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.072	0.073	0.001	0.788
1961	0.071	0.072	0.001	0.773
1962	0.073	0.074	0.001	0.786
1963	0.074	0.075	0.001	0.787
1964	0.075	0.075	0.001	0.782
1965	0.076	0.077	0.001	0.764
1966	0.081	0.082	0.001	0.775
1967	0.085	0.085	0.001	0.756
1968	0.089	0.090	0.001	0.755
1969	0.095	0.096	0.001	0.759
1970	0.102	0.103	0.001	0.735
1971	0.107	0.107	0.001	0.712
1972	0.112	0.113	0.001	0.734
1973	0.122	0.123	0.001	0.768
1974	0.143	0.144	0.001	0.778

TABLE A-73

CAPITALIZED COST PER MILE SUBMODEL
MULTIPLIER ANALYSIS - 1% INCREASE
IN CONSUMER INSTALLMENT CREDIT RATE
COMPACT FOREIGN CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.084	0.085	0.001	0.879
1961	0.083	0.084	0.001	0.862
1962	0.087	0.088	0.001	0.887
1963	0.089	0.090	0.001	0.899
1964	0.091	0.091	0.001	0.889
1965	0.093	0.094	0.001	0.896
1966	0.098	0.099	0.001	0.907
1967	0.104	0.105	0.001	0.895
1968	0.109	0.110	0.001	0.892
1969	0.116	0.117	0.001	0.884
1970	0.127	0.128	0.001	0.881
1971	0.137	0.138	0.001	0.891
1972	0.144	0.146	0.001	0.914
1973	0.157	0.159	0.001	0.946
1974	0.182	0.184	0.002	0.942

TABLE A-74

CAPITALIZED COST PER MILE SUBMODEL
MULTIPLIER ANALYSIS - 1% INCREASE
IN CONSUMER INSTALLMENT CREDIT RATE
LUXURY FOREIGN CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.133	0.135	0.002	1.161
1961	0.134	0.136	0.002	1.164
1962	0.139	0.141	0.002	1.169
1963	0.141	0.143	0.002	1.170
1964	0.144	0.145	0.002	1.173
1965	0.148	0.150	0.002	1.166
1966	0.155	0.156	0.002	1.156
1967	0.160	0.162	0.002	1.132
1968	0.163	0.165	0.002	1.108
1969	0.171	0.172	0.002	1.090
1970	0.188	0.190	0.002	1.087
1971	0.197	0.199	0.002	1.078
1972	0.220	0.222	0.002	1.132
1973	0.250	0.253	0.003	1.179
1974	0.285	0.288	0.003	1.154

TABLE A-75

CAPITALIZED COST PER MILE SUBMODEL
MULTIPLIER ANALYSIS - 1% INCREASE
IN DISCOUNT RATE
SUBCOMPACT DOMESTIC CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.082	0.083	0.001	1.034
1961	0.082	0.083	0.001	1.040
1962	0.083	0.084	0.001	1.010
1963	0.084	0.084	0.001	1.003
1964	0.086	0.087	0.001	1.029
1965	0.089	0.090	0.001	1.020
1966	0.091	0.092	0.001	1.004
1967	0.096	0.096	0.001	0.984
1968	0.099	0.100	0.001	0.971
1969	0.104	0.105	0.001	0.944
1970	0.100	0.101	0.001	0.791
1971	0.105	0.106	0.001	0.772
1972	0.109	0.110	0.001	0.767
1973	0.116	0.117	0.001	0.786
1974	0.139	0.141	0.001	0.849

TABLE A-76

CAPITALIZED COST PER MILE SUBMODEL
MULTIPLIER ANALYSIS - 1% INCREASE
IN DISCOUNT RATE
COMPACT DOMESTIC CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.087	0.087	0.001	1.035
1961	0.086	0.087	0.001	1.018
1962	0.089	0.090	0.001	1.014
1963	0.088	0.089	0.001	0.985
1964	0.091	0.092	0.001	1.001
1965	0.095	0.096	0.001	1.017
1966	0.099	0.100	0.001	1.013
1967	0.106	0.107	0.001	1.004
1968	0.111	0.113	0.001	1.012
1969	0.115	0.116	0.001	0.961
1970	0.120	0.122	0.001	0.902
1971	0.128	0.129	0.001	0.902
1972	0.130	0.131	0.001	0.850
1973	0.138	0.139	0.001	0.856
1974	0.159	0.161	0.001	0.846

TABLE A-77

CAPITALIZED COST PER MILE SUBMODEL
MULTIPLIER ANALYSIS - 1% INCREASE
IN DISCOUNT RATE
MID-SIZE DOMESTIC CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.100	0.101	0.001	1.098
1961	0.099	0.100	0.001	1.104
1962	0.099	0.100	0.001	1.071
1963	0.101	0.102	0.001	1.090
1964	0.100	0.101	0.001	1.046
1965	0.102	0.103	0.001	1.012
1966	0.106	0.107	0.001	1.007
1967	0.113	0.114	0.001	0.995
1968	0.120	0.121	0.001	1.024
1969	0.126	0.128	0.001	1.008
1970	0.136	0.138	0.001	0.991
1971	0.147	0.149	0.001	1.010
1972	0.150	0.151	0.001	0.971
1973	0.159	0.161	0.002	0.974
1974	0.180	0.182	0.002	0.920

TABLE A-78

CAPITALIZED COST PER MILE SUBMODEL
MULTIPLIER ANALYSIS - 1% INCREASE
IN DISCOUNT RATE
FULL-SIZE DOMESTIC CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.111	0.112	0.001	1.171
1961	0.110	0.111	0.001	1.163
1962	0.111	0.112	0.001	1.138
1963	0.111	0.112	0.001	1.125
1964	0.112	0.113	0.001	1.117
1965	0.116	0.117	0.001	1.106
1966	0.120	0.121	0.001	1.099
1967	0.127	0.128	0.001	1.082
1968	0.134	0.135	0.001	1.101
1969	0.142	0.143	0.002	1.093
1970	0.152	0.153	0.002	1.076
1971	0.164	0.165	0.002	1.087
1972	0.167	0.168	0.002	1.058
1973	0.175	0.177	0.002	1.040
1974	0.197	0.199	0.002	0.970

TABLE A-79

CAPITALIZED COST PER MILE SUBMODEL
MULTIPLIER ANALYSIS - 1% INCREASE
IN DISCOUNT RATE
LUXURY DOMESTIC CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.140	0.142	0.002	1.463
1961	0.142	0.144	0.002	1.475
1962	0.145	0.147	0.002	1.448
1963	0.145	0.147	0.002	1.444
1964	0.149	0.151	0.002	1.462
1965	0.151	0.153	0.002	1.425
1966	0.155	0.158	0.002	1.400
1967	0.163	0.165	0.002	1.379
1968	0.169	0.172	0.002	1.370
1969	0.177	0.179	0.002	1.348
1970	0.189	0.192	0.003	1.322
1971	0.203	0.205	0.003	1.327
1972	0.206	0.209	0.003	1.305
1973	0.216	0.219	0.003	1.283
1974	0.248	0.251	0.003	1.245

TABLE A-80

CAPITALIZED COST PER MILE SUBMODEL
MULTIPLIER ANALYSIS - 1% INCREASE
IN DISCOUNT RATE
SUBCOMPACT FOREIGN CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.072	0.073	0.001	0.967
1961	0.071	0.072	0.001	0.939
1962	0.073	0.074	0.001	0.941
1963	0.074	0.075	0.001	0.939
1964	0.075	0.076	0.001	0.931
1965	0.076	0.077	0.001	0.902
1966	0.081	0.082	0.001	0.928
1967	0.085	0.086	0.001	0.905
1968	0.089	0.090	0.001	0.905
1969	0.095	0.096	0.001	0.919
1970	0.102	0.103	0.001	0.883
1971	0.107	0.107	0.001	0.838
1972	0.112	0.113	0.001	0.874
1973	0.122	0.123	0.001	0.931
1974	0.143	0.144	0.001	0.973

TABLE A-81

CAPITALIZED COST PER MILE SUBMODEL
MULTIPLIER ANALYSIS - 1% INCREASE
IN DISCOUNT RATE
COMPACT FOREIGN CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.084	0.085	0.001	1.119
1961	0.083	0.084	0.001	1.089
1962	0.087	0.088	0.001	1.109
1963	0.089	0.090	0.001	1.126
1964	0.091	0.092	0.001	1.113
1965	0.093	0.094	0.001	1.124
1966	0.098	0.100	0.001	1.147
1967	0.104	0.105	0.001	1.139
1968	0.109	0.110	0.001	1.135
1969	0.116	0.118	0.001	1.131
1970	0.127	0.128	0.001	1.133
1971	0.137	0.138	0.002	1.143
1972	0.144	0.146	0.002	1.179
1973	0.157	0.159	0.002	1.231
1974	0.182	0.185	0.002	1.250

TABLE A-82

CAPITALIZED COST PER MILE SUBMODEL
MULTIPLIER ANALYSIS - 1% INCREASE
IN DISCOUNT RATE
LUXURY FOREIGN CLASS CAPITALIZED CPM

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.133	0.135	0.002	1.605
1961	0.134	0.136	0.002	1.609
1962	0.139	0.141	0.002	1.591
1963	0.141	0.144	0.002	1.589
1964	0.144	0.146	0.002	1.594
1965	0.148	0.151	0.002	1.586
1966	0.155	0.157	0.002	1.575
1967	0.160	0.162	0.002	1.544
1968	0.163	0.165	0.002	1.505
1969	0.171	0.173	0.003	1.484
1970	0.188	0.191	0.003	1.487
1971	0.197	0.200	0.003	1.463
1972	0.220	0.223	0.003	1.552
1973	0.250	0.255	0.004	1.627
1974	0.285	0.290	0.005	1.610

APPENDIX B

TABLES FOR SECTION 5.0

TABLE B-1

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN U.S. PERSONAL INCOME
NEW CAR SALES

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	8.993	9.458	0.466	5.178
1961	6.642	6.704	0.063	0.942
1962	7.607	7.571	-0.036	0.470
1963	7.524	7.472	-0.052	0.690
1964	8.091	8.034	-0.057	0.707
1965	10.113	10.063	-0.051	0.500
1966	9.177	9.145	-0.031	0.343
1967	8.117	8.098	-0.020	0.240
1968	9.038	9.031	-0.007	0.079
1969	8.900	8.911	0.011	0.119
1970	7.948	7.963	0.016	0.197
1971	9.754	9.780	0.025	0.259
1972	9.611	9.647	0.036	0.372
1973	11.190	11.222	0.032	0.288
1974	8.490	8.515	0.025	0.296

TABLE B-2

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN U.S. PERSONAL INCOME
SCRAPPAGE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	3.545	3.595	0.051	1.426
1961	3.698	3.723	0.025	0.666
1962	4.531	4.594	0.063	1.393
1963	5.420	5.519	0.099	1.828
1964	6.052	6.064	0.012	0.190
1965	7.361	7.338	-0.023	0.317
1966	7.939	7.907	-0.032	0.405
1967	7.576	7.548	-0.028	0.373
1968	7.665	7.666	0.001	0.018
1969	7.446	7.481	0.036	0.483
1970	6.589	6.637	0.049	0.740
1971	6.021	6.066	0.044	0.738
1972	6.036	6.076	0.040	0.665
1973	7.471	7.506	0.035	0.474
1974	8.067	8.083	0.016	0.196

TABLE B-3

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN U.S. PERSONAL INCOME
SUBCOMPACT CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.127	0.125	-0.002	1.508
1961	0.105	0.105	-0.000	0.161
1962	0.130	0.131	0.001	0.468
1963	0.113	0.115	0.001	1.192
1964	0.175	0.178	0.003	1.495
1965	0.210	0.213	0.003	1.315
1966	0.213	0.215	0.002	1.171
1967	0.294	0.297	0.003	0.941
1968	0.358	0.360	0.003	0.791
1969	0.328	0.330	0.002	0.742
1970	0.292	0.294	0.002	0.732
1971	0.260	0.262	0.002	0.720
1972	0.176	0.177	0.001	0.691
1973	0.131	0.132	0.001	0.676
1974	0.170	0.171	0.001	0.584

TABLE B-4

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN U.S. PERSONAL INCOME
COMPACT CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.280	0.279	-0.001	0.427
1961	0.231	0.230	-0.001	0.616
1962	0.181	0.181	0.000	0.134
1963	0.182	0.184	0.001	0.663
1964	0.122	0.123	0.001	0.812
1965	0.102	0.102	0.001	0.722
1966	0.105	0.106	0.001	0.601
1967	0.083	0.083	0.000	0.467
1968	0.078	0.078	0.000	0.403
1969	0.113	0.113	0.000	0.345
1970	0.161	0.162	0.001	0.360
1971	0.183	0.184	0.001	0.405
1972	0.218	0.219	0.001	0.417
1973	0.206	0.207	0.001	0.366
1974	0.190	0.190	0.001	0.338

TABLE B-5

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN U.S. PERSONAL INCOME
MID-SIZE CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.060	0.060	-0.000	0.206
1961	0.076	0.077	0.001	1.257
1962	0.095	0.096	0.001	1.324
1963	0.103	0.104	0.001	1.228
1964	0.129	0.130	0.001	1.013
1965	0.157	0.159	0.001	0.706
1966	0.179	0.179	0.001	0.371
1967	0.203	0.204	0.000	0.052
1968	0.210	0.209	-0.000	0.168
1969	0.220	0.220	-0.001	0.257
1970	0.216	0.215	-0.001	0.300
1971	0.207	0.207	-0.001	0.292
1972	0.214	0.213	-0.000	0.230
1973	0.194	0.193	-0.000	0.178
1974	0.186	0.185	-0.000	0.164

TABLE B-6

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN U.S. PERSONAL INCOME
FULL-SIZE CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.453	0.456	0.003	0.638
1961	0.505	0.505	-0.000	0.016
1962	0.511	0.508	-0.003	0.605
1963	0.516	0.511	-0.005	0.969
1964	0.488	0.482	-0.006	1.260
1965	0.441	0.435	-0.006	1.300
1966	0.410	0.406	-0.005	1.171
1967	0.324	0.319	-0.004	1.294
1968	0.259	0.255	-0.004	1.409
1969	0.242	0.239	-0.003	1.280
1970	0.237	0.234	-0.003	1.228
1971	0.254	0.252	-0.003	1.125
1972	0.298	0.296	-0.003	0.839
1973	0.374	0.372	-0.002	0.576
1974	0.362	0.360	-0.002	0.611

TABLE B-7

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN U.S. PERSONAL INCOME
LUXURY CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.080	0.081	0.000	0.426
1961	0.083	0.083	0.001	0.875
1962	0.084	0.085	0.001	1.179
1963	0.085	0.086	0.001	1.389
1964	0.086	0.087	0.001	1.435
1965	0.090	0.091	0.001	1.252
1966	0.094	0.095	0.001	1.091
1967	0.096	0.096	0.001	0.969
1968	0.096	0.097	0.001	0.890
1969	0.096	0.097	0.001	0.878
1970	0.095	0.096	0.001	0.884
1971	0.095	0.096	0.001	0.900
1972	0.094	0.095	0.001	0.923
1973	0.095	0.096	0.001	0.908
1974	0.093	0.094	0.001	0.948

TABLE B-8

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN U.S. PERSONAL INCOME
VEHICLE MILES TRAVELED PER FAMILY

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	10.580	10.597	0.017	0.163
1961	11.398	11.499	0.101	0.886
1962	11.591	11.700	0.110	0.945
1963	11.996	12.089	0.093	0.778
1964	12.281	12.361	0.080	0.653
1965	12.480	12.541	0.061	0.486
1966	13.040	13.087	0.047	0.361
1967	13.300	13.335	0.035	0.265
1968	13.399	13.427	0.028	0.211
1969	13.592	13.616	0.024	0.174
1970	13.692	13.714	0.022	0.161
1971	13.593	13.615	0.023	0.166
1972	13.678	13.706	0.028	0.204
1973	13.734	13.768	0.034	0.250
1974	13.364	13.402	0.038	0.285

TABLE B-9

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN TAXES ON NEW AUTOS
NEW CAR SALES

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	8.993	8.853	-0.139	1.550
1961	6.642	6.662	0.020	0.299
1962	7.607	7.617	0.010	0.131
1963	7.524	7.526	0.002	0.026
1964	8.091	8.098	0.006	0.080
1965	10.113	10.122	0.009	0.088
1966	9.177	9.180	0.003	0.034
1967	8.117	8.118	0.001	0.010
1968	9.038	9.037	-0.001	0.010
1969	8.900	8.893	-0.007	0.081
1970	7.948	7.939	-0.008	0.106
1971	9.754	9.743	-0.011	0.116
1972	9.611	9.598	-0.014	0.143
1973	11.190	11.173	-0.017	0.152
1974	8.490	8.479	-0.010	0.124

TABLE B-10

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN TAXES ON NEW AUTOS
SCRAPPAGE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	3.545	3.533	-0.012	0.339
1961	3.698	3.696	-0.002	0.056
1962	4.531	4.519	-0.012	0.263
1963	5.420	5.409	-0.011	0.201
1964	6.052	6.068	0.016	0.267
1965	7.361	7.368	0.007	0.093
1966	7.939	7.936	-0.003	0.032
1967	7.576	7.571	-0.005	0.069
1968	7.665	7.656	-0.009	0.112
1969	7.446	7.431	-0.014	0.193
1970	6.589	6.575	-0.014	0.214
1971	6.021	6.010	-0.011	0.191
1972	6.036	6.025	-0.011	0.175
1973	7.471	7.460	-0.011	0.141
1974	8.067	8.060	-0.008	0.098

TABLE B-11

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN TAXES ON NEW AUTOS
SUBCOMPACT CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.127	0.128	0.001	0.986
1961	0.105	0.106	0.001	0.755
1962	0.130	0.131	0.001	0.909
1963	0.113	0.114	0.001	0.798
1964	0.175	0.176	0.001	0.813
1965	0.210	0.211	0.002	0.772
1966	0.213	0.214	0.001	0.687
1967	0.294	0.296	0.002	0.610
1968	0.358	0.360	0.002	0.664
1969	0.328	0.330	0.002	0.612
1970	0.292	0.294	0.002	0.668
1971	0.260	0.262	0.002	0.678
1972	0.176	0.177	0.001	0.506
1973	0.131	0.131	0.001	0.385
1974	0.170	0.170	0.000	0.288

TABLE B-12

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN TAXES ON NEW AUTOS
COMPACT CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.280	0.281	0.001	0.385
1961	0.231	0.233	0.002	0.689
1962	0.181	0.182	0.001	0.501
1963	0.182	0.183	0.001	0.542
1964	0.122	0.123	0.000	0.404
1965	0.102	0.102	0.000	0.259
1966	0.105	0.105	0.000	0.285
1967	0.083	0.083	0.000	0.150
1968	0.078	0.077	-0.000	0.040
1969	0.113	0.113	0.000	0.136
1970	0.161	0.161	0.000	0.216
1971	0.183	0.184	0.000	0.246
1972	0.218	0.219	0.001	0.411
1973	0.206	0.207	0.001	0.435
1974	0.190	0.190	0.001	0.300

TABLE B-13

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN TAXES ON NEW AUTOS
MID-SIZE CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.060	0.060	0.000	0.186
1961	0.076	0.076	-0.000	0.210
1962	0.095	0.094	-0.000	0.091
1963	0.103	0.103	-0.000	0.086
1964	0.129	0.129	0.000	0.027
1965	0.157	0.158	0.000	0.076
1966	0.179	0.179	0.000	0.082
1967	0.203	0.204	0.000	0.040
1968	0.210	0.209	-0.000	0.017
1969	0.220	0.220	-0.000	0.030
1970	0.216	0.216	-0.000	0.034
1971	0.207	0.207	-0.000	0.022
1972	0.214	0.214	0.000	0.037
1973	0.194	0.194	0.000	0.050
1974	0.186	0.186	-0.000	0.007

TABLE B-14

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN TAXES ON NEW AUTOS
FULL-SIZE CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.453	0.450	-0.002	0.525
1961	0.505	0.503	-0.002	0.427
1962	0.511	0.509	-0.002	0.382
1963	0.516	0.515	-0.002	0.340
1964	0.488	0.486	-0.002	0.389
1965	0.441	0.439	-0.002	0.441
1966	0.410	0.408	-0.002	0.449
1967	0.324	0.322	-0.002	0.594
1968	0.259	0.257	-0.002	0.855
1969	0.242	0.240	-0.002	0.825
1970	0.237	0.235	-0.002	0.899
1971	0.254	0.252	-0.002	0.820
1972	0.298	0.296	-0.002	0.599
1973	0.374	0.373	-0.001	0.381
1974	0.362	0.361	-0.001	0.268

TABLE B-15

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN TAXES ON NEW AUTOS
LUXURY CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.080	0.080	-0.000	0.081
1961	0.083	0.083	-0.000	0.084
1962	0.084	0.084	-0.000	0.064
1963	0.085	0.085	-0.000	0.060
1964	0.086	0.086	-0.000	0.063
1965	0.090	0.090	-0.000	0.065
1966	0.094	0.093	-0.000	0.070
1967	0.096	0.095	-0.000	0.086
1968	0.096	0.096	-0.000	0.100
1969	0.096	0.096	-0.000	0.097
1970	0.095	0.095	-0.000	0.098
1971	0.095	0.095	-0.000	0.090
1972	0.094	0.094	-0.000	0.082
1973	0.095	0.095	-0.000	0.077
1974	0.093	0.093	-0.000	0.081

TABLE B-16

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN TAXES ON NEW AUTOS
VEHICLE MILES TRAVELED PER FAMILY

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	10.580	10.573	-0.008	0.072
1961	11.398	11.368	-0.030	0.267
1962	11.591	11.566	-0.024	0.211
1963	11.996	11.977	-0.019	0.155
1964	12.281	12.264	-0.017	0.139
1965	12.480	12.466	-0.014	0.113
1966	13.040	13.030	-0.010	0.079
1967	13.300	13.294	-0.006	0.048
1968	13.399	13.394	-0.004	0.031
1969	13.592	13.590	-0.002	0.016
1970	13.692	13.691	-0.002	0.011
1971	13.593	13.591	-0.002	0.014
1972	13.678	13.674	-0.004	0.026
1973	13.734	13.729	-0.006	0.041
1974	13.364	13.356	-0.007	0.056

TABLE B-17

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN GAS PRICE
NEW CAR SALES

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	8.993	8.813	-0.179	1.992
1961	6.642	6.497	-0.144	2.174
1962	7.607	7.433	-0.174	2.289
1963	7.524	7.471	-0.053	0.698
1964	8.091	8.100	0.008	0.104
1965	10.113	10.176	0.062	0.616
1966	9.177	9.237	0.060	0.658
1967	8.117	8.158	0.041	0.500
1968	9.038	9.072	0.034	0.373
1969	8.900	8.893	-0.007	0.080
1970	7.948	7.926	-0.022	0.276
1971	9.754	9.707	-0.047	0.483
1972	9.611	9.544	-0.067	0.696
1973	11.190	11.097	-0.093	0.830
1974	8.490	8.412	-0.078	0.914

TABLE B-18

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN GAS PRICE
SCRAPPAGE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	3.545	3.422	-0.123	3.468
1961	3.698	3.471	-0.227	6.134
1962	4.531	4.351	-0.180	3.971
1963	5.420	5.587	0.167	3.090
1964	6.052	6.171	0.119	1.961
1965	7.361	7.487	0.126	1.710
1966	7.939	8.025	0.086	1.088
1967	7.576	7.594	0.018	0.236
1968	7.665	7.641	-0.024	0.309
1969	7.446	7.388	-0.057	0.768
1970	6.589	6.526	-0.063	0.949
1971	6.021	5.962	-0.059	0.982
1972	6.036	5.974	-0.061	1.017
1973	7.471	7.403	-0.069	0.917
1974	8.067	8.023	-0.045	0.554

TABLE B-19

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN GAS PRICE
SUBCOMPACT CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.127	0.136	0.009	7.279
1961	0.105	0.110	0.006	5.346
1962	0.130	0.137	0.007	5.146
1963	0.113	0.120	0.006	5.573
1964	0.175	0.185	0.010	5.913
1965	0.210	0.221	0.012	5.482
1966	0.213	0.225	0.012	5.694
1967	0.294	0.311	0.017	5.644
1968	0.358	0.374	0.016	4.475
1969	0.328	0.345	0.017	5.147
1970	0.292	0.305	0.014	4.665
1971	0.260	0.272	0.012	4.625
1972	0.176	0.187	0.011	6.125
1973	0.131	0.140	0.009	7.105
1974	0.170	0.182	0.013	7.374

TABLE B-20

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN GAS PRICE
COMPACT CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.280	0.285	0.005	1.718
1961	0.231	0.237	0.005	2.251
1962	0.181	0.185	0.004	2.093
1963	0.182	0.186	0.003	1.851
1964	0.122	0.122	0.000	0.209
1965	0.102	0.102	0.000	0.168
1966	0.105	0.105	-0.000	0.160
1967	0.083	0.082	-0.001	1.675
1968	0.078	0.076	-0.001	1.547
1969	0.113	0.111	-0.002	2.028
1970	0.161	0.159	-0.002	1.160
1971	0.183	0.183	-0.001	0.409
1972	0.218	0.217	-0.000	0.227
1973	0.206	0.207	0.001	0.308
1974	0.190	0.191	0.001	0.463

TABLE B-21

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN GAS PRICE
MID-SIZE CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.060	0.060	0.001	1.064
1961	0.076	0.076	0.000	0.422
1962	0.095	0.095	0.000	0.144
1963	0.103	0.103	0.000	0.121
1964	0.129	0.129	-0.000	0.037
1965	0.157	0.158	0.000	0.175
1966	0.179	0.179	0.001	0.308
1967	0.203	0.204	0.000	0.143
1968	0.210	0.209	-0.001	0.344
1969	0.220	0.219	-0.001	0.427
1970	0.216	0.215	-0.001	0.508
1971	0.207	0.207	-0.001	0.325
1972	0.214	0.214	-0.000	0.150
1973	0.194	0.194	0.000	0.233
1974	0.186	0.187	0.001	0.470

TABLE B-22

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN GAS PRICE
FULL-SIZE CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.453	0.438	-0.015	3.276
1961	0.505	0.494	-0.011	2.237
1962	0.511	0.500	-0.011	2.118
1963	0.516	0.506	-0.010	1.933
1964	0.488	0.477	-0.011	2.185
1965	0.441	0.429	-0.012	2.717
1966	0.410	0.398	-0.012	3.024
1967	0.324	0.308	-0.015	4.735
1968	0.259	0.245	-0.014	5.320
1969	0.242	0.229	-0.013	5.493
1970	0.237	0.226	-0.010	4.395
1971	0.254	0.244	-0.010	4.093
1972	0.298	0.288	-0.010	3.300
1973	0.374	0.364	-0.010	2.754
1974	0.362	0.347	-0.014	3.956

TABLE B-23

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN GAS PRICE
LUXURY CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.080	0.081	0.000	0.186
1961	0.083	0.083	0.000	0.213
1962	0.084	0.084	0.000	0.235
1963	0.085	0.085	0.000	0.187
1964	0.086	0.086	0.000	0.125
1965	0.090	0.090	0.000	0.033
1966	0.094	0.093	-0.000	0.081
1967	0.096	0.095	-0.000	0.203
1968	0.096	0.096	-0.000	0.326
1969	0.096	0.096	-0.000	0.339
1970	0.095	0.095	-0.000	0.246
1971	0.095	0.094	-0.000	0.212
1972	0.094	0.094	-0.000	0.128
1973	0.095	0.095	-0.000	0.077
1974	0.093	0.093	0.000	0.059

TABLE B-24

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN GAS PRICE
VEHICLE MILES TRAVELED PER FAMILY

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	10.580	10.372	-0.208	1.963
1961	11.398	11.158	-0.240	2.108
1962	11.591	11.336	-0.254	2.194
1963	11.996	11.704	-0.292	2.437
1964	12.281	11.962	-0.318	2.592
1965	12.480	12.159	-0.321	2.570
1966	13.040	12.721	-0.319	2.445
1967	13.300	12.995	-0.305	2.291
1968	13.399	13.112	-0.286	2.136
1969	13.592	13.322	-0.270	1.988
1970	13.692	13.431	-0.261	1.910
1971	13.593	13.336	-0.256	1.886
1972	13.678	13.416	-0.262	1.918
1973	13.734	13.461	-0.273	1.988
1974	13.364	13.085	-0.279	2.088

TABLE B-25

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN UNEMPLOYMENT RATE
NEW CAR SALES

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	8.993	8.902	-0.091	1.009
1961	6.642	6.573	-0.068	1.031
1962	7.607	7.497	-0.110	1.442
1963	7.524	7.404	-0.119	1.583
1964	8.091	7.958	-0.134	1.650
1965	10.113	9.928	-0.185	1.830
1966	9.177	9.015	-0.162	1.763
1967	8.117	8.000	-0.117	1.444
1968	9.038	8.915	-0.124	1.369
1969	8.900	8.790	-0.110	1.236
1970	7.948	7.905	-0.043	0.536
1971	9.754	9.735	-0.019	0.197
1972	9.611	9.590	-0.021	0.223
1973	11.190	11.124	-0.066	0.593
1974	8.490	8.435	-0.055	0.650

TABLE B-26

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN UNEMPLOYMENT RATE
SCRAPPAGE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	3.545	3.354	-0.191	5.382
1961	3.698	3.583	-0.115	3.105
1962	4.531	4.366	-0.166	3.654
1963	5.420	5.265	-0.155	2.853
1964	6.052	5.912	-0.140	2.320
1965	7.361	7.180	-0.181	2.456
1966	7.939	7.754	-0.185	2.328
1967	7.576	7.483	-0.093	1.226
1968	7.665	7.560	-0.104	1.361
1969	7.446	7.352	-0.093	1.255
1970	6.589	6.651	0.062	0.948
1971	6.021	6.067	0.046	0.757
1972	6.036	6.008	-0.028	0.465
1973	7.471	7.341	-0.130	1.741
1974	8.067	7.977	-0.090	1.121

TABLE B-27

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN UNEMPLOYMENT RATE
SUBCOMPACT CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.127	0.127	0.000	0.038
1961	0.105	0.105	-0.000	0.002
1962	0.130	0.130	0.000	0.116
1963	0.113	0.114	0.000	0.206
1964	0.175	0.175	0.001	0.295
1965	0.210	0.211	0.001	0.398
1966	0.213	0.214	0.001	0.495
1967	0.294	0.296	0.001	0.469
1968	0.358	0.359	0.001	0.411
1969	0.328	0.329	0.001	0.401
1970	0.292	0.293	0.001	0.333
1971	0.260	0.261	0.001	0.252
1972	0.176	0.176	0.000	0.226
1973	0.131	0.131	0.000	0.196
1974	0.170	0.170	0.000	0.071

TABLE B-28

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN UNEMPLOYMENT RATE
COMPACT CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.280	0.280	0.000	0.036
1961	0.231	0.232	0.001	0.243
1962	0.181	0.182	0.001	0.316
1963	0.182	0.183	0.001	0.338
1964	0.122	0.123	0.000	0.403
1965	0.102	0.102	0.000	0.420
1966	0.105	0.105	0.000	0.389
1967	0.083	0.083	0.000	0.274
1968	0.078	0.078	0.000	0.099
1969	0.113	0.113	-0.000	0.079
1970	0.161	0.161	-0.000	0.149
1971	0.183	0.183	-0.000	0.149
1972	0.218	0.218	-0.000	0.094
1973	0.206	0.206	-0.000	0.057
1974	0.190	0.190	-0.000	0.036

TABLE B-29

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN UNEMPLOYMENT RATE
MID-SIZE CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.060	0.060	0.000	0.010
1961	0.076	0.076	-0.000	0.376
1962	0.095	0.094	-0.001	0.643
1963	0.103	0.102	-0.001	0.986
1964	0.129	0.127	-0.002	1.279
1965	0.157	0.155	-0.002	1.561
1966	0.179	0.176	-0.003	1.714
1967	0.203	0.200	-0.003	1.540
1968	0.210	0.207	-0.003	1.259
1969	0.220	0.219	-0.002	0.796
1970	0.216	0.215	-0.001	0.316
1971	0.207	0.207	-0.000	0.012
1972	0.214	0.214	0.000	0.164
1973	0.194	0.194	0.001	0.294
1974	0.186	0.186	0.001	0.333

TABLE B-30

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN UNEMPLOYMENT RATE
FULL-SIZE CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.453	0.453	-0.000	0.039
1961	0.505	0.505	-0.000	0.058
1962	0.511	0.510	-0.000	0.032
1963	0.516	0.517	0.000	0.016
1964	0.488	0.488	0.001	0.105
1965	0.441	0.442	0.001	0.227
1966	0.410	0.412	0.001	0.324
1967	0.324	0.325	0.001	0.378
1968	0.259	0.260	0.001	0.314
1969	0.242	0.243	0.000	0.131
1970	0.237	0.237	-0.000	0.067
1971	0.254	0.254	-0.000	0.155
1972	0.298	0.298	-0.001	0.184
1973	0.374	0.374	-0.001	0.190
1974	0.362	0.361	-0.001	0.182

TABLE B-31

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN UNEMPLOYMENT RATE
LUXURY CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.080	0.080	0.000	0.024
1961	0.083	0.083	0.000	0.021
1962	0.084	0.084	0.000	0.058
1963	0.085	0.085	0.000	0.095
1964	0.086	0.086	0.000	0.146
1965	0.090	0.090	0.000	0.219
1966	0.094	0.094	0.000	0.291
1967	0.096	0.096	0.000	0.317
1968	0.096	0.097	0.000	0.287
1969	0.096	0.096	0.000	0.220
1970	0.095	0.095	0.000	0.112
1971	0.095	0.095	0.000	0.038
1972	0.094	0.094	0.000	0.004
1973	0.095	0.095	0.000	0.001
1974	0.093	0.093	-0.000	0.013

TABLE B-32

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN UNEMPLOYMENT RATE
VEHICLE MILES TRAVELED PER FAMILY

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	10.580	10.587	0.007	0.069
1961	11.398	11.403	0.005	0.045
1962	11.591	11.593	0.003	0.022
1963	11.996	11.992	-0.004	0.034
1964	12.281	12.266	-0.015	0.120
1965	12.480	12.454	-0.026	0.211
1966	13.040	12.999	-0.041	0.312
1967	13.300	13.250	-0.050	0.376
1968	13.399	13.345	-0.053	0.396
1969	13.592	13.538	-0.054	0.398
1970	13.692	13.633	-0.060	0.435
1971	13.593	13.533	-0.059	0.437
1972	13.678	13.629	-0.049	0.358
1973	13.734	13.701	-0.033	0.239
1974	13.364	13.342	-0.021	0.161

TABLE B-33

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO INSURANCE PRICE INDEX
NEW CAR SALES

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	8.993	8.950	-0.043	0.473
1961	6.642	6.626	-0.016	0.240
1962	7.607	7.594	-0.013	0.171
1963	7.524	7.512	-0.011	0.149
1964	8.091	8.080	-0.011	0.142
1965	10.113	10.099	-0.015	0.148
1966	9.177	9.164	-0.013	0.139
1967	8.117	8.106	-0.011	0.141
1968	9.038	9.025	-0.014	0.152
1969	8.900	8.885	-0.015	0.169
1970	7.948	7.932	-0.016	0.204
1971	9.754	9.732	-0.022	0.227
1972	9.611	9.595	-0.016	0.167
1973	11.190	11.175	-0.015	0.132
1974	8.490	8.481	-0.008	0.098

TABLE B-34

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO INSURANCE PRICE INDEX
SCRAPPAGE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	3.545	3.555	0.011	0.304
1961	3.698	3.704	0.006	0.153
1962	4.531	4.531	-0.000	0.009
1963	5.420	5.415	-0.005	0.095
1964	6.052	6.051	-0.001	0.012
1965	7.361	7.360	-0.001	0.015
1966	7.939	7.934	-0.005	0.066
1967	7.576	7.568	-0.008	0.110
1968	7.665	7.654	-0.010	0.135
1969	7.446	7.434	-0.012	0.157
1970	6.589	6.577	-0.012	0.181
1971	6.021	6.010	-0.011	0.179
1972	6.036	6.022	-0.014	0.224
1973	7.471	7.452	-0.019	0.251
1974	8.067	8.047	-0.021	0.258

TABLE B-35

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO INSURANCE PRICE INDEX
SUBCOMPACT CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.127	0.127	0.000	0.009
1961	0.105	0.105	0.000	0.432
1962	0.130	0.130	0.000	0.213
1963	0.113	0.114	0.000	0.280
1964	0.175	0.175	-0.000	0.093
1965	0.210	0.209	-0.000	0.227
1966	0.213	0.212	-0.001	0.269
1967	0.294	0.293	-0.001	0.447
1968	0.358	0.356	-0.002	0.586
1969	0.328	0.326	-0.002	0.620
1970	0.292	0.290	-0.002	0.602
1971	0.260	0.259	-0.001	0.556
1972	0.176	0.176	-0.000	0.127
1973	0.131	0.131	0.000	0.202
1974	0.170	0.170	0.000	0.132

TABLE B-36

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO INSURANCE PRICE INDEX
COMPACT CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.280	0.281	0.001	0.248
1961	0.231	0.232	0.001	0.240
1962	0.181	0.182	0.001	0.365
1963	0.182	0.183	0.001	0.315
1964	0.122	0.123	0.001	0.680
1965	0.102	0.102	0.001	0.939
1966	0.105	0.106	0.001	0.925
1967	0.083	0.084	0.001	1.205
1968	0.078	0.079	0.001	1.286
1969	0.113	0.114	0.001	0.901
1970	0.161	0.162	0.001	0.522
1971	0.183	0.184	0.001	0.385
1972	0.218	0.218	0.000	0.161
1973	0.206	0.207	0.000	0.206
1974	0.190	0.190	0.000	0.226

TABLE B-37

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO INSURANCE PRICE INDEX
MID-SIZE CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.060	0.060	-0.000	0.125
1961	0.076	0.076	-0.000	0.174
1962	0.095	0.094	-0.000	0.211
1963	0.103	0.103	-0.000	0.131
1964	0.129	0.129	-0.000	0.181
1965	0.157	0.157	-0.000	0.229
1966	0.179	0.178	-0.000	0.184
1967	0.203	0.203	-0.000	0.173
1968	0.210	0.209	-0.000	0.103
1969	0.220	0.220	-0.000	0.089
1970	0.216	0.216	-0.000	0.064
1971	0.207	0.207	-0.000	0.069
1972	0.214	0.214	-0.000	0.080
1973	0.194	0.194	0.000	0.008
1974	0.186	0.186	0.000	0.023

TABLE B-38

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO INSURANCE PRICE INDEX
FULL-SIZE CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.453	0.452	-0.001	0.156
1961	0.505	0.504	-0.001	0.188
1962	0.511	0.510	-0.001	0.159
1963	0.516	0.516	-0.001	0.161
1964	0.488	0.487	-0.001	0.107
1965	0.441	0.441	-0.000	0.047
1966	0.410	0.410	-0.000	0.038
1967	0.324	0.324	0.001	0.178
1968	0.259	0.260	0.001	0.468
1969	0.242	0.244	0.001	0.458
1970	0.237	0.238	0.001	0.399
1971	0.254	0.255	0.001	0.306
1972	0.298	0.298	-0.000	0.015
1973	0.374	0.374	-0.001	0.209
1974	0.362	0.361	-0.001	0.210

TABLE B-39

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO INSURANCE PRICE INDEX
LUXURY CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.080	0.081	0.000	0.097
1961	0.083	0.083	0.000	0.088
1962	0.084	0.084	0.000	0.088
1963	0.085	0.085	0.000	0.090
1964	0.086	0.086	0.000	0.099
1965	0.090	0.090	0.000	0.098
1966	0.094	0.094	0.000	0.093
1967	0.096	0.096	0.000	0.096
1968	0.096	0.097	0.000	0.107
1969	0.096	0.096	0.000	0.107
1970	0.095	0.095	0.000	0.112
1971	0.095	0.095	0.000	0.111
1972	0.094	0.094	0.000	0.095
1973	0.095	0.095	0.000	0.082
1974	0.093	0.093	0.000	0.070

TABLE B-40

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO INSURANCE PRICE INDEX
VEHICLE MILES TRAVELED PER FAMILY

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	10.580	10.577	-0.003	0.031
1961	11.398	11.385	-0.013	0.112
1962	11.591	11.574	-0.016	0.140
1963	11.996	11.978	-0.018	0.150
1964	12.281	12.261	-0.019	0.157
1965	12.480	12.460	-0.021	0.165
1966	13.040	13.018	-0.022	0.170
1967	13.300	13.278	-0.022	0.169
1968	13.399	13.376	-0.023	0.169
1969	13.592	13.569	-0.023	0.170
1970	13.692	13.668	-0.024	0.173
1971	13.593	13.568	-0.024	0.180
1972	13.678	13.652	-0.026	0.186
1973	13.734	13.709	-0.025	0.181
1974	13.364	13.341	-0.022	0.167

TABLE B-41

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO REPAIRS PRICE INDEX
NEW CAR SALES

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	8.993	8.922	-0.070	0.781
1961	6.642	6.614	-0.028	0.419
1962	7.607	7.584	-0.023	0.302
1963	7.524	7.505	-0.019	0.251
1964	8.091	8.075	-0.016	0.201
1965	10.113	10.097	-0.017	0.165
1966	9.177	9.163	-0.014	0.149
1967	8.117	8.104	-0.013	0.163
1968	9.038	9.022	-0.017	0.187
1969	8.900	8.881	-0.019	0.213
1970	7.948	7.930	-0.018	0.224
1971	9.754	9.729	-0.025	0.261
1972	9.611	9.586	-0.026	0.269
1973	11.190	11.159	-0.031	0.279
1974	8.490	8.468	-0.021	0.252

TABLE B-42

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO REPAIRS PRICE INDEX
SCRAPPAGE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	3.545	3.562	0.018	0.498
1961	3.698	3.708	0.010	0.283
1962	4.531	4.532	0.001	0.026
1963	5.420	5.413	-0.007	0.130
1964	6.052	6.049	-0.003	0.044
1965	7.361	7.355	-0.006	0.086
1966	7.939	7.926	-0.012	0.156
1967	7.576	7.563	-0.013	0.177
1968	7.665	7.650	-0.014	0.186
1969	7.446	7.428	-0.018	0.237
1970	6.589	6.568	-0.021	0.312
1971	6.021	6.003	-0.019	0.311
1972	6.036	6.017	-0.019	0.315
1973	7.471	7.447	-0.024	0.316
1974	8.067	8.042	-0.025	0.315

TABLE B-43

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO REPAIRS PRICE INDEX
SUBCOMPACT CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.127	0.129	0.002	1.468
1961	0.105	0.107	0.002	1.995
1962	0.130	0.132	0.002	1.516
1963	0.113	0.115	0.002	1.617
1964	0.175	0.177	0.002	0.907
1965	0.210	0.211	0.001	0.649
1966	0.213	0.214	0.001	0.551
1967	0.294	0.295	0.001	0.217
1968	0.358	0.357	-0.000	0.042
1969	0.328	0.328	-0.000	0.044
1970	0.292	0.292	0.000	0.059
1971	0.260	0.261	0.001	0.211
1972	0.176	0.177	0.001	0.808
1973	0.131	0.132	0.002	1.242
1974	0.170	0.171	0.002	0.993

TABLE B-44

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO REPAIRS PRICE INDEX
COMPACT CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.280	0.283	0.002	0.878
1961	0.231	0.233	0.002	0.915
1962	0.181	0.183	0.002	1.079
1963	0.182	0.184	0.002	1.030
1964	0.122	0.124	0.002	1.501
1965	0.102	0.103	0.002	1.754
1966	0.105	0.107	0.002	1.638
1967	0.083	0.085	0.002	1.973
1968	0.078	0.079	0.002	2.093
1969	0.113	0.115	0.002	1.489
1970	0.161	0.162	0.001	0.904
1971	0.183	0.185	0.001	0.737
1972	0.218	0.219	0.001	0.587
1973	0.206	0.208	0.002	0.746
1974	0.190	0.191	0.001	0.774

TABLE B-45

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO REPAIRS PRICE INDEX
MID-SIZE CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.060	0.060	0.000	0.341
1961	0.076	0.076	0.000	0.244
1962	0.095	0.095	0.000	0.149
1963	0.103	0.103	0.000	0.254
1964	0.129	0.129	0.000	0.148
1965	0.157	0.157	0.000	0.026
1966	0.179	0.179	0.000	0.024
1967	0.203	0.203	-0.000	0.065
1968	0.210	0.209	-0.000	0.082
1969	0.220	0.220	-0.000	0.096
1970	0.216	0.216	-0.000	0.068
1971	0.207	0.207	-0.000	0.040
1972	0.214	0.214	0.000	0.003
1973	0.194	0.194	0.000	0.187
1974	0.186	0.186	0.000	0.175

TABLE B-46

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO REPAIRS PRICE INDEX
FULL-SIZE CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.453	0.448	-0.005	1.021
1961	0.505	0.501	-0.004	0.889
1962	0.511	0.506	-0.004	0.816
1963	0.516	0.512	-0.004	0.788
1964	0.488	0.484	-0.004	0.760
1965	0.441	0.438	-0.003	0.737
1966	0.410	0.407	-0.003	0.726
1967	0.324	0.321	-0.002	0.673
1968	0.259	0.258	-0.001	0.517
1969	0.242	0.241	-0.001	0.561
1970	0.237	0.235	-0.002	0.639
1971	0.254	0.253	-0.002	0.727
1972	0.298	0.295	-0.003	0.920
1973	0.374	0.371	-0.004	0.954
1974	0.362	0.358	-0.004	0.975

TABLE B-47

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO REPAIRS PRICE INDEX
LUXURY CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.080	0.081	0.000	0.121
1961	0.083	0.083	0.000	0.125
1962	0.084	0.084	0.000	0.120
1963	0.085	0.085	0.000	0.114
1964	0.086	0.086	0.000	0.112
1965	0.090	0.090	0.000	0.077
1966	0.094	0.094	0.000	0.047
1967	0.096	0.096	0.000	0.037
1968	0.096	0.097	0.000	0.038
1969	0.096	0.096	0.000	0.034
1970	0.095	0.095	0.000	0.034
1971	0.095	0.095	0.000	0.033
1972	0.094	0.094	0.000	0.039
1973	0.095	0.095	0.000	0.044
1974	0.093	0.093	0.000	0.054

TABLE B-48

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO REPAIRS PRICE INDEX
VEHICLE MILES TRAVELED PER FAMILY

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	10.580	10.575	-0.005	0.050
1961	11.398	11.378	-0.021	0.181
1962	11.591	11.564	-0.027	0.229
1963	11.996	11.966	-0.030	0.246
1964	12.281	12.249	-0.031	0.255
1965	12.480	12.448	-0.032	0.254
1966	13.040	13.009	-0.032	0.242
1967	13.300	13.270	-0.030	0.225
1968	13.399	13.370	-0.029	0.215
1969	13.592	13.564	-0.028	0.208
1970	13.692	13.664	-0.028	0.203
1971	13.593	13.565	-0.027	0.200
1972	13.678	13.650	-0.028	0.205
1973	13.734	13.705	-0.029	0.209
1974	13.364	13.335	-0.028	0.211

TABLE B-49

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO INPUT COSTS INDEX
NEW CAR SALES

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	8.993	7.682	-1.311	14.574
1961	6.642	7.153	0.511	7.692
1962	7.607	7.643	0.036	0.476
1963	7.524	7.536	0.012	0.162
1964	8.091	8.189	0.098	1.212
1965	10.113	10.208	0.095	0.936
1966	9.177	9.262	0.085	0.927
1967	8.117	8.201	0.084	1.033
1968	9.038	9.121	0.083	0.916
1969	8.900	8.899	-0.001	0.012
1970	7.948	7.888	-0.060	0.749
1971	9.754	9.591	-0.164	1.679
1972	9.611	9.502	-0.110	1.141
1973	11.190	11.021	-0.169	1.510
1974	8.490	8.374	-0.116	1.365

TABLE B-50

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO INPUT COSTS INDEX
SCRAPPAGE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	3.545	3.427	-0.118	3.318
1961	3.698	3.659	-0.039	1.050
1962	4.531	4.405	-0.126	2.790
1963	5.420	5.329	-0.091	1.684
1964	6.052	6.200	0.148	2.448
1965	7.361	7.364	0.003	0.037
1966	7.939	7.914	-0.025	0.312
1967	7.576	7.549	-0.027	0.353
1968	7.665	7.613	-0.052	0.678
1969	7.446	7.371	-0.075	1.005
1970	6.589	6.526	-0.063	0.952
1971	6.021	5.973	-0.048	0.797
1972	6.036	5.974	-0.061	1.016
1973	7.471	7.372	-0.099	1.319
1974	8.067	7.981	-0.086	1.067

TABLE B-51

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO INPUT COSTS INDEX
SUBCOMPACT CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.127	0.202	0.075	59.260
1961	0.105	0.117	0.012	11.303
1962	0.130	0.147	0.017	13.092
1963	0.113	0.133	0.019	16.823
1964	0.175	0.218	0.043	24.337
1965	0.210	0.255	0.046	21.684
1966	0.213	0.274	0.061	28.691
1967	0.294	0.371	0.076	25.932
1968	0.358	0.443	0.085	23.755
1969	0.328	0.412	0.084	25.657
1970	0.292	0.364	0.072	24.840
1971	0.260	0.297	0.037	14.271
1972	0.176	0.200	0.024	13.730
1973	0.131	0.150	0.019	14.682
1974	0.170	0.186	0.016	9.490

TABLE B-52

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO INPUT COSTS INDEX
COMPACT CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.280	0.250	-0.030	10.693
1961	0.231	0.237	0.006	2.542
1962	0.181	0.179	-0.002	0.904
1963	0.182	0.179	-0.004	2.133
1964	0.122	0.109	-0.014	11.077
1965	0.102	0.088	-0.013	12.819
1966	0.105	0.088	-0.017	16.607
1967	0.083	0.066	-0.017	20.768
1968	0.078	0.060	-0.018	22.621
1969	0.113	0.092	-0.021	18.518
1970	0.161	0.143	-0.018	10.911
1971	0.183	0.181	-0.002	1.125
1972	0.218	0.221	0.003	1.322
1973	0.206	0.211	0.005	2.418
1974	0.190	0.194	0.004	2.332

TABLE B-53

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO INPUT COSTS INDEX
MID-SIZE CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.060	0.060	0.001	1.032
1961	0.076	0.073	-0.003	3.776
1962	0.095	0.093	-0.002	2.120
1963	0.103	0.101	-0.002	2.204
1964	0.129	0.129	-0.000	0.141
1965	0.157	0.158	0.001	0.595
1966	0.179	0.181	0.002	1.399
1967	0.203	0.204	0.001	0.439
1968	0.210	0.206	-0.003	1.650
1969	0.220	0.217	-0.004	1.772
1970	0.216	0.213	-0.003	1.455
1971	0.207	0.206	-0.001	0.415
1972	0.214	0.216	0.002	0.779
1973	0.194	0.197	0.003	1.523
1974	0.186	0.187	0.002	0.831

TABLE B-54

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO INPUT COSTS INDEX
FULL-SIZE CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.453	0.408	-0.045	9.924
1961	0.505	0.491	-0.014	2.824
1962	0.511	0.498	-0.013	2.521
1963	0.516	0.504	-0.012	2.391
1964	0.488	0.460	-0.028	5.756
1965	0.441	0.408	-0.032	7.369
1966	0.410	0.366	-0.045	10.920
1967	0.324	0.266	-0.058	17.940
1968	0.259	0.197	-0.061	23.713
1969	0.242	0.186	-0.057	23.404
1970	0.237	0.187	-0.050	20.959
1971	0.254	0.222	-0.033	12.833
1972	0.298	0.271	-0.027	9.161
1973	0.374	0.348	-0.026	6.916
1974	0.362	0.341	-0.021	5.796

TABLE B-55

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO INPUT COSTS INDEX
LUXURY CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.080	0.080	-0.001	1.152
1961	0.083	0.082	-0.001	0.713
1962	0.084	0.083	-0.001	0.615
1963	0.085	0.084	-0.001	0.684
1964	0.086	0.085	-0.001	0.900
1965	0.090	0.089	-0.001	1.040
1966	0.094	0.092	-0.001	1.311
1967	0.096	0.094	-0.002	2.025
1968	0.096	0.094	-0.003	2.674
1969	0.096	0.094	-0.003	2.654
1970	0.095	0.093	-0.002	2.214
1971	0.095	0.093	-0.002	1.656
1972	0.094	0.093	-0.001	1.471
1973	0.095	0.094	-0.001	1.323
1974	0.093	0.092	-0.001	1.171

TABLE B-56

FULL MODEL
MULTIPLIER EXPERIMENT - 10% INCREASE
IN AUTO INPUT COSTS INDEX
VEHICLE MILES TRAVELED PER FAMILY

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	10.580	10.511	-0.070	0.657
1961	11.398	11.140	-0.258	2.267
1962	11.591	11.443	-0.147	1.272
1963	11.996	11.892	-0.104	0.867
1964	12.281	12.187	-0.094	0.761
1965	12.480	12.425	-0.055	0.439
1966	13.040	13.030	-0.010	0.077
1967	13.300	13.342	0.042	0.315
1968	13.399	13.481	0.083	0.617
1969	13.592	13.714	0.122	0.895
1970	13.692	13.828	0.136	0.992
1971	13.593	13.713	0.121	0.887
1972	13.678	13.759	0.081	0.593
1973	13.734	13.787	0.052	0.382
1974	13.364	13.384	0.021	0.154

TABLE B-57

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN NO. OF U.S. LICENSED DRIVERS
NEW CAR SALES

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	8.993	9.122	0.129	1.436
1961	6.642	6.690	0.049	0.734
1962	7.607	7.649	0.042	0.550
1963	7.524	7.559	0.035	0.466
1964	8.091	8.122	0.030	0.375
1965	10.113	10.145	0.031	0.309
1966	9.177	9.204	0.027	0.300
1967	8.117	8.143	0.025	0.314
1968	9.038	9.068	0.029	0.326
1969	8.900	8.933	0.032	0.362
1970	7.948	7.980	0.033	0.411
1971	9.754	9.797	0.043	0.439
1972	9.611	9.655	0.043	0.452
1973	11.190	11.243	0.053	0.475
1974	8.490	8.530	0.040	0.477

TABLE B-58

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN NO. OF U.S. LICENSED DRIVERS
SCRAPPAGE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	3.545	3.513	-0.032	0.901
1961	3.698	3.681	-0.017	0.462
1962	4.531	4.532	0.001	0.024
1963	5.420	5.436	0.016	0.302
1964	6.052	6.058	0.006	0.100
1965	7.361	7.373	0.012	0.159
1966	7.939	7.958	0.020	0.247
1967	7.576	7.598	0.022	0.292
1968	7.665	7.690	0.025	0.331
1969	7.446	7.478	0.033	0.437
1970	6.589	6.623	0.034	0.515
1971	6.021	6.054	0.032	0.536
1972	6.036	6.069	0.033	0.553
1973	7.471	7.512	0.041	0.551
1974	8.067	8.108	0.040	0.499

TABLE B-59

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN NO. OF U.S. LICENSED DRIVERS
SUBCOMPACT CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.127	0.128	0.001	0.885
1961	0.105	0.106	0.001	0.659
1962	0.130	0.131	0.001	0.476
1963	0.113	0.114	0.001	0.470
1964	0.175	0.176	0.001	0.329
1965	0.210	0.210	0.001	0.293
1966	0.213	0.213	0.001	0.320
1967	0.294	0.295	0.001	0.253
1968	0.358	0.358	0.001	0.233
1969	0.328	0.329	0.001	0.302
1970	0.292	0.293	0.001	0.368
1971	0.260	0.261	0.001	0.398
1972	0.176	0.177	0.001	0.475
1973	0.131	0.131	0.001	0.504
1974	0.170	0.170	0.001	0.451

TABLE B-60

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN NO. OF U.S. LICENSED DRIVERS
COMPACT CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.280	0.279	-0.001	0.306
1961	0.231	0.230	-0.001	0.386
1962	0.181	0.180	-0.001	0.407
1963	0.182	0.182	-0.001	0.340
1964	0.122	0.122	-0.001	0.434
1965	0.102	0.101	-0.000	0.476
1966	0.105	0.105	-0.000	0.471
1967	0.083	0.083	-0.000	0.536
1968	0.078	0.077	-0.000	0.565
1969	0.113	0.112	-0.001	0.501
1970	0.161	0.160	-0.001	0.407
1971	0.183	0.183	-0.001	0.349
1972	0.218	0.217	-0.001	0.253
1973	0.206	0.206	-0.000	0.222
1974	0.190	0.189	-0.001	0.282

TABLE B-61

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN NO. OF U.S. LICENSED DRIVERS
MID-SIZE CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.060	0.060	0.000	0.011
1961	0.076	0.076	0.000	0.342
1962	0.095	0.095	0.000	0.354
1963	0.103	0.103	0.000	0.338
1964	0.129	0.129	0.000	0.293
1965	0.157	0.158	0.000	0.231
1966	0.179	0.179	0.000	0.154
1967	0.203	0.204	0.000	0.084
1968	0.210	0.210	0.000	0.027
1969	0.220	0.220	-0.000	0.010
1970	0.216	0.216	-0.000	0.028
1971	0.207	0.207	-0.000	0.032
1972	0.214	0.214	-0.000	0.026
1973	0.194	0.194	-0.000	0.022
1974	0.186	0.186	-0.000	0.017

TABLE B-62

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN NO. OF U.S. LICENSED DRIVERS
FULL-SIZE CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.453	0.453	-0.000	0.060
1961	0.505	0.505	-0.000	0.015
1962	0.511	0.510	-0.000	0.043
1963	0.516	0.516	-0.000	0.049
1964	0.488	0.488	-0.000	0.084
1965	0.441	0.440	-0.000	0.108
1966	0.410	0.410	-0.000	0.108
1967	0.324	0.323	-0.000	0.141
1968	0.259	0.258	-0.000	0.170
1969	0.242	0.242	-0.000	0.163
1970	0.237	0.236	-0.000	0.150
1971	0.254	0.254	-0.000	0.129
1972	0.298	0.298	-0.000	0.076
1973	0.374	0.374	-0.000	0.041
1974	0.362	0.362	-0.000	0.053

TABLE B-63

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN NO. OF U.S. LICENSED DRIVERS
LUXURY CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.080	0.080	-0.000	0.001
1961	0.083	0.083	0.000	0.022
1962	0.084	0.084	0.000	0.004
1963	0.085	0.085	-0.000	0.007
1964	0.086	0.086	-0.000	0.017
1965	0.090	0.090	-0.000	0.021
1966	0.094	0.094	-0.000	0.018
1967	0.096	0.096	-0.000	0.015
1968	0.096	0.096	-0.000	0.011
1969	0.096	0.096	-0.000	0.006
1970	0.095	0.095	-0.000	0.003
1971	0.095	0.095	-0.000	0.003
1972	0.094	0.094	-0.000	0.003
1973	0.095	0.095	-0.000	0.005
1974	0.093	0.093	-0.000	0.006

TABLE B-64

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN NO. OF U.S. LICENSED DRIVERS
VEHICLE MILES TRAVELED PER FAMILY

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	10.580	10.590	0.010	0.095
1961	11.398	11.438	0.039	0.345
1962	11.591	11.641	0.050	0.434
1963	11.996	12.052	0.056	0.468
1964	12.281	12.341	0.060	0.491
1965	12.480	12.542	0.062	0.494
1966	13.040	13.103	0.063	0.481
1967	13.300	13.361	0.061	0.458
1968	13.399	13.457	0.059	0.440
1969	13.592	13.650	0.057	0.421
1970	13.692	13.748	0.056	0.407
1971	13.593	13.647	0.054	0.401
1972	13.678	13.733	0.055	0.404
1973	13.734	13.790	0.056	0.408
1974	13.364	13.419	0.056	0.416

TABLE B-65

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN U.S. POPULATION AGES 20-29
NEW CAR SALES

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	8.993	8.994	0.002	0.018
1961	6.642	6.642	0.000	0.006
1962	7.607	7.608	0.001	0.007
1963	7.524	7.524	0.001	0.012
1964	8.091	8.092	0.001	0.007
1965	10.113	10.114	0.001	0.007
1966	9.177	9.178	0.001	0.007
1967	8.117	8.118	0.001	0.012
1968	9.038	9.040	0.002	0.017
1969	8.900	8.901	0.001	0.008
1970	7.948	7.949	0.001	0.012
1971	9.754	9.755	0.001	0.007
1972	9.611	9.611	-0.000	0.002
1973	11.190	11.190	-0.000	0.003
1974	8.490	8.489	-0.000	0.004

TABLE B-66

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN U.S. POPULATION AGES 20-29
SCRAPPAGE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	3.545	3.544	-0.000	0.006
1961	3.698	3.698	0.000	0.000
1962	4.531	4.532	0.000	0.010
1963	5.420	5.421	0.001	0.012
1964	6.052	6.052	0.000	0.001
1965	7.361	7.361	0.000	0.003
1966	7.939	7.939	0.000	0.003
1967	7.576	7.576	-0.000	0.001
1968	7.665	7.665	0.000	0.003
1969	7.446	7.446	0.001	0.009
1970	6.589	6.589	0.001	0.008
1971	6.021	6.022	0.001	0.008
1972	6.036	6.036	0.000	0.006
1973	7.471	7.471	0.000	0.005
1974	8.067	8.067	-0.000	0.002

TABLE B-67

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN U.S. POPULATION AGES 20-29
SUBCOMPACT CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.127	0.128	0.001	0.627
1961	0.105	0.105	0.001	0.596
1962	0.130	0.131	0.001	0.555
1963	0.113	0.114	0.001	0.549
1964	0.175	0.176	0.001	0.495
1965	0.210	0.211	0.001	0.456
1966	0.213	0.213	0.001	0.441
1967	0.294	0.296	0.001	0.378
1968	0.358	0.359	0.001	0.333
1969	0.328	0.329	0.001	0.339
1970	0.292	0.293	0.001	0.346
1971	0.260	0.261	0.001	0.359
1972	0.176	0.177	0.001	0.404
1973	0.131	0.131	0.001	0.441
1974	0.170	0.170	0.001	0.401

TABLE B-68

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN U.S. POPULATION AGES 20-29
COMPACT CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.280	0.281	0.001	0.245
1961	0.231	0.232	0.001	0.275
1962	0.181	0.182	0.000	0.264
1963	0.182	0.183	0.001	0.287
1964	0.122	0.123	0.000	0.248
1965	0.102	0.102	0.000	0.224
1966	0.105	0.105	0.000	0.213
1967	0.083	0.083	0.000	0.152
1968	0.078	0.078	0.000	0.102
1969	0.113	0.113	0.000	0.096
1970	0.161	0.161	0.000	0.104
1971	0.183	0.183	0.000	0.121
1972	0.218	0.218	0.000	0.172
1973	0.206	0.207	0.000	0.212
1974	0.190	0.190	0.000	0.170

TABLE B-69

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN U.S. POPULATION AGES 20-29
MID-SIZE CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.060	0.060	-0.000	0.211
1961	0.076	0.076	-0.000	0.176
1962	0.095	0.094	-0.000	0.167
1963	0.103	0.103	-0.000	0.148
1964	0.129	0.129	-0.000	0.140
1965	0.157	0.157	-0.000	0.142
1966	0.179	0.178	-0.000	0.134
1967	0.203	0.203	-0.000	0.150
1968	0.210	0.209	-0.000	0.166
1969	0.220	0.220	-0.000	0.163
1970	0.216	0.215	-0.000	0.161
1971	0.207	0.207	-0.000	0.152
1972	0.214	0.214	-0.000	0.131
1973	0.194	0.193	-0.000	0.103
1974	0.186	0.186	-0.000	0.111

TABLE B-70

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN U.S. POPULATION AGES 20-29
FULL-SIZE CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.453	0.451	-0.001	0.293
1961	0.505	0.504	-0.001	0.220
1962	0.511	0.510	-0.001	0.202
1963	0.516	0.515	-0.001	0.190
1964	0.488	0.487	-0.001	0.201
1965	0.441	0.440	-0.001	0.216
1966	0.410	0.409	-0.001	0.221
1967	0.324	0.323	-0.001	0.284
1968	0.259	0.258	-0.001	0.348
1969	0.242	0.242	-0.001	0.345
1970	0.237	0.236	-0.001	0.341
1971	0.254	0.254	-0.001	0.322
1972	0.298	0.297	-0.001	0.264
1973	0.374	0.374	-0.001	0.214
1974	0.362	0.361	-0.001	0.216

TABLE B-71

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN U.S. POPULATION AGES 20-29
LUXURY CLASS NEW CAR MARKET SHARE

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	0.080	0.080	-0.000	0.033
1961	0.083	0.083	-0.000	0.017
1962	0.084	0.084	-0.000	0.014
1963	0.085	0.085	-0.000	0.012
1964	0.086	0.086	-0.000	0.011
1965	0.090	0.090	-0.000	0.011
1966	0.094	0.094	-0.000	0.013
1967	0.096	0.096	-0.000	0.017
1968	0.096	0.096	-0.000	0.023
1969	0.096	0.096	-0.000	0.024
1970	0.095	0.095	-0.000	0.023
1971	0.095	0.095	-0.000	0.023
1972	0.094	0.094	-0.000	0.019
1973	0.095	0.095	-0.000	0.018
1974	0.093	0.093	-0.000	0.017

TABLE B-72

FULL MODEL
MULTIPLIER EXPERIMENT - 1% INCREASE
IN U.S. POPULATION AGES 20-29
VEHICLE MILES TRAVELED PER FAMILY

YEAR	CONTROL	SHOCK	DIFFERENCE	% DIFF
1960	10.580	10.580	0.000	0.002
1961	11.398	11.399	0.001	0.007
1962	11.591	11.592	0.001	0.008
1963	11.996	11.997	0.001	0.009
1964	12.281	12.282	0.001	0.011
1965	12.480	12.482	0.002	0.013
1966	13.040	13.042	0.002	0.014
1967	13.300	13.302	0.002	0.016
1968	13.399	13.401	0.002	0.017
1969	13.592	13.595	0.003	0.020
1970	13.692	13.695	0.003	0.020
1971	13.593	13.595	0.003	0.021
1972	13.678	13.681	0.003	0.020
1973	13.734	13.737	0.003	0.018
1974	13.364	13.366	0.002	0.016

FOOTNOTES

1. In this report the terms Wharton EFA Automobile Demand Model and Wharton EFA auto model refer to the same model. Wharton EFA, refers to Wharton Econometric Forecasting Associates, Inc.

2. The equations of the model are actually divided into five computational blocks or subroutines within the computer program. These subroutines correspond to the computational blocks as follows:

Computational Block	Wharton EFA Program Subroutine Name
Block A	LINKS
Block B	PRICES
Block C	1st half of DSIRES
Block D	2nd half of DSIRES
Block E	DMANDS
Block F	STOCKS

3. The harmonic mean of x =

$$\frac{n}{\sum_{r=i}^{n} x_r^{-1}}$$

4. The 1974 model by Chase Econometrics Inc., the 1976 model by Eastwood and Anderson, and the 1958 model by Suits examine the effect of credit terms on new car demand. Walker, in his 1968 model, found a relationship between scrappage rates and repair costs.

5. The assumption was also made in the model reported in the U.S. Department of Transportation's _Marketing and mobility panel report_, published in 1976 by the Interagency Task Force on Motor Vehicle Goals Beyond 1980. However, in a recent study [Golomb D.H., and Bunch H.M. 1978. _Stochastic analysis of future vehicle populations_. Ann Arbor, Michigan: The University of Michigan], it was found that the q_i's may actually decrease to close to zero for vehicles aged twelve to twenty years. In addition, it was found that the scrappage probabilities, q_i, differ by size class. Therefore, Wharton EFA's aggregate survival model and assumptions concerning the q_i's may produce biased scrappage estimates by age and size class.

6. An equation is identified as reproducible if the HSRI results (which include the estimated coefficients, standard errors of the

estimated coefficients, the adjusted R^2 ($\bar{R}^2$) statistics, and the standard errors of the estimated equation (SEE)) matched those results reported in the Wharton EFA auto model documentation to at least the fourth or fifth significant digit. Discrepancies in the fourth or fifth significant digit may be due to differences in the computer algorithms used by HSRI and Wharton EFA to estimate the equations.

7. This calculation neglects at least one other impact on the desired stock caused by an increase in income. The increase in income causes "trading up" to larger cars in the market segments; this then implies an increase in the average capitalized cost per mile, which tends to decrease the desired stock. However, the calculation does serve to illustrate the basic point that the net effect of the increase of an income on the desired stock per family is virtually zero in the long run.

8. The Almon lag procedure is one in which the lag weights are assumed to follow a polynomial of a given degree. To formulate it one must specify the appropriate degree of the polynomial and state the number of periods before the weights can be assumed to be zero. The original article on this subject is: Almon, S. 1965. The distributed lag between capital appropriations and expenditures. Econometrica 33:178-96.

9. The formula for SIML R-SQ is

$$\text{SIML R-SQ} = 1 - \frac{\sum_{i=a}^{b} (S_i - h_i)^2}{\sum_{i=a}^{b} (h_i - \bar{h})^2}$$

where

a = starting year of simulation
b = ending year of simulation
S = simulated value for year i
h = historical (actual) value for year i
$\bar{h}$ = average historical value

The formula above is similar to the one used to calculate the R^2 for a single equation model. The only difference between the SIML R-SQ and the single equation R^2 is in the computation of the endogenous (predicted) value, which in this case is the simulation value, S_i. In the single equation model, the endogenous variable is computed using the actual values of the independent variables for each year. In the case of SIML R-SQ, the endogenous variable,

S_i, is computed from values generated by the model rather than from actual values.

Over the forecasting interval (a to b), the SIML R-SQ statistic expresses the variation between the historical and simulated values as a fraction of the total variation in the historical values. Since the total variation of the simulated values from the actual values may exceed the total variation of the actual values from their mean, the SIML R-SQ, unlike the R^2, may have a negative value. That is, $\Sigma\ (S_i - h_i)^2$ may be greater than $\Sigma\ (h_i - \bar{h}_i)^2$.

The SIML R-SQ has the same interpretation for the multi-equation model as the R^2 has for the single equation model over the positive range. That is, the positive SIML R-SQ values indicate the proportion of the variation of the endogenous variable that can be attributed to the predictive capacity of the model. Negative values can be taken to indicate the model's poor ability to predict. These negative values may also indicate changes in the structure of the modeled system, or instability of the estimated coefficients.

10. The SIML R-SQ statistic predicts this same result. A negative SIML R-SQ--which all the new car market shares have--indicates that the sum of squared errors of the simulations is higher than the sum of squared differences of the historical values from their mean, which is the same as HSRI's naive forecast.

    If the sum of squared errors in the simulation is larger than the sum of squared differences in the variable from its mean, the same is true for the squared roots of these sums. The squared roots of these sums divided by the number of years included in the simulation is the RMSE. Thus, a negative SIML R-SQ implies that a naive forecast using the historical mean has a lower RMSE over the historical period than the simulated values generated by the model.

11. The Wharton EFA authors note in their report that there is a third phase in this process that the HSRI results do not show due to the length of the simulation period. Apparently, if the simulation period is extended enough, the increase in small car shares eventually is eroded until small car shares fall below the baseline solution and full-size car shares gain and rise above the baseline solution.

12. It should be noted that these results do not necessarily imply a one-for-one switching from full-size cars to small cars (subcompact and compact). What they more likely indicate is that full-size new car buyers trade down to mid-size and that

mid-size buyers trade down to small cars in equal numbers, resulting in no net impact on the mid-size new car segment.

13. The basic logic of impact elasticity being greater in magnitude than the long-run or steady-state elasticity is well founded in the literature of automobile demand. It is strictly implied by the conventional Chow-Nerlove stock adjustment model as well as by other more empirical approaches to modeling auto demand. For a survey of new car price elasticity estimates see White 1971, pp. 94-95; and Mellman 1975.

14. This result is to be compared with the results of the multiplier experiment in which the price of gasoline (also a component of operating costs)is increased. New car sales and scrappage move in the same direction in that experiment.

15. This is due to the assumption that older cars are driven less, on the average, than newer cars. Thus, number of miles driven per year is believed to be a decreasing function of the age of a vehicle.

16. Note the emphasis on the phrase "long run" here. The model does have a very troublesome result from the point of view of a policymaker interested in the short run impact on sales volume of an increase in new car price. The model has a short run (one year) price elasticity with respect to sales volume of -1.5 which says, for example, that if a federal regulation increases the price of a new car by 5%, then sales can be expected to decline by 7.5% in the first year, other things being equal.

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ABSTRACT

The Wharton EFA Automobile Demand Model is an econometric computerized model that forecasts the long-run sales and scrappage of automobiles, in total and for five size classes. An analysis of the model was performed, consisting of four tasks: a detailed analysis and critique of its structure and theory, reestimation and examination of the key equations by use of historical data, historical simulations of submodels and of the full model, and multiplier or sensitivity analysis of the submodels and the full model. It was found that the model contains several innovations in the forecasting of auto demand, but that it has several serious shortcomings.