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# A REVIEW OF THE REVISIONS TO THE WHARTON EFA AUTOMOBILE DEMAND MODEL: MARK I AND II

## AN INTERIM REPORT

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# CHAPTER ONE
# INTRODUCTION

Following the release of the Wharton Econometric Forecasting Associates' (EFA) Automobile Demand Model and its computer program, staff of the The University of Michigan Highway Safety Research Institute (HSRI) undertook an analysis of that model. Concurrent with the HSRI analysis, Wharton EFA developed the Motor Vehicle Demand Models Mark I and II. These latter models are revised and extended versions of the Automobile Demand Model. The purpose of this paper is to outline the differences among the Wharton EFA Automobile Demand Model and the 1978 Wharton EFA Motor Vehicle Demand Models.

It is assumed that the reader is familiar with the Wharton EFA Automobile Demand Model and the HSRI analysis of that model. The reader who is unfamiliar with this research is referred to the Automobile Demand Model documentation (Schink and Loxley 1977) and the HSRI analysis (Golomb et al. 1979). This paper is based on those reports and the Motor Vehicle Demand Model (Mark I) draft documentation (Loxley et al. 1978) and the Motor Vehicle Demand Model (Mark II) draft documentation (Loxley, Osiecki, and Rodenrys 1978). The computer programs of the Motor Vehicle Demand Models are unavailable at the time of this writing.

This paper is primarily a descriptive outline of the differences among the models and is not intended to be an analysis of the new models. Based on the information available in the draft documentation of the Mark I and Mark II, the following questions are addressed:

- What are the changes made in the revised models?
- Do these changes address the weaknesses of the original model?

The two new Motor Vehicle Demand Model reports, Mark I and Mark

II, actually each contain several models. Multiple models exist because alternate equations for the same endogenous variable have been developed in several cases.

The objective of the Mark I models is to better forecast the impacts of various federal policies on gasoline consumption, scrappage, vehicle miles traveled, and the demand for automobiles. The major differences between the original (1977) and the Mark I models are that the revised behavioral equations are reestimated using data of a different time period, that passenger vans are removed from the vehicle data, and that several alternative models are developed.

The objective of the Mark II models is to forecast the impact of various federal policies on gasoline consumption, scrappage, vehicle miles traveled, and the demand for both automobiles and light-duty trucks (LDTs). Thus, the major difference between the Mark II models and the other models is the capability of forecasting the impact of potential federal laws regulating LDTs.

This paper is organized as follows: Chapter Two contains a comparison of the original model and the models presented in the Mark I report. In Chapter Three the Mark II models are discussed in the context of the original and Mark I models. The findings are summarized in Chapter Four.

# CHAPTER TWO
# THE MARK I MODELS

The Mark I models, unlike the Automobile Demand (original) model, concern only the automobile market. Thus, one effort in the development of those models was the removal of all trucks from the data used to estimate the equations of the original model. Passenger vans were included in the original model as full-size automobiles. Loxley et al. (1978 pp. 1-2) described the other objectives of their Mark I study as:

(1) To the extent possible, add behavioral equation(s) for the share(s) of imported passenger automobiles.

(2) To the extent possible, add behavioral equations for scrappage by size class.

(3) Adapt the model to allow exogenous changes in scrappage by size class.

(4) Reestimate the desired-stock equation, replacing the family units variable with (a) licensed drivers; and (b) population over age sixteen; and compare these alternative formulations.

(5) Develop a procedure for estimating annual baseline fuel consumption based on the forecasts of fleet fuel economy and vehicle miles traveled produced by the new model.

(6) Develop an algorithm for linking the model output to the Wharton Annual Model macroeconomic expenditure and price components.

(7) Modify the output tables to include the above changes, specifically showing scrappage by class; gasoline consumption; linkages to the Annual Model; imports as a share of total registrations; EPA fuel economy ratings by class; and the average total automobile price.

(8) Present a baseline forecast and an alternative scenario specified by the contract monitor.

(9) Revise and update the database, providing full documentation to TSC [Transportation Systems Center].

This section presents a discussion of the attainment of the nine objectives and the removal of trucks from the data used in developing the original model. In addition to the listed objectives, Wharton EFA revised the equations estimating new registrations, scrappage, fuel efficiencies, and prices. These revised equations are also presented and compared in this section.

## 2.1 Removal of Truck Data

The equations in the original model were estimated with data that include passenger vans as full-size automobiles. To remove these vans from the data, Wharton EFA estimated the stock of passenger vans in operation for each year of the sample period. This involved determining scrappage rates for vans of each vintage and new van sales, using data from Wards, Automotive News, and Chilton. In addition, Wharton EFA developed adjustment factors to ensure equality between actual and predicted van scrappage.

The passenger van models included in the original model as full-size automobiles, but excluded from the Mark I models, are the Plymouth Voyager, Dodge Sportsman, Ford Club Wagon, Chevrolet Sportvan, and Volkswagon Bus. The exclusion of these vans from the Mark I models reduces car registrations (both new and total) and the full-size-class market share (thus increasing the other size-class shares) as compared with the original model.

## 2.2 Equations for Foreign and Domestic Size-Class Shares

In the original model, the foreign and domestic shares are set exogenously. The objective of the revisions in Mark I is to make the foreign and domestic shares endogenous. The original model contains five desired size-class share equations for the following shares:

- combined subcompact and compact,
- the subcompact share of the combined share,

- midsize,
- full-size, and
- luxury classes.

The domestic shares are defined as proportions of three size-class submarkets: subcompact, compact, and luxury. Wharton EFA's classification scheme is such that the midsize and full-size classes have no foreign entries. For the original model, Wharton EFA developed equations to estimate the desired domestic proportion of each size class. However, these equations produced poor results, and Wharton EFA made the proportions enter the model exogenously; that is, the domestic shares of the subcompact, compact, and luxury submarkets are set at forty-eight, ninety-three, and eighty-eight percent, respectively, over the period 1976 to 2000.

In the Mark I models, there is a desired-share equation for each of eight shares: foreign subcompact, domestic subcompact, foreign compact, domestic compact, domestic midsize, domestic full size, foreign luxury, and domestic luxury. Tables A-1 to A-8 show these equations and, where applicable, the original equations are included for comparison purposes. In the Mark I study, Wharton EFA estimated more than one specification for several of the desired-share equations. The default and alternate equations are coded in the model computer program and indicated in the tables. Thus, the program user can select alternates to the default equation.

Loxley et al. (1978) report that the approach used in the Mark I study allows the determinants for each class of car (and the relative strengths of the determinants) to vary for foreign and domestic cars of a particular class. For example, the percent of the population living in Standard Metropolitan Statistical Areas (SMSAs) may be a more important determinant of the share of foreign luxury cars than domestic luxury cars.

The second difference between the desired-share equations of the original and Mark I models is the change in the relative capitalized cost per mile variable (CPM). In the original model, the cost variable was the CPM of a car of class i relative to a weighted average CPM of cars of all classes other than class i. The Mark I cost variables limit this cost comparison to only assumed substitutes of the class being estimated. Thus, the relative cost variables for the Mark I models are as follows:

| | |
|---|---|
| For Subcompact: | Relative to a weighted average of other (i.e., foreign or domestic) subcompact and compact class CPMs. |
| For Compact: | Relative to a weighted average of subcompact, midsize, and other compact class CPMs. |
| For Midsize: | Relative to a weighted average of all other class CPMs. |
| For Full-size: | Relative to a weighted average of midsize and luxury class CPMs. |
| For Luxury: | Relative to a weighted average of midsize, full size, and other luxury class CPMs. |

The revised desired-share equations required that the actual share (new registrations by size class) equations be revised. The actual share equations are also affected by data revisions (change of time periods and removal of passenger vans) and the recent increases in the relative prices of foreign cars. These revised equations and, where applicable, the original equations appear in Tables A-9 through A-15.

In the original model, the five actual share equations are for combined subcompact and compact, midsize, full-size, and luxury, and the subcompact share of the combined share. The Mark I models have seven actual share equations: foreign subcompact, domestic subcompact, domestic compact, domestic midsize, domestic full-size, domestic luxury, and combined foreign compact and foreign luxury. The foreign compact and luxury shares are combined under the Wharton EFA classification scheme because in recent years the higher prices of imported compacts have pushed those cars into the luxury class.

The original model's weaknesses related to the estimation of size-class shares as stated by Golomb et al. (1979) are basically: (1) the stock adjustment approach does not work for modeling new car market shares or the foreign and domestic shares; (2) the desired share equations do not consider the potential substitutability between used cars and the low-price end of the new car market; and (3) the estimates of size-class market shares are subject to large errors.

The Mark I models again estimate new car market shares using the questionable stock adjustment approach. However, the foreign and domestic shares are determined endogenously. The substitutability between used cars and the low price end of the new car market is again not considered. The Mark I models' capability of producing accurate forecasts of size-class market shares can be examined by comparing historical values with the models' ex ante forecasts; that comparison is outside the scope of this brief review.

## 2.3 Scrappage Estimates by Size Class

Wharton EFA reports that they were unable to do a behavioral analysis of scrappage by size class in the Mark I "because of inadequate and nonexistent data." Therefore, scrappage by size class is determined by a set of identities.

## 2.4 Exogenous Adjustments to the Scrappage Estimates

Wharton EFA modified the Mark I models to allow scrappage by size class to be adjusted exogenously. This modification to the Mark I computer program would allow a user to override a portion of the model's structure.

## 2.5 Desired-Stock Equations

In the Mark I study, several formulations of the desired automobile stock equation were estimated for experimental purposes. The original model has the desired stock per family unit as the dependent variable. The independent variables are disposable income per family unit, nonauto commuters per family unit, licensed drivers per family unit, percent of the population with incomes greater than $15,000, percent populaton living in SMSAs, and the desired-share-weighted capitalized cost per mile. (Family units are the sum of families and unrelated individuals.) The equations in both the original and Mark I models are estimated with 1972 cross-section state data (excluding Oklahoma, Alaska, and Hawaii). The

Mark I study contained estimates of desired stock based on four formulations:

(A) The same specification as in the original model with the differences in the values of the coefficients resulting from the revised data (i.e., no trucks).

(B) The same specification as in the original model, except licensed drivers is used instead of family units, and the variable, number of licensed drivers, is excluded.

(C) The same specification as in the original model, except population sixteen years of age and older is used instead of family units.

(D) The same specification as in the original model, except population between sixteen and sixty-four years of age is used instead of family units.

Table A-16 contains these four equations, plus the equation from the original model for comparison purposes. The model authors report that the estimated coefficients are "amazingly robust" across the equations. However, while the point estimates are generally close computationally, statistical interpretations can differ. In equation B, the coefficient on the variable, percent population with incomes greater than $15,000, is significantly different from zero at the one percent level. In equation C, that coefficient is not significantly different from zero at the ten percent level.

However, a more important issue is the benefits derived from estimating the various formulations. With the specifications of the equations generally changing only as a result of changes in the population scalar (e.g., family units), the closeness of the point estimates indicates that the scalars are highly correlated across states. The estimation results do not produce additional behavioral information about auto ownership.

The computer program of the Mark I models, as described in the documentation, includes only equation A as an alternative to the estimated equation of the original model; the other equations were estimated solely as part of an experiment and are included in Table A-16 only for comparison purposes.

As in the original model, the Mark I desired-stock equation is used to develop estimates of the desired stock over both the sample and forecast periods. Adjustments are made to ensure that over time the percent of families with incomes of $15,000 or more is at least 20 percent, and that the desired and actual stocks are equal in 1972. A comparison of the original and Mark I historical desired stock series appears in Table A-17. Over the period of 1958 to 1968, the Mark I desired-stock estimates are as much as 2.8 million vehicles (or 5%) higher than the original estimates even though the small van stock is absent. Over the period 1969 to 1974, the Mark I estimates are lower than the original estimates, with the differences as large as 1.8 million vehicles (or 2%).

The Mark I revision of the desired-stock equation does not remove the weaknesses identified by Golomb et al. (1979). That study criticized the original equations for being estimated over cross-section state data that has minimal variation due to fundamental differences in prices, taxes, etc. They concluded that this implies that relationships critical to the simulation of most policy scenarios are a deficient representation of reality. Since the Mark I equation is estimated over the same data (with the minor exception that passenger vans are absent), these criticisms remain applicable.

As in the original model, the capitalized cost-per-mile coefficient in the Mark I equation is still less than its standard error. That is, the model implies that the cost of auto ownership is not an important determinant of the desired stock.

Golomb et al. (1979) report that the original historical (albeit estimated) desired-stock series required a substantial amount of adjustment to forecast over the sample period with reasonable accuracy; the future desired-stock series of the original model is also adjusted. While the Mark I documentation indicates some adjustments were made to the sample-period stock series, there is no indication that adjustments were made to the future desired-stock series.

To summarize, the Mark I desired-stock equation has the same specification as in the original model and only minor differences in the values of the coefficients. The criticisms of the original equation remain applicable to the Mark I equation.

## 2.6 Equations for Fuel Consumption and Vehicle Miles Traveled

Objective (5) calls for the development of a procedure estimating annual gasoline consumption based on fleet fuel economy and vehicle miles traveled (VMT). To do this, Wharton EFA substantially revised the original model's VMT equation and developed an algorithm to estimate gasoline consumption.

The original model has one equation that estimates VMT per family as a function of a constant mileage-weighted sum of vehicle miles by vintage per family unit, real gasoline cost per mile, an income distribution variable, and real disposable permanent income per family unit. The Mark I models have two VMT equations: one each for rural and urban miles traveled per midyear stock of cars. Urban mileage is estimated as a function of real gasoline cost per mile (using city fleet average MPG), real disposable income per capita in the form of a three-year moving average, and licensed drivers per vehicle weighted by the percent of the population living in metropolitan areas. Rural mileage is estimated as a function of real gasoline cost per mile (using highway fleet average MPG), licensed drivers per vehicle, income distribution, and total interstate road mileage per vehicle. These equations appear in Tables A-18 and A-19.

Total VMT is determined as follows:

$$\text{Total VMT} = (\text{VMTR/K} + \text{VMTU/K}) \times \text{KMID} \qquad (2.1)$$

where

VMTR/K = rural VMT per midyear stock of vehicles
VMTR/K = urban VMT per midyear stock of vehicles
KMID = midyear stock of vehicles in operation

Golomb et al. (1979) are critical of the structural content of the VMT equation in the original model. They observe that the coefficients of the estimated equation are negative for income and positive for income distribution. As part of the substantial revisions to the approach in forecasting VMT, Wharton EFA has eliminated the possibility of perverse signs by including only the income variable in each of the VMT equations, and each has the expected positive sign.

Unlike the original model, the Mark I models contain an algorithm to estimate fuel consumption based on VMT and fuel efficiencies. In developing the algorithm, the model authors made two assumptions. First, the fuel economy of a car does not change over time. Second, the scrappage rates are the same across all classes of a particular vintage (i.e., model year). The Mark I models compute gasoline consumption as follows:

$$GASAUTO = M/K \sum_{i=0}^{20} (KV_i \times M_i \times \frac{1}{AVTTMPG_i}) \qquad (2.2)$$

where

GASAUTO = gasoline consumed by automobiles

M/K = estimated average miles traveled per vehicle in a particular year

KV = number of vehicles in vintage i

M = distribution factor, reflecting miles driven by vintage i

AVTTMPG = average mpg for vintage i cars (harmonic mean with the shares by class as weights)

In equation 2.2, the values of GASAUTO over the sample period are known, the values of M are held constant, and KV and AVTTMPG are model projections. M/K is different; its values should be close to average miles per vehicle but are neither known nor projected by the model at this point. Wharton EFA then uses M/K as the equilibrating mechanism to ensure that the model's projections of KV and AVTTMPG will produce reasonably accurate estimates of gasoline consumption. To accomplish this, Wharton EFA developed estimates of M/K over the sample period as follows:

$$M/K = GASAUTO/\left(\sum_{i=0}^{20} KV_i \times M_i \times \frac{1}{AVTTMPG_i}\right) \quad (2.3)$$

Once Wharton EFA derived historical values for M/K, they were able to estimate an equation relating M/K to VMT/K. That estimated equation is:

$$\ln(M/K) = \underset{(1.54)}{0.172612} + \underset{(19.53)}{0.920927} [\ln(VMT/K)] + \underset{(5.88)}{0.0228832} DUM59.64 - \underset{(-5.8)}{0.0258069} DUM74.75 + \underset{(1.99)}{0.014727} DUM73 \quad (2.4)$$

$R^2 = 0.966$  DW = 2.099  SEE = 0.0064762  Period = 1956 to 1976

where t-statistics are in parentheses and

| | | |
|---|---|---|
| VMT/K | = | vehicle miles traveled per midyear stock of vehicles |
| DUM59.64 | = | dummy variable equal to one if the observation is from the years 1959 to 1964, otherwise zero |
| DUM74.75 | = | dummy variable equal to one if the observation is from the years 1974 or 1975, otherwise zero |
| DUM73 | = | dummy variable equal to one if the observation is from 1973, otherwise zero |

For the forecast period of the Mark I models, equation (2.4) estimates M/K using the forecasts for VMT per vehicle. The M/K estimate is then used in equation (2.2) to compute an estimate of gasoline consumption.

## 2.7 Linkages to the Wharton Annual Model

Objective (6) calls for the development of an algorithm linking the output of the Mark I models to the Wharton Annual Model macroeconomic expenditure and price components. Wharton EFA developed three points of direct contact between the Mark I and Annual Models: automobile purchase prices, expenditures on automobiles, and expenditures on gasoline consumption. While the documentation does not mention whether the Mark I models produce feedback to the Annual Model, personal correspondence with the model authors indicates that this interaction is only one way: Annual Model forecasts are used as exogenous inputs to the Mark I models. The algorithm linking the models consists of a group of identities and six estimated equations. These linkages are a significant revision to the original model, but a review of them is outside the scope of this paper. The interested reader is referred to the model documentation for the form and derivation of the equations.

## 2.8 Modification of Output Tables

Objective (7) appears to be a computer programming task. The output tables were modified to specifically show gasoline consumption, Annual Model linkages, imports as a share of total registrations, EPA fuel economy ratings by class, the average total automobile price, and other changes made by Wharton EFA (e.g., exogenous changes in scrappage by class).

## 2.9 Baseline and Alternative Scenario Forecasts

A preliminary forecast is contained in the Mark I documentation. Presumably, this is the baseline case to be compared with alternative policy scenarios. Since the alternative scenario was not specified by the contract monitor prior to the draft publication deadline, it is not included in the documentation.

## 2.10 Database Update

The preliminary forecast presented in the Mark I draft documentation is based on an updated version of the 1977 database. These values of the exogenous variables are revised to consider the latest forecasts developed in conjunction with the Wharton Annual Model. The demographic variables affected include number of families, unrelated individuals, licensed drivers, and total population. The models' economic variables are affected by the updated assumptions of growth in gross national product, inflation, and gasoline prices. In addition, exogenous vehicle characteristic variables are affected by the recent downsizing trends. These trends include lower vehicle weight, decreased engine displacement, relatively more cars with manual transmissions, and a higher percentage of cars having four or six cylinders. These revised data are documented in the Mark I report.

## 2.11 New-Registrations Equation

Although they did not specifically so state in the objectives, Wharton EFA modified several equations or groups of equations in the Mark I models. These estimate new-registrations, scrappage, fuel efficiencies, and automobile prices. The revised new-registrations equation is discussed next, while the latter equations are presented in the following subsections.

The specification of the new-car-registrations equation is the same in both the Mark I and original models. However, the Mark I models' estimates of the coefficients differ from those of the original model, for two reasons. First, the sample period is changed from 1954-1974 to 1959-1975 for the Mark I models. Second, as previously discussed, the Mark I sample data exclude passenger vans (recall that passenger vans were included in the original model as full-size automobiles). Table A-20 contains these equations.

Prices enter the new-registrations equation indirectly through the desired-stock variable and directly through the price-change variable. In their analysis of the original model, Golomb et al. (1979) simulated a long-run price change that boosts all future prices by one percent. The output shows a large short-run impact attributable to the price-change variable and a small long-run impact transmitted through the desired-stock variable. Because of this and the weaknesses of the desired-stock equation, Golomb et al. conclude that the model is price insensitive and state that they had little confidence in the model's estimated price elasticities. With the Mark I specification of the new-registrations equations unchanged, and a similar desired-stock equation, the shortcomings of the original model likely carry through to the Mark I models.

## 2.12 Scrappage Equation

The specification of the aggregate scrappage equation remains the same in the Mark I models as in the original model. However, the estimated coefficients are different because of the two revisions in the data. The revisions are the previously mentioned removal of passenger vans, and a change of sample periods from 1958-1974 to 1959-1975. The estimated coefficients appear in Table A-21.

## 2.13 Fuel-Efficiency Equations

For the Mark I models, Wharton EFA revised both on-the-road and U.S. Environmental Protection Agency (EPA) MPG equations. These equations are numerous and not included in this paper. However, a brief description of their derivation is presented. The specific equations are available in Loxley et al. (1978).

Wharton EFA used the following procedure to develop the on-the-road equations for the original model: test data by model from Consumer Reports are used to estimate two cross-section equations (for city and highway MPGs) as a function of inertia weight, engine displacement, and dummy variables for automatic transmissions, four cylinders, six cylinders, and particular years (sometimes groups of years) over the period of 1950 to 1975; to develop MPGs for all model cars (Consumer Reports does not estimate MPGs for all models), Wharton EFA substituted the characteristics of each model into the cross-section equations. These MPG estimates by model car are used to calculate sales-weighted MPGs by size class for each year in the sample period. Then, these class MPGs are used to estimate time-series on-the-road MPG equations (for city and highway MPG by class) that have the same variables as the cross-section equations. Note that the time-series equations have different values of the coefficients than do the cross-section equations.

The Mark I on-the-road MPG equations are derived using a similar procedure with the following exceptions: First, Wharton EFA reports that since the Consumer Reports test procedure changed in 1967, the test data over the 1950-1977 period are incompatible; thus, the revised cross-section equations are estimated on data from 1967 to 1977. Second, the specifications of both the cross-section and time-series equations are changed: dummy variables for several years were eliminated and new ones were added to reflect the change in sample periods.

The effect of these two changes is to make the on-the-road MPG response to weight reductions much greater in the Mark I models than in the original model. In fact, the estimated increase in city MPG for a given weight reduction is almost fifty percent greater in the Mark I models.

For the original model, the EPA MPG estimates are developed as follows: Using 1975 and 1976 data, the EPA MPGs are estimated as a function of the Consumer Reports MPG estimates; then EPA MPGs for each class are estimated by substituting Consumer Reports-based size-class MPGs into the equations. Wharton EFA notes three weaknesses of this approach: the small sample size (fifty observations covering two years), the lack of an adjustment method when the pooled cross-section results are developed into a time series, and the pure correlation aspects of the approach (since the EPA MPGs were estimated solely as a function of the Consumer Reports-based MPG).

For the Mark I models, Wharton EFA used two different approaches: one similar to the method used for on-the-road MPGs and one similar to the method used to develop the EPA MPGs in the original model. Using the on-the-road approach, Wharton EFA estimated EPA MPGs (city and highway) as a function of inertia weight, engine displacement, and dummy variables for transmission type, number of cylinders, and the years 1975 and 1976. The data used in the regressions are a pooled cross-section of ninety-four observations from the model years 1975 to 1977. The EPA MPG time series is then developed in "exactly the same manner" as the on-the-road MPGs.

The second approach, similar to the one used for the original model, estimates EPA MPG as a function of the on-the-road MPGs for both city and highway. The cross-section equations are estimated with 1975-1977 data. These equations are coded in the computer program as alternates.

To summarize, the revisions to the fuel efficiency equations are substantial. If the revised equations forecast more accurately, then the

Mark I model's capability for policy analysis (particularly, for example, regarding Energy Policy and Conservation Act standards) is enhanced.

### 2.14 Automobile-Price Equations

The Mark I models contain revised equations (by size class) for automobile base prices, options expenditures, and new automobile transportation charges. The specifications of these equations remain generally the same as in the original model except for the foreign base-price equations. The original model has foreign base prices as a function of a weighted average of a foreign car export price index. The Mark I models have foreign base prices as a function of a price deflator for imported manufactured goods. The other price and options expenditure equations differ because of different sample periods and minor specification changes (i.e., elimination of some dummy variables for certain years). These equations appear in Tables A-22 to A-31.

In addition, Wharton EFA incorporated into the Mark I models four new independent equations predicting the operating cost component price indexes using Wharton Annual Model price deflators. The insurance and parking plus miscellaneous price indexes are functions of the implicit deflator for consumer expenditures on services. The maintenance and motor oil price indexes are related to the implicit deflator for all consumer expenditures. These equations are estimated over the period 1960 to 1976 and are shown in Tables A-32 and A-33.

The new automobile transportation cost equations have also been revised for the Mark I models. Those equations as well as the original model equations appear in Tables A-34 to A-38. The differences in the equations are due solely to the longer sample period used for the Mark I models: additional observations from 1975-1976 are included. Wharton EFA observes that the transportation charges (by class) are tending to move closer together over time and that they have incorporated this trend into the Mark I models. Because of this, Wharton EFA introduced the constraint "that the charges for each class may never exceed those for the next (more expensive) class within the domestic and foreign groups" (Loxley et al. 1978).

## 2.15 Summary

In the Mark I study, Wharton EFA revised many of the equations of the original Automobile Demand Model. These revisions range from minor to substantial. Equations that are substantially revised are size-class market shares, foreign and domestic shares, vehicle miles traveled, and fuel efficiencies. In addition, the Mark I models forecast fuel consumption, which the original model did not. Other equations received minor revisions; these include desired automobile stock, new registrations, scrappage, and price equations.

Golomb et al. (1979) noted several weaknesses in the equations for desired auto stock, new registrations, scrappage, and price. Review of the available draft Mark I documentation indicates that many of these weaknesses remain. Of course, the model may change prior to the completion of its final report, and conclusions cannot be drawn without careful examination of the final documentation and computer program of the model.

# CHAPTER THREE
# THE MARK II MODELS

The objective of the Mark II study is the development of the Wharton EFA Vehicle Demand Models (Mark II), which include the demand for both automobiles and light-duty trucks (LDTs). Recall that the Mark I models included only automobiles and that the original model included automobiles and passenger vans (passenger vans being one type of LDT). Wharton EFA describes the Mark II models as permitting "the assessment of the joint impacts on both cars and trucks of changes in government policies and the economic environment for the purposes of forecasting and scenario analysis with respect to the AFER [Automobile Fuel Economy Regulation] program" (Loxley, Osiecki, and Rodenrys 1978).

To attain the objective, Wharton EFA added LDT-related variables to the data base, changed the sample period, and developed an approach using econometric equations for desired stocks, new registrations, scrappage, vehicle miles traveled, and prices for personal vehicles, automobiles, and LDTs. These equations as well as the coverage and assumptions of the Mark II are discussed in the following sections.

## 3.1 Coverage of the Models

The Mark II study splits the light-duty vehicle market into personal vehicles and commercial-use vehicles. Personal vehicles are automobiles and personal-use LDTs such as the lighter vans and pickups, and all sport utility vehicles. Wharton EFA classified all LDTs under 10,000 pounds gross vehicle weight (GVW) by model name plate. The models classified as personal-use LDTs appear in Table 3-1. Those GVW class 1 and 2 truck models not appearing in Table 3-1 are classified as commercial-use LDTs. Wharton EFA notes that this classification scheme was based on availability of data and is subject to revision.

TABLE 3-1

PERSONAL-USE LIGHT-DUTY TRUCKS BY MODEL

- Passenger vans included in automobile registrations:

  Plymouth Voyager
  Dodge Sportvan
  Ford Club Wagon
  Chevrolet Sportvan
  Volkswagen Bus

- The following GVW Class 1 and 2 truck models (1977):

| | |
|---|---|
| Chevrolet: | Vans<br>El Camino<br>LUV<br>Suburban<br>Blazer |
| Dodge: | Vans<br>Trail Duster<br>RamCharger |
| Ford: | Econoline<br>Ranchero<br>Bronco<br>Courier |
| General Motors Corporation: | Vandura<br>Suburban<br>Jimmy<br>Sprint |
| International: | Scout |
| American Motors Corporation: | JEEP® CJ5<br>JEEP® CJ7<br>Commando |
| All Imports | |

Source: Loxley, Osiecki, and Rodenrys 1978, Table A1

### 3.2 Desired-Stock Equations

As with Motor Vehicle Demand Models (Mark I) and the Automobile Demand Model, the Mark II models are based on a stock-adjustment process requiring estimates of desired stock. For the Mark II models, Wharton EFA estimated three desired-stock equations for personal vehicles (which are personal-use LDTs plus automobiles), automobiles, and commercial-use LDTs, using cross-section data from 1976. These equations appear in Table B-1 of Appendix B.

The desired stocks of automobiles and personal vehicles are functions of real disposable income per licensed driver, cost per mile of vehicle operation (by type of vehicle--i.e., automobile or personal vehicle), and percentage of the population earning $15,000 or more. The automobile desired-stock equation of the Mark II models differs from that used in the Mark I models in several ways. First, the cost-per-mile variable in the Mark II models includes registration fees and personal property taxes. Second, the Mark II formulation is in terms of stock per licensed driver rather than per family unit. This is probably a minor issue since the Mark I study showed that for 1972, the number of licensed drivers and number of family units are highly correlated across states. In addition, the following independent variables are not included: licensed drivers per family unit and nonauto commuters per family unit. Third, for the Mark II models, the equation was estimated using 1976 rather than 1972 cross-section data.

The desired stock of commercial-use vehicles is specified to be a function of the percentage of the population living in SMSAs; the percentage of road mileage in rural areas; the percentage of the population over sixty-five years old; and income earned in agriculture, construction, wholesale and retail trade, and services, divided by the cost per mile of commercial-use vehicle operation.

In Mark II, the desired stock of personal-use LDT is equal to a residual (i.e., the difference between the desired stock of personal vehicles and automobiles). Wharton EFA notes that this process is "less desirable" than a ratio (personal-use LDTs to automobiles) function but that its attempts to estimate such a function were unsuccessful.

The desired-stock equations were used to develop-time series estimates in the same manner as in the Mark I study. However, in the Mark II study the desired and actual personal vehicles and commercial-use LDTs are assumed to be in equilibrium in 1976. The automobile stocks, as in the previous models, are assumed by Wharton EFA to be in equilibrium in 1972. The income-saturation variable is constrained in the same manner as in the original and Mark I models.

As a final note, the desired-share equations used in determining new automobile registrations by size class remain the same in the Mark II models as in the Mark I models. These equations are based on 1972 cross-section data and are assumed in equilibrium that year.

### 3.3 New-Registration and Scrappage Equations

As in the Mark I study, the new-registrations equations have the rate of new registrations relative to prior-period stock less current scrappage as a function of the ratio of desired to existing stock, the rate of change in real disposable income, the rate of change in vehicle prices, and a dummy variable for auto strikes. For commercial-use LDTs, income (or economic activity variable) is the same as for the desired-stock equation, and the auto strike dummy is not included. The new-registrations equations appear in Table B-2.

Personal-use LDTs are again calculated as a residual from personal vehicle and automobile estimates. Wharton EFA attempted to estimate a separate new personal-use LDT registrations equation but was unsuccessful. They did estimate an equation relating new car registrations to new personal-use LDTs, but judged the elasticities as unreasonable. While this equation is contained in Table B-3, it is not included in the models.

Personal vehicle and automobile scrappage levels are estimated as functions of a ratio of desired to existing stocks, average age of the vehicle, used car prices relative to the scrap metal price, unemployment rate, ratio of current to lagged VMT per vehicle for the current and two prior periods, and dummy variables for auto strikes and the year 1973. The automobile scrappage equations in the Mark I and II models are different, in that (1) the Mark I equation does not have the two dummy variables, and (2) the Mark II model has a 1960-1976 rather than a 1959-1975 sample period.

Commercial-use LDT scrappage is a function of the ratio of the desired to existing stock, the average age of commercial-use LDTs, and the recent trend in VMT per vehicle. All these scrappage equations appear in Table B-4.

### 3.4 Vehicle-Miles-Traveled Equations

The vehicle-miles-traveled equations appear in Tables B-5 and B-6. These four equations estimate urban and rural automobile miles traveled per family, and personal-use LDT and commercial-use LDT miles traveled per vehicle. For automobile miles traveled, the equations are different from the Mark I models where VMT is in per-vehicle terms and different independent variables are included; however, the same sample period is used for both the Mark I and II models.

Personal-use LDT miles traveled are a function of gasoline cost per mile, percentage of the population earning more than $15,000, percentage of the population living in SMSAs, and a dummy variable for the years 1973 and 1974. Commercial-use LDT miles traveled are a function of gasoline cost per mile, relative commercial personal income (using income earned in agriculture, construction, etc.), and a dummy variable for 1973-1974. Thus, Wharton EFA finds that the determinants of VMT depend on the type of vehicle.

### 3.5 Base-Price Equations

Purchase-price equations were estimated for automobiles, personal-use LDTs, commercial GVW class 1 LDTs, and commercial GVW class 2 LDTs. These four equations appear in Table B-7. Each vehicle price is a function of Wharton EFA's index of motor vehicle industry costs that is derived from an input-output coefficient weighted combination of industry inputs. The Mark II price elasticity of input costs (estimated over 1964-1976) is 1.19, while the Mark I elasticity (estimated over 1959-1976) is 1.09.

### 3.6 Major Assumptions and the Updated Database

The major assumptions incorporated into the Mark II models are:

1. Auto Fuel Economy

   The annual CAFE (corporate average fuel economy) regulations through 1985 are assumed to be met through the automakers' downsizing program that reduces curb weight by 20% and engine displacement by 30-40%, and increases on-the-road MPG by 18% between 1978 and 1985. Thereafter, automobile MPGs are held constant at the 1985 levels.

2. LDT Fuel Economy

   The LDT CAFE standards are assumed to be met through 1982. Thereafter, the LDT MPGs are held constant at 1982 levels:

   | | |
   |---|---|
   | Personal LDT | 15.48 |
   | Commercial GVW Class 1 | 16.20 |
   | Commercial GVW Class 2 | 12.71 |

   The commercial GVW class 2 LDTs are assumed to split evenly between those affected by the standards (i.e., under 8,500 pounds) and those not affected by the standards.

3. Imports

   Domestic subcompact sales are increased and import sales are reduced by 250,000 units starting in 1979-1980 to account for Volkswagen's U.S. production and the "loss of captives."

4. Passive Restraints

   Wharton EFA has assumed that the passive restraint safety standards will come into effect in 1982-1984 and that the standards will be met by the installation of airbags. This will increase base prices by about 3.5%.

Wharton EFA has also incorporated forecasts of the Wharton Annual

Model Control Forecast of September 1978 into the Mark II models. These forecasts affect the demographic, fiscal and monetary policy, and energy variables in the model.

### 3.7 Summary of Mark II

The Mark II study essentially extended the Motor Vehicle Demand Models (Mark I) to incorporate and forecast the demand for light-duty trucks (LDTs). Truck model nameplates were used to classify the LDTs by either personal or commercial use. Trucks within each class are assumed to have the same characteristics. Prices, purchase decisions, and life-cycle characteristics are used to distinguish the two truck classes. Thus, the Mark II models simulate policy impacts on different types of trucks as well as automobiles. Given the high degree of substitutability between automobiles and light trucks, the capability of simulating the substitute market impacts of various policies represents an advancement in motor vehicle demand modeling.

# CHAPTER FOUR
## SUMMARY OF FINDINGS

1. The Wharton EFA Motor Vehicle Demand Models, Mark I and Mark II, are revisions of the Wharton EFA Automobile Demand Model. The Mark I models are similar to the original model, except that some equations have been revised and the capability to forecast gasoline consumption has been added. The Mark II models extend the Mark I models by incorporating the demand for light-duty trucks.

2. Much of the basic structure of the original automobile demand model has not been substantially revised in developing the new Motor Vehicle Demand Models. Thus, many of the major criticisms of the original model raised by Golomb et al. (1979) remain applicable to the newer models. The major revision of the original model's structure involves the foreign, domestic, and size-class market shares; the foreign and domestic shares are determined endogenously in the Mark I and Mark II models.

3. The Mark II study produced a truck sector model that was appended to a revised Mark I model. The Mark I model was revised to be compatible with the truck model; these revisions are relatively minor. The truck sector considers only light-duty trucks divided into two classes, personal and commercial use. The Mark II models break new ground by incorporating automobile and truck demands into a single analytical tool capable of simulating policy impacts on substitute vehicle markets.

# APPENDIX A

# TABLES FOR CHAPTER TWO

TABLE A-1

Desired-Share Equation*
Subcompact Domestic

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | | | | |
|---|---|---|---|---|---|---|---|
| | | ln(Disposable Income Relative to CPM) | ln(% Pop. Incomes ≥$15,000) | ln(Relative Cost Per Mile) | ln(≥5 Member Families Per Total Families) | ln(Licensed Drivers Per Total Families) | ln(Members Age 20-29 Per Family) |
| Mark I | -4.80385<br>(-5.03) | 0.362749<br>(1.51) | | -6.40592<br>(-1.85) | -0.384973<br>(-1.63) | -0.374033<br>(-1.36) | 0.734697<br>(2.16) |
| Mark I Alt 1 | -2.74142<br>(-2.20) | -2.93615<br>(-0.92) | 0.275177<br>(2.64) | -4.7059<br>(-1.42) | -0.311017<br>(-1.39) | | 0.712406<br>(2.25) |
| Mark I Alt 2 | -3.62431<br>(-6.54) | | | -9.01486<br>(-2.96) | -0.345339<br>(-1.45) | -0.307719<br>(-1.11) | 0.668029<br>(1.95) |
| Mark I Alt 3 | -3.53302<br>(-8.58) | | | -6.03953<br>(-2.11) | -0.231279<br>(-1.08) | | 0.497057<br>(1.62) |

* Table continues on following page.

TABLE A-1 continued

Desired-Share Equation[1]
Subcompact Domestic

(t-statistics in parentheses)

| MODEL | INDEPENDENT VARIABLES | | | | | STATISTICS | | |
|---|---|---|---|---|---|---|---|---|
| | Location[2] | | | | ln(% Pop. Living In SMSAs) | Adjusted $R^2$ | DW | SEE |
| | New England | Mountain | Pacific | South Atlantic | | | | |
| Mark I | 0.157733 (2.24) | 0.415821 (5.99) | 0.710566 (6.02) | 0.22813 (3.62) | | 0.645 | 1.942 | 0.13295 |
| Mark I Alt 1 | 0.114885 (1.66) | 0.339668 (4.96) | 0.575919 (4.64) | 0.204312 (3.43) | | 0.686 | 1.985 | 0.12498 |
| Mark I Alt 2 | 0.185331 (2.68) | 0.437897 (6.35) | 0.758697 (6.57) | 0.242995 (3.84) | | 0.633 | 1.935 | 0.13515 |
| Mark I Alt 3 | 0.169096 (2.73) | 0.395589 (6.50) | 0.651905 (6.02) | 0.216459 (3.83) | 0.00265838 (3.35) | 0.707 | 1.856 | 0.12065 |

Notes: 1. The dependent variable is in logit form: ln(SHRX/1-SHRX). The data are cross-sectional from 1971 to 1972.
2. The variable is population in a particular census region relative to the rest of the U.S.

TABLE A-2

Desired-Share Equation[1]
Subcompact Foreign

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ln(Relative Cost Per Mile) | ln(≥5 Member Families Per Total Families) | ln(Licensed Drivers Per Total Families) | ln(Members Age 20-29 Per Family) | Location[2] | | | | |
| | | | | | | New England | Mountain | Pacific | East North Central | West North Central |
| Mark I | -3.38946 (-7.29) | -4.87433 (-1.66) | -0.386194 (-2.06) | 0.658284 (2.37) | | 0.331975 (3.80) | 0.479727 (7.69) | 0.867458 (9.82) | -0.490832 (-6.52) | -0.469395 (-7.47) |
| Mark I Alt 1 | -3.37867 (-7.19) | -5.33475 (-1.74) | -0.457308 (-2.02) | 0.622759 (2.16) | 0.201479 (0.57) | 0.325294 (3.66) | 0.493023 (7.35) | 0.871716 (9.75) | -0.478048 (-6.03) | -0.450721 (-6.31) |

| MODEL | STATISTICS | | |
|---|---|---|---|
| | Adjusted $R^2$ | DW | SEE |
| Mark I | 0.916 | 2.278 | 0.13044 |
| Mark I (Alt1) | 0.914 | 2.24 | 0.13162 |

Notes: 1. The dependent variable is in logit form: ln(SHRX/1-SHRX). The data are cross-sectional from 1971 to 1972.
2. The variable is population in a particular census region relative to the rest of the U.S.

TABLE A-3

Desired-Share Equation[1]
Compact Domestic

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | ln(Relative Cost Per Mile) | ln(Disposable Income Relative to CPM) | ln(% Pop. Income ≥$15,000) | ln(3-4 Member Families Per Total Families) | ln(Licensed Drivers Per Total Family) | Location[2] | | |
| | | | | | | | New England | West South Central | East South Central | Mountain |
| Mark I | 3.54098<br>(3.57) | -2.37497<br>(-3.08) | -1.04112<br>(-3.76) | 0.226864<br>(2.40) | 1.13020<br>(5.41) | -0.432808<br>(-2.00) | 0.119706<br>(2.88) | -0.350547<br>(-5.69) | -0.276576<br>(-4.49) | 0.122279<br>(2.63) |

| MODEL | STATISTICS | | |
|---|---|---|---|
| | Adjusted $R^2$ | DW | SEE |
| Mark I | 0.662 | 1.873 | 0.090182 |

Notes: 1. The dependent variable is in logit form: ln(SHRX/1-SHRX). The data are cross-sectional from 1971 to 1972.
2. The variable is population in a particular census region relative to the rest of the U.S.

TABLE A-4

Desired-Share Equation[1]
Compact Foreign

(t-statistics in parentheses)

| | INDEPENDENT VARIABLES | | | | | | | | | STATISTICS |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Location[2] | | | | | |
| Constant | ln(Relative Cost Per Mile) | ln(3-4 Member Families Per Total Families) | ln($\geq$5 Member Families Per Total Famimies) | ln(Members Age 20-29 Per Family) | New England | West South Central | East North Central | West North Central | East South Central | Adjusted $R^2$, DW, SEE |
| -10.6215 | -5.78683 | -4.67712 | -1.76231 | 2.22688 | 0.970882 | -1.05921 | -1.12274 | -1.0598 | -0.921984 | 0.696 |
| (-6.21) | (-1.02) | (-2.68) | (-2.19) | (1.52) | (3.52) | (-3.51) | (-3.77) | (-3.43) | (-3.39) | 1.492 |
| | | | | | | | | | | 0.4672 |

Notes: 1. The dependent variable is in logit form: ln(SHRX/1-SHRX). The data are cross-sectional from 1971 to 1972.

2. The variable is population in a particular census region relative to the rest of the U.S.

TABLE A-5

Desired-Share Equation[1]
Midsize Domestic

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | | | | STATISTICS | |
|---|---|---|---|---|---|---|---|---|
| | | ln(Relative Cost Per Mile) | ln(Disposable Income Relative to CPM) | ln(3-4 Member Families Per Total Families) | Location[2] | | Adjusted $R^2$ | DW, SEE |
| | | | | | New England | Mountain | | |
| Original | 0.211089<br>(0.39) | -1.98095<br>(-4.57) | -0.161133<br>(-1.31) | 0.785861<br>(4.73) | 0.162809<br>(4.01) | -0.125991<br>(-3.65) | 0.683 | <br>0.0779 |
| Mark I | 0.170431<br>(0.32) | -1.96554<br>(-4.54) | -0.151175<br>(-1.23) | 0.789071<br>(4.94) | 0.163106<br>(3.99) | -0.126228<br>(-3.64) | 0.681 | 1.462<br>0.078171 |

Notes: 1. The dependent variable is in logit form: ln(SHRX/1-SHRX). The data are cross-sectional from 1971 to 1972.

2. For the original model, the variable is a dummy equal to one if the state is in the region, zero otherwise. For the Mark I models, the variable is population in a particular census region relative to the rest of the U.S.

TABLE A-6

Desired-Share Equation[1]

Full-Size Domestic

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ln(Relative Cost Per Mile) | ln(Disposable Income Relative to CPM) | ln(3-4 Member Families Per Total Families) | ln(% Pop. Income ≥$15,000) | Location[2] New England | Location[2] Mountain | Location[2] Pacific | ln(≥5 Member Families Per Total Families) | ln(% Pop. Living In SMSAs) |
| Original | -1.84714 (-1.63) | -8.84702 (-12.81) | 0.831944 (3.01) | -0.771159 (-3.52) | -0.506012 (-6.11) | | | | 0.158820 (1.11) | |
| Mark I | -4.54484 (-3.33) | -2.69743 (-1.56) | 0.964768 (2.73) | -1.53709 (-5.02) | -0.461523 (-3.27) | -0.380533 (-5.46) | -0.439377 (-6.57) | -0.613140 (-6.71) | 0.234735 (1.29) | -0.00159402 (-1.26) |
| Mark I Alt. | -5.296 (-4.08) | -0.827695 (-0.52) | 1.14408 (3.43) | -1.68049 (-5.68) | -0.566527 (-5.24) | -0.410528 (-6.13) | -0.394882 (-5.85) | -0.605177 (-6.39) | 0.220694 (1.18) | |

| MODEL | STATISTICS Adjusted $R^2$ | DW | SEE |
|---|---|---|---|
| Original | .865 | | 0.1070 |
| Mark I | 0.810 | 1.641 | 0.127 |
| Mark I Alternate | .801 | 1.596 | 0.13001 |

Notes: 1. The dependent variable is in logit form: ln(SHRX/1-SHRX). The data are cross-sectional from 1971 to 1972.

2. For the original model, the variable is a dummy equal to one if the state is in the region, zero otherwise. For the Mark I models, the variable is population in a particular census region relative to the rest of the U.S.

TABLE A-7

Desired-Share Equation[1]
Luxury Domestic

(t-statistics in parentheses)

| | | INDEPENDENT VARIABLES | | | | | | STATISTICS | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Location[2] | | | | | |
| MODEL | Constant | ln(Relative Cost Per Mile) | ln(% Pop. Income ≥$15,000) | ln(%Pop. Living in SMSAs) | New England | West South Central | Pacific | Adjusted $R^2$ | DW | SEE |
| Mark I | -2.29697 | -2.9645 | 0.168731 | 0.00238569 | -0.374005 | 0.197402 | -0.251549 | 0.610 | 1.783 | 0.13597 |
| | (-3.89) | (-1.27) | (1.74) | (1.95) | (-5.58) | (2.19) | (-3.0) | | | |

Notes: 1. The dependent variable is in logit form: ln(SHRX/1-SHRX). The data are cross-sectional from 1971 to 1972.

2. The variable is population in a particular census region relative to the rest of the U.S.

TABLE A-8
Desired-Share Equation[1]
Luxury Foreign

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | | | | | STATISTICS | |
|---|---|---|---|---|---|---|---|---|---|
| | | ln(Relative Cost Per Mile) | ln(% Pop. Income ≥$15,000 | ln(% Pop. Living in SMSAs) | Location[2] | | | Adjusted $R^2$ | DW, SEE |
| | | | | | East North Central | West South Central | East South Central | | |
| Mark I | -4.73383<br>(-4.53) | -8.62247<br>(-4.05) | 0.714675<br>(3.41) | | -0.616782<br>(-3.60) | -0.0638977<br>(-0.29) | -0.142541<br>(-0.72) | 0.606 | 1.191<br>0.34114 |
| Mark I Alternate | -3.85531<br>(-3.50) | -8.68357<br>(-4.22) | 0.312479<br>(1.09) | 0.00572897<br>(1.98) | -0.632022<br>(-3.81) | -0.23773<br>(-1.04) | -0.264309<br>(-1.32) | 0.632 | 1.363<br>0.32965 |

Notes: 1. The dependent variable is in logit form: ln(SHRX/1-SHRX). The data are cross-sectional from 1971-1972.
2. The variable is population in a particular census region relative to the rest of the U.S.

TABLE A-9

Actual-Share Equation*
Subcompact Domestic

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | STATISTICS | | | |
|---|---|---|---|---|---|---|---|
| | | ln(Existing Share Per Desired Share) | Dummy Variable 1969 | Adjusted $R^2$ | DW | SEE | Sample Period |
| Mark I | -0.425809<br>(-3.486) | -0.932829<br>(-6.19997) | -1.99422<br>(-4.16) | 0.837 | 1.194 | 0.42871 | 1958-<br>1975 |

Note: *The dependent variable is in logit form.

TABLE A-10

Actual-Share Equation*
Subcompact Foreign

(t-statistics in parentheses)

| MODEL | Constant | ln(Existing Share Per Desired Share) | STATISTICS | | | |
|---|---|---|---|---|---|---|
| | | | Adjusted $R^2$ | DW | SEE | Sample Period |
| Mark I | 0.0830043<br>(6.47562) | -0.331174<br>(-11.7682) | 0.896 | 1.158 | 0.034249 | 1959-<br>1975 |

Note: *The dependent variable is in logit form.

TABLE A-11

Actual-Share Equation*
Compact Domestic

(t-statistics in parentheses)

| MODEL | Constant | ln(Existing Share Per Desired Share) | STATISTICS | | | |
|---|---|---|---|---|---|---|
| | | | Adjusted $R^2$ | DW | SEE | Sample Period |
| Mark I | 0.0612474<br>(3.87496) | -0.340419<br>(-14.6598) | 0.93 | 1.044 | 0.049227 | 1959-<br>1975 |

Note: *The dependent variable is in logit form.

TABLE A-12

Actual-Share Equation*
Midsize Domestic

(t-statistics in parentheses)

| MODEL | Constant | ln(Existing Share Per Desired Share) | STATISTICS | | | |
|---|---|---|---|---|---|---|
| | | | Adjusted $R^2$ | DW | SEE | Sample Period |
| Original | -0.00198516<br>(-0.66) | -0.873077<br>(-82.94) | 0.997 | 1.26 | 0.0101 | 1954-1974 |
| Mark I | 0.00723071<br>(1.04808) | -0.916888<br>(-42.5769) | 0.991 | 1.927 | 0.015492 | 1959-1975 |

Note: *The dependent variable is in logit form.

TABLE A-13

Actual-Share Equation*
Full-Size Domestic

(t-statistics in parentheses)

| MODEL | Constant | ln(Existing Share Per Desired Share) | STATISTICS | | | |
|---|---|---|---|---|---|---|
| | | | Adjusted $R^2$ | DW | SEE | Sample Period |
| Original | -0.0115806<br>(-3.06) | -0.826937<br>(-47.12) | 0.991 | 1.05 | 0.0168 | 1954-<br>1974 |
| Mark I | -0.0203659<br>(-1.77067) | -0.898058<br>(-20.4792) | 0.963 | 0.607 | 0.047227 | 1959-<br>1975 |

Note: *The dependent variable is in logit form.

TABLE A-14

Actual-Share Equation*
Luxury Domestic

(t-statistics in parentheses)

| MODEL | Constant | ln(Existing Share Per Desired Share) | STATISTICS | | | |
|---|---|---|---|---|---|---|
| | | | Adjusted $R^2$ | DW | SEE | Sample Period |
| Mark I | 0.00116789<br>(0.519682) | -0.698699<br>(-21.6122) | 0.967 | 1.926 | 0.0092387 | 1959-<br>1975 |

Note: *The dependent variable is in logit form.

TABLE A-15

Actual-Share Equation*
Compact and Luxury: Foreign

(t-statistics in parentheses)

| MODEL | INDEPENDENT VARIABLES | | | STATISTICS | | | |
|---|---|---|---|---|---|---|---|
| | Constant | ln(Existing Share Per Desired Share) | Dummy Variable 1965 | Adjusted $R^2$ | DW | SEE | Sample Period |
| Mark I | 0.0822068<br>(5.65194) | -0.3704<br>(-10.9929) | -0.116963<br>(-2.71111) | 0.908 | 1.899 | 0.039927 | 1959-1975 |

Note: *The dependent variable is in logit form.

TABLE A-16
Desired-Stock Equations*
(t-statistics in parentheses)

| MODEL | DEPENDENT VARIABLE | Constant | INDEPENDENT VARIABLES | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | ln(Real Income Per Unit) | ln(% Pop. Income ≥$15,000) | ln(Desired Share-weighted CPM) | ln(Licensed Drivers Per Unit) | ln(Nonauto Commuters Per Unit) | ln(% Pop. in SMSAs) |
| Original | Stock Per Family | -1.9059 (-2.40) | 0.563344 (3.13) | -0.100994 (-1.92) | -0.199527 (-0.84) | 0.421187 (3.07) | -0.0536642 (-1.48) | 0.0990056 (1.61) |
| Mark I A | Stock Per Family | -1.91069 (-2.40582) | 0.563472 (3.13435) | -0.101018 (-1.92174) | -0.199696 (-0.846598) | 0.421331 (3.07246) | -0.0536255 (-1.47823) | 0.0990298 (1.60921) |
| Mark I B | Stock Per Driver | -2.11324 (-3.52099) | 0.606904 (4.31181) | -0.112863 (-2.64138) | -0.239518 (-1.13493) | | -0.0501665 (-1.43991) | 0.108841 (1.95328) |
| Mark I C | Stock Per Pop. Age ≥16 | -1.60974 (-2.13381) | 0.475493 (2.57628) | -0.0648301 (-1.06094) | -0.101315 (-0.412957) | 0.403021 (3.12161) | -0.0649099 (-1.74198) | 0.0774198 (1.23811) |
| Mark I D | Stock Per Pop. Age 16-64 | -1.60974 (-2.61579) | 0.564698 (3.06439) | -0.099761 (-1.76712) | -0.202186 (-0.852594) | 0.43038 (3.29983) | -0.0528387 (-1.46824) | 0.10033 (1.64275) |

| MODEL | DEPENDENT VARIABLE | STATISTICS | | |
|---|---|---|---|---|
| | | Adjusted $R^2$ | DW | SEE |
| Original | Stock Per Family | 0.461 | | 0.0596 |
| Mark I (A) | Stock Per Family | 0.461 | 1.684 | 0.059563 |
| Mark I (B) | Stock Per Driver | 0.501 | 1.651 | 0.058947 |
| Mark I (C) | Stock Per Pop. Age ≥16 | 0.538 | 1.730 | 0.058802 |
| Mark I (D) | Stock Per Pop. Age 16-64 | 0.522 | 1.662 | 0.059583 |

Note: *The dependent variable is in log form. The data are cross-sectional from 1972.

TABLE A-17

Estimated Desired Automobile Stock 1958-1975
(Millions)

| Year | Original Model | Mark I Model |
|---|---|---|
| 1958 | 55.9 | 58.7 |
| 1959 | 58.0 | 60.1 |
| 1960 | 60.2 | 62.2 |
| 1961 | 61.8 | 63.1 |
| 1962 | 63.6 | 65.0 |
| 1963 | 65.8 | 67.4 |
| 1964 | 68.4 | 70.2 |
| 1965 | 71.5 | 73.2 |
| 1966 | 74.2 | 75.8 |
| 1967 | 76.3 | 77.9 |
| 1968 | 78.3 | 78.6 |
| 1969 | 80.5 | 79.7 |
| 1970 | 82.8 | 81.8 |
| 1971 | 85.4 | 84.4 |
| 1972 | 88.1 | 87.5 |
| 1973 | 91.0 | 90.7* |
| 1974 | 92.5 | 90.7* |
| 1975 | NA | 93.6 |

Source: Loxley et al. 1978, pp. 2-9.

Note: *This seems peculiar and may be a typographical error.

TABLE A-18

Equation for Urban VMT Per Midyear Stock of Cars[1]

(t-statistics in parentheses)

| MODEL | | INDEPENDENT VARIABLES | | | STATISTICS | | |
|---|---|---|---|---|---|---|---|
| | Constant | ln(Gas Per Mile Cost)[2] | ln(Urban Drivers Per Midyear Stock) | ln(Real Permanent Income)[3] | Adjusted $R^2$ | DW | SEE |
| Mark I | -1.43792<br>(-2.30747) | -0.371407<br>(-7.76729) | 0.298117<br>(2.32539) | 0.61974<br>(19.9262) | 0.988 | 2.618 | 0.010656 |

Notes:

1. The sample period is 1960-1976. The dependent variable is in log form.

2. Calculated as

   (gas price/100/city MPG estimate)/(consumer price index/125.3).

3. Calculated as

   $0.25\ (Y) + 0.5\ (Y_{-1}) + 0.25\ (Y_{-2})$

   where Y = real disposable income per capita less taxes and certain transfer payments.

TABLE A-19

Equation for Rural VMT Per Midyear Stock of Cars[1]

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | | | STATISTICS | | |
|---|---|---|---|---|---|---|---|---|
| | | ln(Gas Cost Per Mile)[2] | ln(Licensed Drivers Per Stock of Cars) | ln(% Pop. Income ≥ $15,000) | ln(Interstate Mileage Per Stock of Cars) | Adjusted $R^2$ | DW | SEE |
| Mark I | -0.945592<br>(-1.73) | -0.355343<br>(-3.78) | 2.05965<br>(3.19) | 0.192317<br>(2.27) | 0.216018<br>(1.95) | 0.851 | 2.789 | 0.016262 |

Notes:

1. The sample period is 1960 to 1976. The dependent variable is in log form.

2. Calculated as

(Gas price/100/City mpg estimate)/(Consumer price index/125.3).

TABLE A-20

Equation for Total New-Car Registrations[1]

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | | | STATISTICS | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | ln(Desired Stock Relative to Existing Stock) | ln(Relative Real Disposable Income Per Family)[2] | $\ln[(\text{Auto Price})/(\text{Auto Price})_{-1}]$ | Dummy for Auto Strikes | Adjusted $R^2$ | DW | SEE | Sample Period |
| Original | -2.9151<br>(-35.20) | 3.79294<br>(9.90) | 6.03907<br>(8.30) | -1.2668<br>(-3.45) | -0.25519<br>(-2.49) | 0.864 | 2.28 | 0.0473 | 1954-1974 |
| Mark I | -2.64204<br>(-32.2094) | 2.45923<br>(5.02245) | 4.21669<br>(5.7421) | -1.06590<br>(-2.64462) | -0.288736<br>(-3.19509) | 0.906 | 1.841 | 0.038985 | 1959-1975 |

Notes:

1. The dependent variable is ln(Total new-car registrations per existing stock).

2. Current-period real disposable income relative to permanent real disposable income.

TABLE A-21

Equation for Total Automobile Scrappage*

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | | | | | | STATISTICS | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ln(Desired/ Actual Stock) | ln(Average Age of Stock) | ln(Old Car Price/ Scrap Price) | ln(Unemployment Rate) | ln[(VMT/ Stock)/ (VMT/ $Stock)_{-1}$] | ln[(VMT/ $Stock)_{-1}$/ (VMT/ $Stock)_{-2}$] | ln[(VMT/ $Stock)_{-2}$/ (VMT/ $Stock)_{-3}$] | Adjusted $R^2$, DW | SEE, Sample Period |
| Original | -6.98289<br>(-7.99) | -3.82763<br>(-4.50) | 2.91080<br>(5.32) | -0.145089<br>(-2.20) | -0.338149<br>(-4.33) | 2.23399<br>(2.42) | 4.19538<br>(3.60) | 3.45071<br>(2.86) | 0.923<br>2.60 | 0.0462<br>1958-74 |
| Mark I | -7.72820<br>(-8.03122) | -3.22087<br>(-5.3199) | 3.45837<br>(6.03368) | -0.143134<br>(-1.92125) | -0.413961<br>(-5.2452) | 3.44981<br>(3.41749) | 4.43955<br>(5.11976) | 3.28961<br>(4.19666) | 0.905<br>2.634 | 0.053941<br>1959-75 |

*Almon Lag on $(VMT/Stock)_{-1}$ is <2,3,FAR>. The dependent variable is ln[(Scrappage of vehicles less than 20 years old)/(Beginning of year stock + New car sales)].

TABLE A-22

Equation for Average Domestic Base Price

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | | STATISTICS | | | |
|---|---|---|---|---|---|---|---|---|
| | | ln(PINPUTA)* | $\ln(PINPUTA)_t - \ln(PINPUTA)_{t-1}$ | Dummy for 1958-63 | Adjusted $R^2$ | SEE | DW | Sample Period |
| Original | 3.58927<br>(13.3650) | 0.978764<br>(16.2937) | 0.425313<br>(1.90291) | 0.0152688<br>(4.74923) | 0.964 | 0.016174 | | 1958-1974 |
| Mark I | 3.10777<br>(12.92) | 1.08658<br>(20.23) | 0.312861<br>(1.45) | 0.0170887<br>(2.93) | 0.984 | 0.019507 | 1.644 | 1959-1976 |

Note: * PINPUTA is the price index for motor vehicle industry inputs. The dependent variable is in log form.

TABLE A-23

Equation for Average Domestic Options Price

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | STATISTICS | | | |
|---|---|---|---|---|---|---|---|
| | | ln(PINPUTA)* | Dummy for 1958-59 | Adjusted $R^2$ | SEE | DW | Sample Period |
| Original | 3.53466<br>(13.1164) | 0.757187<br>(12.7053) | 0.132609<br>(9.14247) | 0.919 | 0.017197 | | 1958-<br>1974 |
| Mark I | 3.76115<br>(21.7355) | 0.704192<br>(18.5655) | 0.130367<br>(8.20553) | 0.951 | 0.019865 | 1.436 | 1958-<br>1976 |

Note: * PINPUTA is the price index for motor vehicle industry inputs. The dependent variable is in log form.

TABLE A-24

Equation for Foreign Subcompact Base Price[1]

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | | STATISTICS | | | |
|---|---|---|---|---|---|---|---|---|
| | | ln(IMPCOST)[2] | ln(PTMEGTMF)[3] | Dummy for 1958-65 | Adjusted $R^2$ | SEE | DW | Sample Period |
| Original | 4.47528<br>(21.0455) | 0.694836<br>(15.347) | | -0.0596612<br>(-3.20585) | 0.969 | 0.02983 | | 1958-1974 |
| Mark I | 3.74281<br>(28.57) | | 0.879238<br>(30.12) | | 0.981 | 0.035146 | 1.08 | 1958-1976 |

Notes:

1. The dependent variable is in log form.

2. IMPCOST is a weighted average of the foreign car export price index.

3. PTMEGTMF is a price deflator for imported manufactured goods.

TABLE A-25

Equation for Foreign Compact Base Price[1]

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | | | STATISTICS | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | ln(IMPCOST)[2] | ln(PTMEGTMF)[3] | Dummy for 1958-65 | Dummy for 1961 | Adjusted $R^2$ | SEE | DW | Sample Period |
| Original | 4.04827<br>(21.2241) | 0.870526<br>(21.4359) | | -0.100992<br>(-5.92270) | -0.0597245<br>(-2.08793) | 0.986 | 0.026756 | | 1958-1974 |
| Mark I | 3.80505<br>(20.642) | | 0.959297<br>(24.0857) | -0.105466<br>(-4.60188) | -0.083732<br>(-2.03693) | 0.985 | 0.038445 | 1.528 | 1958-1976 |

Notes:

1. The dependent variable is in log form.

2. IMPCOST is a weighted average of the foreign car export price index.

3. PTMEGTMF is a price deflator for imported manufactured goods.

TABLE A-26

Equation for Foreign Luxury Base Price[1]

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | STATISTICS | | | |
|---|---|---|---|---|---|---|---|
| | | ln(IMPCOST)[2] | ln(PTMEGTMF)[3] | Adjusted $R^2$ | SEE | DW | Sample Period |
| Original | 3.77860<br>(14.4073) | 1.05045<br>(18.3237) | | 0.955 | 0.048495 | | 1958-<br>1974 |
| Mark I | 3.19897<br>(14.7011) | | 1022316<br>(25.2211) | 0.972 | 0.058384 | 1.178 | 1958-<br>1976 |

Notes:

1. The dependent variable is in log form.

2. IMPCOST is a weighted average of the foreign car export price index.

3. PTMEGTMF is a price deflator for imported manufactured goods.

TABLE A-27

Equation for Subcompact Options Expenditures*

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | | | | | STATISTICS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ln(Real Average Auto Price) | ln(% Pop. Income ≥ $15,000) | ln(Real Disposable Income) | Dummy for 1958 | Dummy for 1959-61 | Dummy for 1968-69 | Adjusted $R^2$ | SEE | DW | Sample Period |
| Original | 27.4189 (7.14) | -4.63344 (-7.39) | -0.853868 (-2.32) | 2.92711 (2.40) | 0.335403 (2.83) | 0.288755 (3.42) | | 0.950 | 0.0823 | 2.210 | 1958-1974 |
| Mark I | 40.3244 (10.03) | -6.69311 (-9.82) | -1.94508 (-5.10) | 5.18096 (4.76) | | | 0.71503 (11.42) | 0.976 | 0.076767 | 2.215 | 1960-1976 |

Note: *Dependent variable is in a logit form.

TABLE A-28

Equation for Compact Options Expenditures*

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | | | STATISTICS | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | ln(Real Average Auto Price) | ln(Real Disposable Income) | Dummy for 1958 | Dummy for 1959 | Adjusted $R^2$ | SEE | DW | Sample Period |
| Original | 28.919<br>(8.28) | -4.74632<br>(-13.01) | 1.79413<br>(3.41) | 1.08065<br>(8.63) | 0.672234<br>(5.49) | 0.970 | 0.1014 | 1.219 | 1958-1974 |
| Mark I | 33.8495<br>(12.29) | -5.21438<br>(-18.88) | 1.0389<br>(2.01) | | | 0.974 | 0.11284 | 1.383 | 1960-1976 |

Note: * Dependent variable is in a logit form.

TABLE A-29

Equation for Midsize Options Expenditures*

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | | | STATISTICS | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | ln(Real Average Auto Price) | ln(Real Disposable Income) | Dummy for 1958 | Dummy for 1959 | Adjusted $R^2$ | SEE | DW | Sample Period |
| Original | 38.5568<br>(6.84) | -5.96986<br>(-10.14) | 1.68008<br>(1.98) | 0.715813<br>(3.54) | 0.802432<br>(4.06) | 0.951 | 0.1636 | 1.035 | 1958-1974 |
| Mark I | 40.7356<br>(9.80) | -6.14463<br>(-14.75) | 1.22318<br>(1.56) | | | 0.957 | 0.17022 | 0.845 | 1960-1976 |

Note: * Dependent variable is in a logit form.

TABLE A-30

Full-Size Options Expenditures Equation*

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | | | STATISTICS | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | ln(Real Average Auto Price) | ln(Real Disposable Income) | Dummy for 1958 | Dummy for 1959 | Adjusted $R^2$ | SEE | DW | Sample Period |
| Original | 37.6617<br>(5.66) | -5.86341<br>(-8.43) | 2.00039<br>(2.00) | 1.03641<br>(4.34) | 0.90639<br>(3.88) | 0.930 | 0.1933 | 0.911 | 1958-1974 |
| Mark I | 32.8134<br>(6.32) | -5.28811<br>(-10.17) | 2.31294<br>(2.37) | | | 0.925 | 0.21254 | 0.639 | 1960-1976 |

Note: * Dependent variable is in a logit form.

TABLE A-31

Equation for Luxury Options Expenditures*

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | | | STATISTICS | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | ln(Real Average Auto Price) | ln(Real Disposable Income) | Dummy for 1958 | Dummy for 1959 | Adjusted $R^2$ | SEE | DW | Sample Period |
| Original | 31.0341 (8.64) | -4.86213 (-12.96) | 2.17749 (4.03) | 0.443425 (3.44) | 0.456031 (3.62) | 0.977 | 0.10431 | 1.135 | 1958-1974 |
| Mark I | 41.2354 (8.93) | -5.91298 (-12.77) | 0.894137 (1.03) | | | 0.942 | 0.18917 | 1.321 | 1960-1976 |

Note: * Dependent variable is in a logit form.

TABLE A-32

Equations for Motor Oil Consumer Price Index and

Maintenance and Repairs Consumer Price Index

(t-statistics in parentheses)

| INDEX | Constant | INDEPENDENT VARIABLES | | STATISTICS | | | |
|---|---|---|---|---|---|---|---|
| | | ln(PDCE)* | $\ln(PDCE_t / PDCE_{t-1})$ | Adjusted $R^2$ | DW | SEE | Sample Period |
| Motor Oil | -0.0440088<br>(-0.359865) | 1.05301<br>(39.8026) | | 0.99 | 0.613 | 0.021122 | 1960-1976 |
| Maintenance and Repairs | -1.002<br>(-7.89057) | 1.30408<br>(39.6549) | -0.499379<br>(-1.8885) | 0.997 | 0.563 | 0.013669 | 1960-1976 |

Note: * PDCE is the implicit deflator for consumer expenditures. The dependent variables are in log form.

TABLE A-33

Equations for Parking and Fees Consumer Price Index and

Insurance Consumer Price Index

(t-statistics in parentheses)

| INDEX | Constant | INDEPENDENT VARIABLES | | | | | STATISTICS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ln(PDCEST)* | $\ln(PDCEST_t/PDCEST_{t-1})$ | Dummy for Insured | Dummy for 1972 | Dummy for 1973 | Adjusted $R^2$ | DW | SEE | Sample Period |
| Parking and Fees | -0.476829<br>(-4.23667) | 1.19065<br>(44.9408) | -0.569233<br>(-3.32827) | | | | 0.995 | 1.334 | 0.017943 | 1960-1976 |
| Insurance | -2.02873<br>(-6.0859) | 1.48049<br>(20.1498) | 0.549752<br>(1.49733) | 0.201332<br>(5.22561) | -0.0609358<br>(-1.28994) | -0.0895137<br>(-1.77074) | 0.988 | 0.763 | 0.035953 | 1960-1976 |

Note: * PDCEST is the implicit deflator for consumer expenditures on services. The dependent variables are in log form.

TABLE A-34

Equation for Subcompact Transportation Charges*

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | | | | | STATISTICS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Dummy for Foreign | ln(Trans. Sector Price Index) | Dummy for 1965-67 | Dummy for 1958 | Dummy for 1959-60 | Dummy for 1972-74 | Adjusted $R^2$ | DW | SEE | Sample Period |
| Original | -1.08046<br>(-4.9186) | -1.0738<br>(-4.88828) | 1.18913<br>(24.0193) | -0.0578934<br>(-3.42713) | -0.104719<br>(-3.82865) | | | 0.959 | | 0.035960 | 1958-1974 |
| Mark I | -4.46017<br>(-20.12) | 0.00566954<br>(0.38) | 1.96<br>(39.25) | | | 0.078037<br>(3.02) | -0.215128<br>(-9.22) | 0.979 | 2.248 | 0.046487 | 1958-1976 |

Note: *The dependent variable is in log form.

TABLE A-35

Equation for Compact Transportation Charges*

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | | | | | STATISTICS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Dummy for Foreign | ln(Trans. Sector Price Index) | Dummy for 1965-67 | Dummy for 1958 | Dummy for 1973-74 | Dummy for 1959-60 | Adjusted $R^2$ | DW | SEE | Sample Period |
| Original | -3.67384<br>(-16.7230) | -3.71638<br>(-16.9167) | 1.81314<br>(36.6208) | -0.0439986<br>(-2.60438) | -0.0776173<br>(-2.83753) | | | 0.980 | | 0.035963 | 1958-<br>1974 |
| Mark I | -5.40656<br>(-33.74) | -0.390938<br>(-3.49) | 2.20501<br>(61.26) | | | -0.113846<br>(-5.72) | 0.0725213<br>(3.78) | 0.992 | 2.498 | 0.03449 | 1958-<br>1976 |

Note: *The dependent variable is in log form.

TABLE A-36

Equation for Midsize Transportation Charges*

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | | | | STATISTICS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ln(Trans. Sector Price Index) | Dummy for 1958 | Dummy for 1964-67 | Dummy for 1959-60 | Dummy for 1973-74 | Adjusted $R^2$ | DW | SEE | Sample Period |
| Original | -2.70790<br>(-9.31492) | 1.61989<br>(24.7648) | -0.104544<br>(-2.93481) | -0.0794565<br>(-3.94944) | | | 0.982 | | 0.032823 | 1958-<br>1974 |
| Mark I | -4.54575<br>(-17.66) | 2.0353<br>(35.48) | | -0.043902<br>(-1.93) | 0.0799527<br>(2.67) | -0.103003<br>(-3.48) | 0.990 | 1.791 | 0.036172 | 1958<br>1976 |

Note: *The dependent variable is in log form.

TABLE A-37

Equation for Full-Size Transportation Charges*

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | | | STATISTICS | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | ln(Trans. Sector Price Index) | Dummy for 1958-60 | Dummy for 1964-67 | Dummy for 1973-74 | Adjusted $R^2$ | SEE | DW | Sample Period |
| Original | -2.96414<br>(-8.39677) | 1.71061<br>(21.6823) | 0.0912733<br>(3.35893) | -0.0727867<br>(-3.13423) | | 0.978 | | 0.034977 | 1958-1974 |
| Mark I | -4.0867<br>(-15.70) | 1.96692<br>(34.05) | 0.114412<br>(4.43) | -0.0624909<br>(-2.78) | -0.086486<br>(-3.07) | 0.99 | 2.168 | 0.034441 | 1958-1976 |

Note: *The dependent variable is in log form.

TABLE A-38

Equation for Luxury Transportation Charges*

(t-statistics in parentheses)

| MODEL | Constant | INDEPENDENT VARIABLES | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Dummy for Foreign | ln(Trans. Sector Price Index) | Dummy for 1965-67 | Dummy for 1959-61 | Dummy for 1959-60 | Dummy for 1967-70 | Dummy for 1973-74 |
| Original | -0.303386 (-1.66225) | -0.349289 (-1.91375) | 1.14735 (28.0423) | -0.0273104 (-2.03501) | 0.0656844 (4.62970) | | | |
| Mark I | -1.57211 (-9.14) | | 1.44173 (37.42) | | | 0.0792536 (3.78) | -0.0605194 (-3.97) | -0.100686 (-4.70) |

| MODEL | STATISTICS | | | |
|---|---|---|---|---|
| | Adjusted $R^2$ | DW | SEE | Sample Period |
| Original | 0.969 | | 0.027302 | 1958-1974 |
| Mark I | 0.978 | 1.221 | 0.036681 | 1958-1976 |

Note: *The dependent variable is in log form.

# APPENDIX B

# TABLES FOR CHAPTER THREE

TABLE B-1

Mark II: Desired-Stock Equations[1]

(t-statistics in parentheses)

| DEPENDENT VARIABLE | | INDEPENDENT VARIABLES | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Type of Vehicle | Constant | ln(Real Disposable Income Per Licensed Driver)[2] | ln(Cost Per Mile For Vehicle) | ln(% Pop. in SMSAs) | ln(% Pop. Income ≥ \$15,000) | ln(YAC/CPM)[3] | ln(% Roads in Rural Areas) | ln(% Pop. Age ≥ 65) |
| Personal Vehicle | -3.47081<br>(-5.01546) | 0.565735<br>(5.43852) | -0.419372<br>(-1.91571) | 0.224497<br>(3.16087) | -0.312691<br>(-3.34128) | | | |
| Autos | -3.7628<br>(-5.00215) | 0.646989<br>(5.69864) | -0.385023<br>(-1.64943) | 0.281795<br>(3.68915) | -0.382618<br>(-3.72906) | | | |
| Commercial Use LDTs | -3.42604<br>(-5.01546) | | | -1.29921<br>(-5.5955) | | 0.633354<br>(2.12316) | -0.628733<br>(-5.59545) | -0.644535<br>(-3.04774) |

| DEPENDENT VARIABLE | STATISTICS | | |
|---|---|---|---|
| Type of Vehicle | Adjusted $R^2$ | DW | SEE |
| Personal Vehicle | 0.495 | 2.004 | 0.068347 |
| Autos | 0.526 | 1.835 | 0.073471 |
| Commercial Use LDTs | 0.764 | 1.646 | 0.24024 |

Notes:
1. The dependent variables are stock per licensed driver. The data are cross-sectional from 1976.
2. Income is calculated as 0.4 (Y) + 0.3 ($Y_{-1}$) + 0.2 ($Y_{-2}$) + 0.1 ($Y_{-3}$) where Y is total personal income after taxes and transfer payments.
3. Personal income earned in agriculture, construction, wholesale and retail trade, and services divided by cost per mile of commercial LDTs.

TABLE B-2

Mark II
New-Registrations Equations[1]

(t-statistics in parentheses)

| DEPENDENT VARIABLE | | INDEPENDENT VARIABLES | | | | STATISTICS | | | |
|---|---|---|---|---|---|---|---|---|---|
| Type of Vehicle | Constant | ln(Desired Stock/ Existing Stock)[2] | ln(Relative Real Disposable Income)[3] | $\ln[(\text{Vehicle Price})/(\text{Vehicle Price})_{-1}]$[2] | Dummy for Auto Strikes | Adjusted $R^2$ | DW | SEE | Sample Period |
| Personal Vehicle | -2.62026 (-26.8354) | 1.09826 (3.94988) | 5.55047 (6.10452) | -1.30338 (-2.91235) | -0.369289 (-3.57047) | 0.846 | 1.562 | 0.047235 | 1960-1976 |
| Auto | -2.54817 (-32.8001) | 1.57795 (4.94024) | 4.46552 (4.87402) | -1.21568 (-2.81217) | -0.35741 (-3.3948) | 0.866 | 1.566 | 0.048115 | 1960-1976 |
| Commercial Use LDTs | -2.70262 (-13.7336) | 0.167762 (1.28219) | 7.32444 (4.38457) | -1.19021 (-1.60062) | | 0.567 | 1.195 | 0.10164 | 1959-1976 |

Notes:

1. The dependent variables are new registrations per existing stock.

2. By type of vehicle.

3. Calculated as real disposable income relative to a lagged weighted average. The income variable for the Commercial-Use-LDT equation uses a different definition for personal income (see Table B-1, notes 2 and 3).

TABLE B-3

Mark II
Equation for New Registrations of Automobiles Relative to LDTs*

(t-statistics in parentheses)

| | INDEPENDENT VARIABLES | | | STATISTICS | | | |
|---|---|---|---|---|---|---|---|
| Constant | ln(Relative Desired Stock) | ln(Relative Real Disposable Income) | ln(Relative Cost Per Mile) | Adjusted $R^2$ | DW | SEE | Sample Period |
| -13.8977<br>(-3.0621) | 8.06846<br>(3.7527) | -24.7582<br>(-4.9248) | -17.7954<br>(-5.02622) | 0.824 | 1.86 | 0.25527 | 1960-1976 |

Note: *The dependent variable is ln(New-Car Sales relative to New-Truck Sales).

TABLE B-4
Mark II
Scrappage Equations[1]
(t-statistics in parentheses)

| DEPENDENT VARIABLE<br>Type of Vehicle | Constant | INDEPENDENT VARIABLES<br>ln(Desired Stock Per Existing Stock)[2] | ln(Average Age of Vehicle)[3] | ln(Old Car Price/ Scrap Metal Price) | ln(Unemployment Rate) | Dummy Auto Strikes | Dummy for 1973 | $\ln[(VMT/Stock)/(VMT/Stock)_{-1}]$ | $\ln[(VMT/Stock)_{-1}/(VMT/Stock)_{-2}]$ | $\ln[(VMT/Stock)_{-2}/(VMT/Stock)_{-3}]$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Personal Vehicle | -7.38438<br>(-5.67406) | -0.869979<br>(-2.47045) | 3.38872<br>(4.15645) | -0.168516<br>(-2.95811) | -0.402411<br>(-5.08192) | -0.264277<br>(-3.17074) | 0.116095<br>(2.5919) | 3.342789<br>(5.08436) | 3.65272<br>(4.90658) | 2.51009<br>(3.45988) |
| Autos | -7.20088<br>(-5.5168) | -1.09537<br>(-2.4753) | 3.25543<br>(4.04197) | -0.165658<br>(-2.83204) | -0.423886<br>(-5.01446) | -0.256622<br>(-2.98241) | 0.119072<br>(2.60484) | 3.55192<br>(5.1658) | 3.66214<br>(4.68848) | 2.47816<br>(3.28273) |
| Commercial LDTs | -8.7627<br>(-6.24947) | -0.340035<br>(-2.54033) | 3.08657<br>(3.99875) | | | | | 0.239848<br>(0.432125) | 1.32409<br>(3.38861) | 1.24414<br>(2.72287) |

| DEPENDENT VARIABLE<br>Type of Vehicle | STATISTICS<br>Adjusted $R^2$ | DW | SEE | Sample Period |
|---|---|---|---|---|
| Personal Vehicle | 0.916 | 2.336 | 0.0038617 | 1960-1976 |
| Autos | 0.909 | 2.261 | 0.039662 | 1960-1976 |
| Commercial LDTs | 0.663 | 1.34 | 0.050871 | 1959-1976 |

Notes:

1. The dependent variables are ln[(Total vehicle scrappage - Given vehicle scrappage)/(Beginning of the year stock + New car sales)]. Given scrappage is stock of vehicles over 20 years old for autos and personal vehicles, and over 30 for Commercial LDTs.
2. By type of vehicle; existing stock equals beginning-of-year stock plus new-vehicle registrations.
3. By type of vehicle.

TABLE B-5

Mark II
Vehicle-Miles-Traveled Equations for Automobiles

(t-statistics in parentheses)

| DEPENDENT VARIABLE | Constant | INDEPENDENT VARIABLES | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | ln(Gasoline Cost Per Mile)[1] | ln(Urban Cars Per Family)[2] | ln(Permanent Real Disposable Income)[3] | ln(% Pop. Earning ≥$15,000) | ln(% Interstate Roadway) | Dummy 1973-74 | Dummy 1974 |
| ln(Urban VMT Per Family) | -3.12253 (-6.92959) | -0.26090 (-4.59022) | 0.826974 (6.0586) | 0.513113 (3.44776) | | | -0.0152489 (-1.43686) | |
| ln(Rural VMT Per Family | -3.08461 (-1.86447) | -0.225772 (-2.58194) | | | 0.113014 (7.73549) | 0.56761 (1.67354) | | -0.0339641 (-1.82574) |

| DEPENDENT VARIABLE | STATISTICS | | | |
|---|---|---|---|---|
| | Adjusted $R^2$ | DW | SEE | Sample Period |
| ln(Urban VMT Per Family | 0.994 | 2.416 | 0.012536 | 1960-1976 |
| ln(Rural VMT Per Family | 0.903 | 2.552 | 0.014698 | 1960-1976 |

Notes: 1. Calculated as real gas price per gallon divided by urban or rural MPG.
2. Calculated as: % of pop. living in SMSA times number of vehicles.
3. Calculated as: $0.25\ (RDI/NPT)_t + 0.5\ (RDI/NPT)_{t-1} + 0.25\ (RDI/NPT)_{t-2}$, where RDI = permanent real disposable income, NPT = population.

TABLE B-6

Mark II
Vehicle-Miles-Traveled Equations for LDTs

(t-statistics in parentheses)

| DEPENDENT VARIABLE | Constant | INDEPENDENT VARIABLES: ln(Real Gasoline Cost Per Mile)[1] | ln(% Pop. Earning ≥$15,000) | ln(% Pop. Living In SMSAs) | ln(Personal Income)[2] | Dummy 1973-4 |
|---|---|---|---|---|---|---|
| ln(VMT of Personal LDTs Per Stock) | -1.63987 (-4.34141) | -0.275636 (-9.27533) | 0.0602594 (3.07526) | 0.673735 (7.21443) | | -0.0179361 (-2.98287) |
| ln(VMT of Commercial LDTs Per Stock) | -3.80197 (-7.44286) | -0.58952 (-5.49224) | | | 2.67362 (9.04371) | -0.056751 (-2.14489) |

| DEPENDENT VARIABLE | STATISTICS: Adjusted $R^2$ | DW | SEE | Sample Period |
|---|---|---|---|---|
| VMT of Personal LDTs Per Stock | 0.984 | 2.048 | 0.0067661 | 1963-1976 |
| VMT of Commercial LDTs Per Stock | 0.889 | 0.92 | 0.028103 | 1960-1976 |

Notes:

1. Calculated as real gasoline price per gallon divided by Commercial or Personal LDT MPG.

2. Calculated as: $0.25\ (YAC/YP\$) + 0.5\ (YAC/YP\$)_{-1} + 0.25\ (YAC/YP\$)_{-2}$
where: YAC = personal income earned in agriculture, construction, wholesale and retail trade, and services; YP$ = total personal income.

TABLE B-7

Mark II: Purchase-Price Equations[1]

(t-statistics in parentheses)

| VEHICLE | Constant | ln(PINPUTA)[2] | STATISTICS | | | |
|---|---|---|---|---|---|---|
| | | | Adjusted $R^2$ | DW | SEE | Sample Period |
| Autos | 2.65967<br>(17.1025) | 1.18584<br>(35.0005) | 0.990 | 1.714 | 0.0191 | 1964-1976 |
| Personal Use LDTs | 2.76606<br>(1.04177) | 1.14779<br>(19.8420) | 0.971 | 2.013 | 0.02747 | 1964-1976 |
| Commercial GVW Class I LDTs | 2.71698<br>(10.7623) | 1.15223<br>(20.9495) | 0.973 | 2.331 | 0.26119 | 1964-1976 |
| Commercial GVW Class II LDTs | 2.79335<br>(11.0091) | 1.16446<br>(21.0652) | 0.974 | 2.291 | 0.026251 | |

Notes: 1. The dependent variables are in log form.

2. PINPUTA is a price index for motor vehicle industry inputs.

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