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MOTOR VEHICLE DEMAND MODELS: ASSESSMENT OF THE STATE OF THE ART AND DIRECTIONS FOR FUTURE RESEARCH

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16. Abstract

This report provides an assessment of the current state of motor vehicle demand modeling. It includes a detailed evaluation of one leading large-scale econometric vehicle demand model, which is tested for both logical consistency and forecasting accuracy. Results of the model evaluation suggest improvements in the specification of existing vehicle demand models and low-cost strategies for further model development. In assessing existing work, this report also provides useful new insights into the structure of U.S. motor vehicle demand.

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PREFACE

We thank the U.S. Department of Transportation for this opportunity to provide an independent evaluation of leading motor vehicle demand models. The reader may notice that this report places major emphasis on still unresolved questions about the structure of the automotive market. This emphasis is not intended to obscure the substantial progress in understanding the automotive market which has occurred in the last several years, encouraged by the research sponsorship of DOT and other federal agencies.

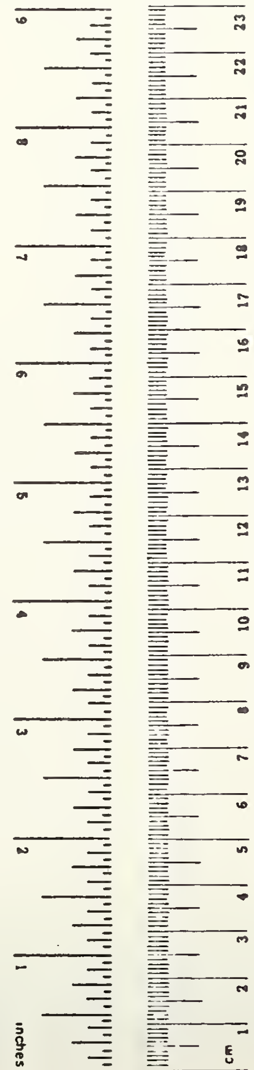
The contract monitors at TSC -- Nick Schaeffer, Rene Smith, and Steward Butler -- were especially helpful in defining the appropriate scope of this assessment of the state of the art of vehicle demand modeling. The staff of WEFA, Inc. provided assistance in the use of the WEFA-TSC motor vehicle data base and model estimation and simulation softwares. Professor Jerry Hausman of MIT contributed valuable advice throughout the project and made a major contribution to the final chapter. Of course, full responsibility for the contents of this report belongs to Charles River Associates Incorporated.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

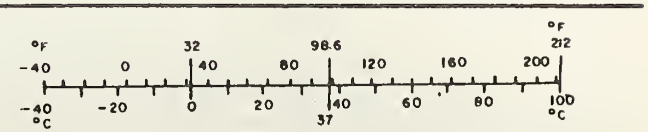
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

Statistical models of motor vehicle demand are used for policy analysis purposes by government agencies and for investment and product planning purposes by private corporations. This report provides a detailed evaluation of the forecasting reliability of a leading vehicle demand model which was developed by Wharton Econometric Forecasting Associates (WEFA) for the U.S. Department of Transportation's Transportation Systems Center. The WEFA model was chosen as representative of large-scale models which are estimated on aggregate national or state data.

This report contains compelling evidence that the WEFA model fails to provide accurate forecasts of key market variables, and it explores reasons for the model's failings. Chapters 3 and 4 indicate that the aggregate level WEFA data base lacks sufficient variation in important explanatory variables to provide precise parameter estimates or to allow the model-builder to discriminate among alternative reasonable model specifications. These chapters also show that the WEFA model does a poor job of tracking past patterns of vehicle sales. Chapter 5 focuses on one particularly unfortunate characteristic of the model -- a negative net income elasticity of demand for motor vehicles. Chapter 6 is methodological and explains that the appropriate uses of the WEFA model are severely constrained by the model's failure to address the market effects of further vehicle downsizing or of other changes in noncost vehicle characteristics.

The final phase of the study described in this report examined relatively inexpensive research methods for a better understanding of the vehicle market. Chapter 7 demonstrates how disaggregate household-level vehicle ownership data from different time periods can be analyzed to better understand causal relationships in the market and to test competing hypotheses about vehicle demand. The chapter suggests that thoughtful examination of disaggregate data is a logical precondition to the development of more reliable multi-equation forecasting models.

Chapter 1
INTRODUCTION AND SUMMARY

Introduction

This report evaluates the probable accuracy, for the purposes of forecasting and policy analysis, of the model of the U.S. motor vehicle market developed by Wharton Econometric Forecasting Associates (WEFA) for the U.S. Department of Transportation's Transportation Systems Center (TSC). The WEFA model is representative of leading motor vehicle demand models used for long-run business forecasting and policy analysis purposes. This report concludes that WEFA's use of aggregate national-and state-level data for model estimation places severe limitations on the reliability of forecasts of key vehicle market variables. The final chapter of the report shows how household-level disaggregate data can be used to better understand the vehicle market.

The WEFA-TSC auto market model is a large-scale econometric model which forecasts U.S. sales of new cars and light trucks, and disaggregates sales into each of eight car classes and two light truck classes. The model also forecasts other features of the auto market, including vehicle travel, fuel consumption, and scrappage levels. The WEFA-TSC model is estimated using a stock-adjustment specification. Predictors of the national desired stock or equilibrium stock of vehicles are estimated on state-level cross-section data. Predictors of vehicle sales and scrappage, which act as mechanisms to move the size and composition of the actual stock toward equilibrium, are estimated on national time-series data.[1] Because the WEFA-TSC model is intended to be used for long-run forecasting and policy analysis, the model assessment in this report concentrates on the predictors of the desired vehicle stock. These equations determine the long-run properties of the model, and also determine forecasts of steady-state sales and scrappage levels. We give considerably less attention in this report to the vehicle travel and scrappage predictors than to the vehicle stock/sales predictors, both because the definition of the project emphasizes vehicle sales and because data constraints which hinder the development of more sophisticated travel and scrappage predictors also hinder the evaluation of the existing WEFA-TSC predictors.[2]

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[1]A more detailed description of the model appears in Appendix I to this report.

[2]Data constraints related to vehicle travel forecasting are described in Leon Rudman, "Vehicle Miles Traveled: An Evaluation of Existing Data Sources," presented at the Transportation Research Board, Washington, D.C., January 1979; and Robert E. Mellman, "Aggregate Auto Travel Forecasting: State of the Art and Suggestions for Future Research," U.S. Department of Transportation Report No. DOT-TSS-OST-76-51 (Springfield, Va.: NTIS, December 1976). Analogous data constraints hinder the modeling of vehicle scrappage.

Summary of Findings

The WEFA-TSC auto market model is one of the largest and most detailed auto market forecasting models in existence. Output of the model is used as a source of auto market forecasts by numerous WEFA commercial clients, and the model has been used as a policy analysis tool by DOT and also by other government agencies.

Our evaluation of the WEFA-TSC model finds that although the existing data base and software are extremely helpful to the user trying to understand the auto market, and although the model output may be regarded as one well-educated "best guess" forecast or sensitivity analysis of the auto market, there is little evidence that the WEFA-TSC model provides forecasts or policy analyses which are likely to be more accurate than other econometric models or educated subjective judgments. We do find evidence of quite serious flaws in the workings of the model, and indeed evidence that WEFA acknowledges these flaws and chooses to make large subjective corrections to the model output when presenting forecasts. These corrections take the form of adjustment factors to the model output which are embedded in the model's computer software but not described in written model documentation.

Organization of the Report

Chapter 2 describes the forecasts provided by the estimated WEFA-TSC econometric model of the vehicle market and compares them with the WEFA baseline forecasts in which the model output is adjusted by subjective adjustment factors. We find that WEFA makes significant adjustments to most of the major model outputs, and very large adjustments to the forecasts of the distribution of car sales by size class. Thus, WEFA does not use the econometrically estimated model as a "black box" for forecasting and policy analysis factors, but makes substantial adjustments to the model output.

The following chapters of the report explore reasons why WEFA and the model user may choose to not treat the model outputs as reliable forecasts, and why adjustments may be required. Chapter 3 evaluates the model equations which forecast total demand for automobiles and personal trucks, and Chapter 4 evaluates the equations which decompose sales into size class of car and use class of truck. Among the findings in these chapters are:

1. The model's estimation data base contains very little variation in vehicle prices and user costs, and consequently estimated vehicle price/cost demand elasticities are imprecise. This finding is important because the reliability of the model for many policy analysis exercises depends on the model's ability to accurately predict the market responses to changes in the components of vehicle costs such as gasoline price or vehicle price.
2. The total income elasticity of demand for cars and for all personal vehicles in the current version of the WEFA model is negative. This result is clearly implausible and may lead to long-run forecasts of vehicle demand which are too low.
3. Demand elasticity estimates in the WEFA model are quite sensitive to the precise model specification. For example insertion of an employment level term, often suggested as a determinant of personal vehicle demand, into the WEFA demand equations leads to lower estimated elasticities for other demand determinants.
4. The equilibrium desired vehicle stock equations are estimated on cross-section data. Backcasting exercises show that these equations translate very poorly to the time domain. The poor fit of predicted to actual

variables in the historic data base raises doubts about the forecasting accuracy of the model.

5. The past few years have seen a dramatic shift in U.S. automobile purchase patterns away from larger cars and toward smaller cars, presumably in response to higher fuel prices. Scenario analyses of WEFA model forecasts under alternative gas prices show that the model grossly underpredicts the shift of the size class distributions in response to changes in the fuel price.
6. The WEFA-TSC model currently forecasts personal light truck demand as the difference between total personal vehicle demand and automobile demand. This model logic arose from admitted failures by WEFA to develop independent behavioral demand models of personal light truck demand. Because WEFA could not develop a personal light truck demand model, the existing algorithm should be treated by the user as an imprecise placeholder algorithm.

Chapter 5 discusses in more detail the use of an income saturation term, defined as the percentage of families with incomes of $15,000 or above, in the demand equations. The purpose of the saturation term is to allow a declining income elasticity of demand for motor vehicles. We find that WEFA's application of this variable leads to a negative income elasticity of demand in the model, and that without ex post adjustments to forecasts of the variable the income elasticity would be not only negative but very highly negative.

Chapter 6, although nonquantitative, is probably the most important chapter for the policy analyst to read. That chapter explains that within the WEFA-TSC model motor vehicle demand is assumed to be sensitive to changes in vehicle prices and costs but not to changes in other vehicle physical attributes, operating attributes, or creature comforts. Since changes in vehicle fuel economy levels are necessarily associated with changes in nonprice and noncost attributes, such as downsizing, the WEFA model cannot fully capture the market effects of federal fuel economy rules or other incentives which lead to improved vehicle fuel economy. Insomuch as public debate about future levels of mandated fuel economy centers on the question of what degree of downsizing (and related changes) is acceptable to the public, the substance of the policy question is beyond the scope of the WEFA auto market model.

The analysis of household-level data to investigate causal relationships and test alternative hypotheses about the motor vehicle market appears to be a precondition for the construction of more reliable multi-equation models. Chapter 7 describes the potential for greater use of household level micro-data to better understand changes in patterns of vehicle ownership, purchase, and use. Examples of data analysis using 1977 and 1980 University of Michigan household survey data are provided as illustrations of how cross-section micro-data from different years can be used to better understand the motor vehicle market.

Finally, Appendix I to the report provides a description of the WEFA-TSC auto market model for readers unfamiliar with that model. That Appendix describes the structure of the original Mark 0 version of the model, its respecification in a Mark I version, and the addition of a light truck sector in the current Mark II version of the model. Appendix II contains an overview of the state of the art of motor vehicle demand modeling.

Chapter 2
FORECASTING ACCURACY OF THE WEFA MODEL

It is difficult for the disinterested model evaluator working in 1979-1980 to grade the actual forecasting record of the 1978 WEFA Mark II model. If the model has performed well in 1979-1980, given inputs of actual 1979-1980 levels of exogenous variables, we might reasonably conclude that the test was too easy. Not enough time has passed to show whether the WEFA-TSC model is a reliable instrument for long-run policy analysis. If the model has not performed well, there are plenty of rationalizations which defenders of the model might offer. The model is not intended to be a short-run forecasting tool. The years 1979 and 1980 were marked by supply limitations on some small cars. Actual 1979-1980 gasoline prices did not reflect consumer expectations of far higher prices in the future. Each of these rationalizations may be perfectly valid.

WEFA Mark II Adjustment Factors

While we thus have no perfect measure of the reliability of the WEFA-TSC model as a forecasting model, we fortunately do have a measure of WEFA's own confidence in the model. Since

WEFA does base its reputation on accurate economic forecasting for major corporate and government clients, and since WEFA certainly is familiar with the model and the auto market, WEFA's opinion of the model's forecasting accuracy is one highly educated measure of the model's forecasting accuracy. The way in which we can assess WEFA's confidence in the forecasts of the model is by examining the model's "adjustment factors." "Adjustment factors" are embedded in the model software and alter the actual output of the model algorithms to reflect the subjective forecasts of the model builder or model user.[1] The size of the adjustment factor for any output variable relative to the predicted level of that variable by the WEFA Mark II econometric model is the percentage error that WEFA anticipates that the model is making.

Effects of Adjustment Factors

In examining the size of the adjustment factors used to derive actual forecasts in the WEFA-TSC Mark II model, we compare model output under three scenarios. The BASELINE forecast is the actual control forecast provided by WEFA incorporating all of their subjective adjustments.[2] The PARADJ forecast is a forecast in which adjustment factors on all endogenous variables (such as new registrations, or scrappage, and sales shares by size class) are set to zero. A comparison of PARADJ and BASELINE indicates WEFA's subjective confidence in the output of the model. Finally, a third forecast called

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[1]Although "adjustment factors" are quite common in large-scale econometric forecasting models, the WEFA report to TSC does not explain that they are used in the WEFA-TSC auto market model.

[2]This is the control forecast in the WEFA Mark II version of the model submitted under contract to TSC in 1979.

NOADJ results when adjustments to exogenous and endogenous variables are removed. NOADJ and PARADJ provide similar forecasts. The tables and graphs in Appendix 2A at the end of this section show the impact of the adjustment factors on new car sales, scrappage, and sales shares by size class.

In summarizing the results we compare the 1980 WEFA BASELINE forecast, which includes adjustment factors, with the PARADJ simulation forecast in which adjustment factors for all endogenous variables are removed. We find that WEFA subjectively factors down the model forecasts of both new car sales and scrappage by roughly 5 percent. The WEFA adjustments to the model forecasts of the size class shares are much more extreme; the 1980 PARADJ forecast of the full-size market share is reduced by nearly half to arrive at the 1980 baseline forecast of 16 percent.[1] Subcompact, compact, and mid-size share forecasts of the model are also extensively altered. Little adjustment is made to the import penetration forecast.

1980 WEFA MARK II FORECASTS

Output Variable	Baseline	PARADJ
Total Registrations	10.61	11.50
Scrappage, Personal Vehicles	9.59	10.17
Subcompact Share	16.4	22.1
Compact Share	21.7	30.1
Mid-Size Share	25.6	18.5
Full-Size Share	16.5	30.1
Luxury Share	9.8	9.7
Import Share	16.5	16.6

[1]For later years the percentage change in model output due to adjustment factors is somewhat reduced for most variables. The time pattern of adjustment factors is evident in the set of graphs contained in Appendix 2A.

We thus find that WEFA uses extensive "tuning" of their model to generate forecasts which they feel will be reliable. This in itself is not proof of the unreliability of the model. There is some chance that the model actually is more accurate than WEFA's subjective judgment. However, if the model builder is unwilling to use the estimated model as a "black box" for forecasting purposes, then the model user should certainly avoid using the model as a "black box" tool for policy evaluation purposes.

The graphs and tables in Appendix 2A provide a more detailed comparison of the WEFA forecast output (adjusted) with the actual forecasts of the WEFA model. The reader is directed to note the especially large adjustments to the model's predictions of scrappage and compact, mid-size, and full-size car sales shares. The following chapters examine the equations which WEFA uses in predicting vehicles sales and the distribution of sales by vehicle class, explaining why the adjustment factors are required to augment the econometrically-estimated relationships.

Appendix 2A

EFFECTS OF ADJUSTMENT FACTORS TO THE WEFA-TSC AUTO MARKET MODEL

Table 2A-1

TOTAL NEW REGISTRATIONS & SCRAPPAGE:
THREE SCENARIOS

(Million Vehicles)

Total New Registrations (VAR279)

Year	Baseline	PARADJ	No ADJ
77	10.52	10.33	10.51
78	10.98	11.39	11.35
79	10.62	11.56	11.59
80	10.61	11.50	11.57
81	10.65	11.34	11.31
82	11.13	11.50	11.58
83	11.58	11.90	12.04
84	12.01	12.18	12.26
85	11.82	11.93	11.96
86	11.63	11.79	11.83
87	11.83	11.99	12.04
88	12.05	12.18	12.24
89	12.04	12.21	12.26
90	12.05	12.27	12.32

Scrappage, Personal Vehicles (VAR797)

Year	Baseline	PARADJ	No ADJ
77	9.0077	10.143	9.9313
78	9.7907	10.779	10.562
79	9.4923	10.366	10.364
80	9.5864	10.169	10.451
81	9.9185	10.130	10.392
82	10.2620	10.589	10.750
83	10.7940	11.180	11.220
84	10.9610	11.656	11.636
85	10.7910	11.974	12.007
86	10.7690	12.209	12.351
87	11.3030	12.563	12.763
88	11.8510	12.823	12.931
89	12.2270	12.897	13.014
90	12.6670	12.856	12.935

SOURCE: Prepared by CRA using WEFA-Motor Vehicle Demand Model

Table 2A-2

SHARE OF TOTAL NEW REGISTRATIONS
· BY SIZE CLASS:
Three Scenarios

Subcompact Share of Total New Registrations

Year	Baseline	PARADJ	No ADJ
77	0.25243	0.23677	0.22759
78	0.26137	0.22695	0.21757
79	0.26360	0.21672	0.20921
80	0.26394	0.22161	0.21680
81	0.26323	0.22533	0.22319
82	0.25949	0.23010	0.22589
83	0.26031	0.23911	0.22862
84	0.25200	0.23519	0.23189
85	0.25587	0.24164	0.23953
86	0.25539	0.24412	0.24373
87	0.25750	0.24731	0.24835
88	0.25961	0.25047	0.25194
89	0.26219	0.25433	0.25598
90	0.26604	0.25902	0.26078

Compact Share
of Total New Registrations (VAR327)

Year	Baseline	PARADJ	No ADJ
77	0.20221	0.31401	0.31931
78	0.21592	0.21027	0.32609
79	0.21693	0.31205	0.32625
80	0.21657	0.30099	0.30871
81	0.21726	0.29302	0.29711
82	0.22056	0.27412	0.28887
83	0.21473	0.27425	0.28334
84	0.21665	0.26945	0.27860
85	0.21877	0.25800	0.26505
86	0.22103	0.25268	0.25703
87	0.22253	0.24824	0.25034
88	0.22389	0.24397	0.24526
89	0.22602	0.23848	0.23916
90	0.22782	0.23285	0.23299

Table 2A-2 (Continued)

SHARE OF TOTAL NEW REGISTRATIONS BY SIZE CLASS: THREE SCENARIOS

Share of Domestic Mid-Size In Total New Registrations (VAR 328)

Year	Baseline	PARADJ	No ADJ
77	0.26295	0.17696	0.16081
78	0.25483	0.18123	0.18205
79	0.25700	0.18522	0.18835
80	0.25625	0.18545	0.19646
81	0.25599	0.18668	0.20023
82	0.26267	0.19081	0.20570
83	0.25566	0.18637	0.20939
84	0.25709	0.18932	0.21041
85	0.25707	0.19146	0.21164
86	0.25829	0.19286	0.21249
87	0.25978	0.19308	0.21236
88	0.26101	0.19371	0.21202
89	0.21659	0.19531	0.21150
90	0.26142	0.19653	0.21034

Full-Size Share of Total New Registrations (VAR 329)

Year	Baseline	PARADJ	No ADJ
77	0.16463	0.31401	0.31931
78	0.16423	0.31027	0.32609
79	0.16335	0.31205	0.32625
80	0.16499	0.30099	0.20871
81	0.16541	0.29302	0.29711
82	0.16121	0.27412	0.28837
83	0.17161	0.27425	0.28334
84	0.17471	0.26945	0.27860
85	0.16663	0.25800	0.26505
86	0.16335	0.25268	0.25703
87	0.15731	0.24824	0.25034
88	0.15141	0.24397	0.24526
89	0.14503	0.23848	0.23916
90	0.13842	0.23285	0.23299

Table 2A-2 (Continued)

SHARE OF TOTAL NEW REGISTRATIONS BY SIZE CLASS:
THREE SCENARIOS

Luxury Share of Total New Registration (VAR 330)

Year	Baseline	PARADJ	No ADJ
77	0.117830	0.111680	0.125990
78	0.103650	0.099283	0.105980
79	0.099115	0.097793	0.102890
80	0.098256	0.096955	0.102410
81	0.098108	0.096022	0.101200
82	0.096070	0.095002	0.099552
83	0.097690	0.095353	0.098510
84	0.099555	0.097028	0.099297
85	0.101610	0.098683	0.100910
86	0.101930	0.099201	0.101490
87	0.102830	0.100180	0.102700
88	0.104090	0.100960	0.102460
89	0.105200	0.101510	0.102990
90	0.106300	0.102410	0.104910

SOURCE: Prepared by CRA using WEFA Motor Vehicle Demand Model.

Table 2A-3

FOREIGN AND DOMESTIC SHARES
OF TOTAL NEW REGISTRATIONS

Foreign Share of Total New Registration (VAR 428)

Year	Baseline	PARADJ	No ADJ
77	0.20405	0.19020	0.21526
78	0.18110	0.16192	0.18710
79	0.17023	0.15843	0.17686
80	0.16544	0.16577	0.18127
81	0.17163	0.17122	0.18629
82	0.17083	0.17593	0.18695
83	0.17126	0.18253	0.18799
84	0.17069	0.18231	0.19061
85	0.17345	0.18951	0.19702
86	0.17262	0.19266	0.19975
87	0.17596	0.19738	0.20471
88	0.17801	0.20167	0.20876
89	0.18092	0.20687	0.21374
90	0.18392	0.21220	0.21875

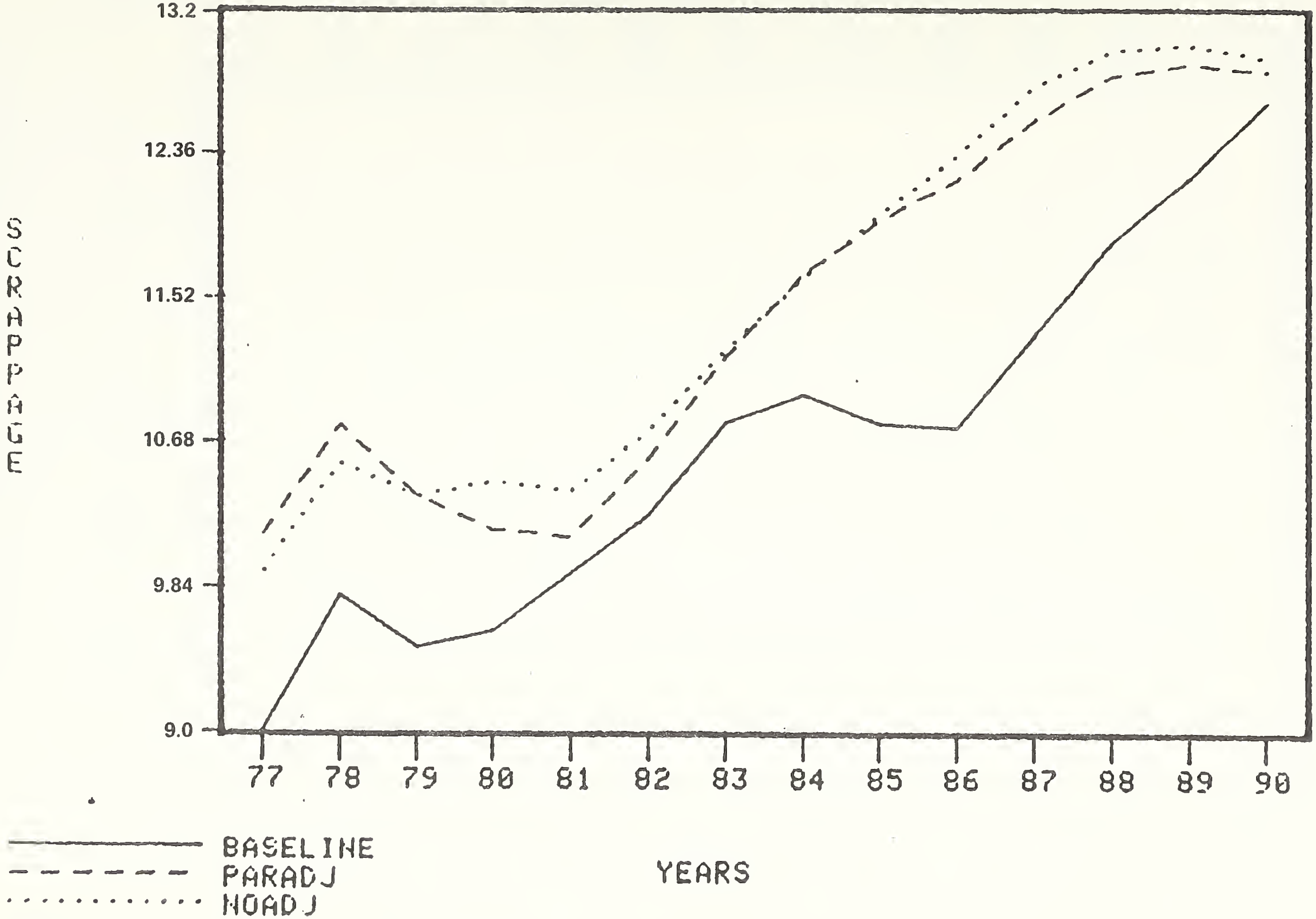
Domestic Share of Total New Registration (VAR 429)

Year	Baseline	PARADJ	No ADJ
77	0.79595	0.80980	0.78474
78	0.81190	0.83808	0.81290
79	0.82977	0.84157	0.82314
80	0.83456	0.83423	0.81873
81	0.82832	0.82878	0.81371
82	0.82917	0.82407	0.81305
83	0.82874	0.81747	0.81201
84	0.82931	0.81769	0.80939
85	0.82655	0.81049	0.80298
86	0.82738	0.80734	0.80025
87	0.82404	0.80262	0.79529
88	0.82199	0.79833	0.79124
89	0.81908	7.79313	0.78626
90	0.81608	0.78780	0.78125

SOURCE: Prepared by CRA using WEFA Motor Vehicle Demand Model.

Figure 2A–1

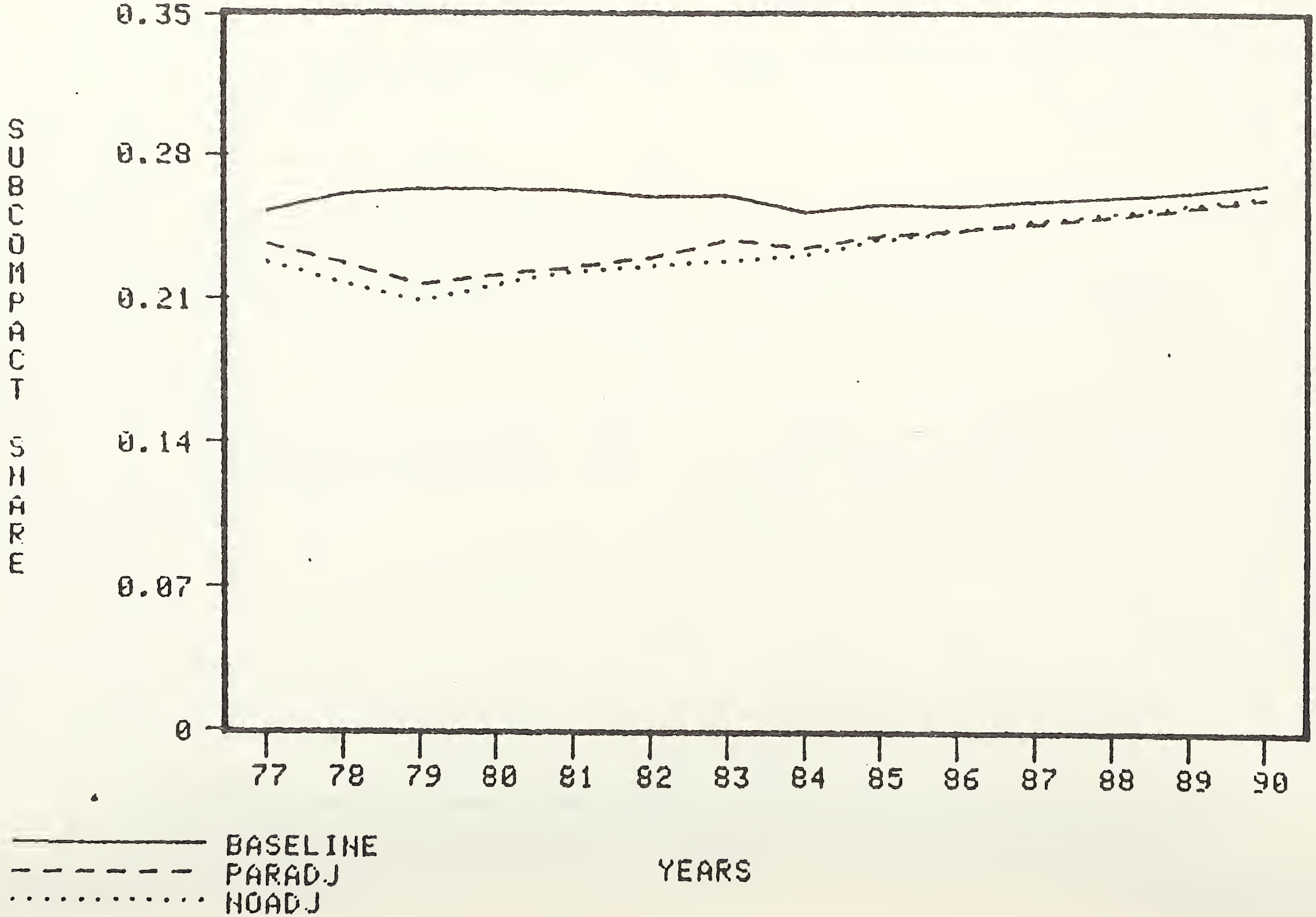
SCRAPPAGE GRAPH (VAR797)



SOURCE: Calculated by Charles River Associates Incorporated, 1980.

Figure 2A–2

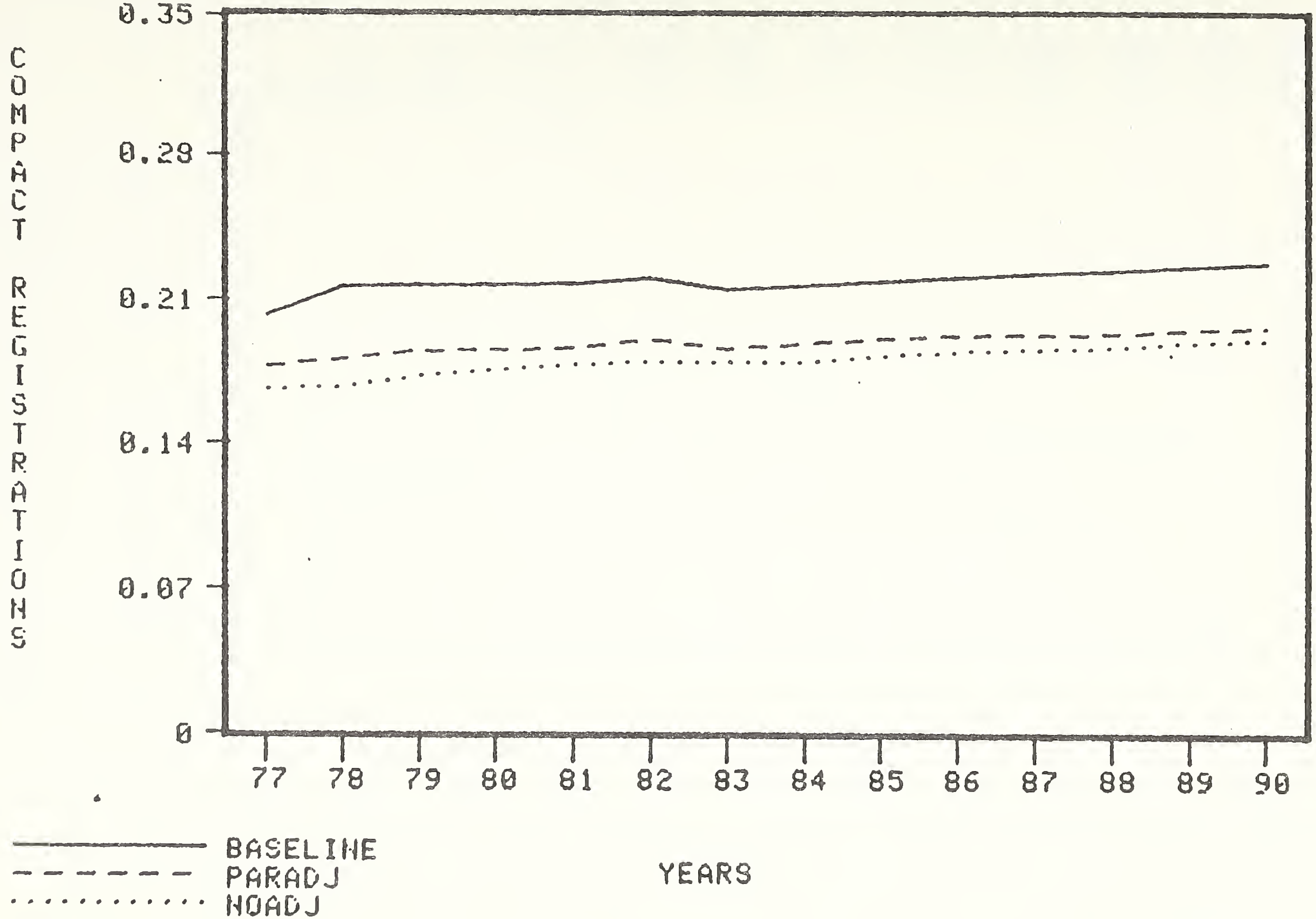
SUBCOMPACT REGISTRATIONS SHARE (VAR326)



SOURCE: Calculated by Charles River Associates Incorporated, 1980.

Figure 2A—3

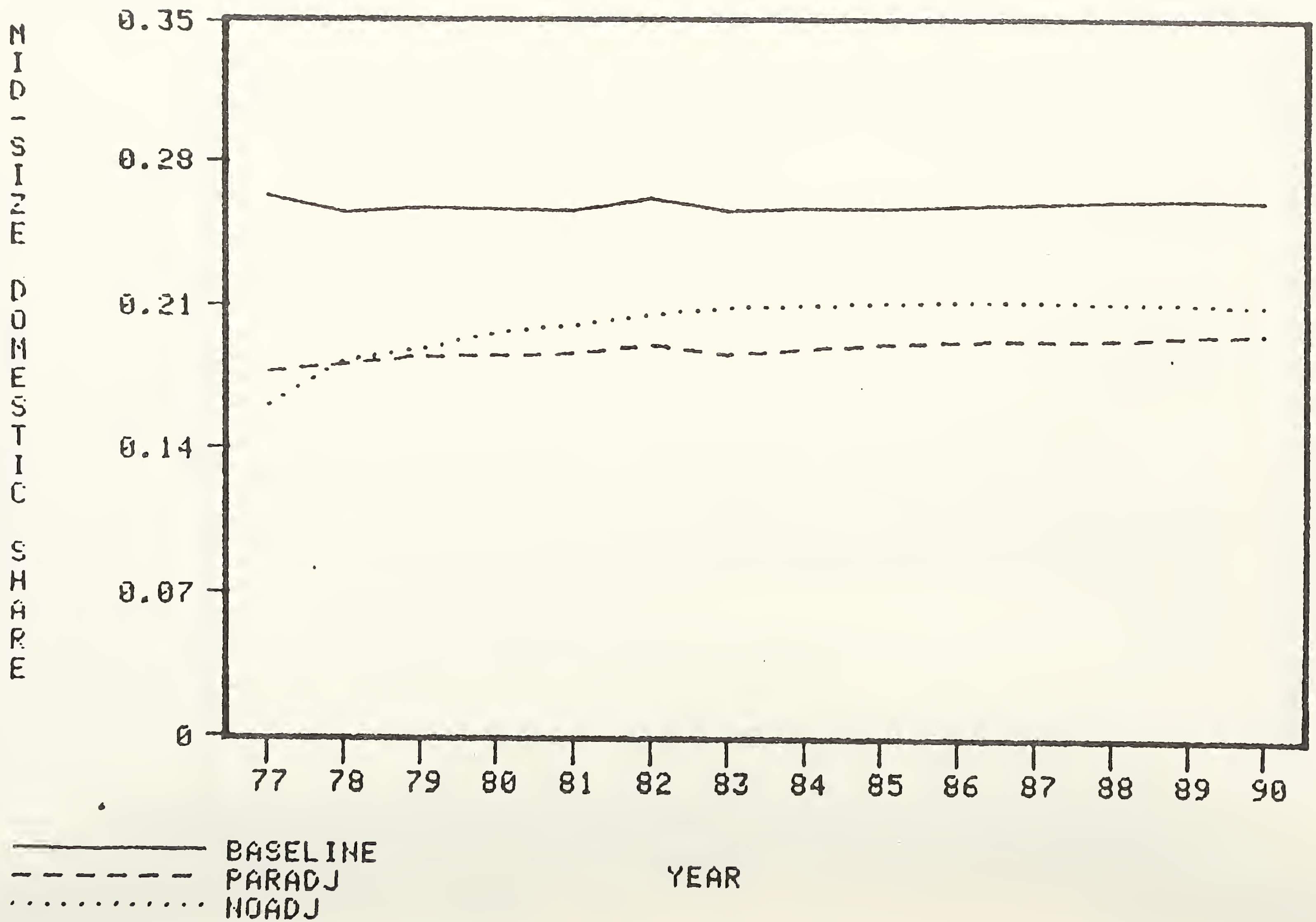
COMPACT REGISTRATIONS SHARE (VAR327)



SOURCE: Calculated by Charles River Associates Incorporated, 1980.

Figure 2A–4

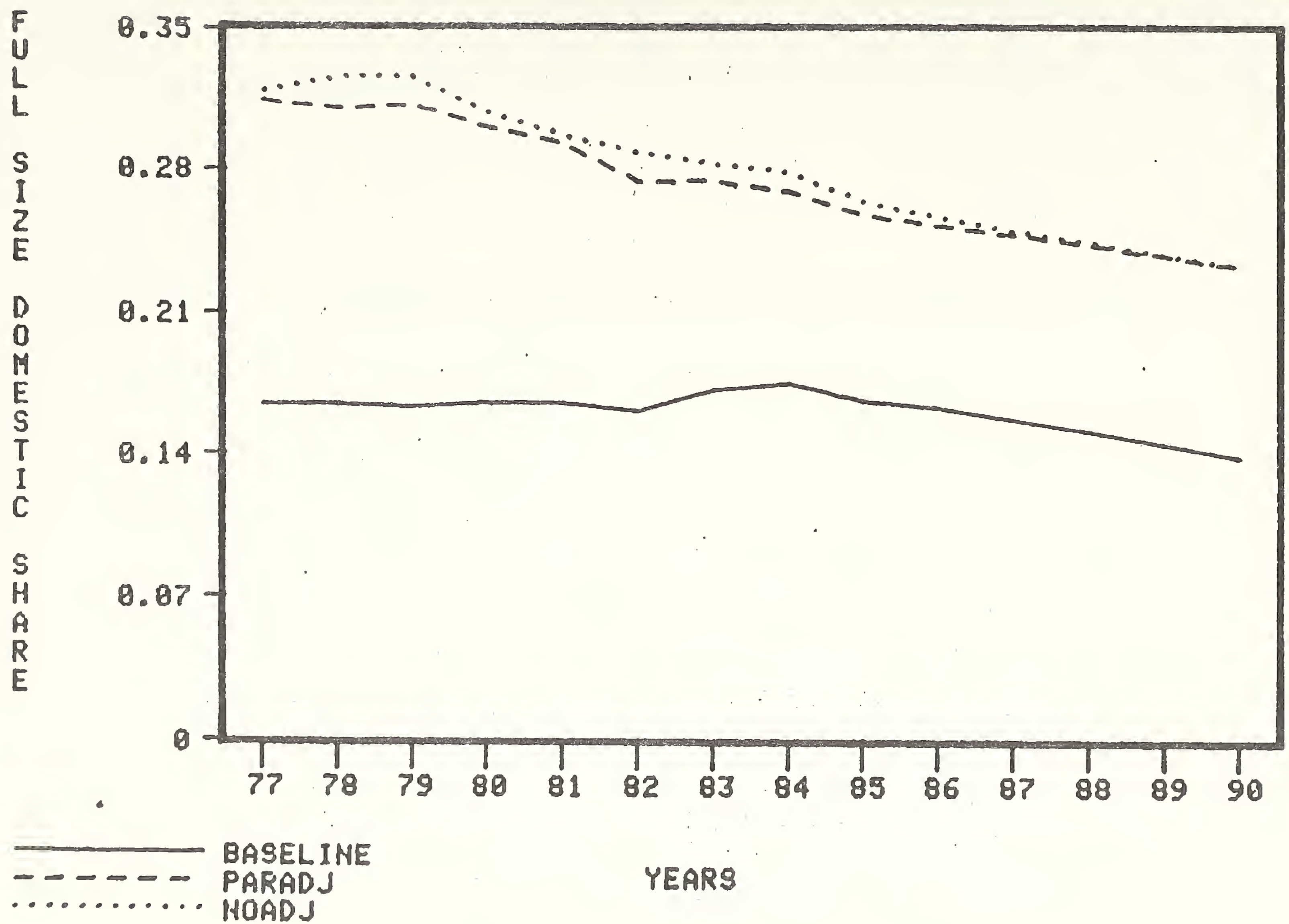
MID-SIZE DOMESTIC SHARE (VAR328)



SOURCE: Calculated by Charles River Associates Incorporated, 1980.

Figure 2A–5

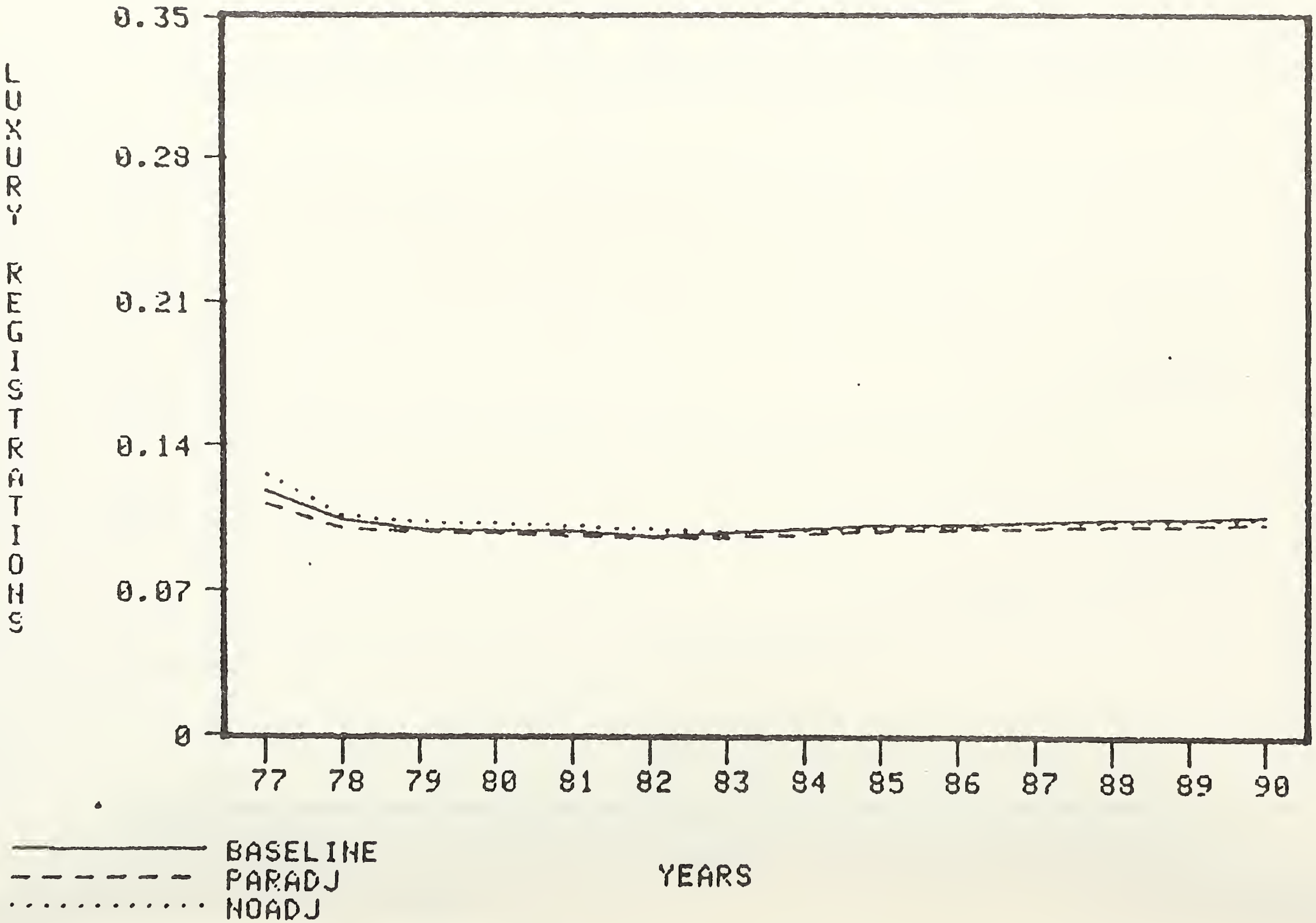
FULL SIZE DOMESTIC SHARE (VAR329)



SOURCE: Calculated by Charles River Associates Incorporated, 1980.

Figure 2A–6

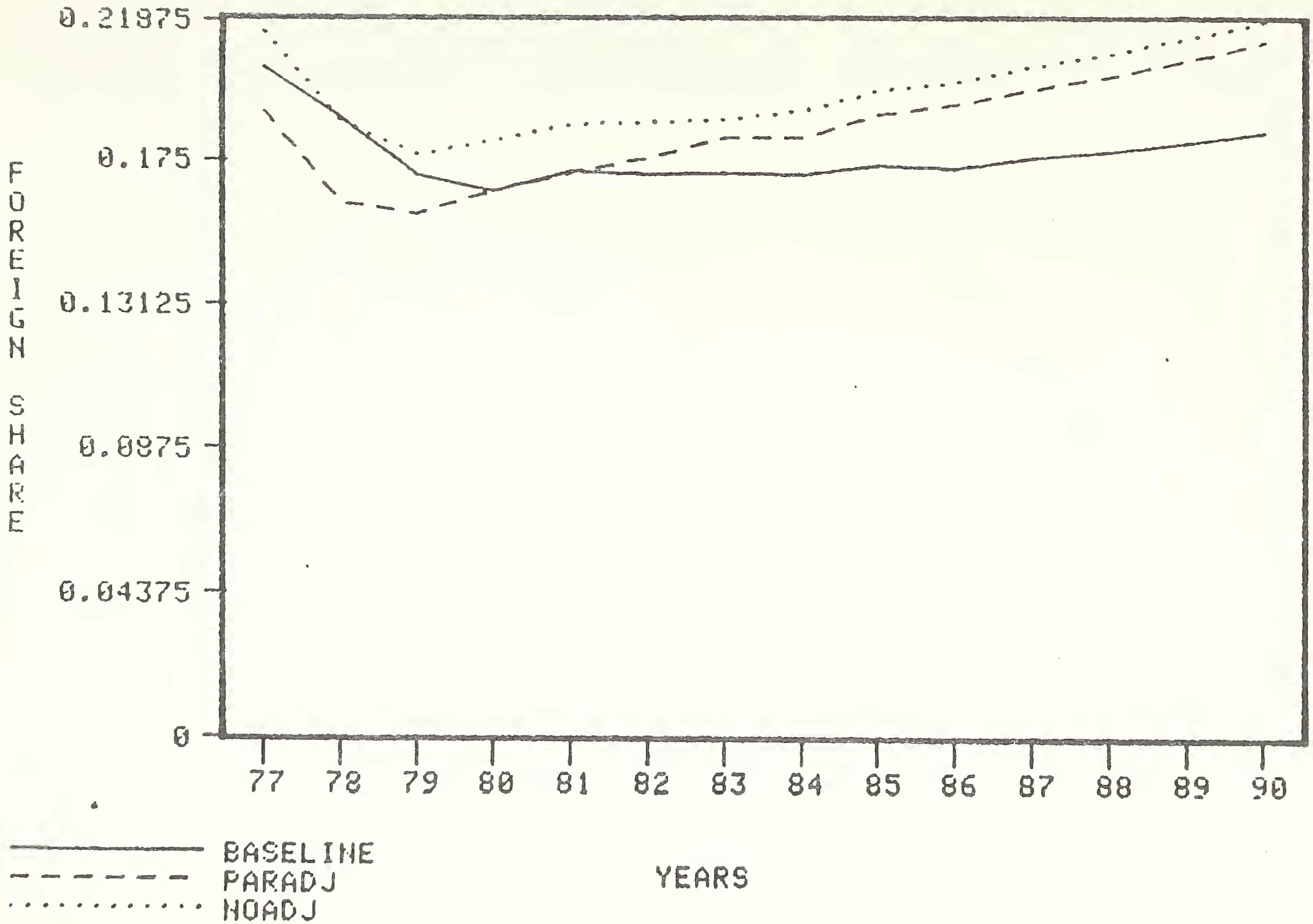
LUXURY SHARE (VAR330)



SOURCE: Calculated by Charles River Associates Incorporated, 1980.

Figure 2A–7

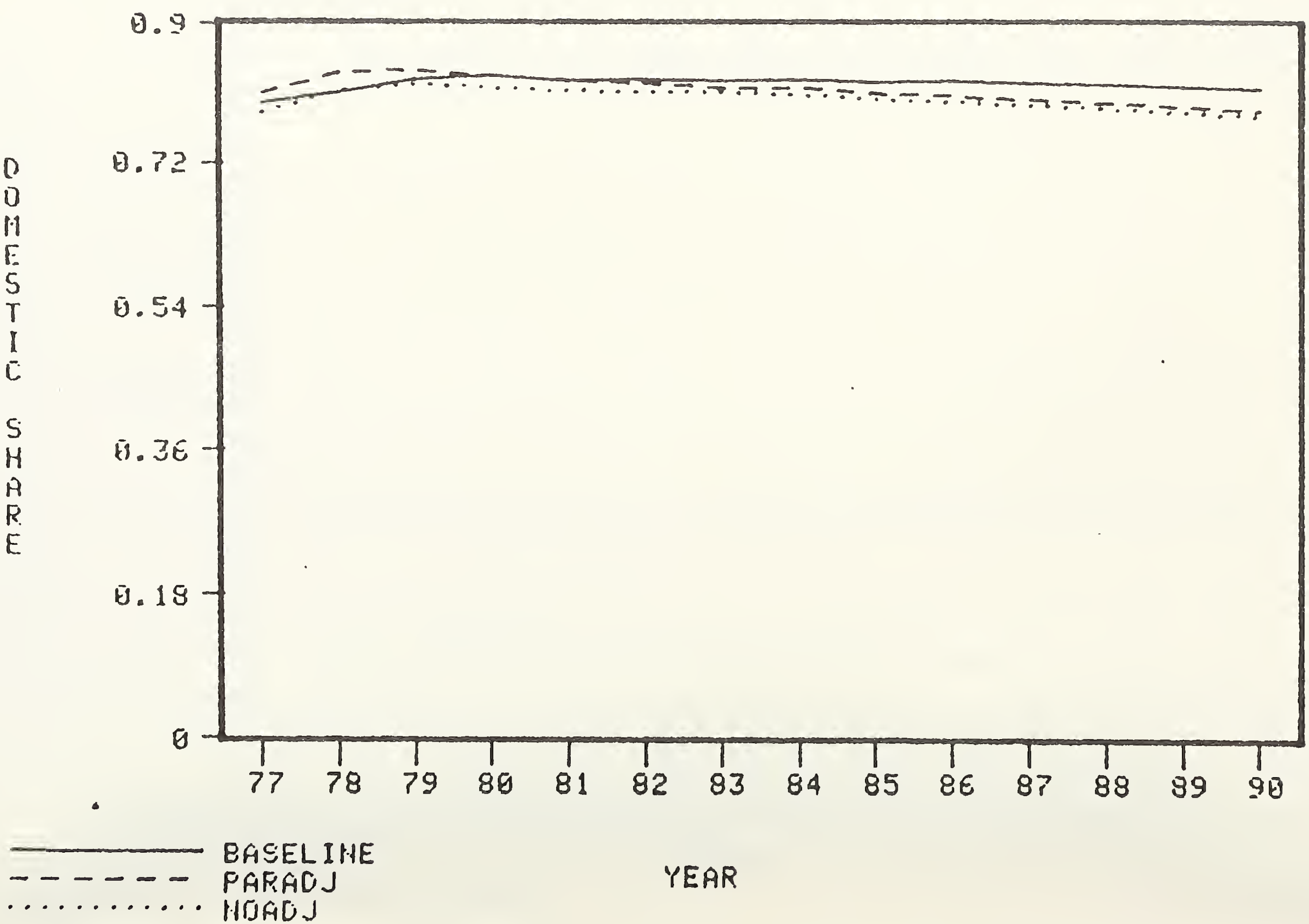
FOREIGN REGISTRATION SHARE (VAR428)



SOURCE: Calculated by Charles River Associates Incorporated, 1980.

Figure 2A–8

DOMESTIC REGISTRATIONS SHARE (VAR429)



SOURCE: Calculated by Charles River Associates Incorporated, 1980.

Chapter 3

EVALUATION OF THE WEFA-TSC "DESIRED" AUTOMOBILE STOCK EQUATION

The equation that forecasts the total "desired" automobile stock[1] for the United States is conceptually the most important single algorithm of the entire WEFA-TSC auto market model. This equation indicates the sensitivity of national demand for auto holdings to changes in national levels of income, auto costs, and demographic/geographic variables. Under steady-state conditions forecasts of this equation lead directly to forecasts of annual new car registrations. Even under more realistic nonsteady-state assumptions this equation has a paramount influence on the car sales projections of the complete WEFA-TSC model, and elasticities from the equation are approximations of the model's long-run demand elasticities. This equation is examined in detail because it so strongly influences the model's projections of how much federal policy

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[1] Appendix 3A evaluates the parallel desired motor vehicle stock equation. Because the equations are nearly identical, the evaluation results are also nearly identical.

will affect the national automotive sales level and the health of the auto industry. Because the capitalized cost per mile variable is the primary instrument by which policy affects the desired stock and thus actual stock, the estimate of the cost per mile coefficient is given special attention.

Description of the Equation

The "desired" automobile stock equation is estimated on 1976 state cross-section data. It is assumed that in 1976 the actual stock approximates the desired stock. In the Mark II WEFA specification the stock of autos per licensed driver is assumed to depend on the ratio of U.S. permanent disposable income to licensed drivers, the capitalized cost per mile of auto ownership, the percentage of total households living in suburban areas, and an income/market saturation term defined as the percentage of families with income of more than $15,000 in 1976 dollars. The equation holds that the desired stock of automobiles in the United States would be increased by increased disposable income per licensed driver, by lower automobile ownership and use costs, and by greater suburbanization. The income saturation term is a mechanism for introducing a declining income elasticity.[1] This equation is a reestimation of the original WEFA Mark 0 model in which the left-hand variable is desired stock per <u>family unit</u> and the right-hand variables are real disposable family income, the income saturation term, the capitalized cost per mile of auto ownership measure, licensed drivers per family unit, the number of persons per family unit using nonauto transportation to work

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[1]The total income elasticity of the equation depends on the combined coefficients of the income per licensed driver and income saturation terms.

(which is a proxy for the availability of public transit), and the percentage of population living in metropolitan areas.

In preparation of this report the WEFA-Mark II desired automobile stock equation as estimated by WEFA was replicated. The replication results do agree with those reported by WEFA in their Mark II draft report in most cases to two decimal places. The estimation results are followed by the variable definitions. A capital L preceding any variable name indicates that the log of the variable is used in the equation specification.

Dependent Variable: LVAR94 R-Square = .568
F-Ratio = 13.79
SSE = 0.227

Variable	Parameter Estimate	Standard Error	T Ratio
INTERCEPT	-3.767	0.751	-5.010
LVAR274	0.647	0.113	5.706
LVAR19P	-0.384	0.233	-1.648
SUB	0.281	0.076	3.680
LVAR232	-0.382	0.102	-3.729

where on a state basis:

VAR94 = Stock of autos/licensed drivers;

VAR274 = Ratio of four-year weighted disposable income to licensed drivers;

VAR19P = VAR19/VAR230 = Capitalized cost per mile for all cars divided by the CPI;

SUB = VAR55/VAR56 = Number of households in suburbs divided by total number of households in state; and

VAR232 = Percentage of families with income greater than $15,000 in 1976 dollars.

All coefficients other than the cost coefficient are significantly different from zero at the 95 percent confidence level. The estimated elasticity of auto stock with respect to capitalized cost per mile is -.38. The R-squared of .57 indicates that slightly more than half of the state-to-state variation in auto stock per licensed driver is explained by the independent variables.

Summary of Model Assessment Findings

Several strong findings emerge from our examinations of the WEFA "desired auto stock" equation:

1. Employment per family unit and geographic measures of suburbanization each have a strong influence on auto ownership. Although the WEFA model description emphasizes the importance of the income and cost economic variables as influences on the auto ownership decision, within the range of variation in variable levels offered by the 1976 state cross-section data we find that labor employment levels and suburbanization are of greater importance.
2. Within the range of 1976 state-to-state variation in auto costs, there is great uncertainty as to the degree to which costs affect the size of the desired auto stock; the WEFA elasticity of demand with respect to cost of -.38 seems to be greatly overstated.[1] We find that the estimation of the cost elasticity is hindered by a low level of variation in costs across states and by the

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[1]This says nothing about the willingness of the public to shift to smaller, less costly cars in reaction to higher auto ownership costs, or about the effect of auto costs outside the observed range of auto costs in 1976.

omission of significant costs, especially insurance costs, from the capitalized cost construct.

3. On logical grounds the model should be estimated on a per-family-unit rather than a per-licensed-driver basis. However, the empirical effects of this model misspecification seem to be small.
4. Backcasting exercises show that the model estimated on 1976 cross-section data performs very poorly when translated to the time domain. One obvious reason is that the total income elasticity for desired stock in the model, combining both the income and income saturation terms, is <u>negative</u>. This is clearly an implausible result. There may also be other reasons for the poor fit of the model's predicted values to the actual automobile stock. For example, we suspect that changes in the quality of highway infrastructure over the past 25 years have affected auto demand, yet highway quality is difficult to measure in a cross-section (or even time-series) data base. The poor backcasting record of the model and the negative income elasticity of demand must raise considerable doubts about the forecasting accuracy of the model.

Evaluation Methodology

The review of the desired automobile stock equation is performed in four stages. First the WEFA Mark II model is analyzed on its own terms. The range of variation in dependent and independent variables is described, and tests of parameter stability are performed. In the second section, elasticity estimates of the WEFA Mark II equation are compared with those of an identical equation to which a level of employment variable is added as an explanatory variable. Employment has often been mentioned as a significant determinant of auto ownership. A third stage of model evaluation discusses whether automobile stock per licensed driver is an appropriate left-hand variable, since the level of licensed drivers has historically not been independent of the demand for auto ownership. The model is reestimated with auto stock per family unit on the left-hand side (as in the Mark 0 version) and results are compared with the Mark II WEFA equation. Finally, the review evaluates the application of the desired stock equation, estimated on cross-section data, to national auto demand backcasting or forecasting in the time domain.

Description of the Estimation Data Base

The basic "desired auto stock" equation of the WEFA model contains five variables. The dependent variable is LVAR94, the log of desired stock per licensed driver. Independent variables are LVAR274, log of permanent income per licensed driver; LVAR19P, real cost of auto ownership; SUB, the percentage of households in suburban areas and LVAR232, the log of percentage of families with income greater than $15,000 in 1976 dollars.

In 1976 the mean state average automobile stock per licensed driver was .71 and the standard deviation was .07.[1] The state with the lowest number of cars per licensed driver was Wyoming with .51. Other states with fewer than .6 cars per

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[1]The sample of states includes the District of Columbia and all states except Alaska, Hawaii, and Oklahoma.

licensed driver include West Virginia, Montana, and Idaho. The state with the most cars per licensed driver is Alabama with .87. Other states with more than .8 cars per licensed driver in 1976 are Connecticut, New Jersey, Illinois, and South Carolina.

Real permanent income per licensed driver, adjusted for cost of living differences as measured by the 1976 BLS cost of living indices, ranges from $5,030 in West Virginia to $8,790 in Illinois. The mean is $6,540 and the standard deviation of the state averages is $850. The percentage of families earning more than $15,000 in 1976 dollars averages 44 across states and the state measures range from 29 to 59. The state average percentage of population in suburban areas is 30 and the state percentages range from 0 to 65. For each of these three explanatory variables there is substantial state-to-state variation in the 1976 data base.

The variable of primary interest for policy analysis purposes is the final explanatory variable, the capitalized cost per mile (CCM). Policy analysis exercises typically examine the effects of automobile excise taxes or gasoline taxes on desired holdings of automobiles and on new car sales. In the WEFA model these policy instruments influence the level of car sales primarily through the effect on the capitalized cost per mile on the desired stock of automobiles. Before beginning the model evaluation exercises, three methodological issues related to the cost per mile variable need to be raised. First, there is <u>not</u> substantial state-to-state variation in the cost measure. The average of the state costs is 22.1 cents per mile for 1976 and the standard deviation is only 1.2 cents. The range of all states is only about 10 percent below and above the states' average. Any policy analysis scenario of costs much different from their 1976 values forces the model to extrapolate outside of the cost range of the data on which the model is estimated.[1]

Second, in interpreting the cost per mile elasticity estimate of the WEFA model it is important to examine which states have high measured auto costs and which states have low measured auto costs. Because other costs of living (food costs, housing costs, taxes, etc.) vary more across states than do auto ownership costs, states with high costs of living overall have low measured real auto costs; states with low costs of living overall have high measured real auto costs. In the 1976 data base constructed by WEFA the five highest auto cost states are Mississippi, Texas, Georgia, Nevada, and South Carolina, while the five lowest cost states are the four Northern New England States and Oregon, with Massachusetts described as the lowest cost state for auto ownership in the entire country.[2] Table 3-1 on the next page shows the states and their WEFA-measured cost per mile of automobile ownership in order from the lowest cost to the highest cost state.

Third, there is a strong possibility of a serious "error in variables" problem for the following reasons: 1) insurance costs are not included in the cost per mile measure; 2) insurance costs are now an important component of actual auto costs in many parts of the country; 3) insurance costs appear to be negatively correlated with the WEFA capitalized cost per mile estimates; and 4) the variation in costs per mile among states is so small. How serious the problem is depends

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[1]The fact that variation in vehicle costs across states continues to be small relative to variations over time suggests that a preferred modeling strategy would place more emphasis on evidence from time-series data.

[2]This is not to say the WEFA cost per mile measure is incorrect, only to point out that state-to-state variations in real automotive costs are primarily determined by state-to-state variations in nonautomotive costs.

Table 3-1

CAPITALIZED COST PER MILE BY STATE: 1976
(1975 Dollars)

State	Capitalized Cost Per Mile
MASS	0.191879
VT	0.197209
NH	0.199712
ORE	0.199933
ME	0.203299
RI	0.204884
NY	0.205180
NJ	0.208846
WASH	0.210064
CAL	0.212483
MICH	0.213711
WISC	0.213767
PENN	0.214542
ID	0.215086
COL	0.216116
MD	0.216172
CONN	0.216305
NM	0.216334
SD	0.216529
UT	0.217082
DEL	0.217130
OHIO	0.218043
ND	0.219166
AR	0.221762

Table continued on following page.

Table 3-1 (Continued)

CAPITALIZED COST PER MILE BY STATE: 1976
(1975 Dollars)

State	Capitalized Cost Per Mile
IND	0.223189
MINN	0.223431
IOWA	0.225147
VA	0.226321
WVA	0.226489
MO	0.226548
WY	0.227016
TEN	0.227574
ARK	0.228581
ILL	0.228967
KEN	0.229760
MON	0.231143
LA	0.231546
NC	0.232543
KAN	0.233237
FLA	0.233393
ALA	0.233773
NEB	0.234532
SC	0.235400
NEV	0.235855
GE	0.237445
TEX	0.238236
MISS	0.242089

SOURCE: Computer software provided by Wharton Econometric Forecasting Associates.

on the actual size of insurance payments relative to other costs, and the correlation of real capitalized cost per mile as measured by WEFA with real state average insurance costs. Unfortunately, this issue cannot be settled because of a lack of adequate statewide data on real insurance costs.[1]

Having discussed the variables, we present a correlation coefficient matrix of the included variables:

	Auto Stock VAR94	Income VAR274	Cost VAR19P	Suburban SUB	Income Saturation VAR232
VAR94	1.00				
VAR274	.61	1.00			
VAR19P	.02	.05	1.00		
SUB	.46	.42	-.19	1.00	
VAR232	.22	.58	-.40	.63	1.00

We see that auto stock per licensed driver, VAR94, is most closely correlated with income and suburbanization. The simple correlation with capitalized cost is a positive .02.

Tests of Parameter Stability

One relatively simple and straightforward way to test the reliability of coefficient estimates within the "desired auto stock" model component is to estimate the same model specification on different subsets of states. A model which is characterized by similar coefficient estimates when estimated across subsets of the data base is likely to be more reliable for forecasting purposes than one for which coefficient estimates are highly dependent on the specific estimation data base. In this exercise we reestimate the model on different geographic regions of the United States and compare these results. The first method of choosing subsets is to divide the

[1]Some evidence appears in Appendix 3B to this chapter.

observations into Northern and Southern states. Southern states are defined as the East South Central, South Atlantic, and West South Central Census regions, and Northern states as all others.

Separate regressions were run for the Northern and Southern states using the WEFA Mark II Model specifications with the following results. Variables are defined on pages 3-3 and 3-4.

NORTH

Dependent Variable: LVAR94 R-Square = .637
F-Ratio = 11.83
SSE = .123

Variable	Parameter Estimate	Standard Error	T Ratio
INTERCEPT	-3.432	0.912	-3.761
LVAR274	0.574	0.123	4.656
LVAR19P	-0.347	0.248	-1.397
SUB	0.313	0.088	3.532
LVAR232	-0.331	0.160	-2.069

SOUTH

Dependent Variable: LVAR94 R-Square = .605
F-Ratio = 3.83
SSE = .072

Variable	Parameter Estimate	Standard Error	T Ratio
INTERCEPT	-3.447	2.119	-1.626
LVAR274	0.905	0.265	3.407
LVAR19P	0.574	1.059	0.542
SUB	0.342	0.306	1.120
LVAR232	-0.550	0.309	-1.779

In the separate regressions, the cost elasticities are of opposite sign indicating that the estimate of cost elasticity is highly dependent on the data set and that one should not place a high degree of confidence in the cost elasticity estimated in the WEFA model. The two cost-elasticity estimates are -.35 and +.57. We also see that the income elasticity of demand and the saturation impact coefficient are noticeably different between the two regions.

A similar test is run dividing the United States into Eastern and Western regions. The East is defined as the East North Central, East South Central, Middle Atlantic, New England, and South Atlantic Census regions, and the West as all other states. The following regression results are observed.

EAST

Dependent Variable: LVAR94 R-Square = .614
F-Ratio = 6.35
SSE = .086

Variable	Parameter Estimate	Standard Error	T Ratio
INTERCEPT	-4.848	1.447	-3.349
LVAR274	0.752	0.207	3.616
LVAR19P	-0.351	0.401	-0.874
SUB	0.319	0.108	2.943
LVAR232	-0.266	0.158	-1.680

WEST

Dependent Variable: LVAR94 R-Square = .539
F-Ratio = 6.14
SSE = .120

Variable	Parameter Estimate	Standard Error	T Ratio
INTERCEPT	-3.544	0.934	-3.792
LVAR274	0.620	0.145	4.265
LVAR19P	-0.360	0.354	-1.018
SUB	0.204	0.140	1.450
LVAR232	-0.376	0.175	-2.145

These results are much more alike than the North/South regressions. Coefficients, including the estimated cost elasticity terms, are similar across regions and no perverse signs are found. The table below compares the coefficients estimated on the four samples of states.

	North	South	East	West
Income	.57	.91	.75	.62
Cost	-.35	.57	-.35	-.36
Suburbanization	.31	.34	.32	.20
Saturation	-.33	-.55	-.27	-.38

Formal Statistical Tests

Finally, a series of statistical tests were made to test for significant differences in coefficient estimates across regions. In the first test a new regression equation is estimated of the form:

$$Y = B1 + B2(X1) + B3(X1^*) + B4(X2) + B5(X2^*) + \ldots$$

where:

$Xi^* = Xi$ if Xi is in group one.

$Xi^* = -Xi$ if Xi is in group two.

Estimated in this way, the T-statistic of each of the B* coefficients tests the hypothesis of regional differences in coefficients of the WEFA Mark II specification. If B* is not significantly different from zero, then Bi is not significantly different from zero and then Bi does not significantly differ across regions.

The results of doing this for the North-South and East-West equations are:

NORTH-SOUTH

Dependent Variable = LVAR94

R-Square = .628
F-Ratio = 8.02
SSE = .195

Variable	Parameter Estimate	Standard Error	T Ratio
INTERCEPT	-3.436	0.852	-4.030
LVAR274	0.739	0.118	6.229
LVAR274NS	-0.165	0.089	-1.836
LVAR19P	0.115	0.392	0.294
LVAR19PNS	-0.463	0.323	-1.430
SUB	0.328	0.133	2.464
SUBNS	-0.015	0.126	-0.118
LVAR232	-0.440	0.150	-2.919
LVAR232NS	0.109	0.154	0.708

EAST-WEST

Dependent Variable = LVAR94

R-Square = .603
F-Ratio = 7.21
SSE = .005

Variable	Parameter Estimate	Standard Error	T Ratio
INTERCEPT	-3.911	0.777	-5.032
LVAR274	0.653	0.119	5.462
LVAR274EW	0.017	0.063	0.272
LVAR19P	-0.314	0.261	-1.201
LVAR19PEW	-0.125	0.214	-0.585
SUB	0.267	0.088	3.035
SUBEW	-0.069	0.086	-0.802
LVAR232	-0.325	0.117	-2.768
LVAR232EW	-0.072	0.115	-0.625

The test results indicate that we cannot reject the hypothesis that coefficients are identical across regions at the 95 percent confidence level. However, particularly in the case of the cost-elasticity estimate, failure to find differences across regions results largely from the high standard errors of the estimates rather than from the similarity of the estimates in different regions.

A second test was performed to check for regional differences in auto holdings. The WEFA specification, with Census region dummy variables added, is estimated with the following results:

EAST-WEST

Dependent Variable = LVAR94

R-Square = .711
F-Ratio = 6.98
SSE = .151

Variable	Parameter Estimate	Standard Error	T Ratio
INTERCEPT	-3.521	0.908	-3.875
VAR20	0.097	0.059	1.637
VAR21	0.095	0.051	1.853
VAR22	0.024	0.070	0.343
VAR23	0.049	0.055	0.898
VAR24	0.156	0.069	2.236
VAR25	0.077	0.069	1.118
VAR26	0.015	0.047	0.314
VAR27	0.108	0.052	2.060
LVAR274	0.720	0.131	5.493
LVAR19P	-0.033	0.347	-0.097
SUB	0.375	0.087	4.305
LVAR232	-0.458	0.134	-3.410

VAR20 through VAR27 are regional dummy variables. Regional variables which are significantly different from zero at the 90 percent confidence level are VAR21 (East South Central) and VAR24 (New England). Note that in this plausible model specification of desired auto holdings the estimated cost elasticity falls to -.03 and has a standard error ten times as high. This is further evidence of the lack of precision of the WEFA cost per mile elasticity estimate of -.38.

Other Tests

Another set of tests was run in which city and rural household percentages by state were used to replace the suburban percentage variable. We find that the original results of WEFA are quite robust with respect to the geographic variable choice. The following regression takes out SUB and replaces it with both a CITY and RURAL variable measuring population percentages in city and rural areas. Income and cost elasticities are similar to those of the WEFA specification. A city coefficient which is not significantly different from zero and a negative rural coefficient replaces the positive suburban coefficient in the WEFA equation.

Dependent Variable = LVAR94 R-Square = .579
F-Ratio = 11.01
SSE = .220

Variable	Parameter Estimate	Standard Error	T Ratio
INTERCEPT	-3.457	0.774	-4.462
LVAR274	0.632	0.114	5.535
LVAR19P	-0.409	0.234	-1.749
CITY	-0.141	0.149	-0.946
RURAL	-0.256	0.079	-3.226
LVAR232	-0.385	0.102	-3.763

In a similar experiment the WEFA "permanent" income variable was replaced with an actual 1976 state real disposable income per licensed driver variable. The resulting estimated equation is similar to the WEFA equations, but with both the income and cost coefficients lower in absolute value.

Dependent Variable = LVAR94 R-Square = .521
F-Ratio = 11.42
SSE = .251

Variable	Parameter Estimate	Standard Error	T Ratio
INTERCEPT	-2.480	0.6213	-3.991
LVAR276	0.472	0.0939	5.028
LVAR19P	-0.211	0.2363	-0.894
SUB	0.337	0.0800	4.221
LVAR232	-0.338	0.1057	-3.200

Summary

A series of tests of the stability of parameter estimates of the "WEFA Mark II desired auto stock" equation were performed. These tests were primarily intended to determine the degree to which the WEFA results are dependent on the specific data set or are sensitive to slight variations in model specification. The tests indicate that four of the five estimated coefficients are relatively stable, but that estimated cost elasticity is highly dependent on the model specification and the estimation data base. The results actually support the WEFA finding that the cost elasticity of demand is not significantly different from zero at the 95 percent confidence level, but warn us that the WEFA estimated cost elasticity of -0.38 may be specification-dependent and form a biased estimate.

Inclusion of an Employment Level Term

In addition to the variables discussed above, the number of employed workers may also influence automobile ownership.[1]

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[1]This has been suggested by students of the disaggregate auto ownership literature, including Nick Schaeffer of project sponsor TSC.

A person who is employed needs to get to and from work and, unless there is a convenient public transit or carpool arrangement, needs a motor vehicle for this purpose. Thus, we can hypothesize that the number of workers per licensed driver directly influences the auto stock per licensed driver. In the following represented regression results we have added the variable LEMP, the log of employment per licensed driver, to the WEFA Mark II desired auto stock equation.

The regression results are as follows.

Dependent Variable = LVAR94

R-Square = .650
F-Ratio = 15.21
SSE = .184

Variable	Parameter Estimate	Standard Error	T Ratio
INTERCEPT	-4.583	0.733	-6.245
LEMP	0.469	0.151	3.098
LVAR274	0.312	0.149	2.085
LVAR19P	-0.088	0.233	-0.380
SUB	0.286	0.069	4.122
LVAR232	-0.276	0.099	-2.784

The employment term is highly significant with an estimated ownership elasticity of .47. The income and income saturation coefficient terms both drop in absolute value, and the ownership elasticity with respect to cost falls to -.08 with a standard error of .23. This result indicates that if one believes that employment is a determinant of auto holdings, both the income and cost elasticities reported by WEFA are overstated, and that some of the strength of these variables is really attributable to the employment variable. Alternative specifications using the labor force rather than the employment level as an explanatory variable yield very similar results.

The following table shows the simple correlation coefficient between EMP, employment per licensed driver, and other variables included in the equation specification:

	Auto Stock	Income	Cost	Suburb	Income Saturation
Employment (EMP)	.66	.67	-.12	.20	.28

The employment variable is highly correlated with both the auto ownership and the income variable and slightly negatively correlated with the cost measure.

Because the employment variable is so highly significant, is theoretically plausible, and raises the explanatory power of the model, we conclude that a preferred specification would include it. This specification applied to the 1976 state-level data supports the assertion that the elasticity of total desired auto ownership with respect to total auto ownership and operating costs is -.09, rather than the -.38 that WEFA estimates. However, both estimates are subject to quite high standard errors indicating imprecision in each estimate.

Desired Stock Per Family Unit

In the original Mark 0 WEFA model the desired auto stock was modeled on a per-family-unit basis, where family unit is defined as the sum of families and unrelated individuals. In the current Mark II version the decision unit has been changed to the licensed driver, and income per licensed driver is a right-hand variable. To the extent that the same variables which influence desired auto holdings also influence the percentage of the population with drivers' licenses, the denominator of the desired stock variable is endogenous to the auto model system. The WEFA Mark II model specification thus may lead to simultaneous equation type bias since it is estimated using ordinary least squares techniques. Since the model fails to determine the number of licensed drivers endogenously, the model would also be subject to the criticism that it only forecasts desired stock per licensed driver and not the total desired auto stock. The user is required to forecast the number of licensed drivers. On the other hand, one can convincingly argue that for 1976 data, at the time of the model, nearly all persons in most states who were of driving age did have drivers' licenses. If this is the case, the number of licensed drivers is largely exogenous, predictable, and determined purely by demographics.

In this section the model is reestimated on a per-family-unit basis. While the results do not provide a formal statistical test of what the correct model specification is, they do offer evidence as to how sensitive the elasticity estimates are to the choice of decision unit. For 1976, the mean state average level of number of autos per family unit is 1.27. The mean state average level of employment per family unit is 1.16.

The following table gives the correlation coefficient of the relevant variables:

	CAR	EMP	INC	SUB	VAR19P	VAR232	LDFU
CAR	1.00						
EMP	.52	1.00					
INC	.43	.46	1.00				
SUB	.23	-.13	.27	1.00			
VAR19P	.17	.03	.25	-.19	1.00		
VAR232	.16	.21	.59	.64	-.40	1.00	
LDFU	.28	.39	.20	-.33	.15	-.09	1.00

where:

CAR = Stock of cars per family unit;
EMP = Number of employed persons per family unit;
INC = Income per family unit;
SUB = Percentage of households in suburbs;
VAR19 = Real capitalized auto cost;
VAR232 = Percent families with incomes greater than $15,000; and
LDFU = Licensed drivers per family unit.

First we run the WEFA Mark II "desired auto stock" equation on the data normalized by family unit. The R^2 drops by about half and all estimated coefficients are reduced somewhat in absolute value and also in statistical significance.

Dependent Variable = LCAR R-Square = .317
F-Ratio = 4.87
SSE = .248

Variable	Parameter Estimate	Standard Error	T Ratio
INTERCEPT	-3.142	1.136	-2.764
LINCOME	0.582	0.167	3.470
SUB	0.189	0.083	2.263
LVAR19P	-0.200	0.291	-0.689
LVAR232	-0.289	0.138	-2.083

Thus, if one does regard the number of licensed drivers as a truly exogenous variable, then the WEFA Mark II equation does provide a better fit and by such statistical standards is a better model.

We then run the above regression with an employment per-family-unit term.

Dependent Variable = LCAR R-Square = .452
F-Ratio = 6.76
SSE = .195

Variable	Parameter Estimate	Standard Error	T Ratio
INTERCEPT	-1.153	1.205	-0.957
LEMP	0.507	0.159	3.180
LINCOME	0.305	0.175	1.742
SUB	0.242	0.077	3.123
LVAR19P	-0.022	0.269	-0.082
LVAR232	-0.250	0.126	-1.982

COMPARISON OF COEFFICIENTS

	Per Licensed Driver	Per Family Unit
Employment	.47	.51
Income	.31	.31
Suburbanization	.29	.24
Cost	-.09	-.02
Income Saturation	-.28	-.25

The R^2 value improves by 68 percent, and the estimated cost elasticity is also reduced. The coefficients of this equation are quite similar to those which are estimated on a per-licensed-driver basis, and these results indicate that the choice of behavioral decision unit makes little difference in the estimated elasticities. Employment, income, and suburbanization significantly affect the desired stock of cars; the cost effect (within the range of costs observed) is practically zero.

Finally, regressions on a per-family-unit basis are run, which include as a right-hand variable a term measuring the number of licensed drivers per family unit. Regressions are run without and with the employment per family unit term. The results show that the coefficient of licensed drivers per family unit is marginally statistically significant and that its inclusion has only a minor effect on the other coefficient estimates.

Dependent Variable = LCAR   R-Square = .339
F-Ratio = 4.20
SSE = .235

Variable	Parameter Estimate	Standard Error	T Ratio
INTERCEPT	-5.588	2.487	-2.246
LINCOME	0.440	0.181	2.426
SUB	0.209	0.085	2.458
LVAR19P	-0.175	0.308	-0.566
LVAR232	-0.229	0.139	-1.645
LGLDFU	0.295	0.134	2.196

Dependent Variable = LCAR   R-Square = .485
F-Ratio = 6.28
SSE = .183

Variable	Parameter Estimate	Standard Error	T Ratio
INTERCEPT	-1.127	1.183	-0.953
LEMP	0.450	0.160	2.812
LINCOME	0.279	0.172	1.619
SUB	0.272	0.078	3.473
LVAR19P	-0.041	0.265	-0.154
LVAR232	-0.248	0.124	-1.999
LGLDFU	0.198	0.123	1.604

The following table compares estimated coefficients of regressions on a per-family-unit basis with and without the licensed driver term.

PER FAMILY UNIT

Mark II		Without Employment		With Employment	
		Without LD	With LD	Without LD	With LD
INC	.64	.58	.44	.31	.28
SUB	.28	.19	.15	.24	.27
19P	-.38	-.20	-.18	-.02	-.04
232	-.38	-.29	-.22	-.25	-.25
EMP				.51	.45
LD			.30		.20

The above table shows that the effect of the licensed driver per family unit term is relatively minor while the effect of the employment per family unit term is stronger. The inclusion of the employment term leads to substantially lower income and cost coefficients, sending the cost elasticity to practically zero.

On the 1976 cross-section data base we find that it makes little difference whether desired car stock is estimated on a per-licensed-driver or on a per-family-unit basis. However, such a finding is probably due to the high percentage of 1976 driving age population that had drivers' licenses and the result that by 1976 the number of licensed drivers in most states depended primarily on the age distribution of the population.

Translation to the Time Domain

Even a seemingly satisfactory cross-sectional model of auto holdings may not perform well as a forecasting tool if structural changes in demand occur over time which are not discerned in a point of time snapshot. For this reason the use of a backcasting simulation exercise is useful in evaluating the reliability of the WEFA desired auto stock equation.

Although desired auto stock should not necessarily exactly equal the actual stock at any given point of time, the adjustment mechanisms of car sales and scrappage can vary rapidly enough that there should not be a long-run secular divergence between the actual and desired stock.

If the WEFA desired stock equation were transferable to the time domain we would expect the plot of actual versus desired stock per licensed driver to take a form in which the actual and desired stock cycle around each other, as shown in Figure 3-1. On the other hand, if the WEFA equation were not transferable to the time domain the backcasting exercise might yield a plot of the form shown in Figure 3-2.

A Backcasting Exercise

A backcasting exercise was performed which compared the actual auto stock per licensed driver (RAUTO) with the WEFA Mark II predicted desired stock per licensed driver (WAUTO) and the prediction of the WEFA specification to which has been added an employment per licensed driver variable (EMPA). As will be explained in the next section, the procedure used is not exactly the same as that used by WEFA, but the plot in Figure 3-3 is extremely instructive. (Table 3-2 presents the data used to construct the graph.) In it we see a wide and long-lasting divergence between backcasted stocks on the one hand and actual auto stock per licensed driver on the other. The WEFA equation is obviously not directly transferable to the time domain. One reason for the poor fit of the WEFA desired auto stock equation is that its backcast actually slopes downward; the estimated desired stock per licensed driver declines over time. Why should this be so? The answer is described more fully in Chapter 5, but stated briefly, the combined income/income saturation terms yield a negative income elasticity of demand for automobiles. This is clearly an untenable and illogical model property.

Figure 3–1

EXAMPLE OF GOOD FIT OF MODEL TO ACTUAL DATA

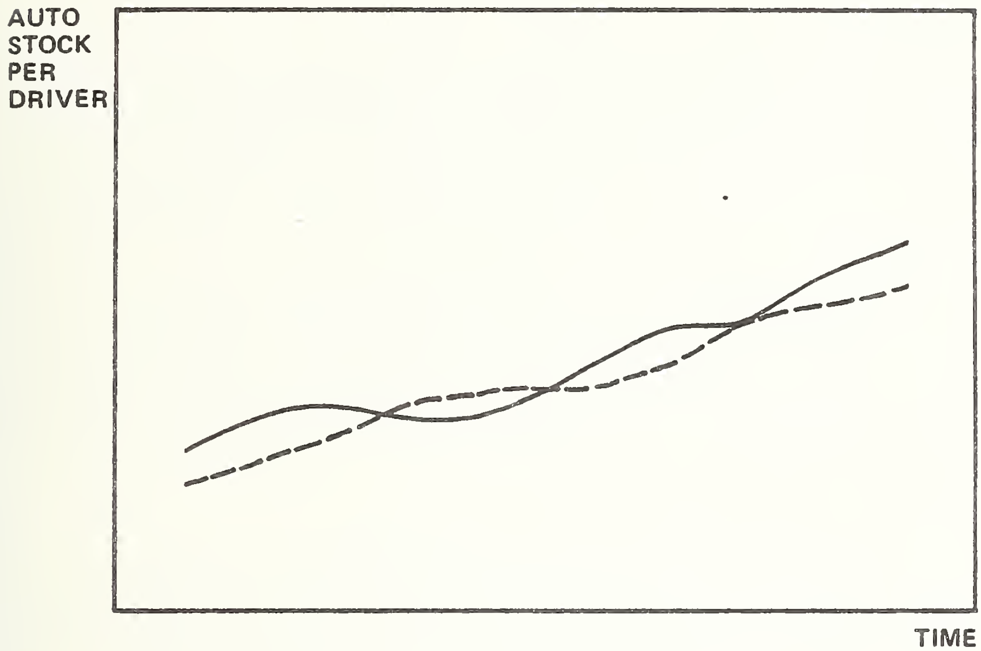

Figure 3–2

EXAMPLE OF POOR FIT OF MODEL TO ACTUAL DATA

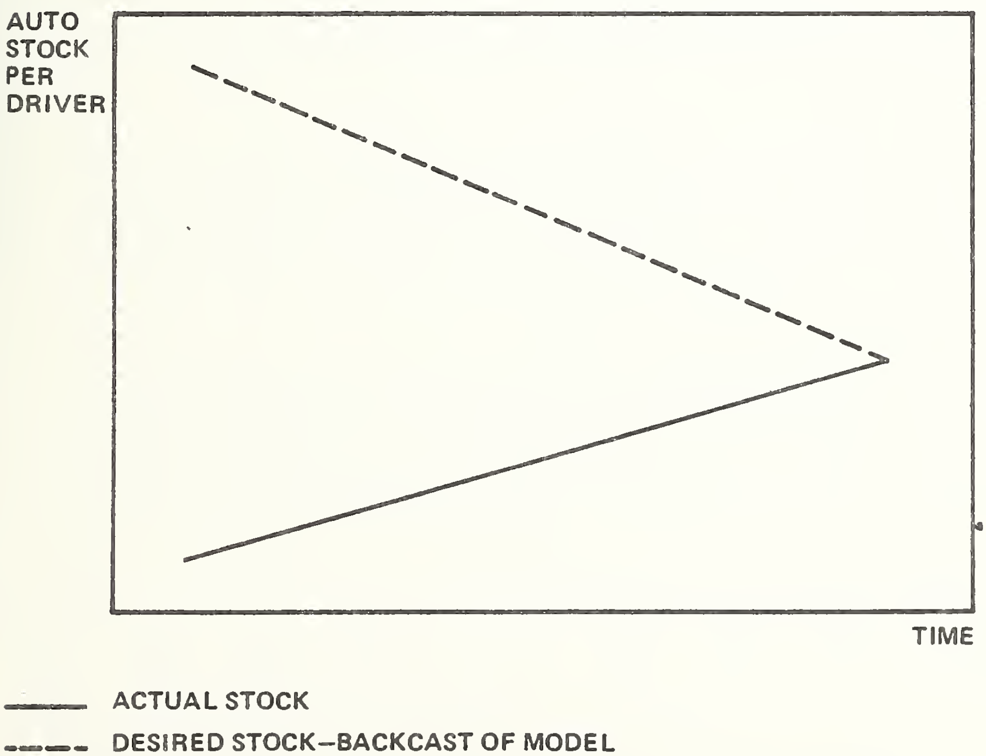

Figure 3—3

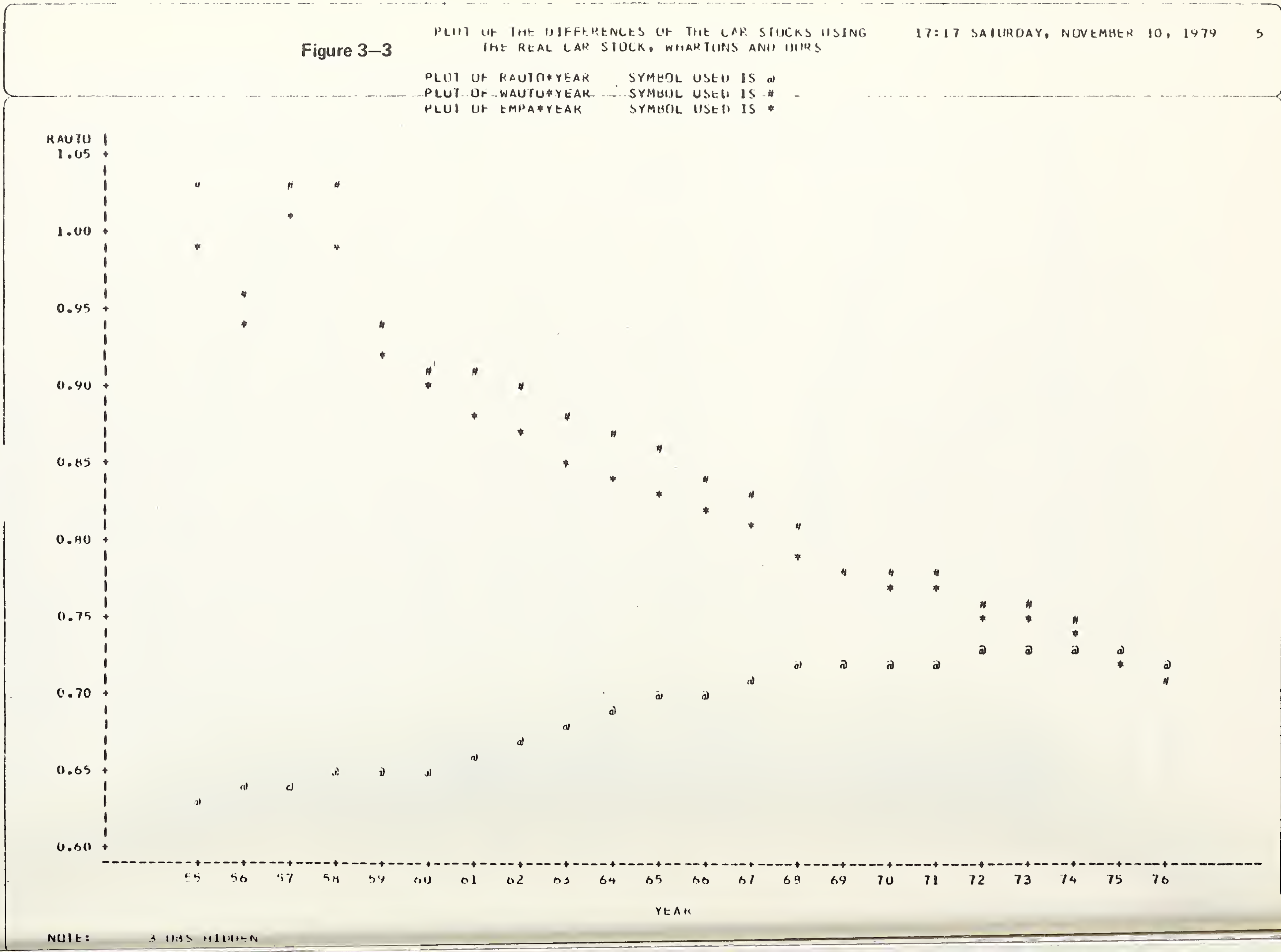
PLOT OF THE DIFFERENCES OF THE CAR STOCKS USING THE REAL CAR STOCK, WHARTONS AND DRIS
17:17 SATURDAY, NOVEMBER 10, 1979
5
PLOT OF RAUTO*YEAR SYMBOL USED IS @
PLOT OF WAUTO*YEAR SYMBOL USED IS #
PLOT OF EMPA*YEAR SYMBOL USED IS *
RAUTO
1.05
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76
YEAR
NOTE: 3 OBS HIDDEN

Table 3-2

DIFFERENCES BETWEEN THE REAL AUTO STOCK AND THE AUTO STOCK
FROM WHARTONS EQUATIONS AND EQUATIONS ESTIMATED BY CRA

RAUTO	WAUTO	EMPA	WER	EMPAER	PWAUTO	PERCMP
0.632475	1.03108	0.98809	-0.39860	-0.35561	-63.023	-56.225
0.639741	0.95572	0.93566	-0.31698	-0.29692	-49.625	-46.485
0.644217	1.03235	1.00969	-0.38814	-0.36547	-60.249	-56.732
0.648491	1.02558	0.98787	-0.37709	-0.33938	-58.149	-52.334
0.650217	0.93703	0.92430	-0.28682	-0.27408	-44.111	-42.152
0.652888	0.91443	0.89936	-0.26154	-0.24647	-40.059	-37.751
0.663103	0.90735	0.88289	-0.24425	-0.21978	-36.834	-33.145
0.672697	0.89587	0.86996	-0.22317	-0.19726	-33.176	-29.324
0.677453	0.87931	0.85317	-0.20186	-0.17571	-29.797	-25.938
0.692693	0.87172	0.84439	-0.17903	-0.15168	-25.845	-21.898
0.698262	0.85926	0.83339	-0.16100	-0.13513	-23.057	-19.352
0.703761	0.83558	0.81512	-0.13182	-0.11136	-18.731	-15.824
0.707905	0.82816	0.80948	-0.12026	-0.10157	-16.988	-14.348
0.715320	0.80629	0.79411	-0.09097	-0.07879	-12.717	-11.014
0.720052	0.78215	0.77799	-0.06210	-0.05794	-8.624	-8.046
0.720117	0.78343	0.77279	-0.06331	-0.05268	-8.792	-7.315
0.724442	0.77804	0.76596	-0.05359	-0.04152	-7.398	-5.731
0.725607	0.76281	0.75302	-0.03720	-0.02742	-5.127	-3.778
0.731871	0.76353	0.75269	-0.03166	-0.02082	-4.326	-2.845
0.731908	0.74563	0.74455	-0.01373	-0.01264	-1.875	-1.727
0.726801	0.72835	0.72465	-0.00155	0.00215	-0.213	0.296
0.721396	0.71167	0.71283	0.00972	0.00857	1.348	1.188

where:

RAUTO = Number of cars in country divided by number of licensed drivers, actual;
WAUTO = Desired stock of cars per licensed driver using Wharton's equation;
EMPA = Desired stock of cars per licensed driver using the employment regression;
WER = RAUTO - WAUTO;
EMPAER = RAUTO - EMPA;
PWAUTO = Percent difference between WAUTO and RAUTO; and
PERCMP = Percent difference between EMPA and RAUTO.

Table 3-2

DIFFERENCES BETWEEN THE REAL AUTO STOCK AND THE AUTO STOCK FROM WHARTONS EQUATIONS AND EQUATIONS ESTIMATED BY CRA

SOURCE: Data for RAUTO and WAUTO columns: Computer software provided by Wharton Econometric Forecasting Associates.

Data for EMPA, WER, EMPAER, PWAUTO and PERCMP columns: Calculated by Charles River Associates Incorporated, 1980.

If backcasting accuracy is any guide to a model's forecasting accuracy, the WEFA "desired stock" predictor should be treated with a great deal of suspicion.

WEFA Backcasting Procedure

In backcasting, WEFA explains that the auto saturation term does not perform well outside the range of actual 1976 experiences and the variable is arbitrarily set at 20 percent, its 1968 level, for all previous years.[1] Using this arbitrary procedure WEFA produces the plot in Figure 3-4, reproduced from the WEFA Mark II report. We see that this backcasting exercise fits the data much better than the backcast in Figure 3-3, using unadjusted data.

In evaluating the transferability of the WEFA cross-section model to the time domain, one must realize that the apparent fit of the backcast to the data in the WEFA graph only occurs because of their arbitrary floor on the income saturation variable. While this data adjustment is valid if the backcasting errors are really due to the workings of the saturation term, no evidence is offered that the large backcasting error found in the uncorrected backcast is really due to the application of the saturation term to levels outside the range of 1976 experience. Even in 1976 the model exhibits a negative income elasticity. Another hypothesis is that the equation is simply misspecified. The poor backcasting record may result from other factors, perhaps the omission of some structural variable such as "quality of the road infrastructure" which has improved secularly but which was not included in the state cross-section level regression.

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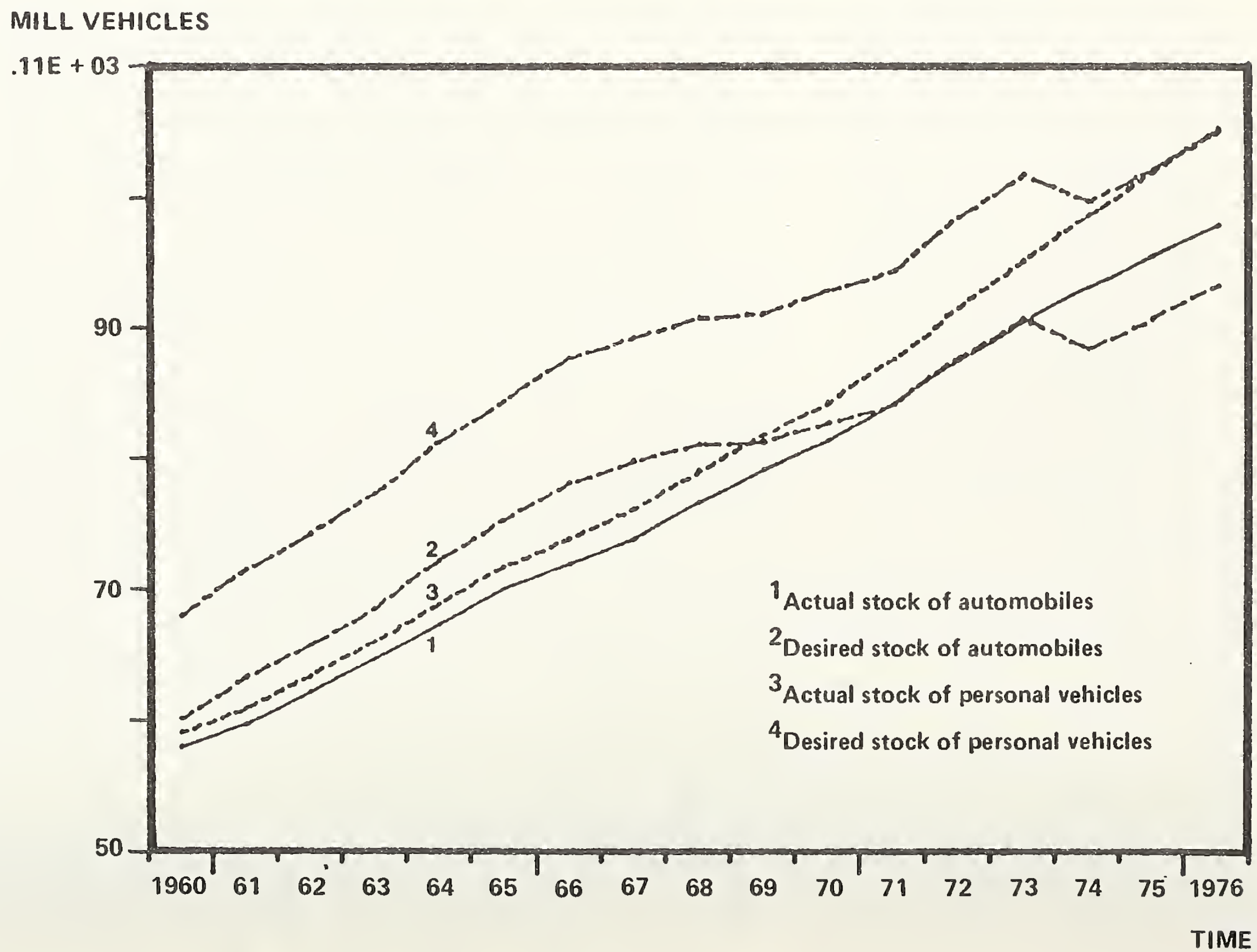
[1]This is explained in the Mark 0 version of the report. The 20 percent figure in 1968 is in 1970 dollars.

Figure 3–4

WHARTON EFA MOTOR VEHICLE MODEL DESIRED VERSUS ACTUAL STOCKS



SOURCE: Reproduced from Figure 3–1 of Wharton Econometric Forecasting Associates, *The Demand for Light-Duty Trucks: The Wharton EFA Motor Vehicle Demand Model,* December 1978, p. 3–7.

We conclude therefore that the WEFA cross-section equation does not translate directly to the time domain for backcasting or forecasting exercises, that WEFA provides an adjustment that does provide a better data fit, but that no evidence is offered that the WEFA adjustment addresses itself to the root cause of backcasting error.

Appendix 3A
EVALUATION OF THE WEFA-TSC "DESIRED MOTOR VEHICLE STOCK" EQUATION

After completion of the WEFA-TSC Mark 0 automobile demand model, government policy analysts recognized the value of broadening the model to encompass demand for light trucks. One reason is that in many respects cars and light trucks comprise a single motor vehicle market that should be modeled as such. A second reason is the feeling that policy analysis of automobile regulations should be extended to the light truck market as federal rules including fuel economy standards are applied to light trucks. In addition, policy analysts would benefit from a model that could explain the market shift of the past decade from cars to light trucks and which could test the hypothesis that part of this shift has been reduced by more stringent regulation of cars. This chapter reviews and evaluates the "desired motor vehicle stock" equation using procedures similar to those used in evaluating the "desired auto stock" equation.

The "Desired Personal Vehicle Stock" Equation*

The WEFA-TSC Mark II model splits the motor vehicle market into personal motor vehicles and commercial vehicles. In the estimation data base, the division of trucks into personal and commercial types is somewhat arbitrary and based on type of truck rather than on actual use. Equations are estimated for the desired stock of personal vehicles and the desired stock of cars. The desired stock of personal use trucks is calculated as the difference.

The desired personal vehicle stock equation, like the desired auto stock equation, is estimated on 1976 state cross-section data. In the Mark II WEFA specification, the explanatory variables of the personal vehicle equation are strictly analogous to those of the automobile. Desired personal motor vehicles per licensed driver is assumed to depend on permanent disposable income per licensed driver, the average capitalized cost per mile of personal motor vehicles, the percentage of households living in suburban areas, and the percentage of families with incomes over $15,000 (in 1976 dollars) which is a market saturation proxy. All variables except the suburbanization measure are in log form.

The desired motor vehicle stock equation, as replicated using the WEFA data base, is as follows:[1]

Dependent Variable: LPVLD

R-Square = .537
F-Ratio = 12.16
SSE = .199

Variable	Parameter Estimate	Standard Error	T Ratio
INTERCEPT	-3.482	0.695	-5.004
LV274	0.566	0.104	5.417
LCPM	-0.416	0.220	-1.889
SUB	0.223	0.071	3.141
LV232	-0.310	0.094	-3.295

[1] In most cases, results are identical to those reported by WEFA to the second decimal place.

where on a state basis:

LPVLD = Log of personal vehicles per licensed driver;
LV274 = Log of permanent disposable income per licensed driver;
LCPM = Log of motor vehicle capitalized cost per mile;
SUB = Percentage of householders in suburban areas; and
LV232 = Percentage of families with incomes over $15,000.

The estimated capitalized cost elasticity of motor vehicle stock holdings is -.42.

Personal Motor Vehicles
and Personal Light Duty Trucks

The construction of the WEFA personal motor vehicle stock equation evolved out of the unsuccessful attempt to explicitly model the demand for personal light-duty trucks separately from the demand for cars. Efforts to explain the historic distribution of sales between cars and trucks as a function of the relative capitalized cost per mile of cars and trucks failed because the growing popularity of trucks in the 1970s has not been associated with a shift in capitalized costs favoring trucks. Other competing hypotheses about the growing popularity of trucks including the influence of "lifestyle" changes and the adverse effect of federal regulations on the design of large cars could not be tested with the WEFA aggregate state-level data.

In the WEFA Mark II model, desired personal light-duty trucks are calculated as the residual between desired total personal motor vehicles and desired automobiles. Because a separate truck model could not be built and because the motor vehicle demand model is really only a minor adjustment to the car demand model (cars constituting a large majority of motor vehicles), we must conclude that the combined equations are unlikely to be a reliable guide to understanding the truck market. If a model of this structure could forecast future patterns of personal light truck demand, a separate truck model could have been successfully built to show that the historic cross-section patterns of personal truck demand depend on differences in income, truck capitalized costs, and the level of suburbanization. Although for the reasons outlined we do not believe that the personal motor vehicle stock predictor should be regarded as a serious predictor of personal light truck sales, it may be used by some model users as a placeholder or as a predictor of total personal motor vehicle sales, including sales of automobiles. In this section we evaluate the reliability of the model as used for this purpose. Because the desired motor vehicle stock equation so closely resembles the desired auto stock equation, the evaluation results are similar.

Discussion of the Estimation Data Base

The explanatory variables of the "desired personal vehicle" equation are all either identical or very similar to the explanatory variables described in the relevant section of the "desired auto stock" discussion. However, the dependent variable is different because of state-to-state variation in the ratio of personal light trucks to cars. As Table 3A-1 shows, the percentage difference between total personal motor vehicles and cars varies from less than 4 percent in Kentucky and Alabama to more than 10 percent in Colorado, Nevada, Idaho, Oregon, and Wyoming. In the table, states are listed in order of the percentage difference between personal vehicles and cars.

Table 3A-2 lists states in order of personal vehicles per licensed driver. The states with the lowest number of personal vehicles per driver are Wyoming, West Virginia, Idaho, and

Table 3A-1

DIFFERENCE BETWEEN PERSONAL VEHICLES AND CAR OWNERSHIP BY STATE, 1976[1]

State	Personal Vehicles	Car	Percent Difference
KEN	1.6121	1.5520	3.8777
ALA	1.8863	1.8154	3.9061
NJ	3.7400	3.5951	4.0299
RI	0.4545	0.4363	4.1551
CONN	1.6164	1.5509	4.2266
SC	1.3566	1.3007	4.3039
OHIO	5.6363	5.4036	4.3058
MASS	2.5865	2.4792	4.3284
NY	7.0062	6.7144	4.3454
TEN	1.8413	1.7619	4.5077
MISS	1.0276	0.9823	4.6210
ILL	5.5419	5.2934	4.6940
MO	2.2747	2.1705	4.8040
DEL	0.3106	0.2959	4.9540
GE	2.2346	2.1283	4.9917
LA	1.6960	1.6144	5.0500
IOWA	1.4942	1.4223	5.0588
VA	2.3247	2.2115	5.1154
NC	2.6410	2.5124	5.1186
WISC	2.2074	2.0994	5.1409
MINN	1.9226	1.8275	5.1988
PENN	5.3696	5.1039	5.2064
MD	1.7263	1.6399	5.2680
KAN	1.2085	1.1480	5.2698
NEB	0.7952	0.7536	5.5132
ARK	0.8886	0.8421	5.5257
IND	2.5739	2.4390	5.5276
ND	0.3018	0.2856	5.6470
TEX	5.9293	5.6060	5.7666
SD	0.3356	0.3167	5.9670
FLA	4.3191	4.0687	6.1540
MICH	4.5450	4.2746	6.3267

[1]Vehicles measured in millions.

Table continued on following page.

Table 3A-1 (Continued)

DIFFERENCE BETWEEN PERSONAL VEHICLES AND CAR OWNERSHIP BY STATE, 1976[1]

State	Personal Vehicles	Car	Percent Difference
ME	0.4956	0.4627	7.1305
WVA	0.7966	0.7424	7.2979
NH	0.3792	0.3527	7.4930
UT	0.5675	0.5240	8.3155
NM	0.5371	0.4953	8.4538
AR	1.0823	0.9962	8.6387
WASH	1.8486	1.6995	8.7726
CAL	10.9539	10.0687	8.7922
VT	0.2202	0.2007	9.7573
MON	0.3364	0.3060	9.9268
COL	1.3943	1.2624	10.4480
NEV	0.3561	0.3215	10.7565
ID	0.3646	0.3285	10.9890
ORE	1.2810	1.1539	11.0100
WY	0.1723	0.1543	11.6641

[1]Vehicles measured in millions.

SOURCE: Computer software provided by Wharton Econometric Forecasting Associates.

Table 3A-2

PERSONAL VEHICLES PER LICENSED DRIVER BY STATE, 1976

State	Number of Personal Vehicles Per Licensed Driver
~~WY~~	~~0.574400~~
WVA	0.601654
ID	0.607683
~~MON~~	~~0.628822~~
ARK	0.654345
NH	0.675865
~~MISS~~	~~0.682371~~
FLA	0.690395
MD	0.694129
~~OHIO~~	~~0.695236~~
KAN	0.703463
SD	0.709598
~~MASS~~	~~0.709794~~
NM	0.712401
TEN	0.727216
~~VT~~	~~0.729305~~
IND	0.747129
MINN	0.747496
~~UT~~	~~0.747734~~
MO	0.749753
MICH	0.751248
~~TEX~~	~~0.753409~~
VA	0.757468
RI	0.762517

Table continued on following page.

Table 3A-2 (Continued)

PERSONAL VEHICLES PER LICENSED DRIVER BY STATE, 1976

State	Number of Personal Vehicles Per Licensed Driver
IOWA	0.762746
ME	0.766074
GE	0.771073
PENN	0.773945
NEB	0.775039
NC	0.776089
CAL	0.779806
ND	0.781788
NY	0.784130
COL	0.785986
LA	0.787724
AR	0.788259
NEV	0.791244
WISC	0.795739
ORE	0.800125
WASH	0.807597
DEL	0.815171
KEN	0.823786
ILL	0.846215
CONN	0.855259
SC	0.855931
NJ	0.887097
ALA	0.905130

SOURCE: Computer software provided by Wharton Econometric Forecasting Associates.

Montana. The states with the highest ratio of personal vehicles to drivers are Alabama, New Jersey, South Carolina, and Connecticut.[1]

The following table shows the correlations among variables in the "desired motor vehicle stock" equation:

	Personal Vehicles	Income	Cost	Suburb.	Income Saturation
Personal Vehicles	1.00				
Income	.60	1.00			
Cost	-.08	.01	1.00		
Suburbanization	.45	.42	-.25	1.00	
Income Saturation	.24	.58	-.42	.64	1.00

We see that the variable for personal vehicles per licensed driver is highly correlated with income and suburbanization and has a small negative correlation with cost.

Tests of Parameter Stability

As in the evaluation of the "desired automobile stock" equation the WEFA-TSC predictor of desired motor vehicle holdings is tested for stability by reestimating the model on subsets of the national data set. The subsets of states -- North, South, East, and West -- are defined in the

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[1]An issue which deserves further explanation is the observed negative relationship between personal vehicle stocks per licensed driver and the percentage of trucks as personal vehicles. Perhaps trucks are bought for multi-car purposes as a substitute for multiple cars.

corresponding section of the "desired automobile stock" equation. Below are the regressions on Northern and Southern states, where:

LV272 = Log of permanent disposable income per licensed driver;

LCPM = Log of cost per mile;

SUB = Percentage of households in suburban areas; and

LV232 = Income saturation term.

NORTH

Dependent Variable: LPVLD

R-Square = .627
F-Ratio = 11.34
SSE = .099

Variable	Parameter Estimate	Standard Error	T Ratio
INTERCEPT	-2.937	0.801	-3.665
LV274	0.502	0.109	4.576
LCPM	-0.334	0.221	-1.508
SUB	0.276	0.080	3.432
LV232	-0.313	0.143	-2.177

SOUTH

Dependent Variable: LPVLD

R-Square = .599
F-Ratio = 3.73
SSE = .065

Variable	Parameter Estimate	Standard Error	T Ratio
INTERCEPT	-3.190	2.003	-1.592
LV274	0.849	0.249	3.408
LCPM	-0.581	1.032	0.563
SUB	0.326	0.292	1.116
LV232	-0.504	0.289	-1.738

The results are similar to those of the "automobile stock" equation. Most parameters are relatively stable, but the cost per mile coefficient is of the wrong sign (+.58) in the Southern regression. Thus, the cost-elasticity estimate is not stable across these two divisions of the country.

Results are more encouraging when an East-West partition of the country is used. The East and West regression results appear below. Although there are noticeable differences in the intercepts, suburbanization, and income saturation coefficients, all coefficients are of the expected signs and at least reasonable in magnitude.

EAST

Dependent Variable: LPVLD

R-Square = .528
F-Ratio = 5.88
SSE = .106

Variable	Parameter Estimate	Standard Error	T Ratio
INTERCEPT	-3.499	0.878	-3.983
LV274	0.595	0.135	4.383
LCPM	-0.427	0.340	-1.256
SUB	0.151	0.130	1.160
LV232	-0.353	0.163	-2.154

WEST

Dependent Variable: LPVLD

R-Square = .663
F-Ratio = 7.86
SSE = .063

Variable	Parameter Estimate	Standard Error	T Ratio
INTERCEPT	-4.613	1.223	-3.770
LV274	0.609	0.174	3.481
LCPM	-0.566	1.359	-1.575
SUB	0.293	0.094	3.095
LV232	-0.146	0.134	-1.088

Adding an Employment Term

Tests of parameter stability using geographic subsets of the data base, identical to those performed on the regression without the employment variable, were performed using an equation with the employment term added. The coefficients are given in the table below and, while they are not statistical confidence intervals, they should give the reader a good feel for the range of coefficient estimates. The coefficients of the employment, income, cost, and income saturation terms can be regarded as demand elasticities.

COEFFICIENT ESTIMATES FROM THE PARTITIONED DATA SET

	North	South	East	West
Employment	.39	.08	.32	.62
Income	.31	.74	.33	.30
Cost	-.06	.61	-.12	-.57
Suburbanization	.30	.33	.18	.26
Income Saturation	-.31	-.47	-.26	-.10

Again, we note that the outlier region is the South. The estimated cost elasticity in the South is positive and the estimated employment elasticity in the South is extremely small.

Geographic Variables

Another test of parameter stability was performed by slightly changing the model specification. The table below compares results of the WEFA equation with alternative specifications in which the suburban measure is replaced by a rural and then an urban measure. The income and cost-elasticity estimates are little changed, and we learn that rural population has a negative effect on personal vehicle ownership while city population has a positive effect. In alternative specifications in which the suburban variable is retained, the results of a negative rural influence and a positive urban influence are confirmed.

	WEFA		Alternative 1		Alternative 2	
	Coef.	T-Stat.	Coef.	T-Stat.	Coef.	T-Stat
Income	.57	5.4	.55	5.2	.57	5.1
Cost	-.42	-1.9	-.45	-2.1	-.47	-2.0
Suburbanization	.22	3.1				
Income Saturation	-.31	-3.3	-.30	-3.4	-.21	-2.3
Rural			-.16	-3.3		
City					.19	1.9

Inclusion of an Employment Term

In this section we test the widely held belief that employment is a significant determinant of the personal vehicle stock, independent of income and other variables included in the WEFA desired stock equation. The results are similar to those reported in the discussion of the "desired automobile stock" equation. We find that employment does have a significant influence on motor vehicle holdings and that its inclusion in the equation reduces the income and cost coefficients. The following table gives the simple correlation for states in 1976 among employment per licensed driver and other variables of the equation.

CORRELATIONS

	Personal Vehicles per Licensed Driver	Income	Cost	Suburb- anization	Income Saturation
Employment per Licensed Driver	.62	.67	-.17	.20	.28

Employment per licensed driver is highly correlated with personal vehicles per licensed driver and with income per licensed driver.

The following table compares results of the regression with an employment term with the original WEFA-TSC "desired motor vehicle stock" equation.

	WEFA-TSC		With Log Emp.	
	Coef.	T-Stat.	Coef.	T-Stat.
Log Employment			.36	2.40
Log Income	.57	5.41	.31	2.15
Log Cost	-.42	-1.89	-.18	-.76
Suburbanization	.22	3.14	.23	3.44
Log Income Saturation	-.31	-3.30	-.23	-2.43

In this model specification, the cost-elasticity estimate falls to -.18, and it is not statistically significantly different from zero.

Desired Stock per Family Unit

As in the evaluation of the "desired auto stock" equation, the motor vehicle equation is reestimated on a per-family-unit basis. Theoretical reasons for preferring the per-family-unit specification were contained in the auto stock discussion. On practical grounds, there is reason to believe that the alternative specification might make a major difference in the coefficient specification. The vehicle stock per family unit has a correlation of only .48 with the vehicle stock per licensed driver. The vehicle stock per family unit series appears in Table 3A-3. We see, for instance, that South Dakota, which has the highest personal vehicle stock per family unit, has only the twelfth highest personal vehicle stock per licensed driver. New York, which has the lowest ratio of personal vehicles to family units, is well above average, ranking thirty-third in vehicles per licensed driver.

The correlations of personal vehicles per family unit and employment per family unit with other relevant variables appear below.

CORRELATION MATRIX

	Personal Vehicle	Employment	Income	Cost	Suburb-anization	Income Saturation
Per Personal Vehicle	1.00	.50	.47	.12	.18	.18
Employment	.50	1.00	.54	.04	-.13	.21

Personal vehicles per family unit are highly correlated with employment per family unit, and both are highly correlated with income per family unit.

Table 3A-3

PERSONAL VEHICLES PER FAMILY UNIT BY STATE

State	Number of Personal Vehicles Per Family Unit
NY	1.04717
ARK	1.14747
MD	1.20535
WVA	1.20934
TEN	1.23049
MASS	1.23898
MON	1.23912
ID	1.25124
ME	1.26830
WY	1.27080
VT	1.27239
FLA	1.27871
NH	1.28051
AR	1.28308
PENN	1.28346
MO	1.28991
GE	1.29121
CAL	1.29718
VA	1.30989
TEX	1.31044
MISS	1.31919
LA	1.32560
NM	1.34456
WASH	1.35052

Table continued on following page.

Table 3A-3 (Continued)

PERSONAL VEHICLES PER FAMILY UNIT BY STATE

State	Number of Personal Vehicles Per Family Unit
WISC	1.35223
KEN	1.36681
RI	1.37009
MINN	1.37130
IND	1.37404
ORE	1.38651
NEB	1.39263
ND	1.39321
NC	1.39767
ILL	1.39893
COL	1.41457
MICH	1.42179
UT	1.43424
KAN	1.43875
IOWA	1.44509
CONN	1.48584
SC	1.49164
NEV	1.49291
ALA	1.50242
OHIO	1.51566
NJ	1.52063
DEL	1.53070
SD	1.61210

SOURCE: Computer software provided by Wharton Econometric Forecasting Associates.

The table below compares results of the regression including personal vehicles per family unit and employment per family with the original WEFA vehicles per licensed driver equation and with the vehicles per licensed driver/employment per licensed driver equation. The regression on a family unit basis is labeled Alternative 3.

ALTERNATIVE EQUATION SPECIFICATIONS[1]

	Alternative 1		Alternative 2		Alternative 3	
	Coef.	T-Stat.	Coef.	T-Stat.	Coef.	T-Stat.
Income	.57	5.41	.31	2.15	.28	1.60
Cost	-.42	-1.89	-.18	-.76	-.03	-.11
Suburbanization	.22	3.14	.23	3.44	.17	2.16
Income Saturation	-.31	-3.30	-.23	-2.43	-.18	-1.42
Employment			.36	2.40	.42	2.58
	$R^2 = .54$		$R^2 = .59$		$R^2 = .37$	

Estimation on a per-family-unit basis reduces the R^2 by about one-third and also reduces the estimated cost elasticity of demand from -.18 to -.03. Of the three plausible alternative model specifications, WEFA adopts the one with the most strongly negative cost elasticity of demand. For variables other than the cost elasticity, estimation on a per-family-unit basis makes little difference.

---

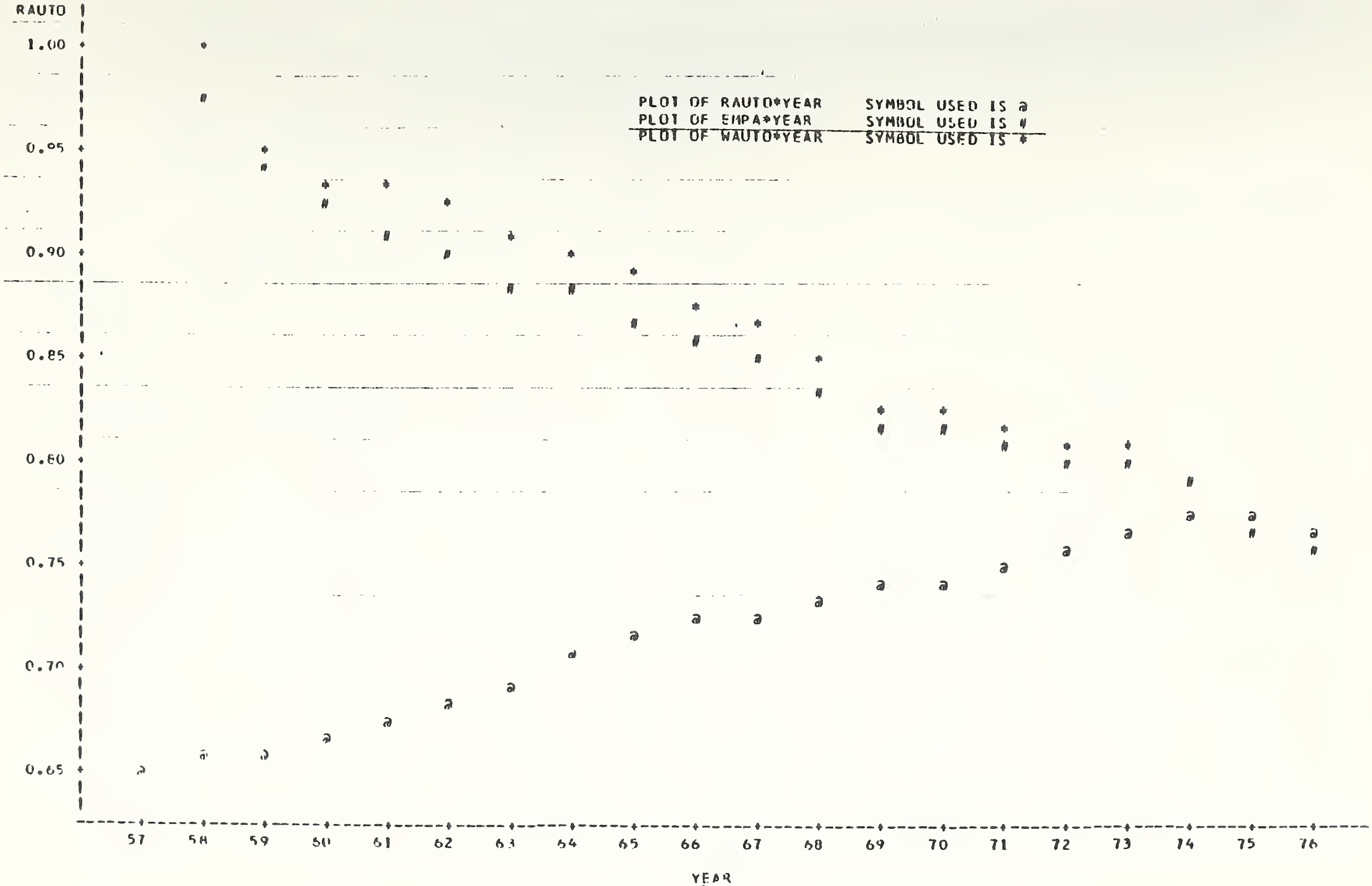
[1]Alternative 1 is the WEFA Mark II (per licenced driver) equation. Alternative 2 is WEFA with an employment per licensed driver term. Alternative 3 is specified on a per family unit basis and includes employment per family unit.

Specifications of Alternative 3, the per family unit equation, which substituted city or rural household percentage geographic variables for the suburban variable, were tested. Results were not much different. The city variable proved positive (.02) but insignificant, and the rural variable proved negative (-.10) but statistically insignificant.

Backcasting Personal Motor Vehicles

A backcasting exercise identical to that performed on the "desired auto stock" equation is also performed on the WEFA Mark II "desired personal vehicle stock" equation, and with the same results. Figure 3A-1 plots actual U.S. personal vehicle stock per capita against the stock estimated with the WEFA Mark II equation (normalized to equal actual in 1976) and with the WEFA equation with the employment variable added. Table 3A-4 presents the data from which the plots are drawn.

Figure 3A-1 shows that there is a wide divergence between the actual stock per licensed driver and predicted stock in the late 1950s; the two series move in opposite directions to converge in 1976. The WEFA Mark II equation obviously cannot be accurately translated to the time domain. As in the case of the desired auto stock equation, one reason for the poor backcasting record is that the net estimated income elasticity, taking into account both income and income saturation terms, is negative. This result is described more thoroughly in Chapter 5. Given the poor backcasting record and the negative income elasticity of this basic equation, this forecasting model should be treated with extreme caution. As in the case of the desired automobile equation, backcasts can be "adjusted" to fit actual data better. This is no evidence of the quality of the model.



NOTE: 2 OBS HAD MISSING VALUES 3 OBS HIDDEN

FIGURE 3A-1. PERSONAL VEHICLE PLOTS OF DESIGNED STOCKS FOR LICENSED DRIVERS

Table 3A-4

REAL VERSUS ESTIMATED PERSONAL VEHICLE STOCK PER LICENSED DRIVER
(1956 - 1975)

RAUTO	WAUTO	EMPA	WER	EMPR	PWER	PEMP
0.652419	.	.	.	.	.	.
0.657702	0.995837	0.974003	-0.33814	-0.31630	-51.412	-48.092
0.660809	0.951281	0.940371	-0.29047	-0.27956	-43.957	-42.306
0.663992	0.934633	0.921405	-0.27064	-0.25741	-40.760	-38.767
0.675021	0.930851	0.909894	-0.25583	-0.23487	-37.899	-34.795
0.685431	0.922135	0.899913	-0.23670	-0.21448	-34.534	-31.292
0.691670	0.908531	0.886063	-0.21686	-0.19439	-31.353	-28.105
0.707996	0.903735	0.880165	-0.19574	-0.17217	-27.647	-24.318
0.714780	0.892431	0.870227	-0.17765	-0.15545	-24.854	-21.747
0.721837	0.872704	0.854747	-0.15087	-0.13291	-20.900	-18.413
0.727368	0.865887	0.849505	-0.13852	-0.12214	-19.044	-16.792
0.736213	0.846920	0.835745	-0.11071	-0.09953	-15.037	-13.519
0.742564	0.823341	0.819975	-0.08078	-0.07741	-10.878	-10.425
0.744556	0.824559	0.815832	-0.08000	-0.07128	-10.745	-9.573
0.751514	0.818006	0.808361	-0.06649	-0.05685	-8.848	-7.564
0.756152	0.808342	0.799048	-0.05219	-0.04290	-6.902	-5.673
0.767118	0.808463	0.799279	-0.04135	-0.03216	-5.390	-4.192
0.771931	0.789852	0.788680	-0.01792	-0.01675	-2.322	-2.170
0.771373	0.769974	0.767777	0.00140	0.00360	0.181	0.466
0.770823	0.755708	0.757263	0.01511	0.01356	1.961	1.759

where:

RPV = Actual personal vehicles per licensed driver;
WPV = Personal vehicles per licensed driver predicted by WEFA Mark II;
EMPPV = Personal vehicles per licensed driver predicted by WEFA Mark II with an employment per licensed driver term added;
WER = RPV minus WPV (absolute error);
EMPER = RPV minus EMPPV (absolute error);
PWER = WER divided by RPV (percentage error); and
PEMPER = EMPPV divided by RPV (percentage error).

SOURCE: Data for RPV and WPV columns: Computer software provided by Wharton Econometric Forecasting Associates.

Data for EMPPV, WER, EMPER, PWER, and PEMPER columns: Calculated by Charles River Associates Incorporated, 1980.

Appendix 3B
AUTOMOBILE INSURANCE COSTS

Although it is widely recognized that auto insurance costs are a major component of automobile ownership costs, this component is omitted from existing cross-section auto demand data bases. This omission occurs because of the lack of reliable cross-section data measuring insurance costs. As part of this report a source of 1978 data on average insurance costs per car on a statewide basis was found.[1] This data series is calculated as 1978 state auto insurance premiums divided by the number of cars registered in the state. There is no attempt to adjust for state differences in vehicle population composition, driving population composition, or insurance coverage so the series is not a price index. Nonetheless, initial regression runs proved quite interesting. To report the results of one regression run, the WEFA "desired automobile stock equation" was reestimated with 1978 insurance costs per car as a variable:

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[1]National Association of Insurance Commissioners, *NAIC Report on Profitability by Line and by State For the Year 1978*.

Dependent Variable: LVAR94

F Ratio = 23.34
R Square = .74
SSE = .136

Variable	Coefficient Estimate	T-Ratio
INTERCEPT	.53	.53
LINSURCAR	-.39	-5.21
LVAR274	.61	6.88
LCPM	-.47	-2.56
SUB	.27	4.46
LVAR232	-.20	-2.30

where:

LVAR94 = Log of automobiles per licensed driver;
LINSURCAR = Log of insurance costs per car;
LVAR274 = Log of permanent disposable income per licensed driver;
LCPM = Log of capitalized cost per mile;
SUB = Percentage of families living in suburbs; and
LVAR232 = Percentage of families with incomes of more than $15,000.

Although the regression results should not be taken literally, because 1978 insurance costs are mixed with 1976 levels of other variables, because the estimated elasticity of the equilibrium auto stock with respect to insurance costs seem unreasonably high, and because the insurance cost series is not a price index, we do find that insurance costs are a highly significant determinant of the automobile stock. Furthermore, the other explanatory variables also remain significant. A similar specification with an employment level variable added gave similar results. Encouraged by these results, the size class equations were also run with the insurance cost variables included. It was hypothesized that higher insurance costs might move the market toward smaller, less expensive cars. Unfortunately, insurance costs did not prove statistically significant in most size class equations. It is unclear whether this is because the level of causality is actually small, or because the 1978 insurance cost data are incompatible with the 1972 size class shares data. State insurance cost data for 1972 or 1978 state size class sales share data were not available. Table 3B-1 below lists the reported 1978 insurance costs per car by state in order of increasing costs.

Table 3B-1

INSURANCE COSTS PER CAR BY STATE, 1978[1]

Rank	State	Insurance Cost (dollars)
1	ALA	262
2	NC	273
3	ME	275
4	RI	282
5	KEN	291
6	OHIO	293
7	NEB	295
8	DEL	296
9	SD	300
10	ARK	302
11	VT	303
12	CONN	303
13	IOWA	304
14	KAN	305
15	ND	305
16	WISC	307
17	MISS	308
18	MASS	310
19	IND	314
20	SC	314
21	TEN	317
22	COL	324
23	WVA	325
24	MD	328
25	ILL	328
26	WASH	333
27	UT	333
28	VA	340
29	MINN	344
30	NJ	348
31	TEX	349
32	PENN	352
33	NM	353
34	MICH	358
35	NH	364
36	GE	367
37	AR	371
38	NY	371
39	ORE	374
40	MON	381

Table continued on following page.

Table 3B-1 (Continued)

INSURANCE COSTS PER CAR BY STATE, 1978[1]

Rank	State	Insurance Cost (dollars)
41	FLA	385
42	MD	386
43	CAL	391
44	NEV	403
45	ID	418
46	LA	427
47	WY	501

[1]Only states in WEFA data base included.

SOURCE: National Association of Insurance Commissioners, NAK Report on Profitability by Line and by State for the Year 1978, unpublished.

Chapter 4
EVALUATION OF THE WEFA-TSC MODEL OF SIZE CLASS SHARES

The WEFA motor vehicle demand model, unlike simpler market demand models, decomposes total automobile sales into sales shares by automobile size class. This chapter brings available evidence to bear on the likely accuracy of forecasts of sales shares by size class made with the WEFA model. Three types of model evaluation procedures are employed. First, the fit of the model to the 1971-1972 cross-section data base is examined in several ways. Then backcasting exercises are performed to see whether the historic relationship of WEFA-estimated desired class shares to the actual sales and stock by size class make sense. Finally, the sensitivity of forecasted sales shares to rising gasoline prices is compared with recent experience.

The Wharton demand model employs a two-step stock adjustment process in forecasting sales shares by size class. The model initially determines the desired total stock and size class shares, based on the capitalized cost per mile of each size class and on other variables, and then translates the desired stock into sales by size class based partly on the gap between the estimated desired and actual stock in each size class. Figure 4-1 outlines in more detail the steps taken by the model in simulating the decision process which determines the size class sales shares. Because the "desired size class share" equations determine the long-run forecasting properties of the model, this chapter focuses on those equations. This evaluation decision is like that made in Chapter 3 in which attention was given to the total desired vehicle stock equations.

The Size Class Share Equations

In the Mark II model, WEFA estimates shares of desired stock for each of eight size classes, five domestic and three imported car size classes. These equations were estimated in the "odds form" in which the dependent variable is the log of the size class share divided by one minus its share:

$$\ln \left(\frac{SHR^{*}_{sc}}{1-SHR^{*}_{sc}} \right)$$

where:

SHR^{*}_{sc} = the desired share of size class in the total stock.

To estimate these equations, the share of new car sales by class in each state over the period 1971-1972 was used as a proxy for the 1972 desired shares in each state.[1] Table 4-1

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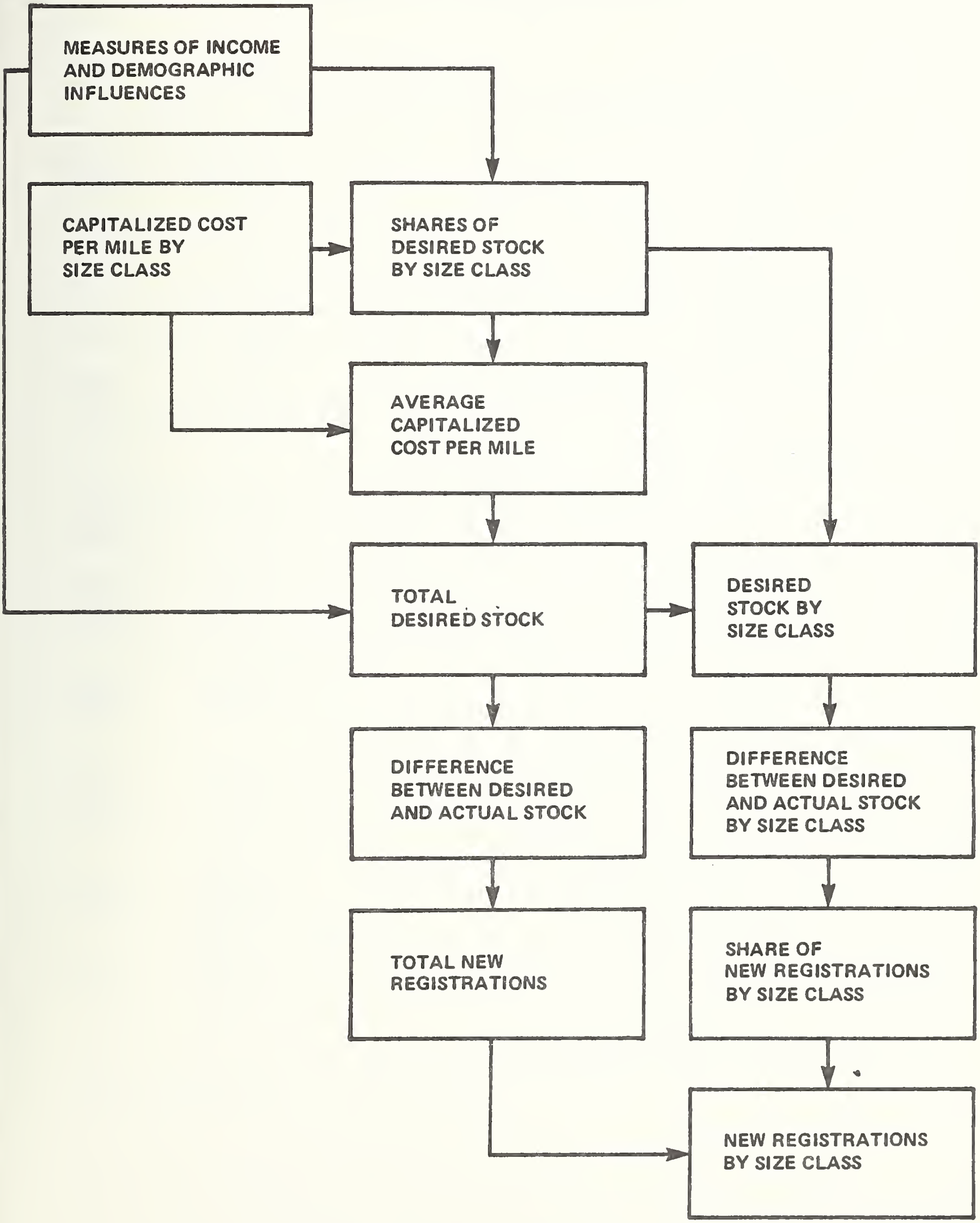
[1]For a fuller explanation of this process see Wharton EFA, An Analysis of the Automobile Market: Modeling the Long-Run Determinants of the Demand for Automobiles, Volume I, Section 3.2.4, February 1977. Note that the share equations have been revised since the publication of this document.

Figure 4—1

DESCRIPTION OF TWO-STAGE DECISION PROCESS AND STOCK-ADJUSTMENT APPROACH TO SIZE-CLASS SHARES IN THE WEFA AUTOMOBILE DEMAND MODEL



SOURCE: Charles River Associates, Incorporated, March 1980

Table 4-1

REPLICATION OF EQUATION COEFFICIENTS
SIZE CLASS SHARES OF DESIRED STOCK

	WEFA	CRA
Subcompact Foreign Equation		
Intercept	-3.389 (7.29)	-3.411 (7.08)
Relative cost per mile	-4.874 (1.66)	-4.769 (1.59)
Fraction of families with five or more members	-0.386 (2.06)	-0.386 (2.05)
Licensed drivers per family unit	+0.658 (2.37)	+0.654 (2.34)
Regional Dummies:[1]		
New England	+0.332 (3.80)	+0.338 (3.90)
Mountain	+0.480 (7.69)	+0.481 (7.65)
Pacific	+0.867 (9.82)	+0.876 (9.80)
East North Central	-0.491 (6.52)	-0.493 (6.54)
West North Central	-0.469 (7.47)	-0.470 (7.45)
$\bar{R}^2$	0.916	0.915

Table continued on following page.

Table 4-1 (Continued)

REPLICATION OF EQUATION COEFFICIENTS
SIZE CLASS SHARES OF DESIRED STOCK

	WEFA	CRA
Subcompact Domestic Equation		
Intercept	+2.741 (2.20)	-2.780 (2.23)
Relative cost per mile	-4.706 (1.42)	-4.482 (1.40)
Disposable income over number of family units over fixed weight cost per mile	-0.294 (0.92)	-0.283 (0.89)
Fraction of families with five or more members	-0.311 (1.39)	-0.317 (1.42)
Number of persons in resident population between 20 and 29 years old over number of family units	+0.712 (2.25)	+0.711 (2.24)
Percentage of families earning $15,000 or more in 1970 dollars	0.275 (2.64)	0.278 (2.68)
Regional Dummies:[1]		
New England	+0.115 (1.66)	0.117 (1.67)
Mountain	+0.340 (4.96)	0.341 (4.89)
Pacific	0.576 (4.64)	0.576 (4.61)
South Atlantic	0.204 (3.43)	0.203 (3.42)
$\overline{R}^2$	0.686	0.685

Table continued on following page.

Table 4-1 (Continued)

REPLICATION OF EQUATION COEFFICIENTS
SIZE CLASS SHARES OF DESIRED STOCK

	WEFA	CRA
Compact Foreign Equation		
Intercept	-10.622 (6.21)	-10.653 (6.12)
Relative cost per mile	-5.787 (1.02)	-5.085 (0.92)
Fraction of families with three or four members	-4.677 (2.68)	-4.581 (2.60)
Fraction of families with five or more members	-1.762 (2.19)	-1.746 (2.17)
Number of persons in resident population between 20 and 29 years old over number of family units	+2.227 (1.52)	2.174 (1.48)
Regional Dummies:[1]		
New England	+0.971 (3.52)	0.990 (3.60)
West South Central	-1.059 (3.51)	-1.050 (3.48)
East North Central	-1.123 (3.77)	-1.102 (3.70)
West North Central	-1.060 (3.43)	-1.037 (3.35)
East South Central	-0.922 (3.39)	-0.920 (3.38)
$\bar{R}^2$	0.696	0.694

Table continued on following page.

Table 4-1 (Continued)

REPLICATION OF EQUATION COEFFICIENTS
SIZE CLASS SHARES OF DESIRED STOCK

	WEFA	CRA
Compact Domestic Equation		
Intercept	+3.541 (3.57)	+3.528 (3.55)
Relative cost per mile	-2.375 (3.08)	-2.279 (3.03)
Disposable income over number of family units over fixed weight cost per mile	-1.041 (3.76)	-1.033 (3.74)
Percentage of families earning $15,000 or more in 1970 dollars	+0.227 (2.40)	+0.227 (2.39)
Fraction of families with three or four members	+1.130 (5.41)	1.127 (5.38)
Licensed drivers per family unit	-0.433 (2.00)	-0.448 (2.08)
Regional Dummies:[1]		
New England	+0.120 (2.88)	0.121 (2.88)
West and South Central	-0.351 (5.69)	-0.350 (5.66)
East South Central	-0.227 (4.49)	-0.274 (4.44)
Mountain	+0.122 (2.63)	+0.121 (2.59)
$\bar{R}^2$	0.662	0.659

Table continued on following page.

Table 4-1 (Continued)

REPLICATION OF EQUATION COEFFICIENTS
SIZE CLASS SHARES OF DESIRED STOCK

	WEFA	CRA
Mid-Size Domestic Equation		
Intercept	+0.170 (0.32)	+0.154 (0.28)
Relative cost per mile	-1.966 (4.54)	-1.968 (4.40)
Disposable income over number of family units over fixed weight cost per mile	-0.151 (1.23)	-0.149 (1.20)
Fraction of families with three or four members	+0.789 (4.74)	+0.781 (4.64)
Regional Dummies:[1]		
New England	+0.163 (3.99)	+0.165 (3.95)
Mountain	-0.126 (3.64)	-0.128 (3.65)
$\bar{R}^2$	0.681	0.675

Table continued on following page.

Table 4-1 (Continued)

REPLICATION OF EQUATION COEFFICIENTS
SIZE CLASS SHARES OF DESIRED STOCK

	WEFA	CRA
Full-Size Domestic Equation		
Intercept	-4.545 (3.33)	-4.717 (3.37)
Relative cost per mile	-2.677 (1.56)	-1.351 (0.76)
Disposable income over number of family units over fixed weight cost per mile	0.965 (2.73)	0.987 (2.74)
Fraction of families with three or four members	-1.537 (5.02)	-1.564 (4.96)
Fraction of families with five or more members	+0.235 (1.29)	+0.223 (1.19)
Percentage of families earning $15,000 or more in 1970 dollars	-0.462 (3.27)	-0.464 (3.23)
Percentage of people in state who live in metropolitan area	-0.002 (1.26)	-0.001 (1.01)
Regional Dummies:		
New England	-0.381 (5.46)	-0.417 (6.26)
Mountain	-0.439 (6.57)	-0.416 (5.85)
Pacific	-0.613 (6.71)	-0.618 (6.45)
$\bar{R}^2$	0.810	0.801

Table continued on following page.

Table 4-1 (Continued)

REPLICATION OF EQUATION COEFFICIENTS
SIZE CLASS SHARES OF DESIRED STOCK

	WEFA	CRA
Luxury Domestic Equation		
Intercept	-2.297 (3.89)	-2.207 (3.66)
Relative cost per mile	-2.965 (1.27)	-3.369 (1.41)
Percentage of families earning $15,000 or more in 1970 dollars	+0.169 (1.74)	+0.169 (1.74)
Percentage of people in state who live in metropolitan areas[1]	+0.002 (1.95)	+0.002 (1.99)
Regional Dummies:		
New England	-0.374 (5.58)	-0.370 (5.54)
West South Central	+0.197 (2.19)	+0.193 (2.15)
Pacific	-0.251 (3.00)	-0.245 (2.92)
$\bar{R}^2$	0.610	0.614

Table continued on following page.

Table 4-1 (Continued)

REPLICATION OF EQUATION COEFFICIENTS
SIZE CLASS SHARES OF DESIRED STOCK

	WEFA	CRA
Luxury Foreign Equations		
Intercept	-3.855 (3.50)	-3.791 (3.44)
Relative cost per mile	-8.684 (4.22)	-8.792 (4.28)
Percentage of families earning $15,000 or more in 1970 dollars	+0.312 (1.09)	+0.297 (1.04)
Percentage of people in state who live in metropolitan areas[1]	+0.006 (1.98)	0.006 (2.05)
Regional Dummies:		
East North Central	-0.632 (3.81)	-0.625 (3.78)
West South Central	-0.238 (1.04)	-0.249 (1.10)
East South Central	-0.264 (1.32)	-0.275 (1.38)
$\overline{R}^2$	0.632	0.634

NOTE: Numbers in parentheses are t-statistics.

[1]These variables are in linear form. All other variables are in log form.

SOURCE: Data in WEFA Column: The Wharton EFA Motor Vehicle Demand Model (Mark I), Equation Book, July 1978.

Data in CRA Column: Calculated by Charles River Associates Incorporated, 1980.

lists the explanatory variables in each of the eight size class share equations, the coefficients of the variables as estimated by WEFA using 1972 data,[1] and the coefficients in the estimated equation as replicated in the model evaluation process. In most instances the pairs of coefficients are the same to the first or second decimal place.[2] Any discrepancies are probably explained by the fact that the replication exercise did not employ the exact same version of the cross-sectional data base.

Model Specification

Four characteristics of the set of regression results cast doubt on the forecasting accuracy of the equations as estimated either by WEFA or CRA. First, the R-squared statistic is in most instances relatively low.[3] Second, the equations are estimated using ordinary least squares (OLS) techniques as if they were independent. Because the sales shares must sum to 100 percent, the equations are actually interdependent. Third, the t-statistics suggest that the relative cost-per-mile

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[1]In the model, alternative specifications of these equations are provided. The equations described here are the ones used by Wharton in producing their baseline forecasts. Note that in the WEFA specification many independent variables are in the log form.

[2]The most notable exception is the coefficient on the relative cost per mile for full-size domestic automobiles.

[3]The R-squared statistic measures the fraction of the variation in the dependent variable which is explained by the equation. An equation which exactly modeled the dependent variable would have an R-squared of 1.

variable is not significant at the 95 percent level in six out of the eight equations. That is, there is a significant (i.e., greater than 5 percent) probability that within the range of observed vehicle costs the cost-per-mile variable has no influence on the dependent variable. Finally, the frequent occurrence of regional dummies suggests that there are factors that influence size class choice which are not fully explained by the model. Each of these three items is discussed in more detail below.

<u>Explanatory Power</u>

The corrected coefficient of determination (R^2) ranges from a high of 91.6 percent for foreign subcompacts, to a low of 61.0 percent for luxury domestic. Six of the eight equations have an R^2 below .70. The R^2 is not by itself an adequate measure of the quality of an econometrically estimated forecasting equation. However, the relatively low R^2 levels, indicating a relatively large amount of unexplained variation, do suggest that the equations may not be fully specified. One can hypothesize numerous additional variables which might be added to the equations to increase their explanatory power. Insomuch as these currently excluded variables do influence the distribution of auto sales by size class, their omission lowers the forecasting accuracy of the model.

Possible additional explanatory variables include those that would allow a more explicit articulation of the relationship between the household choice of number of vehicles to own and the choice of types of vehicles to own. Another plausible set of explanatory variables might more accurately measure the level of auto congestion in a state; more congested areas in which both driving and parking are more difficult may be associated with a larger share of smaller cars. A third influence on the sales distribution of cars by size class in

1971-1972, the years on which the model is estimated, might be the supply-side availability (or convenient availability) of smaller imported cars. In 1971-1972 the now popular Japanese imports were just establishing their dealer networks in some parts of the country. While the regional dummy variables may explain some of the state-to-state variation in imported car availability, they probably are not a perfect proxy. Finally, one can think of a series of noneconomic sociological-psychological-cultural factors which might influence the consumer choice of vehicle size class, differ across states, and yet fail to be correlated with the "objective" variables included in the WEFA equations. If these attitudes are mutable over time, independent of changes in the included "objective" variables, the WEFA equations may provide inaccurate forecasts. The possibility of model underspecification raises the possibility of two kinds of model failings. As has already been mentioned, model forecasts may be inaccurate. Furthermore, if determining variables excluded from the equations are correlated with any of the included variables, the coefficient estimates of the included variables will be biased. This may lead to misleading sensitivity analyses or policy simulations. Since construction of an alternative model is beyond the scope of this report, the suggested hypotheses of model underspecification were not tested.

Another Model Specification Issue

The WEFA size class shares are estimated with ordinary least squares (OLS) regressions as if they are truly independent relationships. However, the state size class observations are only seemingly unrelated. Actually one should expect interaction among the size class predictors and some nonzero correlation among error terms of the equations because the sum of shares must equal a constant 100 percent. Certainly if the share of one size class was observed to be unexpectedly high in one instance, the share of some other class would be observed to be compensatingly low. To correct for this correlation in the error terms, the share equations were reestimated using a "seemingly unrelated regression" (SUR) technique.[1] Table 4-2 compares the equations estimated by CRA using ordinary least squares regression with those estimated using seemingly unrelated regression. In all cases the seemingly unrelated regression reduces the standard error of the coefficients. This implies that there is a higher probability that the coefficients from the seemingly unrelated regression are more nearly correct than those generated by ordinary least squares procedures. Although not all equations show dramatic changes in all estimated coefficients, the seemingly unrelated regression estimation procedure does lead to quite different estimates of certain key parameters. For example, the relative cost per mile coefficient is changed by more than 20 percent in five of the eight equations. In the full-size domestic car equation this coefficient changes from -1.35 to +0.30, a clearly implausible result from the WEFA specification. However, neither of these relative cost estimates are significantly different from zero.

We have seen that the application of seemingly unrelated regression leads to some substantial changes in the equations,

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[1]Briefly, if the errors of the equations are not correlated, this methodology will yield the same estimates as ordinary least squares. If the errors are correlated, this method will produce estimates with smaller standard errors than ordinary least squares. For a more complete discussion of seemingly unrelated regression, see Jan Kmeta, Elements of Econometrics (New York: MacMillan Publishing Co., Inc., 1971), pp. 517-529.

Table 4-2

COMPARISON OF EQUATIONS ESTIMATED USING ORDINARY LEAST SQUARES (OLS) AND SEEMINGLY UNRELATED REGRESSIONS (SUR)

	OLS	SUR
Subcompact Foreign Equation		
Intercept	-3.411 (7.08)	-3.349 (8.08)
Relative cost per mile	4.769 (1.59)	-4.709 (1.93)
Fraction of families with five or more members	-0.386 (2.05)	-0.356 (2.05)
Licensed drivers per family unit	+0.654 (2.34)	+0.590 (2.50)
Regional Dummies:[1]		
New England	+0.338 (3.90)	+0.362 (4.63)
Mountain	+0.481 (7.65)	+0.505 (8.70)
Pacific	+0.876 (9.80)	0.895 (10.41)
East North Central	-0.493 (6.54)	-0.398 (6.39)
West North Central	-0.470 (7.45)	-0.399 (7.42)

Table continued on following page.

Table 4-2 (Continued)

COMPARISON OF EQUATIONS ESTIMATED USING ORDINARY LEAST SQUARES (OLS) AND SEEMINGLY UNRELATED REGRESSIONS (SUR)

	OLS	SUR
Subcompact Domestic Equation		
Intercept	-2.780 (2.23)	-3.221 (2.82)
Relative cost per mile	-4.482 (1.40)	-4.061 (1.56)
Disposable income over number of family units over fixed weight cost per mile	-0.283 (0.89)	-0.137 (0.46)
Fraction of families with five or more members	-0.317 (1.42)	-0.484 (2.62)
Numbers of persons in resident population between 20 and 29 years old over number of family units	+0.711 (2.24)	0.912 (3.46)
Percentage of families earning $15,000 or more in 1970 dollars	0.278 (2.68)	0.204 (2.16)
Regional Dummies:[1]		
New England	0.117 (1.67)	0.089 (1.36)
Mountain	0.341 (4.89)	0.314 (5.02)
Pacific	0.576 (4.61)	0.516 (4.93)
South Atlantic	0.203 (3.42)	0.125 (2.55)

Table continued on following page.

Table 4-2 (Continued)

COMPARISON OF EQUATIONS ESTIMATED USING ORDINARY LEAST SQUARES (OLS) AND SEEMINGLY UNRELATED REGRESSIONS (SUR)

	OLS	SUR
Compact Domestic Equation		
Intercept	+3.528 (3.55)	3.160 (3.61)
Relative cost per mile	-2.279 (3.03)	-2.484 (3.85)
Disposable income over number of family units over fixed weight cost per mile	-1.033 (3.74)	-0.985 (4.09)
Percentage of families earning $15,000 or more in 1970 dollars	+0.227 (2.39)	+0.214 (2.66)
Fraction of families with three or four members	1.127 (5.38)	+0.982 (5.43)
Licensed drivers per family unit	-0.448 (2.08)	-0.413 (2.58)
Regional Dummies:[1]		
New England	0.121 (2.88)	0.136 (3.30)
West South Central	-0.350 (5.66)	-0.314 (6.54)
East South Central	-0.274 (4.44)	-0.225 (5.05)
Mountain	+0.121 (2.59)	0.132 (3.07)

Table continued on following page.

Table 4-2 (Continued)

COMPARISON OF EQUATIONS ESTIMATED USING ORDINARY LEAST SQUARES (OLS) AND SEEMINGLY UNRELATED REGRESSIONS (SUR)

	OLS	SUR
Compact Foreign Equation		
Intercept	-10.653 (6.12)	-10.905 (6.55)
Relative cost per mile	-5.085 (0.92)	-6.794 (1.31)
Fraction of families with three or four members	-4.581 (2.60)	-4.766 (2.88)
Fraction of families with five or more members	-1.746 (2.17)	-1.623 (2.13)
Number of persons in resident population between 20 and 29 years old over number of family units	+2.174 (1.48)	+1.557 (1.15)
Regional Dummies:[1]		
New England	+0.990 (3.60)	+0.936 (3.50)
West South Central	-1.050 (3.48)	-1.106 (3.78)
East North Central	-1.102 (3.70)	-1.232 (4.43)
West North Central	-1.037 (3.35)	-1.135 (3.89)
East South Central	-0.920 (3.38)	-0.914 (3.53)

Table continued on following page.

Table 4-2 (Continued)

COMPARISON OF EQUATIONS ESTIMATED USING ORDINARY LEAST SQUARES (OLS) AND SEEMINGLY UNRELATED REGRESSIONS (SUR)

	OLS	SUR
Mid-Size Domestic Equation		
Intercept	+0.154 (0.28)	+0.191 (0.38)
Relative cost per mile	-1.968 (4.40)	-2.708 (6.58)
Disposable income over number of family units over fixed weight cost per mile	-0.149 (1.20)	-0.165 (1.42)
Function of families with three or four members	+0.781 (4.64)	+0.761 (5.16)
Regional Dummies:[1]		
New England	+0.165 (3.95)	+0.206 (5.11)
Mountain	-0.128 (3.65)	-0.102 (3.31)

Table continued on following page.

Table 4-2 (Continued)

COMPARISON OF EQUATIONS ESTIMATED USING ORDINARY LEAST SQUARES (OLS) AND SEEMINGLY UNRELATED REGRESSIONS (SUR)

	OLS	SUR
Full-Size Domestic Equation		
Intercept	-4.717 (3.37)	-3.728 (3.46)
Relative cost per mile	-1.351 (0.76)	+0.295 (0.27)
Disposable income over number of family units over fixed weight cost per mile	0.987 (2.74)	0.704 (2.56)
Fraction of families with three or four members	-1.564 (4.96)	-1.431 (5.91)
Fraction of families with five or more members	+0.223 (1.19)	+0.169 (1.26)
Percentage of families earning $15,000 or more in 1970 dollars	-0.464 (3.23)	-0.398 (3.88)
Percentage of people in state who live in metropolitan area[1]	-0.001 (1.01)	-0.002 (0.27)
Regional Dummies:[1]		
New England	-0.417 (6.26)	-0.418 (7.07)
Mountain	-0.416 (5.86)	-0.331 (5.83)
Pacific	-0.618 (6.45)	-0.600 (7.96)

Table continued on following page.

Table 4-2 (Continued)

COMPARISON OF EQUATIONS ESTIMATED USING ORDINARY LEAST SQUARES (OLS) AND SEEMINGLY UNRELATED REGRESSIONS (SUR)

	OLS	SUR
Luxury Domestic Equations		
Intercept	-2.207 (3.66)	-2.760 (5.66)
Relative cost per mile	-3.369 (1.41)	-1.597 (0.82)
Percentage of families earning $15,000 or more in 1970 dollars	+0.169 (1.74)	+0.210 (2.49)
Percentage of people in state who live in metropolitan area[1]	+0.002 (1.99)	+0.003 (2.67)
Regional Dummies:[1]		
New England	-0.370 (5.54)	-0.417 (6.81)
West South Central	+0.193 (2.15)	+0.147 (1.96)
Pacific	-0.245 (2.92)	-0.331 (4.59)

Table continued on following page.

Table 4-2 (Continued)

COMPARISON OF EQUATIONS ESTIMATED USING ORDINARY LEAST SQUARES (OLS) AND SEEMINGLY UNRELATED REGRESSIONS (SUR)

	OLS	SUR
Luxury Foreign Equations		
Intercept	-3.791 (3.44)	-4.524 (4.56)
Relative cost per mile	-8.792 (4.28)	-7.650 (4.28)
Percentage of families earning $15,000 or more in 1970 dollars	+0.297 (1.04)	+0.457 (1.72)
Percentage of people in state who live in metropolitan area[2]	0.006 (2.05)	0.005 (1.73)
Regional Dummies:[1]		
East North Central	-0.625 (3.78)	-0.574 (4.22)
West South Central	-0.249 (1.10)	-0.187 (0.918)
East South Central	-0.275 (1.38)	-0.205 (1.20)

NOTE: Numbers in parentheses represent t-statistics.

[1]These variables in linear form. All other variables in log form.

SOURCE: Calculated by Charles River Associates Incorporated, 1980.

but how do these changes feed through to forecasts? Table 4-3 shows total new registrations and shares by size class using both the OLS and SUR equations and WEFA baseline exogenous variables. The change in the size class shares from the SUR specification is relatively small in absolute terms. Each class share of total new registrations changes by less than 1 percentage point. A difference of 1 percentage point in the share, however, means a difference of approximately 100,000 cars in sales of that size class.

Cost-per-Mile

The desired share equations were estimated using cross-sectional data for a single year. A relevant question is whether these cross-sectional data have sufficient variation for statistical analysis to capture the impact of changes in this variable. Although relative costs undoubtedly have some effect on the relative sales shares of the different size classes, the estimated coefficients in five of the eight size class equations are not statistically significantly different from zero. Table 4-4 gives the mean and standard deviation of the cost variables. We see that there is very little variation in the cross-sectional cost measure, and that many interesting policy simulation exercises will assume costs that are well outside the range of experience of 1972 state average costs. For most size classes the standard deviation of the cost measure is less than 3 percent of the state average cost.

To provide another test of the reliability of the cost per mile parameter estimates, the desired size class equations were reestimated on partitions of the total U.S. cross-section data set. As in the last chapter, the United States was divided into North and South and then East and West regions.[1] Below we

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[1]Definitions of the regions are provided in the previous chapter. They follow the Census definition of regions.

Table 4-3

NEW REGISTRATIONS BY SIZE CLASS RESULTING FROM ORDINARY LEAST SQUARES (OLS)
AND SEEMINGLY UNRELATED REGRESSION (SUR) ESTIMATES
OF DESIRED SHARE EQUATIONS
(Million Vehicles)

	OLS	SUR	Percent Difference
Subcompact Domestic			
1980	0.560	0.650	15.58
1985	0.620	0.710	14.91
1990	0.600	0.670	11.60
Subcompact Foreign			
1980	0.161	0.153	-4.76
1985	0.178	0.168	-5.48
1990	0.201	0.190	-5.56
Total Subcompact			
1980	0.217	0.218	0.52
1985	0.240	0.239	-0.23
1990	0.261	0.257	-1.63

Table continued on following page.

Table 4-3 (Continued)

NEW REGISTRATIONS BY SIZE CLASS RESULTING FROM ORDINARY LEAST SQUARES (OLS) AND SEEMINGLY UNRELATED REGRESSION (SUR) ESTIMATES OF DESIRED SHARE EQUATIONS (Million Vehicles)

	OLS	SUR	Percent Difference
Compact Domestic			
1980	0.168	0.170	1.4
1985	0.177	0.178	0.2
1990	0.187	0.186	-0.3
Compact Foreign			
1980	0.080	0.080	*
1985	0.060	0.060	*
1990	0.040	0.040	*
Total Compact			
1980	0.176	0.178	1.3
1985	0.183	0.183	0.2
1990	0.191	0.190	-0.3

*Difference less than 0.1 percent.

Table continued on following page.

Table 4-3 (Continued)

NEW REGISTRATIONS BY SIZE CLASS RESULTING FROM ORDINARY LEAST SQUARES (OLS) AND SEEMINGLY UNRELATED REGRESSION (SUR) ESTIMATES OF DESIRED SHARE EQUATIONS
(Million Vehicles)

	OLS	SUR	Percent Difference
Mid-Size Domestic			
1980	0.196	0.198	1.0
1985	0.212	0.212	0.3
1990	0.210	0.210	-0.2
Full-Size Domestic			
1980	0.309	0.304	-1.5
1985	0.265	0.264	-0.4
1990	0.233	0.236	1.2
Luxury Domestic			
1980	0.890	0.910	1.5
1985	0.880	0.900	2.0
1990	0.920	0.940	2.9
Luxury Foreign			
1980	0.130	0.110	-17.65
1985	0.130	0.120	-13.5
1990	0.130	0.130	*
Total Luxury			
1980	0.102	0.101	-0.9
1985	0.101	0.102	0.7
1990	0.105	0.107	2.3

*Difference less than 0.1 percent.

Table 4-4

COST PER MILE AND RELATIVE COST PER MILE
BY SIZE CLASS CROSS-SECTIONAL DATA

	Cost Per Mile		
	Mean	Standard Deviation	Coefficient of Variation[1]
Subcompact Foreign	0.111	0.0029	2.612
Subcompact Domestic	0.108	0.0031	2.848
Compact Foreign	0.143	0.0037	2.603
Compact Domestic	0.128	0.0044	3.474
Mid-size Domestic	0.147	0.0052	3.511
Full-size Domestic	0.164	0.0059	3.617
Luxury Foreign	0.216	0.0080	3.700
Luxury Domestic	0.202	0.0085	4.210

	Relative Cost Per Mile		
	Mean	Standard Deviation	Coefficient of Variation[1]
Subcompact Foreign	0.912	0.0011	1.154
Subcompact Domestic	0.891	0.009	1.005
Compact Foreign	1.117	0.024	2.189
Compact Domestic	0.995	0.027	2.706
Mid-size Domestic	1.005	0.032	3.215
Full-size Domestic	0.997	0.018	1.777
Luxury Foreign	1.324	0.036	2.725
Luxury Domestic	1.277	0.013	1.054

[1] 100 x standard deviation/mean

report the coefficients and t-statistics of the estimated cost per mile from the different regional regressions:

COST COEFFICIENT ESTIMATES OF SIZE CLASS EQUATIONS

	U.S.	North	South	East	West
Subcompact Foreign	-4.87	-3.74	-3.78	-0.44	-8.06
	(1.66)	(0.85)	(0.48)	(0.01)	(2.94)
Subcompact Domestic	-4.71	-2.43	-18.64	-3.01	-6.52
	(1.42)	(0.50)	(4.72)	(0.55)	(1.21)
Compact Foreign	-5.79	-8.76	-35.80	3.73	-19.18
	(1.02)	(1.96)	(1.52)	(0.40)	(2.27)
Compact Domestic	-2.38	-2.37	-13.29	-3.21	-6.11
	(3.08)	(5.27)	(2.16)	(2.09)	(2.10)
Mid-size	-1.97	-3.28	1.02	-2.07	3.27
	(4.54)	(6.65)	(1.39)	(2.95)	(4.05)
Full-size	-2.70	1.44	-11.16	-2.88	-2.52
	(1.56)	(0.71)	(2.15)	(1.18)	(0.73)
Luxury Foreign	-2.96	-11.08	0.50	-4.91	-14.40
	(1.27)	(4.10)	(0.15)	(1.94)	(5.83)
Luxury Domestic	-8.68	-1.33	-9.08	2.29	-4.85
	(4.22)	(0.51)	(2.12)	(0.47)	(1.65)

We see that the cost coefficients are quite sensitive to the estimation data set and do vary across regions. Although this result is not unexpected, given the small degree of variation in costs across states, it does warn the model user that size class cost coefficients in the WEFA model are estimated quite imprecisely.

Regional Dummy Variables

A final cause for possible concern about the forecasting accuracy of the estimated size class share equations comes from evaluating the strong influence of the regional dummy variables in these size class equations. A preliminary approach to measuring the influence of the dummy variables is to reestimate the equations in two alternative specifications: first omitting the regional dummies and then omitting all variables except the regional dummies. Table 4-5 reports the results of these exercises. In seven of the eight equations the dummy variables have more explanatory power (as measured by R^2) than the combined economic/demographic variables.

The fact that regional dummy variables are important to the desired size class share predictors is not by itself an argument that model forecasts will be inaccurate. The forecasting problem arises because there is no evidence presented as to what the regional dummy variables mean and whether their coefficients might be expected to change over the forecast period. If evidence were presented that the dummies actively do represent persistent, long-standing, and stable regional differences in geography, highway infrastructure, or lifestyle, the model user might feel confident in using the dummy variables in a forecasting model. However, because the regional differences are only estimated at one point in time, 1972, there is no evidence that the regional differences are stable over time. If 1971-1972 regional differences in sales shares were partly due to regional differences in foreign car

Table 4-5

IMPACT OF REGIONAL DUMMIES
ON DESIRED SIZE CLASS SHARE EQUATIONS

	CRA	No Regional Dummies	Only Regional Dummies
Subcompact Foreign Equation			
Intercept	-3.411 (7.08)	-6.015 (4.87)	-1.985 (60.11)
Relative cost per mile	-4.769 (1.59)	-15.545 (2.83)	
Fraction of families with five or more members	-0.386 (2.05)	-0.964 (1.82)	
Licensed drivers per family unit	+10.654 (2.34)	+1.947 (2.546)	
Regional Dummies:			
New England	+0.338 (3.90)		+0.432 (6.54)
Mountain	+0.481 (7.65)		+0.483 (8.12)
Pacific	+0.876 (9.80)		+0.927 (10.60)
East North Central	-0.493 (6.54)		-0.571 (8.07)
West North Central	-0.470 (7.45)		-0.462 (7.40)
$\bar{R}^2$	0.915	0.178	0.902

Table continued on following page.

Table 4-5 (Continued)

IMPACT OF REGIONAL DUMMIES
ON DESIRED SIZE CLASS SHARE EQUATIONS

Subcompact Domestic Equation	CRA	No Regional Dummies	Only Regional Dummies
Intercept	-2.780 (2.23)	-0.939 (0.60)	-2.655 (80.20)
Relative cost per mile	-4.482 (1.40)	8.019 (3.06)	
Disposable income over number of family units over fixed weight cost per mile	-0.283 (0.89)	-0.498 (1.20)	
Fraction of families with five or more members	-0.317 (1.42)	-0.496 (1.84)	
Number of persons in resident population between 20 and 29 years old over number of family units	+0.711 (2.24)	+1.067 (2.78)	
Percentage of families earning $15,000 or more in 1970 dollars	0.278 (2.68)	0.494 (4.08)	
Regional Dummies:			
New England	115 (1.67)	0.117	+0.113 (1.58)
Mountain	0.341 (4.89)		+0.292 (4.55)
Pacific	0.576 (4.61)		+0.584 (6.11)
South Atlantic	0.203 (3.42)		+0.228 (3.56)
$\overline{R}^2$	0.685	0.447	0.515

Table continued on following page.

Table 4-5 (Continued)

IMPACT OF REGIONAL DUMMIES
ON DESIRED SIZE CLASS SHARE EQUATIONS

	CRA	No Regional Dummies	Only Regional Dummies
Compact Foreign Equation			
Intercept	-10.653 (6.12)	-10.945 (4.08)	-4.695 (43.09)
Relative cost per mile	-5.085 (0.92)	+0.519 (0.08)	
Fraction of families with three or four members	-4.581 (2.60)	-3.803 (1.68)	
Fraction of families with five or more members	-1.746 (2.17)	-2.337 (1.68)	
Number of persons in resident population between 20 and 29 years old over number of family units	2.174 (1.48)	+3.053 (1.22)	
Regional Dummies:			
New England	+0.990 (3.60)		+1.121 (4.76)
West South Central	-1.050 (3.48)		-1.210 (3.85)
East North Central	-1.102 (3.70)		-0.987 (3.90)
West North Central	-1.037 (3.35)		-0.651 (2.94)
East South Central	-0.920 (3.38)		-1.120 (4.03)
$\bar{R}^2$	0.694	0.030	0.635

Table continued on following page.

Table 4-5 (Continued)

IMPACT OF REGIONAL DUMMIES
ON DESIRED SIZE CLASS SHARE EQUATIONS

	CRA	No Regional Dummies	Only Regional Dummies
Compact Domestic Equation			
Intercept	+3.528 (3.55)	+0.947 (0.69)	-1.702 (63.26)
Relative cost per mile	-2.279 (3.03)	-1.055 (1.03)	
Disposable income over number of family units over fixed weight cost per mile	-1.033 (3.74)	-0.642 (1.55)	
Percentage of families earning $15,000 or more in 1970 dollars	+0.227 (2.39)	+0.300 (2.10)	
Fraction of families with three or four members	1.127 (5.38)	+0.678 (2.28)	
Licensed drivers per family unit	-0.448 (2.08)	-0.096 (0.300)	
Regional Dummies:			
New England	0.121 (2.88)		+0.121 (1.96)
West South Central	-0.350 (5.66)		-0.261 (3.13)
East South Central	-0.274 (4.44)		-0.072 -0.098
Mountain	+0.121 (2.59)		-0.031 (0.56)
$\overline{R}^2$	0.659	0.173	0.217

Table continued on following page.

Table 4-5 (Continued)

IMPACT OF REGIONAL DUMMIES
ON DESIRED SIZE CLASS SHARE EQUATIONS

Mid-Size Domestic Equation	CRA	No Regional Dummies	Only Regional Dummies
Intercept	+0.154 (0.28)	+0.080 (0.11)	-1.367 (73.73)
Relative cost per mile	-1.968 (4.40)	-1.448 (2.82)	
Disposable income over number of family units over fixed weight cost per mile	-0.149 (1.20)	-0.067 (0.39)	
Fraction of families with three or four members	0.781 (4.68)	+1.010 (4.53)	
Regional Dummies:			
New England	+0.165 (3.95)		+0.059 (1.25)
Mountain	-0.128 (3.65)		-0.225 (5.36)
$\bar{R}^2$	0.675	0.365	0.408

Table continued on following page.

Table 4-5 (Continued)

IMPACT OF REGIONAL DUMMIES
ON DESIRED SIZE CLASS SHARE EQUATIONS

Full-Size Domestic Equation	CRA	No Regional Dummies	Only Regional Dummies
Intercept	+4.717 (3.37)	-8.259 (3.40)	-0.542 (14.44)
Relative cost per mile	-1.351 (0.76)	0.712 (0.31)	
Disposable income over number of family units over fixed weight cost per mile	-0.987 (2.74)	2.246 (3.70)	
Fraction of families with five or more members	-1.564 (4.96)	-0.086 (0.27)	
Fraction of families with three or four members	+0.223 (1.19)	-0.866 (1.55)	
Percentage of families earning $15,000 or more in 1970 dollars	-0.464 (3.23)	-0.968 (3.94)	
Percentage of people in state who live in metropolitan area	-0.001 (1.01)	+0.002 (0.84)	
Regional Dummies:			
New England	-0.417 (6.26)		-0.440 (4.78)
Mountain	-0.416 (5.86)		-0.275 (3.36)
Pacific	-0.618 (6.45)		-0.661 (5.30)
$\overline{R}^2$	0.801	0.334	0.501

Table continued on following page.

Table 4-5 (Continued)

IMPACT OF REGIONAL DUMMIES
ON DESIRED SIZE CLASS SHARE EQUATIONS

Luxury Domestic Equation	CRA	No Regional Dummies	Only Regional Dummies
Intercept	-2.207 (3.66)	-0.320 (0.46)	-2.400 (86.77)
Relative cost per mile	-3.369 (1.41)	-10.040 (3.46)	
Percentage of families earning $15,000 or more in 1970 dollars	+0.169 (1.74)	+0.017 (0.14)	
Percentage of people in state who live in metropolitan area	+0.002 (1.99)	+0.005 (3.20)	
Regional Dummies:			
New England	-0.370 (5.54)		-0.405 (5.61)
West South Central	+0.193 (2.15)		+0.159 (1.61)
Pacific	-0.245 (2.92)		-0.187 (1.90)
$\overline{R}^2$	0.614	0.286	0.436

Table continued on following page.

Table 4-5 (Continued)

IMPACT OF REGIONAL DUMMIES
ON DESIRED SIZE CLASS SHARE EQUATIONS

Luxury Foreign Equation	CRA	No Regional Dummies	Only Regional Dummies
Intercept	-3.791 (3.44)	-3.528 (3.27)	-5.037 (58.73)
Relative cost per mile	-8.792 (4.28)	-10.226 (4.48)	
Percentage of families earning $15,000 or more in 1970 dollars	+0.297 (1.04)	+0.354 (1.38)	
Percentage of people in state who live in metropolitan area	0.006 (2.05)	+0.004 (1.24)	
Regional Dummies:			
East North Central	-0.625 (3.78)		-0.538 (2.22)
West South Central	-0.249 (1.10)		-0.450 (1.47)
East South Central	-0.275 (1.38)		-0.571 (2.13)
$\bar{R}^2$	0.634	0.365	0.128

SOURCE: Estimated using WEFA data base and estimation software.

availability, then one would expect the regional coefficients to converge as foreign car availability has become more nearly ubiquitous. If the 1971-1972 sales shares differences are due to regional cultural differences, and if the popular belief that the rest of the county follows cultural trends on the two coasts with a lag is true, then one would also expect the pattern of regional differences to change over time. To give another example, if regional differences in the pattern of car sales as measured by the dummy variables are due to differences in geography, and if Sunbelt growth does bring increasing industrialization, urbanization, and congestion to that region, then the 1971 pattern of regional differences might not persist. Unfortunately WEFA does not provide a comparison of "desired sales shares" patterns by state for different years -- such as 1961, 1971, and 1979 -- to show how much the regional differences do shift over time.

Desired Size Class Shares and Historic Sales Shares

In the WEFA model the desired size class shares are predicted using an estimation based on a single 1972 state cross-section set of observations. There is no a priori assurance that this model can be translated reliably to the time domain for forecasting purposes. Whether it can or not depends on whether the model is really fully specified, and whether the model specification issues raised in the previous section point to real problems with the size class share equations. Unfortunately, we cannot directly observe the past values of the desired sales shares to compare the predicted to actual levels. However, by comparing the past levels of predicted desired shares, actual size class shares, and actual sales shares by size class, one can evaluate the reliability of the translation of the desired equilibrium shares predictors to the time domain. Plots of these three variables for each of the five size classes (domestic and foreign shares are aggregated) occur in Figures 4-2 through 4-6.

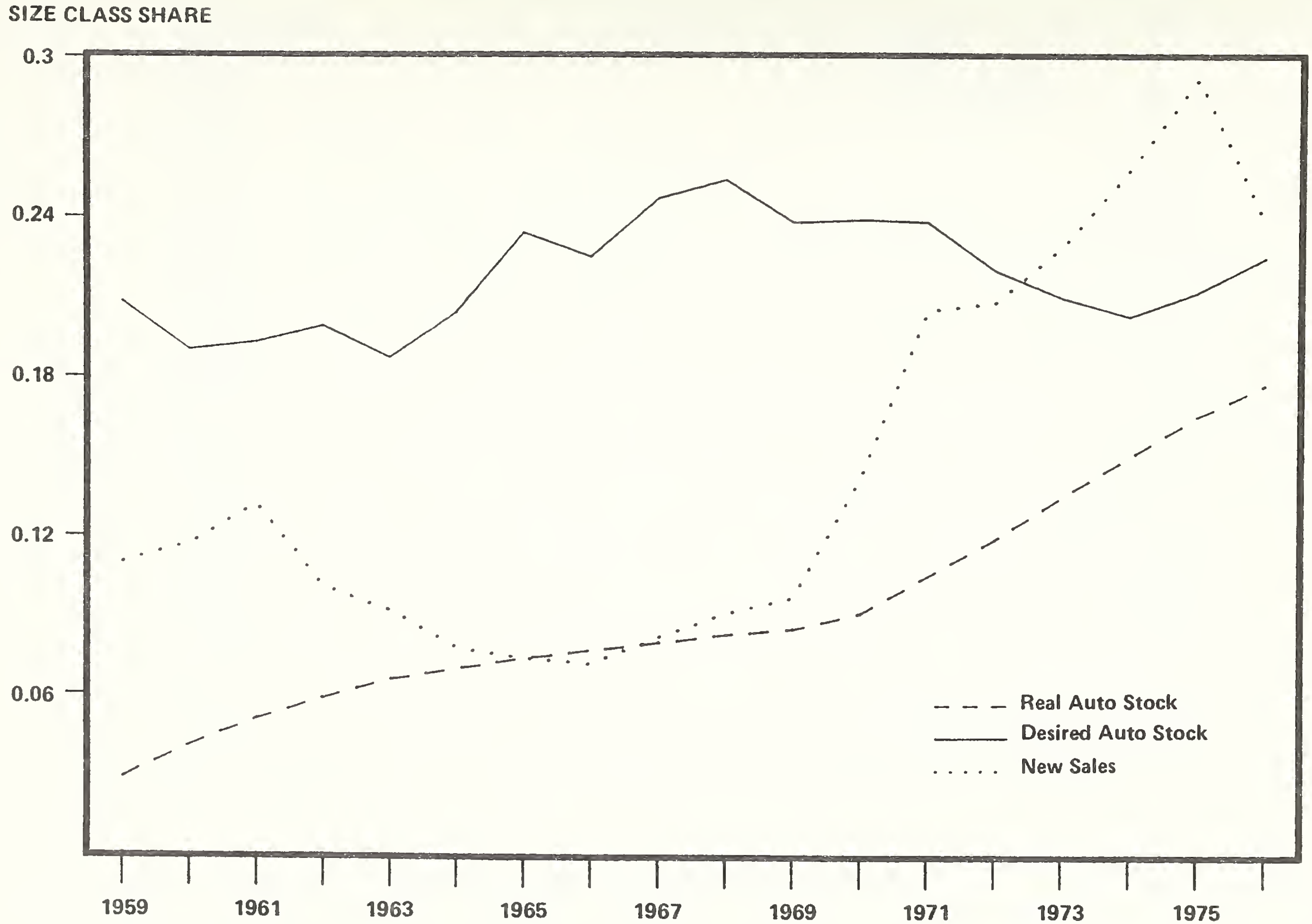
Convergence of Actual to Desired Shares

In the WEFA model the pattern of new car sales provides the primary mechanism by which the size class shares of the actual vehicle stock in use adjust toward the size class shares that are really desired. If the desired share of any size class is above the actual existing share determined by vehicle purchases in past years, then the new car sales share of that class should be high enough to pull the actual share toward the desired share. To do so the sales share would be greater than the desired share (which is of course above the actual share). Because a very high percentage of the actual stock will be scrapped and replaced within ten years, the convergence of actual to desired stock, assuming desired stock stayed roughly constant, should certainly happen within ten years. If one takes the stock adjustment model seriously, and realizes that there are no great barriers to relatively rapid adjustment, the convergence of actual to desired stock should happen rather quickly, probably in less than five years. Therefore, one would expect the graphs of actual and desired shares in Figures 4-2 through 4-6 to oscillate around one another.

Failure of the share of the desired stock to persistently be between the share of the actual stock and the share of new car sales for any size class is evidence that the WEFA size class equation does not provide sensible backcasts of the desired sales shares. Similarly, failure of the actual and desired stocks to converge in less than a decade is evidence that the desired shares equations, estimated on cross-section data, are not validly translated to time series. These tests of the model's translation to time series are required because the real "desired" sales shares are not observable.

Figure 4–2

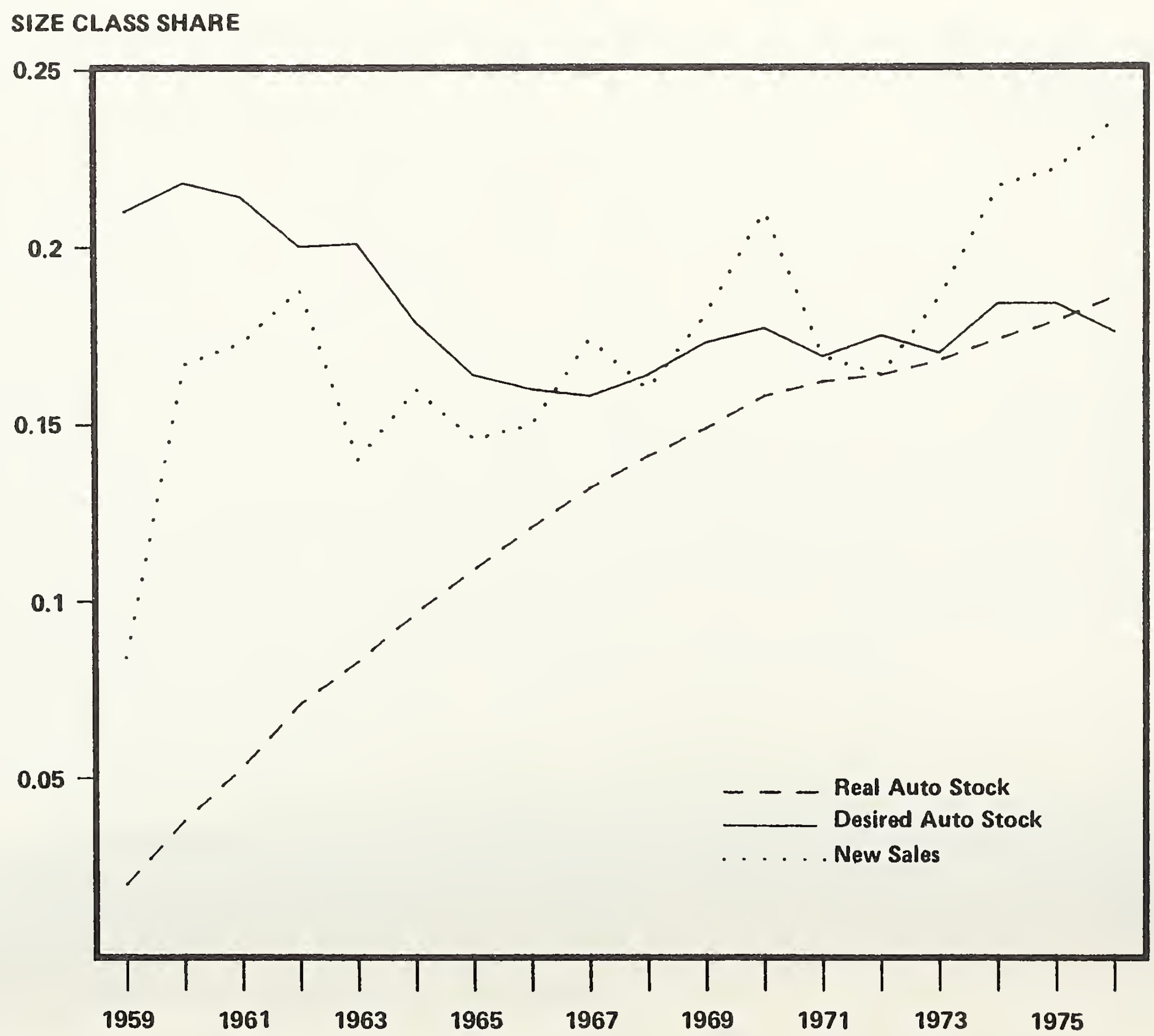
STOCK AND NEW SALES SUBCOMPACT AUTOMOBILES



SOURCE: Charles River Associates Incorporated, April 1980.

Figure 4–3

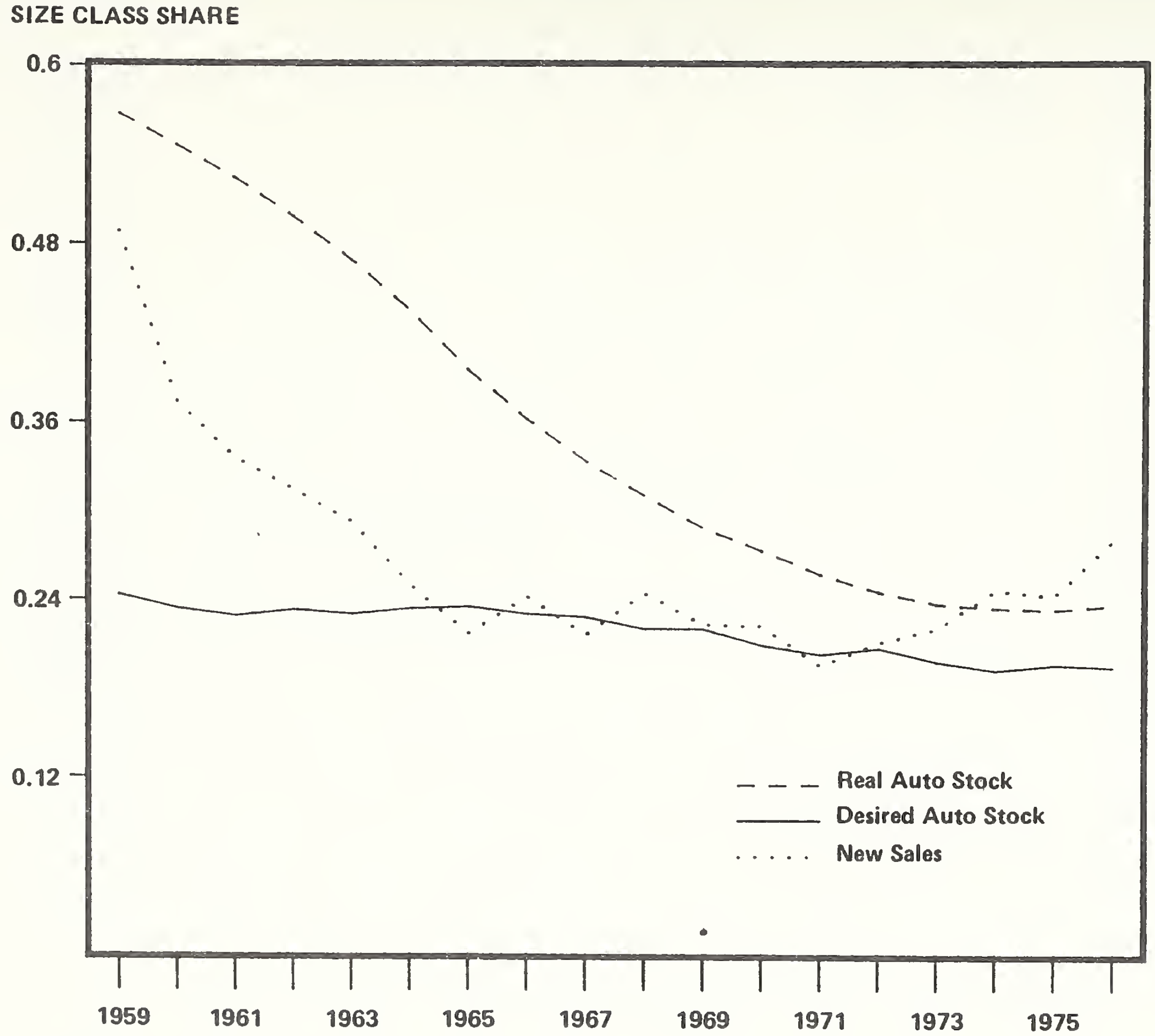
STOCK AND NEW SALES COMPACT AUTOMOBILES



SOURCE: Charles River Associates Incorporated, April 1980.

Figure 4–4

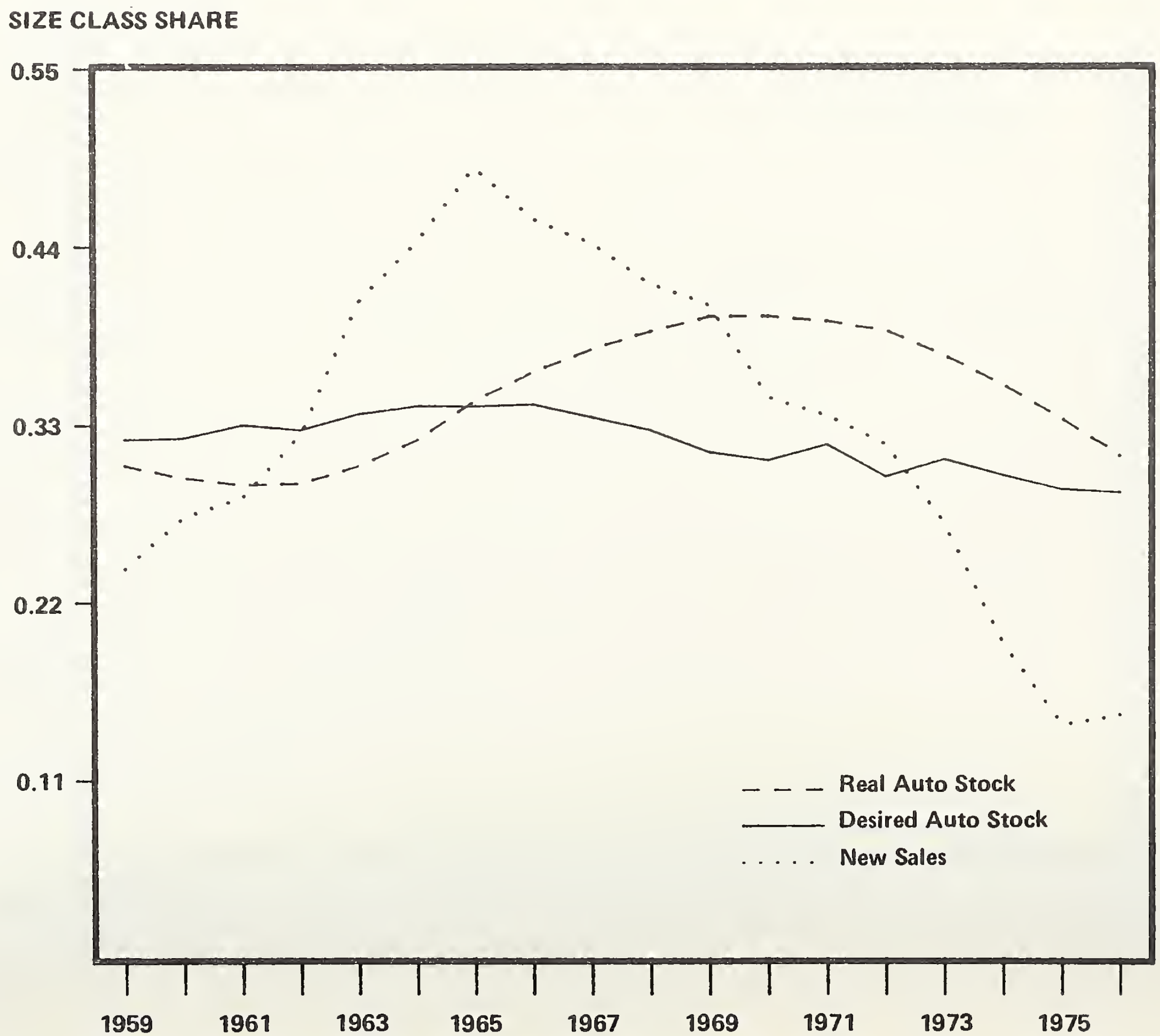
STOCK AND NEW SALES MIDSIZE AUTOMOBILES



SOURCE: Charles River Associates Incorporated, April 1980.

Figure 4–5

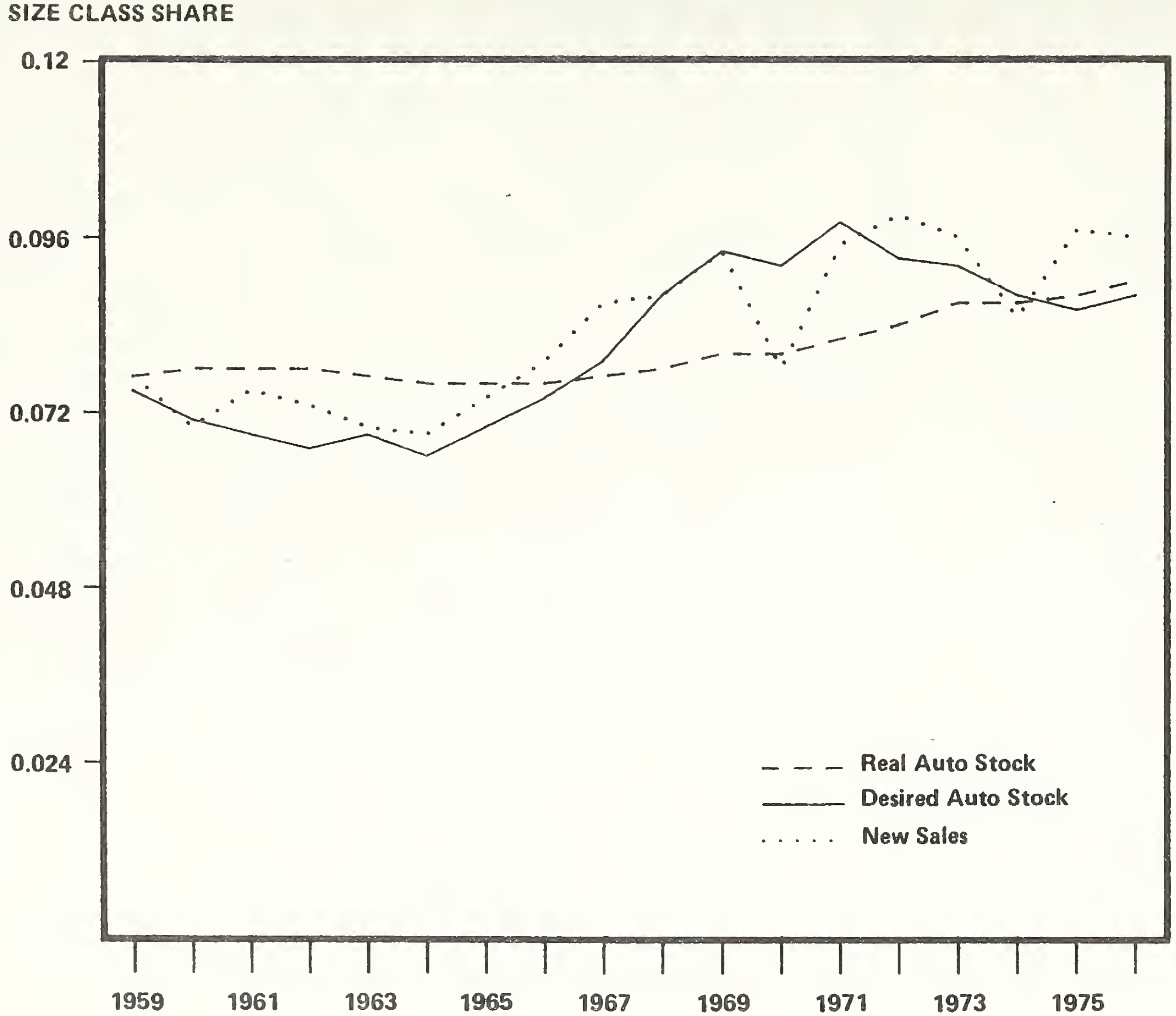
STOCK AND NEW SALES FULLSIZE AUTOMOBILES



SOURCE: Charles River Associates Incorporated, April 1980.

Figure 4–6

STOCK AND NEW SALES LUXURY AUTOMOBILES



SOURCE: Charles River Associates Incorporated, April 1980.

Figure 4-2 graphs the combined desired shares of domestic and foreign subcompacts, the actual shares, and the sales shares. We see that from 1959-1972 the actual subcompact share is well below the predicted desired share, yet the sales share is also below the actual share. This runs counter to the logic of the stock-adjustment model, which holds that the sales shares of subcompacts should be at least as high as the desired share. Furthermore, over the 17 years of the backcasted data, the actual and desired shares fail to converge. This also runs counter to the logic of the model, and argues that the desired subcompact share equation overpredicts the desired share in the time domain.

Of course, one could argue that subcompacts were essentially supply-constrained by the limited domestic production prior to 1971. This argument states that domestic manufacturers chose not to meet the latent demand for subcompacts prior to 1971 either through ignorance or because this would shift buyers from higher-profit, larger cars to lower-profit, smaller cars. Without critiquing the possible merits of this rationalization, we note that the actual and estimated desired subcompact stocks still failed to converge between 1971 and 1976. This provides further evidence that the desired subcompact share may be overestimated.

The graphs of compact size car actual and desired shares behave similarly to those of the subcompact cars, although domestic supply constraints disappear as early as 1960. From 1960 to 1967 the actual share of compacts in the stock is well below the estimated desired share, yet sales of compacts are also below the desired share of compacts. Furthermore, it takes 13 years, from 1960-1972, for the actual share of compacts in the stock to converge to the estimated desired stock. Both these observations argue that over the historic time period the desired share of compact cars is overpredicted.

The graph of mid-size car shares provides just the opposite results, indicating that desired share of mid-size cars may be consistently underpredicted over the historic time period. The full-size and luxury car size class share graphs show more sensible patterns, although from 1965-1972 the full-size desired share is below the actual, yet the full-size sales share exceeds the desired share. In summary, the backcasting relationship of desired class shares, actual shares, and sales shares does not fit the pattern one would expect in a stock adjustment model with accurately backcasted desired size class shares.

Desired Stock or Sales?

In the estimation of the WEFA desired stock equations, the sum of 1971 and 1972 sales shares at the state level acts as a proxy for observed desired stock. Since the desired shares predictors are estimated on sales shares rather than stock shares observations, the question naturally arises whether one might be predicting sales shares rather than desired stock shares with the algorithm. Although we cannot answer this question definitively, the graphs of shares in Figures 4-3 and 4-4, for the compact and mid-size shares especially indicate that for at least some size classes the desired stock predictor probably acts as a better predictor of sales shares than of desired stock shares. However, we must conclude that when translated to the time domain, the set of "desired size class share" equations do not backcast either desired shares or sales shares very well.

Forecasts of Sales Shares

The WEFA-TSC model was estimated on data through 1976. Since that time there has been a dramatic increase in the sales share of subcompact cars and a decline in the sales shares of large cars. This has been widely attributed to rising fuel prices. Table 4-6 compares the 1977-1980 forecasts of size class shares made using 1976 forecasts of exogenous variables with a forecast using identical inputs except that the actual gasoline price is substituted for the forecasted gas price.[1] Both WEFA model forecasts are compared to actual sales shares as compiled by Ward's Automotive Reports.[2] We find that the WEFA sales shares forecasts underpredict the market sensitivity to rising fuel prices.

We begin by comparing 1976 size class shares of sales as predicted by WEFA and as reported by WEFA in the WEFA data base:

1976 SALES SHARES BY SIZE CLASS

	Actual	WEFA Prediction
Subcompact	23.8	22.8
Compact	23.6	16.6
Mid-size	28.0	16.1
Full-size	15.1	31.9
Luxury	9.6	12.6

We see that WEFA drastically overpredicts the sales shares of full-size cars and underpredicts the sales shares of compact and mid-size cars on the final year of the estimation data base. We also see that the WEFA 1976 actual size class shares fit quite well to the Ward's size class designations reported

[1]Cost and time constraints precluded substituting actual values of all exogenous variables.

[2]We did not have 1977-1980 size class sales shares using WEFA-defined size classes.

Table 4-6

COMPARISON OF ACTUAL SHARES OF NEW REGISTRATIONS WITH ESTIMATES

	1977			1978			1979			1980		
	WEFA1[1]	WEFA[2]	Actual[3]	WEFA1[1]	WEFA2[2]	Actual[3]	WEFA1[1]	WEFA[2]	Actual[3]	WEFA1[1]	WEFA[2]	Actual[4]
Subcompact Domestic	5.57	5.57	8.60	5.61	5.78	10.6	5.39	5.60	16.7	5.62	5.86	18.1
Subcompact Foreign	17.19	17.19	16.1	16.14	17.12	15.7	15.53	16.81	19.2	16.06	17.59	23.6
Total Subcompact	22.76	22.76	24.70	21.76	22.90	26.3	20.92	22.40	35.9	21.68	23.44	41.7
Compact Domestic	15.64	15.64	20.20	15.86	16.52	20.1	16.47	17.72	18.4	16.80	18.26	18.1
Compact Foreign	0.98	0.98	1.4	0.87	0.90	1.3	0.81	0.85	1.7	0.77	0.81	21.0
Total Compact	16.63	16.63	21.6	16.73	17.42	21.4	17.28	18.56	20.1	17.56	19.06	20.1
Mid-size Domestic	16.08	16.08	27.0	18.31	18.31	27.1	18.89	18.56	22.1	19.65	19.24	19.4
Full-size Domestic	31.93	31.93	20.7	32.61	30.23	19.1	32.63	21.14	16.2	30.87	26.86	13.5
Luxury Domestic	9.25	9.25	5.1	8.90	9.17	5.1	8.94	9.40	4.6	8.94	9.42	3.7
Luxury Foreign	3.35	3.35	1.0	1.70	2.17	1.0	1.35	1.94	1.2	1.30	1.97	1.5
Total Luxury	12.60	12.60	6.1	10.60	11.35	6.1	10.29	11.34	5.8	10.24	11.39	5.2
Total Domestic	78.47	78.47	81.6	81.29	79.81	82.0	82.31	80.41	78.0	81.87	79.63	72.9
Total Foreign	21.52	21.52	18.4	18.71	20.19	18.0	17.69	19.59	22.0	18.13	20.37	27.1

[1]Prepared by Charles River Associates using WEFA's model and their 1976 forecast of fuel prices.

[2]Prepared by Charles River Associates using WEFA's model and the actual gas prices.

[3]Prepared from Ward's Automotive Reports, various issues.

[4]Year to date. Calculated from data for January and February 1980, published in Ward's Automotive Reports, March 10, 1980.

in Table 4-6. The main difference is that WEFA reports a higher luxury share and Ward's a higher full-size share.[1]

Examining the forecasted shares for 1977-1980 using the WEFA model and actual gas prices (WEFA2) with actual sales shares as reported by Ward's (ACTUAL), we find that WEFA predicts the subcompact share would increase by less than 1 percentage point (22.76 to 23.44 percent), while it actually increased 17 percentage points (24.7 to 41.7 percent). WEFA predicts that the size class share of full-size and luxury cars would only change by about 6 percentage points (44.53 to 38.25 percent), but it actually decreased by about 8 percentage points (26.8 to 18.7 percent). Mid-size cars are predicted by WEFA to increase in market share, but actually fall by 7.5 percentage points. By 1979 and the first two months of 1980, WEFA is severely underpredicting the sales share of subcompact cars and overpredicting the sales shares of full-size cars.

To further test the sensitivity of the WEFA model to rising gasoline prices, three model simulations were run through 1990 under different gas price scenarios. In Table 4-7 the first column shows predicted sales by size class under the WEFA baseline of quite moderate increases in the price of gasoline. In the second column actual gas prices are assumed for 1980 and the real price is assumed to rise by half by 1985 and then remain constant. The results of the third column show WEFA size class sales predictions under the assumption of a doubling of real gasoline prices by 1985. Changes in gasoline prices are not fed back to affect other economic variables. Under the extreme scenario in the third column, predicted total car sales decline between 1980 and 1990 from 11.7 to 11.4

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[1]Table 4-6 begins in 1977. However, WEFA 1976 actual size class sales shares also fit the Ward's 1976 size class sales shares data quite well.

Table 4-7

NEW REGISTRATION GAS PRICE SCENARIOS
(Million Vehicles)

	WEFA	50% Real Gas Price Increase, 1980-1985	100% Real Gas Price Increase, 1980-1985
Total Subcompact			
1980	2.508	2.582	2.582
1985	2.866	2.879	2.871
1990	3.213	3.147	3.108
Total Compact			
1980	2.032	2.099	2.099
1985	2.188	2.323	2.405
1990	2.353	2.425	2.464
Mid-size Domestic			
1980	2.273	2.118	2.118
1985	2.532	2.360	2.260
1990	2.592	2.406	2.314
Full-size Domestic			
1980	3.572	2.958	2.958
1985	3.171	2.545	2.200
1990	2.871	2.399	2.179

Table continued on following page.

Table 4-7 (Continued)

NEW REGISTRATION GAS PRICE SCENARIOS
(Million Vehicles)

	WEFA	50% Real Gas Price Increase, 1980-1985	100% Real Gas Price Increase, 1980-1985
Total Luxury			
1980	1.185	1.255	1.255
1985	1.207	1.257	1.290
1990	1.293	1.296	1.300

SOURCE: Data for WEFA column: Created by Charles River Associates Incorporated using WEFA Motor Vehicle Demand model.

Data for other columns: Calculated by Charles River Associates Incorporated, 1980.

million. However, even at $2.50 per gallon of gasoline the predicted subcompact size class sales share falls far short of the actual 1979 share and the predicted full-size share fails to decline to the actual 1979 level. We find that the WEFA model greatly understates the market's actual response to rising fuel prices and must tentatively conclude that it is likely to be a poor predictor of the sensitivity of sales shares by size class to relative user costs by size class.

Chapter 5
INCOME SATURATION

The specifications of the desired vehicle stock equations and some of the desired size class share equations include an income saturation term. The purpose of this term is to allow a mechanism through which a declining income elasticity of demand for personal vehicles can be incorporated into the model. WEFA hypothesizes, probably correctly, that at increasing levels of income and higher levels of vehicle ownership, further increments in income lead to smaller increments in the vehicle stock.

To model a declining income elasticity of demand WEFA combines as explanatory variables in the vehicle demand equations an income term, with a positive coefficient, and an income saturation term, with a negative coefficient. WEFA hoped that the interaction of the two income terms would yield an income elasticity of demand for motor vehicles which would be positive but decline with rising income. The measure of income saturation used is the percentage of families with real disposable income greater than $15,000. In the Mark II version of the model the $15,000 is measured in 1975 dollars in the total desired car and motor vehicle equations, and in 1970 dollars in the size class share equations.

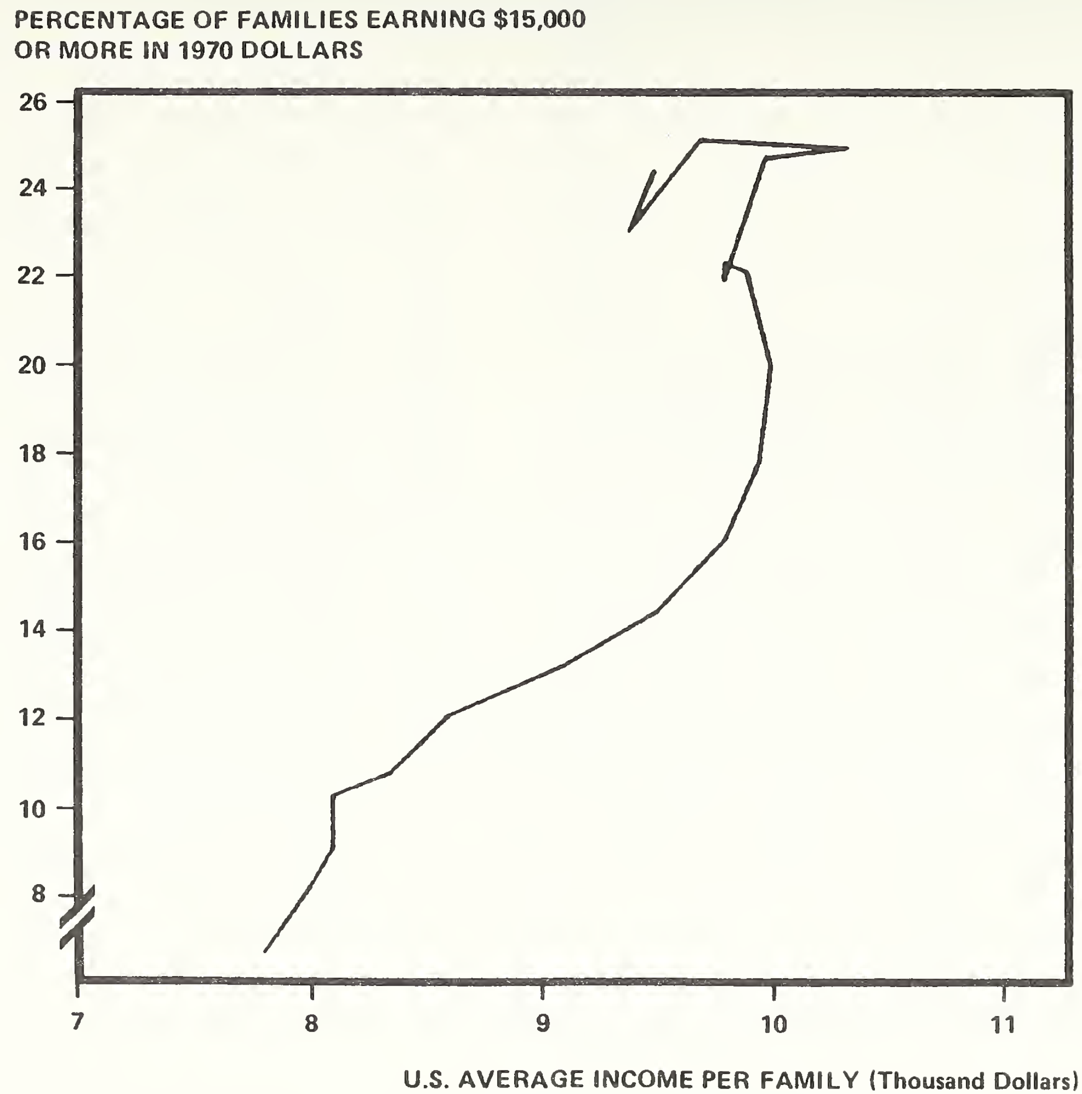
Forecasting the Income Saturation Variable

Since the income saturation variable does have an influence on the output of the WEFA auto market model, the accuracy of the model forecasts will depend partly on the accuracy of the forecasts of the income saturation term. Unfortunately, accurate forecasts of the income saturation term may not be simple. WEFA takes the wholly logical position that the percentage of families with incomes greater than $15,000 depends primarily on the average income level. Unfortunately, the functional form of the relationship between income and income saturation is both ambiguous and critical to the forecasts of the income saturation term.

Figure 5-1 plots the national historic time series of average income per family against the percentage of families with incomes greater than $15,000, in 1970 dollars. No simple relationship is apparent. In the Wharton Mark I report it is reported that the income saturation variable is estimated in log-odds form as a weighted average of the last four to five years of disposable income. The equation was estimated using an Almon-lag technique and is reproduced in Table 5-1. This equation fits the data quite well. However, we find that the WEFA auto model software contains equally reasonable alternative specifications of the income saturation predictors with a different kind of lag structure. These are reported as Equations B and C in Table 5-1. No test statistics are available for evaluating these equations. Moreover, in the actual baseline simulations of the model the forecasts of the predictor are adjusted upwards by as much as 23 percent which acts to arbitrarily dampen forecasts of the desired stock and

Figure 5–1

GRAPH OF INCOME SATURATION VS. INCOME
(ANNUAL OBSERVATIONS CONNECTED SEQUENTIALLY, 1958–1976)



SOURCE: Charles River Associates Incorporated, April 1980.

thus of new car sales and other vehicle sales. WEFA thus uses adjustment factors so that model output corresponds to their subjective forecasts rather than to the "black box" predictions of the statistically estimated model.

To compare the effect of WEFA's choice of forecasts of the income saturation term with that of equally reasonable forecasts of the national income saturation level, the predictive equations were reestimated using simple log-log and odds specifications without the multiperiod lag. These alternative equations are reported in Tables 5-2 and 5-3. Figures 5-2 and 5-3 compare the income saturation and auto market forecasts produced by WEFA with those derived using the alternative income saturation predictor equations. Clearly the WEFA forecast produces lower levels of vehicle sales than alternative reasonable forecasts of the income saturation term, and the range of vehicle stock forecasts resulting from alternative reasonableness forecasts of the income saturation term is quite large.

WEFA Model Income Elasticity

The total income elasticity of demand of the model can be calculated as the sum of the direct effect of the income term and the indirect effect by which income levels to changes in the income saturation term. In the Mark I version of the WEFA model the total income elasticity was positive, as it should be. However, specification of the Mark II version of the model leads to a negative income elasticity of demand for vehicles. The total income elasticity of demand for cars at 1976 levels of exogenous variables is calculated to be -.162. This is obviously an implausible result, and a compelling reason to doubt the accuracy of the model forecasts.

Table 5-1

EQUATION FOR SATURATION VARIABLE

Equation A

$$
\begin{aligned}
\ln(\text{PER15+} / (100-\text{PER15})) = & -10.235 \\
& (-31.3372) \\
& +1.39976 \quad \ln(\text{YPDNET} / \text{FM}) \\
& (3.55613) \\
& +1.22843 \quad \ln(\text{YPDNET} / \text{FM}(-1)) \\
& (27.0171) \\
& +.938021 \quad \ln(\text{YPDNET} / \text{FM}(-2)) \\
& (5.20493) \\
& +.528546 \quad \ln(\text{YPDNET} / \text{FM}(-3)) \\
& (2.8941)
\end{aligned}
$$

$R^2 = 0.980$ DW = 1.534 SEE = 0.05852

Period of fit = 1960-1976

Equation B

$$
\begin{aligned}
\ln(\text{PER15+} / (100-\text{PER15+})) = & -11.476 \\
& +0.36412 \quad \ln(\text{YPDNET} / \text{FM}) \\
& +0.96988 \quad \ln(\text{YPDNET} / \text{FM}(-1)) \\
& +1.2364 \quad \ln(\text{YPDNET} / \text{FM}(-2)) \\
& +1.1635 \quad \ln(\text{YPDNET} / \text{FM}(-3)) \\
& +0.75141 \quad \ln(\text{YPDNET} / \text{FM}(-4))
\end{aligned}
$$

Table continued on following page.

Table 5-1 (Continued)

EQUATION FOR SATURATION VARIABLE

Equation C

$$\ln(PER15{+}75 / (100-PER15{+}75)) = -9.76119$$
$$+0.70340 \quad \ln(YPDNET / FM)$$
$$+0.98152 \quad \ln(YPDNET / FM(-1))$$
$$+1.0502 \quad \ln(YPDNET / FM(-2))$$
$$+0.90956 \quad \ln(YPDNET / FM(-3))$$
$$+0.55948 \quad \ln(YPDNET / FM(-4))$$

where:

PER15+ = Percentage of families with income of $15,000 or more in 1970 dollars;

PER15+75 = Percentage of families with income of $15,000 or more in 1975 dollars;

YPDNET/FM = Real disposable income excluding transfer payments.

SOURCES: Equation A: Loxley et al., Revisions to the Wharton EFA Automobile Demand Model (Mark I), Draft, June 1978, pp. 7-10.

Equations B and C: Computer software provided by Wharton Econometric Forecasting Associates.

Table 5-2

ALTERNATE EQUATIONS FOR SATURATION VARIABLES MEASURED IN 1970 DOLLARS

Alternate 1

$$\ln(PER15+) = \underset{(7.79)}{-7.334} \; \underset{(10.68)}{+4.542} \; \ln(YPDNET/FM)$$

R^2 = 0.86 DW = 0.53 SSE = 0.565

Alternate 2

$$\ln(PER15+ / (100-PER15+)) = \underset{(11.98)}{-13.411} \; \underset{(10.39)}{+5.290} \; \ln(YPDNET / FM)$$

R^2 = 0.86 DW = 0.49 SSE = 0.809

where:

PER15+ = Percentage of families earning $15,000 or more in 1970 dollars;

YPDNET/FM = Real disposable income per family.

SOURCE: Calculated by Charles River Associates, 1980.

Table 5-3

ALTERNATE EQUATIONS FOR SATURATION VARIABLES MEASURED IN 1975 DOLLARS

Alternate 1

$$\ln(PER15{+}75) = \underset{(6.29)}{-3.775} + \underset{(12.23)}{3.309}\ \ln(YPDNET/FM)$$

$R^2 = 0.89$ DW = 0.50 SSE = 0.229

Alternate 2

$$\ln(PER15{+}75 / (100-PER15{+}75)) = \underset{(12.43)}{-11.512} + \underset{(11.81)}{4.936}\ \ln(YPDNET / FM)$$

$R^2 = 0.89$ DW = 0.41 SSE = 0.546

where:

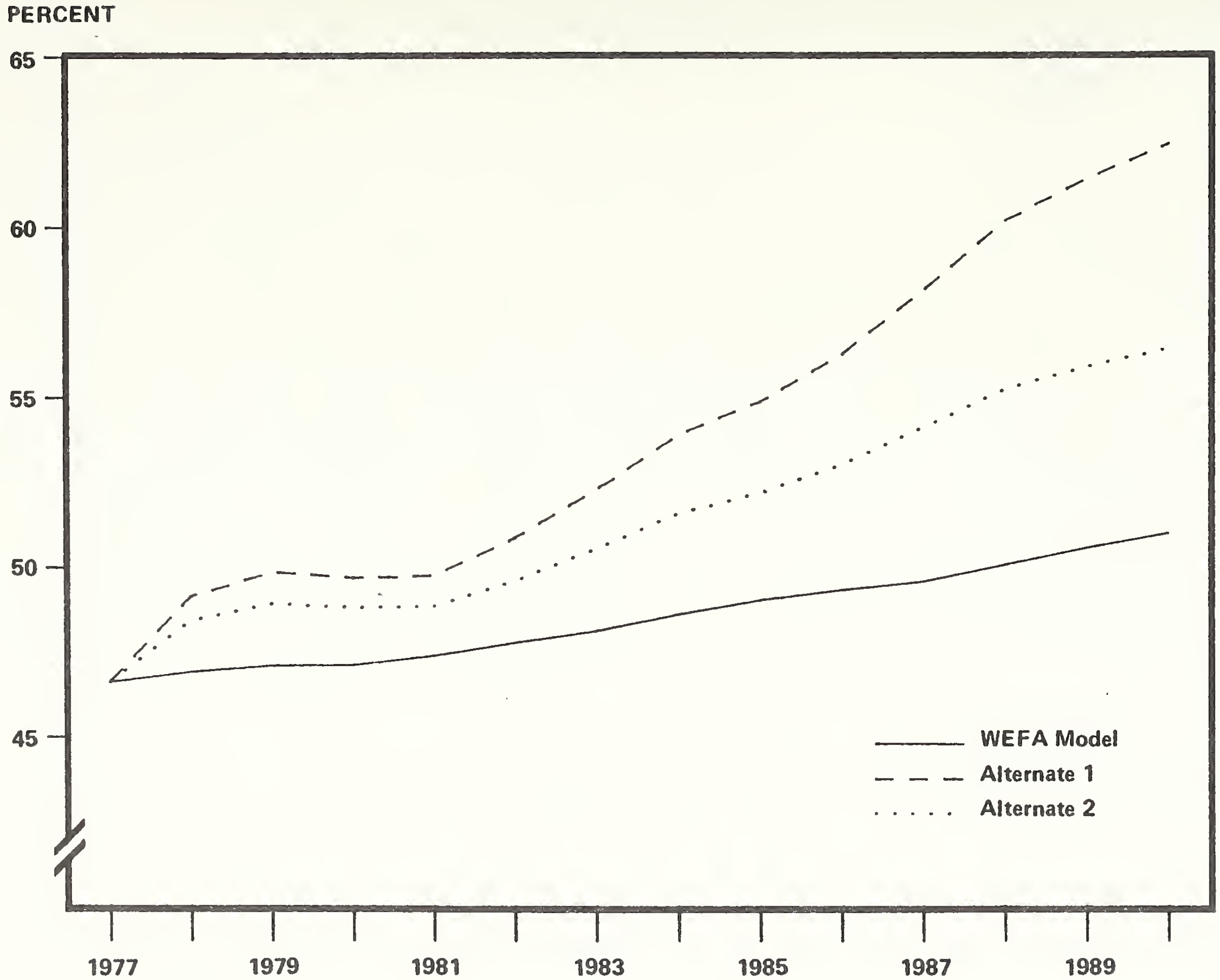
PER15+75 = Percentage of families earning $15,000 or more in 1975 dollars;

YPDNET/FM = Real disposable income per family.

SOURCE: Calculated by Charles River Associates, 1980.

Figure 5–2

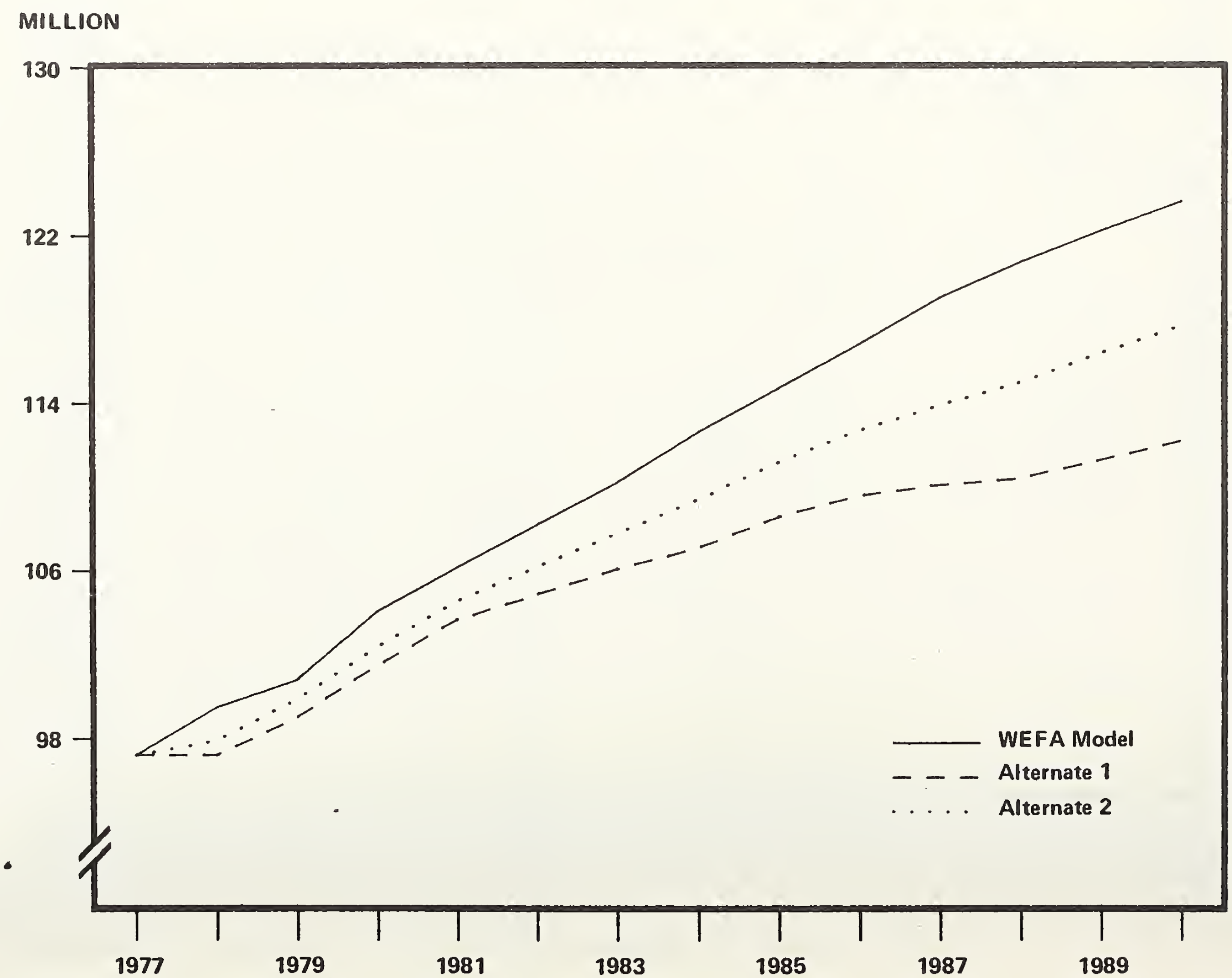
PERCENT OF FAMILIES EARNING $15,000 OR MORE IN 1975 DOLLARS



SOURCE: Charles River Associates Incorporated, April 1980.

Figure 5—3

ALTERNATIVE FORECASTS OF TOTAL AUTO STOCK



SOURCE: Charles River Associates Incorporated, April 1980.

Table 5-4 summarizes the elasticity of desired stocks and shares with respect to a change in income as determined by the Mark II model. As income increases, so does the share of subcompact and luxury cars at the expense of full-size, mid-size, and compact automobiles. This may not be unreasonable since people will tend not only to trade up larger cars but also to purchase more second cars, which tend to be subcompact.

Table 5-4

TOTAL ELASTICITY OF DESIRED STOCK AND DESIRED SIZE CLASS SHARES WITH RESPECT TO INCOME IN THE WEFA AUTOMOBILE DEMAND MODEL

	Elasticity[1]
Desired Stock	
Personal vehicle	-0.095
Automobiles	-0.162
Desired Shares	
Subcompact, Domestic	0.564
Subcompact, Foreign	--[2]
Compact, Domestic	-0.228
Compact, Foreign	--[2]
Mid-size, Domestic	--[2]
Full-size, Domestic	-0.445
Luxury, Domestic	0.517
Luxury, Foreign	1.040

[1]The percentage change that results from a 1 percent increase income either directly or through the saturation variable.

[2]Neither the income nor the saturation variable appears in the equation for this size class.

SOURCE: Calculated by Charles River Associates, 1980.

Chapter 6
POLICY EVALUATION SCOPE OF THE WEFA-TSC MODEL

The WEFA-TSC model of motor vehicle demand can be used to simulate the effects of changes in vehicle prices and fuel economy on the level and pattern of demand for cars and light trucks. However, the model does not have the capacity to simulate the effects of changes in nonprice or noncost vehicle characteristics (including vehicle downsizing) on car and light truck demand. This chapter explains why changes in price and fuel economy cannot be separated from changes in other vehicle characteristics associated with fuel economy improvements when considering the effects of federal automotive policy, and why this places severe limitations on the validity and scope of policy analysis conducted with the WEFA-TSC model.

Purpose of the WEFA-TSC Motor Vehicle Model

The WEFA-TSC model of the U.S. motor vehicle market was constructed originally to help the U.S. Department of Transportation evaluate the effectiveness of alternative energy conservation policies directed toward the automotive sector of the U.S. economy. Initial analyses of conservation options by DOT were undertaken shortly after the 1973 OPEC oil embargo and oil price increases. These indicated that dramatic national gasoline savings could be realized by federal policies which would encourage fewer personal motor vehicles, reduced annual use per motor vehicle, and improved average fuel efficiency of the motor vehicle fleet. Shortly thereafter it became apparent that in any sensible national automotive energy conservation program the improvement in fleet fuel economy would become the dominant means of automotive fuel conservation.[1] The 27.5 mile per gallon new car fuel economy average mandated for 1985 was deemed achievable with only slight improvements of the most fuel-efficient design features already in mass production and on the U.S. market in 1974. This represented about a doubling of the estimated average fuel economy embedded in the total 1974 new car fleet.[2]

The WEFA-TSC model was designed to simulate the effects of three types of federal policies being considered to encourage automotive energy conservation and vehicle fuel economy improvements. The first policy type is vehicle pricing incentives related to vehicle fuel economy; the federal government was considering taxes on vehicles with low fuel economy and possible refunds of the collected revenues to owners or buyers of vehicles with superior fuel economy. The

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[1]A streamlined analysis of the effectiveness of vehicle redesign relative to other transportation energy conservation options is contained in Eric Hirst, "Transportation Energy Conservation Policies," _Science_ 192 (April 1976): 15-20.

[2]Office of the Secretary, U.S. Department of Transportation, _The Report by the Federal Task Force on Motor Vehicle Goals Beyond 1980_ (Washington, D.C.: U.S. Department of Transportation, 1976).

second type of policy is a fuel price incentive in the form of a gasoline tax which would also shift consumer preferences toward vehicles with higher fuel economy levels. The third type of policy, which was enacted into law, is a rule requiring auto manufacturers to meet specified new car (and light truck) fleet average fuel economy levels.

The Mechanism Through Which Policy Works

To evaluate the accuracy of the WEFA-TSC model in simulating the effects of alternative policies, one must first understand the mechanisms by which these policies affect consumer behavior. Vehicle or fuel pricing incentives shift consumer demand preferences toward the purchase of vehicles with better fuel economy.[1] In the short run some consumers shift their vehicle choice toward already available vehicles with better fuel economy. In the longer run the vehicle manufacturers react to the increased demand for fuel economy by improving the efficiency of their products. The third type of federal policy, mandated fuel economy rules, circumvents consumer demand and acts directly to force manufacturers to improve the fuel efficiency of vehicles (or restrict the sales of less efficient vehicles). Most policy analysis has shown that supply-side engineering and design changes are the main source of fuel savings resulting from the federal policies.

The vehicle engineering and design changes, which are now taking place and will continue to take place in response to higher fuel prices and federal fuel economy rules, include the visible downsizing of the exterior size and weight of vehicles

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[1]Of course, a fuel tax also lowers the demand for vehicle travel. Both fuel and vehicle taxes may lower the total vehicle stock.

in each passenger carrying capacity size class. These changes improve fuel economy while maintaining roughly constant interior passenger and cargo space, allowing manufacturers to meet requirements of greatly increased fuel economy while continuing to give consumers the choice of purchasing four-, five-, or six-passenger cars (including station wagons), pick-up trucks, utility vehicles, or vans. However, each type of vehicle, while functionally similar to its 1974 counterpart, will be lighter, smaller in exterior dimensions, and may have a more energy-efficient engine, transmission, or other parts.

Types of Supply-Side Responses

The automotive changes which are currently being made (and will continue to be made throughout the 1980s) in response to federal policy and to consumer preferences may affect the following vehicle characteristics which influence automotive buying patterns.

- Fuel Economy: Vehicle fuel economy is being dramatically improved. Mandated corporate average automobile fuel economy rises from 20 miles per gallon in 1980 to 27.5 miles per gallon in 1985. The fuel economy of large cars is expected to improve more than the economy of smaller cars. Light-duty trucks are undergoing changes similar to those of cars.
- Price: Most industry analysts expect that the accelerated rate of vehicle redesign which is required to meet fuel economy rules and the enormous investment required to implement the redesign will lead to higher real vehicle prices. Investment costs are expected to more than offset possibly reduced materials costs. Changes in vehicle prices by size class are uncertain, but will likely depend on the strength of demand for large relative to small vehicles.

- Weight: Vehicles will continue to get lighter. Balanced against the fuel economy improvement which consumers value are consumer perceptions that vehicles may be less substantial, less crashworthy, and may have a less stable ride.
- Exterior Size/Styling: Vehicles are becoming smaller in exterior size and designed for packaging efficiency in order to improve fuel economy. One result is that many vehicles look boxier and less streamlined; many consumers perceive that they are getting "less car for more money."[1]
- Acceleration: One way that fuel economy is being improved is by reducing engine size and in some vehicles by reducing even the horsepower-to-weight ratio. The result may be somewhat poorer acceleration performance.

In addition to these more obvious changes, there are also changes in reliability and creature comforts which may occur. These changes are much less certain, since automotive manufacturers are striving to maintain traditional levels of reliability and luxury in lighter vehicles. However, possible changes include:

- Reliability: As the speed of product change increases in the auto industry, quality control becomes more difficult and reliability may suffer. At the very least, each year there will be more new vehicle models untested by years of actual driving. Some consumers may be hesitant to purchase newer designs.

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[1]This view was expressed by focus group panelists in each of three studies funded by the National Highway Traffic Safety Administration (NHTSA) in 1978-1979. See, for example, Charles River Associates, Consumer Behavior Towards Fuel Efficient Vehicles, prepared for NHTSA (Boston, Mass.: CRA, April 1979).

- Comfort: As the weight of cars is reduced, the soft ride characteristic of traditional large cars may be impossible to maintain at a reasonable cost. Cars may become less comfortable.
- Noise: If weight reduction requires the use of less noise-insulating material, vehicle interiors may become significantly more noisy.

There are also numerous more subtle changes in motor vehicles which are being made by auto manufacturers as a means of meeting the demands of the market and the federal government for improved fuel economy. These include, for example, the manufacture of cars with rear windows that do not open and with deflated spare tires.

To summarize, a principal mechanism of fuel economy improvement is the inducing of supply-side vehicle design changes, including downsizing, which allow improved fuel economy in vehicles of roughly constant passenger and cargo carrying capacity. For each vehicle "concept" there may be changes in price, fuel economy, weight, exterior size, styling, acceleration, reliability, comfort, and luxury. These changes will occur whether the federal policy instrument utilized is fuel taxes or vehicle taxes which shift consumer preferences toward more fuel-efficient vehicle designs, or manufacturer fuel economy rules which require the manufacturers to make design changes regardless of consumer preferences at existing market vehicle and fuel prices.

The accuracy of any auto market demand forecasting model is likely to depend on how accurately the model user can quantify consumer preferences for vehicles of different configuration and prices at given levels of exogenous economic and demographic variables (including fuel price) and also on how accurately the model user can forecast the range of vehicle configurations and prices that will be manufactured at given levels of exogenous economic and demographic variables. The U.S. Department of Transportation and most other auto market modelers forecast vehicle configurations using information in the trade press about manufacturer product plans and restrict the use of formal models for demand-side forecasting, given expected vehicle configurations.

The Ideal Forecasting Model

The above discussion should allow the reader to understand that the ideal auto market policy analysis model would necessarily be extremely complex. For any future year, 1990 for example, the actual vehicle designs placed on the market by auto manufacturers and the sales shares of each design will depend on the technological costs of alternative vehicle designs (including supply-side tradeoffs among fuel economy, price, and other consumer-relevant characteristics), on consumer preferences for vehicles with alternative designs, on consumer expectations of fuel prices over the vehicle life, on how well the manufacturers understand consumer preferences and expectations, and on the usual demographic/economic variables included in auto demand models.

Any attempt at a complete forecasting model is sure to be both extremely complex and riddled with uncertainties. There is today considerable uncertainty about the costs of alternative fuel-efficient vehicle designs; about the effect of reduced vehicle weight on the comfort, reliability, and perceived luxury levels of vehicles; about consumer preferences for alternative vehicle designs including tradeoffs between fuel economy and other characteristics; about consumer fuel price expectations and future expectations; and about how well manufacturers understand consumer preferences and expectations. In addition, of course, there is uncertainty about future levels of the traditional demand-determining demographic/ economic variables. Given the WEFA-TSC auto modeling budget of time and money, it was inherent that certain forecasting uncertainties be squarely faced but others be assumed away. An assessment of the reliability of the WEFA-TSC auto market model must begin by outlining just which forecasting issues that model addresses and which it does not.

The Overall Scope of the WEFA-TSC Auto Demand Model

The WEFA-TSC auto demand model explicitly abstracts from many of these real forecasting issues. First and foremost the model assumes that while several kinds of economic/demographic/ geographic descriptors of the consuming public influence vehicle buying patterns, only two types of vehicle characteristics -- the capitalized cost per mile and the size class/country of origin designations -- influence these patterns. Implicit in this model structure is the assumption that systematic changes in vehicle weight, exterior size, styling, acceleration, reliability, or comfort that may be associated with fuel economy improvements will not affect the total demand for new motor vehicles, the desirability of large cars relative to small cars, or the desirability of light-duty trucks relative to cars.[1] Another way of describing the

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[1]Alternatively, one could think of the WEFA model as the "reduced form" of a more fully specified model in which supply-side responses to federal policies are implicit. Unfortunately, such a reduced form would likely be terribly inaccurate since the historic estimation data base ignores the considerable technological progress in improving fuel economy since 1973. Furthermore, future changes in vehicle characteristics are, in salient respects, outside the bounds of past experience.

structure of the WEFA model is to note that the capitalized cost per mile price indices of motor vehicles in the different vehicle classes are not adjusted for any changes in vehicle quality that may have occurred in the past or that may occur in the future. The model assumes that the noncost characteristics of vehicles in the different classes do not change relative to each other, or that these changes are small enough so that the effects on patterns of vehicle sales are insignificant.

While this WEFA assumption about the unimportance of changes in quality characteristics is possibly a realistic theory of the auto market,[1] it is a rebuttable presumption which has been extensively rebutted. In fact this question about the effects of changes in noncost vehicle characteristics is really at the very heart of public debate about the effects of fuel economy rules on the auto market. There are strong arguments that the imposition of various government automotive rules will lead to a determination of the motor vehicle price-quality tradeoff facing the individual consumer,[2] but there are also strong arguments that massive industry investment for vehicle redesign and innovation may improve the price-quality tradeoff facing the individual. To assume that downsizing and other fuel economy improvement measures will not affect the perceived quality of motor vehicles is to largely beg the question of the effects of federal automotive fuel economy policy on the auto market.

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[1]For one small-scale study of consumer buying preferences for new cars that finds vehicle passenger capacity and price/costs to be of paramount importance, see M. Murtagh and H. Gladwin, "A Hierarchical Decision-Process Model for Forecasting Automobile Type Choice," School of Social Sciences, University of California at Irvine (unpublished).

[2]This deterioration in the tradeoff facing the individual may be outweighed by the social gains from fuel economy, emissions, safety, and damageability rules.

Examples of Scope Limitations

Because the WEFA-TSC model ignores the market effects of changes in nonprice, noncost vehicle characteristics, its applicability to current policy questions is limited. Three examples of automotive demand questions which cannot be addressed within the scope of the WEFA-TSC model will illustrate the severity of the model's scope limitations.[1]

The Question of Import Penetration

As this chapter is being written import penetration in the United States has risen to a record 27 percent of total car sales. This has resulted from a recent increase in gasoline price and a belief on the part of consumers that gasoline prices will soon go still higher. It may also be due to a belief by many buyers that foreign manufacturers build better small cars than American manufacturers.[2] There are several hypotheses about future levels of import penetration. One holds that the increased favorable public experience with imported cars will allow import penetration to increase still further.[3] Another hypothesis holds that as domestic manufacturers design small cars that are more like imported cars these domestic cars will sell well and the level of import penetration will decline considerably. A review of the WEFA model structure will show why it should not be relied on to answer this question.

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[1]This criticism of the WEFA-TSC model should not indicate that any other existing auto market models are superior. Rather, this criticism illustrates the difficulty of formally modeling demand for the heterogeneous product in a time of rapid product change.

[2]See, for example, "Japanese Building Best Car -- Survey," The Boston Globe, February 28, 1980, p. 25.

[3]See Business Week, "U.S. Autos: Losing a Big Segment of the Market Forever?" March 24, 1980, pp. 78-88.

In the WEFA Mark II model, imported cars in the subcompact, compact, and luxury size classes are treated as separate classes of cars from domestic subcompact, compact, and luxury cars. This division into separate classes is consistent with a marketing literature which finds that imported and domestic cars are not considered close substitutes by most car buyers.[1] Implicit in the division into separate classes for imported and domestic cars and the use of these equations for forecasting is the assumption that historic qualitative differences between imported and domestic cars within any size class will continue into the future; the WEFA model assumes that the nonprice characteristics of imported and domestic cars in the same size classes will not converge.

Therefore, the WEFA model fails to address the issue of what the imported cars market share would be if imports were faced with competition from more similar domestic cars. Changes being made by domestic manufacturers are not restricted to fuel economy improvements which are reflected in the WEFA capitalized cost per mile measure. Improvements are also being made in reliability, handling, durability, comfort, and handling, relative to first-generation American subcompacts Vega and Pinto, and these changes are not captured by the WEFA model.

A second and in many ways more obvious reason why nonprice characteristics of domestic vehicles are bound to change relative to those of imports is that the definitions of imports and domestic cars are being blurred. Volkswagen now manufactures cars in the United States and is planning a second U.S. plant. Honda is committed to assembling motor vehicles in the United States, and there are constant rumors of other foreign manufacturers soon following. At the same time

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[1]See, for example, Market Facts, Inc., A Foreign Automobile Impact Study, submitted to the U.S. Department of Labor, March 1976.

American manufacturers are thinking in terms of "world" cars with complementarity of parts among cars built for many different world markets. Thus, the world automobile market is becoming more homogeneous.

Because the WEFA-TSC model does not allow one to incorporate changes in nonprice characteristics as a scenario of future auto competition, in this case a merging of imported and domestic auto designs, the model cannot possibly predict the result of these changes. In fact, the WEFA-TSC model implicitly assumes that differences in nonprice characteristics that have sharply differentiated imported and domestic cars in the past will persist into the future.

The Effects of Downsizing

A second automobile demand question which the WEFA-TSC model cannot be expected to answer reliably concerns the effect of "downsizing" on the relative demand for large and small cars. Traditional econometric models, including the WEFA model, note that fuel economy improvements and owner cost savings resulting from downsizing are expected to be proportionately greater in larger cars than in small cars. Since the sales shares by size classes are influenced by relative costs of cars in the different size classes, the models generally forecast that the effect of fuel economy rules (independent of actual changes in fuel prices) will be to shift the car market toward larger cars. However, other industry observers argue that in the process of downsizing, vehicles in the larger size classes are perceived to be losing many of the positive attributes associated with size and weight including perceived safety, ride stability, soundproofing, and (some believe) durability. At the same time, these observers argue, manufacturers are making changes in subcompact and compact cars which are making them more attractive to the American public. The success of the compact-size X-body GM cars is cited as an example. These observers argue that because larger cars are perceived to be losing quality while smaller cars are perceived to be improving in quality, the car market will shift toward more sales of smaller cars. Again, because the WEFA-TSC model does not address the issue of how important individual quality measures are to buyers in different segments of the market, it cannot answer questions about the effects of noncost changes in the auto market.

The Shift to Light Trucks

An exactly parallel motor vehicle demand issue concerns the behavior of car buyers who have allegedly switched to the light truck market in response to fuel economy rules affecting large cars. If this is the case, then the rules may be forcing some consumers into less efficient vehicles and may be counterproductive. Both the government and the auto industry are interested in the strength of this phenomenon, and whether it might accelerate as still more stringent fuel economy rules come into force. However, because the switch from cars to personal light-duty trucks is not induced by relative cost changes, this market phenomenon is not addressed by the WEFA-TSC model. The model will not tell the user the extent to which stricter downsizing of large cars will lead the market to shift to light trucks. In fact, insomuch as downsizing and weight reduction are associated with lower vehicle costs of operation, repair, and perhaps even purchase price due to smaller and lighter materials and parts, the WEFA-TSC model would predict that stricter downsizing of larger cars would lead to reduced sales of personal use light-duty trucks and a switch from trucks to cars.

A Central Public Policy Issue

These three illustrations are examples of uncertainties in market responses to motor vehicle fuel economy improvements.

Will the market permanently shift to vehicles made by foreign manufacturers? to cars in the smaller size classes? to light trucks? Insomuch as these shifts might be influenced by downsizing or other design changes, the WEFA-TSC auto market does not even address these questions.

At a more general level the following central question related to public policy encouraging more fuel-efficient vehicles arises: at what mandated fuel economy level will corporate compliance with the rules cause major economic damage to the auto industry? The auto industry has argued that the public enjoys considerable consumer sovereignty in deciding whether or not to buy vehicles placed on the market. The industry further argues that at some mandated corporate average fuel economy level which may well become law manufacturers will be constrained to produce large numbers of vehicles with price/quality characteristics which the public will resist buying. The result will be large-scale unemployment in the motor vehicle and related industries, financial losses which will retard future vehicle improvements by the manufacturers, and a decline in the rate at which older gas-guzzlers in the fleet are replaced by a generation of vehicles designed for use at post-1974 gasoline prices.

There is almost certainly some schedule of corporate average fuel economy requirements which would realize the worst fears of the auto industry. At some required rate of fuel economy improvements cars would be so uncomfortable, noisy, lacking in acceleration, nondurable, unreliable, cramped, and lacking in engine power that the fuel economy rules themselves would force the industry into a serious cyclical (or perhaps secular) downturn. This is clearly not the case in 1980 with gasoline prices at about $1.30 and a mandated fuel economy level of 20 miles per gallon. The government argues that this is not the case in 1985 at a mandated fuel economy level of

27.5 miles per gallon. Some members of the U.S. Senate are now arguing for a standard of 40 miles per gallon in the 1990s. Whether the public will accept cars that meet a 40 mpg standard or even a 27.5 mpg standard, is still an open question.

The WEFA-TSC model has been used as one (of many) tools for evaluating the market effects of alternative fuel economy standards. The results of simulations using the WEFA-TSC model have been used as one (of many) pieces of evidence by the Office of the Secretary of Transportation in setting model year 1981-1985 fuel economy standards. To the reader of this chapter, the failings of the WEFA-TSC model for this use should be obvious. The WEFA-TSC model only accounts for market responses to changes in price and operating cost characteristics which must be made as part of the downsizing program. Other types of models or other types of evidence must be used to analyze the public acceptance of changes in nonprice and noncost vehicle characteristics.

Chapter 7

STRATEGIES FOR UNDERSTANDING THE VEHICLE MARKET

The contents of the previous six chapters of this report strongly indicate that one leading mathematical model of the motor vehicle market fails to provide accurate long-run forecasts of key market variables. An overview of the state of the art of demand modeling provided in Appendix II to this volume and the annotated bibliography from which that appendix is drawn show that the forecasting problems of the WEFA-TSC model are not unique and that competing models share certain of the deficiencies of the WEFA model. For example, many models depend primarily on pre-1976 data and fail to incorporate more recent evidence concerning the relative strength of different auto market influences on the structure of the personal motor vehicle market. Furthermore, many models fail to include important determinants of vehicle ownership and purchase, such as the level of employment, in the vehicle demand equation specification. Many models also completely ignore the impact of downsizing and other changes in noncost vehicle characteristics on the structure of vehicle demand. Those existing models that do incorporate noncost characteristics as variables in a vehicle choice framework are estimated using cross-section data, and their reliability for time-series forecasting has never been validated.

Sources of Forecasting Difficulties

Given the considerable resources and attention that have been devoted to vehicle demand forecasting, it is sensible to ask why existing statistical models of the vehicle market cannot forecast more reliably. One important reason is simply that model users are now asking extremely difficult questions. Although statistical auto demand forecasting models have been used routinely for decades by both industry and government, until the mid-1970s the purpose of these models was primarily limited to explaining changes in aggregate vehicle sales and industry revenue due to national demographic growth, economic growth, and business cycles. Simple and straightforward models proved to be relatively accurate predictors of the size of the aggregate market, particularly when markets changed slowly.

However, these simpler models lack the detail required for answering other questions that have become vitally important. Both industry and government are now greatly interested in forecasting shifts in the vehicle market composition between large cars and small cars, between imported vehicles and domestically manufactured vehicles, and between cars and light trucks. Industry and government are also greatly interested in forecasting the consumer acceptance of vehicles which will be further downsized to meet perceived consumer preferences and federally imposed fuel economy rules. Aggregate vehicle market models do not address these aspects of the vehicle market, and it is these more detailed aspects that have proved to be difficult to forecast reliably.

Although there are doubtless many reasons why existing forecasting models do not apparently make reliable long-run forecasts of components of the total personal vehicle market, the discussion in the past six chapters points to three reasons that are of major importance. First, there is now a larger number of significant influences on the vehicle market than there were even ten years ago, including consumer concern about the future price and availability of fuel. With a larger number of relevant variables it becomes more difficult to measure the independent influence of each variable. Second, models are now asked to predict the consumer acceptance of vehicles that do not yet exist -- for example, "full-size cars" that get 26 miles per gallon but which will be much smaller in exterior size and weight and which may lack the traditional "big car ride." This task is beyond the scope of traditional simple econometric models. Although more advanced models do exist to forecast the demand for "new" products, there is logically a greater level of uncertainty surrounding forecasts made by these models than surrounds forecasts of changes in demand for products that are currently in use. Finally, questions about the composition of the future market are inherently much more difficult to address rigorously than questions about the size of the future market because there is a greater noneconomic element to the choice of type of vehicle to purchase than there is to the decision whether to purchase a vehicle.

Strategies for Understanding the Market

Inherent difficulties in market modeling do not free firms within the auto industry from the need to forecast for purposes of investment and product planning, nor does it free the government from the need to forecast in order to understand the implications of alternative public policies. The research performed for this report bears on the choice of forecasting method and suggests that different forecasting strategies may be appropriate for different sets of forecasting questions.

Size of the Market

As relatively simple models were used to forecast the total vehicle market size prior to the mid-1970s, so simple models are likely to continue to be reasonably accurate in forecasting the size of the market. The total vehicle stock will continue to be largely determined by the size of the population, the level of employment, income levels (with a declining income elasticity), and the cost of vehicle ownership. Sales of new vehicles are determined by net additions to stock plus replacement demand within the existing stock. These components of new vehicle demand are primarily influenced by population and income growth, the cost of new relative to used cars, and cyclical influences including changes in consumer confidence and credit conditions. Appendix II describes other existing enhancements to the causal structure, but even without such enhancements the structure (similar to models provided by commercial economic forecasting firms) should prove adequate for many long-run aggregate market forecasting purposes. Such simple models are likely to continue to perform well because vehicle demand is likely to continue to be determined largely by the number of households, the level of income and employment, and macrocyclical influences. Of course unforeseen changes in the urban geographic structure or public transit availability could lead to unanticipated errors in forecasts of total vehicle demand. However, because of the durability of the nation's building stock and supply-side constraints on explosive growth in transit availability, the impacts of unforeseen changes in urban structure or transit availability on vehicle demand over the next 10 to 15 years are likely to be minor.

Vehicle Travel

Although vehicle travel could conceptually also be forecasted using relatively small-scale and simple models, existing travel data is not of sufficient accuracy and historic variation in vehicle travel from a trend growth line is not great enough to construct a model characterized by a high degree of forecast accuracy. It is clear that travel is related to the size of the vehicle stock, to demographic and income levels, to spatial patterns, and to the cost of driving. But in the near to medium run there is considerable uncertainty about the degree to which discretionary travel might be cut back in response to higher fuel prices and growing congestion, and in the longer run there is uncertainty as to how spatial patterns will be affected by energy prices and how travel will be affected by spatial patterns. At this time an appropriate research and policy analysis strategy may be to use small-scale and inexpensive travel forecasting models estimated on existing data, while recognizing the significant uncertainty in long-run travel forecasts and the difficulties in improving model forecasting reliability.

Vehicle Market Composition

Chapter 6 of this report, and especially page 6-7, discusses the requirements of a fully specified model of the composition of vehicle demand and also the uncertainties inherent in estimating such a model. While further analysis of updated aggregate national or state data, similar in spirit to the WEFA model, might lead to some improvements in market forecasting, it is doubtful that aggregate data can be used reliably to separate influences of different vehicle characteristics, household characteristics, and macroeconomic characteristics on the structure of vehicle demand. Aggregate data do not contain enough independent variation among states (or other levels of observation) in certain key variables to measure the independent influence of these variables. Moreover, since the vehicle choice decision is made at the household level, the use of data collected at a level much more aggregate than the household necessarily excludes potential information about the market.

The preferred modeling approach is to use household level data describing household characteristics and vehicle characteristics to model the structure of vehicle demand. Unfortunately, the construction of a fully dynamic micro level model of the vehicle market composition estimated on household data from different points of time is both complicated and expensive. The models described in Appendix II which use household data have been estimated on single cross-sections. As has been noted, there has not yet been verification of how well these models translate to the time domain for forecasting purposes.

Micro Level Analysis of the Vehicle Market

The development of a fully dynamic large scale micro-simulation model of the motor vehicle market is now an expensive and uncertain task. However, analysis of household level data short of full-scale modeling could lead to significant improvements in the understanding of the vehicle market at modest cost. Such analysis could test alternative hypotheses about the causal structure of vehicle demand, and act as a natural precondition for the construction of a reliable full-scale multi-equation model.

The final part of the research project described in this report consisted of an evaluation of strategies for vehicle market forecasting that would be less costly and hopefully less uncertain than the construction of yet another large-scale demand model. In this section we briefly describe the results of three small-scale exercises analyzing changes in consumer behavior between 1976 and 1979 using household level data. The first provides summary data on the switch by market segment to purchases of smaller cars, and the second uses simple regression analysis to examine changes in gasoline consumption patterns. The third outlines a streamlined statistical model of vehicle ownership. The three simple exercises show that modest expenditures of effort can yield useful insights into the vehicle market. A more complete analysis of the same data could yield considerably more information about the determinants of automotive demand and use and the causes of changes in demand and use in the past few years. We caution that the three exercises are merely illustrations of the use to which disaggregate data can be put, and are by no means intended a a final work product or as a complete analysis of available data.

The choice of a household-level data set to use for examining recent changes in the vehicle market was guided by requirements that the data set:

- Provide information about each household's size, economic status, and geographic location;
- Provide information about each household's motor vehicle holdings including, if possible, the make, model, and age of each vehicle;
- Provide information about each household's vehicle use including, if possible, estimates of annual vehicle miles of travel of each vehicle;

- Provide information on a consistent basis for several different time periods; and
- Provide information that is based on a nationally representative sample.

The data set identified that best met these criteria is the continuing Survey of Consumer Sentiment collected by the Survey Research Center at the University of Michigan. Since this is a telephone survey, it may somewhat overrepresent higher income households, and since it is not primarily a motor vehicle survey, questions about auto usage appear only sporadically. Nonetheless, its scope and apparent accuracy make this Michigan survey the preferred source of general market analysis.[1] Because the Michigan Survey is not a panel, there is no overlap in survey respondents between the two years. Thus, the data are two cross sections of different households.[2]

Switch Toward Smaller Cars

The first example of household level data analysis shows how simple tabulations of vehicle ownership patterns by

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[1]This is not to say that other information about the motor vehicle market should be ignored. Certain government surveys provide detailed information about household characteristics and number of vehicles owned, but no detail about the kinds of vehicles owned. Other press and marketing surveys provide detail about vehicle choice, but the survey samples are typically not nationally representative and response rates are often poor. Although we choose to use the Michigan data set as a primary market analysis information source, other survey data sets may be preferred for specialized purposes.

[2]The survey is actually a revolving panel with considerable overlap in survey respondents in surveys for adjoining quarters.

household type can provide insights into the motor vehicle market and suggest hypotheses relevant to market forecasting. Data were drawn from the University of Michigan surveys taken during the first quarters of 1977 and 1980. Table 7-1 compares 1977 and 1980 "new" vehicle ownership patterns for two types of families, where "new" vehicles are defined as vehicles three years old or newer. In preparing Table 7-1 CRA assigned each make and model of car to one of six size classes ranging from subcompact cars to luxury cars. Light duty trucks comprise a seventh vehicle classification. The vehicle size class assignments correspond closely to those made by Ward's Automotive Reports.

Results from the Michigan Survey contained in Table 7-1 show that between 1977 and 1980 the shift to subcompact cars among one- and two-person families is dramatic. For these families in the survey sample the subcompact share of all new vehicles rose from about 10 percent in 1977 to nearly 40 percent in 1980. The light duty truck share nearly doubled. The shares of compact, mid-size, and full-size cars in new vehicle holdings dropped from a combined total of 69 percent in 1976 to 24 percent in 1979. "New" vehicle ownership trends in the sample of families with three or more members follow the same general pattern, a shift toward more subcompacts, but the strength of the market shift is much less pronounced.

Table 7-1 is an example of how simple tabulations of household level vehicle ownership patterns can lead to hypotheses relevant to market forecasting. Table 7-1 suggests

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"New" vehicles are defined as vehicles manufactured in the current or two previous model years. This definition is used to expand the sample size. Trends in the ownership patterns of all vehicles are similar in direction, but of course less volatile than those for "new" vehicles.

Table 7-1

"NEW"[1] CARS PER FAMILY UNIT

	1-2 Person Families		3+ Person Families	
	1977	1980	1977	1980
Subcompact	.04	.13	.06	.09
Compact	.08	.03	.06	.05
Mid-Size	.08	.02	.04	.05
Full-Size	.13	.03	.07	.05
Luxury	.02	.02	.02	.03
Specialty	.04	.04	.04	.02
LDT (Truck)	.05	.09	.06	.07
TOTAL[2]	.42	.34	.35	.36
No. of Families	200	200	302	351

[1]Cars less than 3 years old.

[2]Rows do not add to total due to rounding.

SOURCE: Tabulated by Charles River Associates Incorporated from University of Michigan Survey Data.

that one- and two-person families tend to be less constrained in their vehicle choice by functional needs than are larger families, and that this flexibility allows their purchase patterns to be quite volatile in response to changes in influences such as fuel prices. On the other hand, larger families may be constrained by a need for vehicle interior space and be less flexible in their purchase patterns. This reasoning implies that the subcompact car market share may be approaching a saturation point, given the large shift to subcompact cars that has already occurred in one- and two-person families. Of course, more recent data patterns and a careful study of the size distribution of families who buy new cars in the United States would be required before one could accept this hypothesis, given the limited evidence contained in Table 7-1.

Changes in Vehicle Travel and Family Travel

More complex analysis of household level data, including regression analysis and statistical tests can provide stronger inferences about the personal vehicle market than can simple tables. In this section we perform a preliminary analysis of the winter 1977 and 1980 Michigan surveys to learn what they imply about the causes of recent declines in fuel consumption. Data on vehicle ownership and annual travel by vehicle (VMT) are combined with household socioeconomic information. We note that miles driven per car per year is estimated by the survey respondent, and it is likely to be measured with considerable noise. However, since the classical conditions of measurement error in the endogenous variable seem likely to be satisfied, regression estimates should not be biased by this measurement problem. We do note, however, that the precision of coefficient estimates is adversely affected.

Vehicle Miles Traveled (VMT) Per Car

Vehicle miles traveled (VMT) is a focus of much research in transportation economics, and numerous models including the WEFA-TSC model have attempted to forecast trends in VMT as a function of the automobile stock, per capita income, and gasoline price. Micro level data allows a different approach.

In the 1977 Michigan survey mean VMT (per car) is 11,235 miles with one standard deviation equal to 7,963 miles. In 1980 mean VMT is 10,033 with a standard deviation of 8,222 miles.[1] Thus, mean VMT fell by 11.3 percent in the three-year period. The standard error of the difference is 438 miles so that the difference is statistically significant at the 5 percent level. Although one can speculate that the lower VMT is a response to higher fuel prices, analysis of the household level data may allow us to understand more clearly the way in which the household adjustment to higher fuel prices works.

We begin with a simple model of VMT with five family-size dummy variables, log income, and the number of other vehicles owned by the household as regressors. The results of the regression exercises for 1977 and 1980 and variable definitions appear in Table 7-2 and immediately point out one important empirical fact which does not change subseouently across different VMT regressions: the R^2 is very low and the regression model does a poor job of prediction since the mean square error is very high. The standard error of the regression is 7,966 miles in 1977 and 8,295 miles in 1980. Furthermore, nearly all estimated coefficients fail standard tests of statistical significance. However, in these regressions the number of other vehicles held by the household

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[1]Throughout this section 1977 and 1980 refer to years of the survey. Most 1977 VMT actually occurred in 1976 and most 1980 VMT actually occurred in 1979.

Table 7-2

1977 AND 1980 VMT REGRESSIONS

1977 VMT Regressions

DEP VAR: MILEZ

F RATIO	2.20
PROB>F	0.0416
R-SQUARE	0.0248

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>¦T¦
INTERCEPT	1	2731.22	4206.615	0.6493	0.5165
FAM_DUM2	1	-1418.02	1384.774	-1.0240	0.3063
FAM_DUM3	1	-1033.36	1365.466	-0.7568	0.4495
FAM_DUM4	1	-1555.41	1618.518	-0.9610	0.3370
FAM_DUM5	1	-3870.87	2039.338	-1.8931	0.0582
LNY	1	1270.293	452.110021	2.8097	0.0051
VEH	1	-792.729723	539.390968	-1.4697	0.1423

1980 VMT Regressions

DEP VAR: MILEZ

F RATIO	1.17
PROB>F	0.3220
R-SQUARE	0.0101

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>¦T¦
INTERCEPT	1	6618.407	4780.598	1.3844	0.1667
FAM_DUM2	1	567.735875	1178.996	0.4815	0.6303
FAM_DUM3	1	1590.108	1131.819	1.4049	0.1605
FAM_DUM4	1	-477.656925	1221.564	-0.3910	0.6959
FAM_DUM5	1	1379.602	1596.555	0.8641	0.3878
LNY	1	346.099791	496.614768	0.6969	0.4861
VEH	1	-422.136764	380.886484	-1.1084	0.2681

where: FAM-DUM = family size dummy variable, ranging from one family member to five or more

LNY = log of nominal family income

VEH = number of additional vehicles owned by the family has a negative effect on vehicle VMT as expected and the estimated income elasticity of VMT at the mean is .113 in 1977 and .034 in 1980, estimates in the expected range. Note that these estimates are not the income elasticities of family miles or gasoline consumption since we condition on the number of family vehicles which is also positively affected by family income.

We now expand our specification in Table 7-3 by introducing vehicle size class dummy variables. We use a 12 entry classification for cars and trucks with car size increasing with increasing class order from Class 1 to Class 6. Trucks are entered in Classes 7 to 12. Small trucks are Class 7, vans are Class 8, pick-ups are Class 10 and so on. We continue to include family size variables and also now include 4 regional dummies, 3 urban-suburban dummies, 2 separate dummies for other vehicles owned, and dummies for newest and smallest vehicles owned. The unexplained variance decreases by 6 percent in 1977 and by 10 percent in 1980, but still the R^2s are low.

The results of the expanded 1977 and 1980 VMT equations in Table 7-3 show that the vehicle class dummy variables are almost all statistically insignificant and that their inclusion raises the R-squared values for the two equations to only .08 and .10. The implication is that, holding other things equal, vehicles of different sizes are driven about the same number of miles per year. Furthermore, 90 percent of the variation in vehicle use is explained by factors other than the variables contained in Table 7-3.

However, Table 7-3 does indicate that the "newest car" coefficient is statistically significant and its value increases between 1977 and 1980. This increase in coefficient value may be related to increased fuel prices and to the improved fuel efficiency of new vehicles. However, a hypothesis about the influence of higher fuel price on the

Table 7-3

EXPANDED 1977 AND 1980 VMT REGRESSIONS

1977 VMT Regressions

DEP VAR: MILEZ

F RATIO	1.79
PROB>F	0.0111
R-SQUARE	0.0822

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>¦T¦
INTERCEPT	1	-3914.61	4564.834	-0.8575	0.3916
NEWEST	1	2689.801	820.439423	3.2785	0.0011
SMALLEST	1	-433.761972	1032.519	-0.4201	0.6746
FAM_DUM2	1	-1451.49	1431.995	-1.0136	0.3113
FAM_DUM3	1	-1284.65	1425.748	-0.9010	0.3680
FAM_DUM4	1	-1253.34	1633.43	-0.7673	0.4433
FAM_DUM5	1	-3215.52	2064.316	-1.5577	0.1199
REG_DUM2	1	2216.419	1049.029	2.1128	0.0351
REG_DUM3	1	1424.243	1104.087	1.2900	0.1977
REG_DUM4	1	1935.564	1016.725	1.9037	0.0575
OTHER1	1	-2125.47	1248.749	-1.7029	0.0892
OTHER2	1	-3249.01	1339.376	-2.4258	0.0156
URB_DUM1	1	-2108.93	913.388341	-2.3089	0.0214
URB_DUM2	1	-1569.44	1049.963	-1.4948	0.1356
CL_DUM2	1	1831.796	1319.848	1.3879	0.1658
CL_DUM3	1	-190.020633	1297.055	-0.1465	0.8836
CL_DUM4	1	1112.164	1154.832	0.9631	0.3360
CL_DUM5	1	369.100786	2182.519	0.1691	0.8658
CL_DUM6	1	849.334158	1626.006	0.5223	0.6017
CL_DUM7	1	4992.26	5745.92	0.8688	0.3854
CL_DUM8	1	3369.541	2435.346	1.3836	0.1671
CL_DUM9	1	-1356.82	3268.6	-0.4151	0.6782
CL_DUM10	1	969.029721	1615.28	0.5999	0.5488
CL_DUM11	1	-4831.24	8098.788	-0.6027	0.5470
CL_DUM12	1	2483.730	2312.634	1.0740	0.2833
LNY	1	1819.637	486.011464	3.7440	0.0002

1980 VMT Regressions

DEP VAR: MILEZ

F RATIO	2.98
PROB>F	0.0001
R-SQUARE	0.1001

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>¦T¦
INTERCEPT	1	4859.804	4845.259	1.0030	0.3162
NEWEST	1	3508.114	751.320395	4.5693	0.0001
SMALLEST	1	-1208.35	873.749564	-1.3829	0.1671
FAM_DUM2	1	360.846198	1187.067	0.3040	0.7612
FAM_DUM3	1	1176.467	1152.154	1.0211	0.3076
FAM_DUM4	1	-634.679029	1211.483	-0.5239	0.6005
FAM_DUM5	1	1786,719	1579.376	1.1313	0.2583
REG_DUM2	1	-2086.01	912.939023	-2.2849	0.0226
REG_DUM3	1	-648.750149	955.295136	-0.6791	0.4973
REG_DUM4	1	1031.18	834.909597	1.2351	0.2172
OTHER1	1	-1908.18	849.073985	-2.2474	0.0249
OTHER2	1	-2607.87	1046.081	-2.4916	0.0130
URB_DUM1	1	753.407956	737.828147	1.0211	0.3076
URB_DUM2	1	473.499146	1062.09	0.4458	0.6559
CL_DUM2	1	309.877833	1119.615	0.2768	0.7820
CL_DUM3	1	-641.789244	1103.178	-0.5816	0.5609
CL_DUM4	1	-1116.33	975.529247	-1.1443	0.2529
CL_DUM5	1	190.881422	1662.031	0.1148	0.9085
CL_DUM6	1	-851.110092	1312.449	-0.6485	0.5169
CL_DUM7	1	-1950.1	5794.154	-0.3366	0.7366
CL_DUM8	1	2755.255	1824.571	1.5101	0.1315
CL_DUM9	1	-2921.06	3711.112	-0.7871	0.4315
CL_DUM10	1	-1124.71	1283.893	-0.8760	0.3813
CL_DUM11	1	-5964.52	5864.713	-1.0170	0.3095
CL_DUM12	1	7491.046	2488.388	3.0104	0.0027
LNY	1	531.461850	488.916213	1.0870	0.2774

distribution of travel by vehicle type requires further confirmation since the coefficient of the "smallest" car variable is not statistically different from zero.

Table 7-3 does indicate that the number of vehicles owned by a family is a significant influence on the VMT of each vehicle. The low explanatory power of the VMT per vehicle equations and the apparent importance of the number of other vehicles owned by the family in determining VMT suggests the hypothesis that miles traveled per family, rather than miles traveled per vehicle, is the appropriate unit of investigation. In fact, as the next section demonstrates, travel per family is more systematic than travel per vehicle.

Family Miles Traveled (FMT)

Economic models typically view vehicle travel as a derived demand for transportation. Accordingly, one would expect household level models of travel (FMT) to perform better than vehicle level models of travel (VMT) since the family rather than the vehicle is the logical decision unit.

In the Michigan survey sample we find that estimated mean family travel in 1977 is 15,402 miles (with a standard deviation of 10,641 miles) and that 1980 mean FMT is 15,506 (with a standard deviation of 12,148 miles). FMT for the two years are not significantly different from each other. Although, as we saw, miles of travel per vehicle declined between 1977 and 1980, mean vehicles per family in the sample rose from 1.90 in 1977 to 2.05 in 1980, roughly compensating for the decline in VMT.

In Table 7-4 we first note that the FMT regressions have more predictive power than the VMT regressions, and that the R-squared has risen to approximately .33. Thus, we do find that FMT appears to be a better basis for modeling vehicle usage than VMT. The 1977 regression indicates that increasing

Table 7-4

FMT REGRESSIONS

1977 FMT Regressions

DEP VAR: TVMT

SSE	23893151141	F RATIO	21.43
DFE	242	PROB>F	0.0001
MSE	98732030	R-SQUARE	0.3470

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>¦T¦
INTERCEPT	1	-14076.1	7305.894	-1.9267	0.0552
FAM_DUM2	1	-415.942221	2122.068	-0.1960	0.8448
FAM_DUM3	1	305.495656	2108.054	0.1449	0.8849
FAM_DUM4	1	-2271.46	2330.739	-0.9746	0.3307
FAM_DUM5	1	-4601.44	3055.267	-1.5061	0.1334
LNY	1	1936.98	777.288119	2.4918	0.0134
VEH	1	9433.369	1050.417	8.9806	0.0001

1980 FMT Regressions

DEP VAR: TVMT

SSE	42298384339	F RATIO	33.00
DFE	396	PROB>F	0.0001
MSE	106814102	R-SQUARE	0.3334

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>¦T¦
INTERCEPT	1	-5064.92	7028.295	-0.7206	0.4716
FAM_DUM2	1	745.055094	1734.095	0.4297	0.6677
FAM_DUM3	1	2810.564	1704.556	1.6489	0.1000
FAM_DUM4	1	71.605730	1689.309	0.0424	0.9662
FAM_DUM5	1	2220.669	2276.799	0.9753	0.3300
LNY	1	656.039161	739.867460	0.8867	0.3758
VEH	1	8242.674	790.750128	10.4239	0.0001

vehicles per family and increasing real family income both would have led us to expect a significant increase in FMT by 1980. However, FMT remained relatively constant as VMT per vehicle fell. Although FMT did not fall between 1977 and 1980, it grew less than we might have expected based on the 1977 cross-section regression. One obvious explanation for this phenomenon is the fuel shortages that existed during part of 1979.

We now consider one additional model of FMT in Table 7-5 which we expand from the specification of Table 7-4 by using the number of vehicles owned by the family in each of the twelve vehicle classes. We find that families are driving cars in Class 1 (subcompacts) and Class 5 (luxury cars) significantly more in 1980 than in 1977 while they are driving the larger cars in Classes 2-4 and 6 significantly less. We do not find an equivalent fall in miles driven in vans and trucks. Thus, there is some evidence of a shift into driving smaller cars more in 1980 than in 1977. However, considerably more exploration is needed before we can be at all confident of these findings, especially since the R-squared levels of the regression are relatively low.

Vehicle Ownership

The last topic we explore is vehicle ownership. Our previous findings on VMT and FMT indicate that the level of vehicle ownership is an important determinant of household vehicle travel. Indeed, it is probably incorrect to treat vehicles owned as exogenous in the VMT and FMT specifications. Here, we develop a streamlined model of vehicle ownership. The predictions from this type of model could be used as instrumental variables in further research where the number of vehicles would be treated as an endogenous variable in the VMT and FMT specifications.

Table 7-5
EXPANDED FMT REGRESSIONS

1977 FMT Regressions

SSE	26503985203	F RATIO	5.52
DFE	232	PROB>F	0.0001
DEP VAR: TVMT MSE	114241316	R-SQUARE	0.2756

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>¦T¦
INTERCEPT	1	-12633.6	8269.401	-1.5278	0.1279
FAM_DUM2	1	902.425707	2327.511	0.3877	0.6986
FAM_DUM3	1	1318.805	2371.733	0.5560	0.5787
FAM_DUM4	1	-2807.3	2549.507	-1.1011	0.2720
FAM_DUM5	1	-4257.38	3370.974	-1.2630	0.2079
LNY	1	2459.994	886.102647	2.7762	0.0059
FCLAS2	1	7733.85	1833.354	4.2069	0.0001
FCLAS3	1	4139.438	1874.907	2.2078	0.0282
FCLAS4	1	4458.965	1390.68	3.2063	0.0015
FCLAS5	1	3335.973	3447.499	0.9677	0.3342
FCLAS6	1	6899.564	2333.565	2.8946	0.0042
FCLAS7	1	8725.443	10988.04	0.7941	0.4280
FCLAS8	1	7652.558	3304.413	2.3159	0.0214
FCLAS9	1	2276.445	5628.259	0.4045	0.6862
FCLAS10	1	7498.137	1705.731	4.3959	0.0001
FCLAS11	1	-583.293013	10908.68	-0.0535	0.9574
FCLAS12	1	7724.263	3199.172	2.4145	0.0165

1980 FMT Regressions

SSE	42088047214	F RATIO	12.24
DFE	386	PROB>F	0.0001
DEP VAR: TVMT MSE	109036392	R-SQUARE	0.3367

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>¦T¦
INTERCEPT	1	-8767.67	7227.113	-1.2132	0.2258
FAM_DUM2	1	1641.014	1776.294	0.9238	0.3561
FAM_DUM3	1	4912.072	1770.663	2.7741	0.0058
FAM_DUM4	1	43.869179	1743.664	0.0252	0.9799
FAM_DUM5	1	3089.398	2345.017	1.3174	0.1885
LNY	1	1705.576	746.603626	2.2844	0.0229
FCLAS2	1	3635.509	1403.927	2.5895	0.0100
FCLAS3	1	3656.305	1359.32	2.6898	0.0075
FCLAS4	1	1330.745	1100.59	1.2091	0.2274
FCLAS5	1	11755.17	2335.459	5.0333	0.0001
FCLAS6	1	3872.465	1479.834	2.6168	0.0092
FCLAS7	1	-1825.45	7485.298	-0.2439	0.8075
FCLAS8	1	12018.56	2037.853	5.8977	0.0001
FCLAS9	1	-2415.33	5368.108	-0.4499	0.6530
FCLAS10	1	7025.489	1291.536	5.4396	0.0001
FCLAS11	1	-2096.77	7482.745	-0.2802	0.7795
FCLAS12	1	13128.99	3256.705	4.0314	0.0001

It seems clear from the underlying problem that a regression specification is statistically inappropriate for a vehicle ownership model because the number of vehicles is an integer value, and perhaps more importantly almost all respondents reply 0, 1, 2, 3 or 4. To take account of the special integer character of the problem, we initially specified two models: a multinomial logit and a Poisson specification. Because of a limited budget we estimated the parameters by minimum chi square techniques. A larger-scale effort would use maximum likelihood techniques and would produce more precise estimates. Also, because minimum chi square estimation depends on grouped data, our specification is quite simple. We use five family classes and five income classes.

The Poisson specification proved to be better so that we only present the results for it in Table 7-6. The Poisson probability of observing x vehicle in a family is

$$p(x/\lambda) = e^{-\lambda}\lambda^{x}/x!$$

We specify $\lambda = Z^{\beta}$ where the Zs are family and income dummy variables. Again, maximum likelihood estimation would allow a much extended list of Zs with region and urban-suburban variables present. But even our first attempt is successful. The results in Table 7-6 can be interpreted by remembering for a Poisson distribution, $EX = \lambda$. Family type 3 which is children present leads to an increase in λ as does increasing income. Other socioeconomic variables, e.g., wife working, might also have a significant effect and could be included in further statistical examination of an analogous type.

Table 7-6

POISSON MODEL FOR VEHICLE OWNERSHIP

1980 Vehicle Ownership

VARIABLE	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>|T|
FAM1	-0.482782	0.636871	-0.7581	0.4536
FAM2	0.464471	0.632110	0.7348	0.4675
FAM3	1.616936	0.718829	2.2494	0.0311
FAM4	-0.237147	0.632110	-0.3752	0.7099
FAM5	0.255458	0.632110	0.4041	0.6886
INC2	0.004482572	0.662695	0.0068	0.9946
INC3	0.506288	0.671667	0.7538	0.4562
INC4	0.888017	0.662695	1.3400	0.1891
INC5	2.329350	0.662695	3.5150	0.0013

Summary

We find that examination of changes in household-level vehicle ownership and usage patterns can provide interesting results with extremely modest expenditures of resources. This chapter has provided an outline of the types of analysis that could be conducted with household-level data. As such it is more useful as an indication of future directions such analysis might take than as a self-contained commentary on the vehicle market. We speculate that one could rather easily construct a "placeholder" micro-level vehicle ownership-FMT-VMT model and somewhat more tentatively, but also rather easily, construct a micro-level fleet composition model. Such a "model" could be regularly updated as new cross-sections of survey results provide more evidence as to actual parameter values and, more importantly, parameter values from different cross-sections could be compared to determine whether the placeholder models represent stable relationships. If not, the results might suggest additional explanatory variables which should be included.

Household-level data could also be used for numerous additional exercises. For example, a vehicle characteristics data set could be appended to the Michigan vehicle ownership data set and demand for different vehicle characteristics -- such as interior space, acceleration, or creature comforts -- could be charted over time. Such an analysis might provide insights into the likely consumer acceptance of even more dramatically downsized vehicles.

Appendix I
DESCRIPTION OF THE WEFA-TSC MOTOR VEHICLE DEMAND MODEL

Background

In the aftermath of the OPEC oil embargo of 1974 and the subsequent increase in world oil prices, government and corporate attention turned to developing long-run strategies for reducing U.S. use of high-priced and uncertain foreign petroleum. Studies found that conservation strategies in the motor vehicle sector of the economy would be both effective and cost-effective. Straightforward calculations showed that the application of "best use" design and engineering already present in 1975 cars to the entire new car fleet could lead to a doubling of new car fleet fuel economy by 1985 with only minor impacts on vehicle carrying capacity, ownership costs, or safety and pollution characteristics.[1] Similar calculations

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[1] Results of these studies are summarized in Office of the Secretary, U.S. Department of Transportation, The Report by the Federal Task Force on Motor Vehicle Goals Beyond 1980 (Washington, D.C.: U.S. Department of Transportation, 1976).

show that large fuel economy improvements in light-duty trucks are also possible.

Given a strong interest by the federal government in implementing a national program to improve motor vehicle fuel economy, alternative policies were devised for encouraging such actions. These policies included several variants of vehicle fuel economy standards, vehicle fuel economy taxes and subsidies, and gasoline taxes. To compare the effectiveness of alternative policies, mathematical models of the auto market were constructed. These models allowed policy analysts to estimate the impacts of alternative policies over time in the level of sales of new vehicles, on the distribution of vehicle sales by size or fuel economy class, on industry revenues, on scrappage of older less efficient vehicles, and, of course, on national fuel consumption. Models built to assess the impacts of fuel-related regulations on the motor vehicle industry could be easily adopted for use in measuring the impacts of other regulatory standards related to environmental protection, safety, or damageability.

One of the most prominent and widely used models of the motor vehicle market is the model developed by WEFA (Wharton Econometric Forecasting Associates) for the U.S. Department of Transportation's Transportation Systems Center. The WEFA-TSC model has been used by federal policy analysts as one of several tools to estimate the impacts of a variety of fuel conservation proposals on the auto industry and on national fuel usage. Proposals which have been examined using the WEFA-TSC model include alternative mandated fuel economy standards, a "gas-guzzler" tax on fuel-inefficient cars, a gasoline tax, and the encouragement of introduction of electric cars into the marketplace.[1]

The WEFA-TSC model is a long-term econometric model of new car and light-duty truck demand in which the structure of new vehicle demand is decomposed by vehicle type (car versus truck, size class of car, and by domestic or imported car). The market determination of total sales and sales shares by vehicle type is assumed to depend on national economic and demographic conditions and on the relative prices and operating costs of the different classes of vehicles. The WEFA-TSC model is also an accounting and econometric model of the vehicle stock which keeps track of the number of vehicles in use and their age distribution, use level, and fuel consumption. Econometrically estimated relationships forecast vehicle scrappage and vehicle miles of travel (VMT) by vintage of vehicle. Finally, the model contains supply-side predictors of vehicle prices and costs based on economic forecasts of vehicle manufacturing input costs and certain characteristics of motor vehicles. The model review contained in this appendix focuses exclusively on the new vehicle demand and on the vehicle stock holdings and usage modules of the model.

Because of the broad scope of the WEFA-TSC motor vehicle demand model, the actual operating software contains about 400 equations employing more than 600 variables. However, the long-run forecasting properties of the model are largely determined by a relatively small number of "desired stock"

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[1]For an interesting discussion of uses of the WEFA model the reader is referred to a report by the University of Michigan's Highway Safety Research Institute, Federal Policy Applications of the Wharton EFA Automobile Demand Model (Ann Arbor, Mich.: The University of Michigan Research Press, 1979).

equations which describe what the pattern of auto holdings and sales would be in a state of long-run equilibrium. Other equations determine the dynamic path by which the long-run vehicle holdings patterns are approached.

The form of the model which was originally developed for TSC and which has been most often used to examine the likely impacts of federal regulatory policy is now called the Mark 0 version of the model. The final report describing the Mark 0 model of new car demand was completed early in 1977.[1] Since that time certain enhancements of the model, including the development of a light truck and van demand module, have been made in what are called the Mark I and Mark II versions of the model. However, these changes are primarily adjustments to the model rather than a restructuring of model logic. This discussion provides an overview of the Mark 0 model and Mark I and Mark II adjustments. The reader interested in a more detailed model description is referred to an excellent description of the model included in Chapters 1 and 2 of the report by the University of Michigan Highway Safety Research Institute (HSRI)[2] or to the three-volume WEFA report.[3] The HSRI model description conveniently arranges the parts of the model according to the major subroutines of the WEFA model software.

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[1]Wharton Econometric Forecasting Associates Inc., An Analysis of the Automobile Market: Modeling the Long-Run Determinants of the Demand for Automobiles, Final Report to the Transportation Systems Center, February 1977.

[2]The University of Michigan Highway Safety Research Institute, Analysis of WEFA Automobile Demand Model (Ann Arbor, Mich.: The University of Michigan Research Press, 1979).

[3]WEFA, An Analysis of the Automobile Market.

Model Structure of the Mark 0 Model

The WEFA-TSC motor vehicle demand model is a large-scale, long-run, econometrically estimated model of the U.S. auto market. The model logic holds that for purposes of long-run demand forecasting vehicle demand can be thought of as following a "stock-adjustment" process. In the stock adjustment framework, at any given time consumers are assumed to want to hold some equilibrium stock of cars which depends on economic conditions, household or consumer characteristics, and vehicle prices and costs. Any change in the desired stock caused by changes in any of the determining variables is translated into a change in the actual stock through the processes of new vehicle sales and changes in the vehicle scrappage rate. However, the stock adjustment process is not instantaneous because of such factors as transaction costs and buyer inertia. Therefore, a dynamic adjustment process by which new vehicle sales and scrappage allow the actual stock to approach the "desired" stock, in size and composition, is estimated. If due to increased income, lower vehicle costs, or other reasons the equilibrium "desired" stock should increase, this will force an increase in new car sales and a decline in the scrappage rate. In long-run equilibrium the levels of sales and scrappage are largely determined by the level of the "desired stock." For this reason an evaluation of the long-run forecasting accuracy of the WEFA-TSC model focuses on the "desired stock" equations.

In disaggregating the market for automobiles by size classes, the WEFA-TSC model assumes that sales by size class are similarly determined by a stock adjustment process. At given levels of exogenous variables and vehicle prices and operating costs, there is some "desired" distribution of the stock by size class. Sales shares are determined largely by the gap between the desired and actual share of any size class. The Mark 0 WEFA-TSC model assigns all cars to one of five size classes, which are called subcompact, compact, mid-size, full-size, and luxury. The size class designation of any car in the historic data base depends mainly on the vehicle's wheelbase and price. However, in constructing the historic size class share data base, wheelbase is a convenient proxy for seating capacity. For model forecasting purposes the WEFA authors intend vehicle size class designations to be determined by a car's seating capacity rather than wheelbase.

In the Mark 0 version of the model, the algorithms for forecasting the desired automobile stock and its composition by size class are estimated on state-level 1972 data. The desired automobile stock and size class shares are influenced by vehicle prices and operating and ownership costs, income and macroeconomic variables, and the geographic and age distribution of the population. WEFA argues that using cross-section data allows the modeler to hold the choice set including technology constant, and that 1972 is an appropriate year for estimation because domestic manufacturers were selling cars in each of the size classes, there were no major supply/demand imbalances, and the national economy was fairly stable. Having estimated algorithms for predicting the desired size and composition of the stock, the algorithms are applied to the historic national estimation data base to predict the desired national stock and composition of the vehicle fleet.

The new car sales predictors and the scrappage predictors are then estimated on the national time-series data base. Both sales and scrappage are a function of the gap between the actual stock and the estimated desired stock. An increase in the desired relative to actual stock leads to a higher sales level and reduced scrappage level.

Sales-Scrappage-VMT Module

Although the long-run forecasting properties of the WEFA-TSC motor vehicle demand model are primarily determined by the equilibrium "desired" stock and "desired" sales share equations, actual annual sales (and scrappage) are forecast as the intermediate path toward the equilibrium. Both sales and scrappage are also influenced by the level of vehicle miles of travel (VMT). The sales, scrappage, and VMT equations are estimated using ordinary least squares regression techniques, but are conceptually simultaneous with annual sales and scrappage influencing each other, both influencing VMT through the fuel economy and age distribution of the stock, and VMT influencing scrappage through physical deterioration.

New Car Sales

New car sales, the principal intended output of the model, depends primarily on the size of the gap between the actual existing stock and the estimated desired stock. However, in the model the sales level is also influenced by the annual change in the real price of the new car since automobiles are found to have a high short-run price elasticity. Sales also depend on cyclical changes in personal income as measured by the ratio of current to permanent (lagged) income levels. Scrappage, which subtracts from the actual stock, also influences new car sales. The split of new car sales into sales of cars in different size classes is specified in a similar manner, with the share of sales in each size class depending on the difference between desired and actual stock by size class.

Scrappage Levels

In the WEFA-TSC model scrappage levels are influenced by the level of auto travel, the desired relative to actual stock, the new car sales level, the average age of the stock, and the average price of older cars. High levels of travel and a relatively old stock lead to higher scrappage levels; a high desired relative to actual stock leads to reduced scrappage, although this factor may be mitigated by high levels of new car sales. A low price of older used cars relative to the price of scrap metal leads to higher scrappage rates.

The Vehicle Miles of Travel (VMT) Estimator

Fuel consumption of the vehicle fleet depends on the size of the fleet, the average fuel economy of the fleet, and the fleet's vehicle miles of travel. In the WEFA-TSC model, vehicle travel is strongly influenced by the age distribution of the existing fleet, under the hypothesis that newer cars are driven more miles than older cars. Real gasoline cost per mile, vintage-weighted fleet fuel economy divided into the inflation-adjusted price of gasoline, is also an important determinant of the national level of auto travel.

Foreign versus Domestic Sales Split

In the Mark 0 version of the model various attempts were made to model the import penetration rate by size class as dependent on the relative prices of imported and domestic cars. However, the model did not provide believable results so in the Mark 0 version import penetration is set exogenously. Apparently, the omission of nonprice/noncost characteristics of domestic and imported automobiles does severely impair the representation of this aspect of the consumer's auto choice decision. In later versions of the WEFA-TSC model the authors do provide a behavioral model of domestic versus imported vehicle sales, but the logic of the specification creates skepticism as to the forecasting accuracy of the model. This issue is discussed in Chapter 6 of this report.

The Used Car Market

The structure of the used car market module, which plays only a minor role in long-run forecasting, is conceptually the weakest link of the WEFA-TSC vehicle demand model. Equations are specified to predict total used car transactions, the price of one-year-old cars relative to new cars, and the price depreciation rate of two- through twenty-year-old cars. Unfortunately, the model fails to separate out demand and supply functions, and for this reason one cannot place confidence in either the price or transactions volume forecasts. Used car prices should properly be a market clearing mechanism.

The Accounting Framework

In addition to the empirically estimated relationships, a large part of the WEFA-TSC acts as an accounting framework to keep track of the stock of cars by size class and age. Central to this portion of the model are several reasonable algorithms based on limited amounts of available evidence which disaggregate total vehicle scrappage into scrappage by size class and vintage (or age) of vehicle. This accounting module allows the model to calculate average fleet fuel economy, VMT, and fuel consumption. Fuel consumption depends partly on the size and composition of the automobile stock by size class and vintage.

Adjustments for Supply-Side Constraints

Two types of adjustments are made to the historic data base to reflect supply-side limitations on the vehicle choice set. Limitations exist because small cars were not widely available to the American public in the early years of the estimation period and domestic subcompacts were not widely available until the 1970s. The first adjustment is that the size class equations use 1971 plus 1972 sales share by class by state as the desired stock, rather than the actual 1972 stocks. WEFA felt subcompacts were underrepresented in the 1972 actual stock, but not in 1972 sales, because of the lack of domestic production in the 1950s and 1960s.

In the estimation of the sales shares by size class equations on time-series data, similar adjustments in the total "actual" size class shares are made to reflect the following supply-side limitations:

- Lack of domestic subcompacts until the 1970s;
- Lack of domestic compacts until the mid-1960s;
- Lack of Japanese imports until the late 1960s; and
- Shifts in size class all at once of Ford, Chevrolet, and Plymouth cars in the late 1950s.

Clearly, these supply-side data adjustments imposed an arbitrary component to the time-series results that are not "dictated" by the data. However, we find no obvious distortion of the data done by WEFA; the adjustments do seem reasonable.

Price and Cost Variables

For many types of government policies, the mechanism by which the policy affects the auto market is through vehicle prices or operating costs. Such policies include fuel taxes, excise taxes, or manufacturer costs of meeting pollution or safety standards which might be assumed to be passed on to consumers through higher prices. Because of the paramount importance of the price and cost variables, they receive more detailed attention.

Measure of Vehicle Costs

The "desired" stock of motor vehicles is assumed to depend on the economic and demographic characteristics of consumers and on the prices and ownership and operating costs of cars. Because of multicollinearity in the cross-section data among cost categories, all costs of motor vehicle ownership and operation are collapsed into a single measure: the capitalized cost per mile. The capitalized cost per mile is really a cost-benefit index consisting of the discounted lifetime stream of expenditures all owners would be expected to make on a given car to the discounted sum of miles the car would be expected to be driven. This assumes a 10-year/100,000 mile vehicle lifetime across all states for all years. Implicit in the aggregation of purchase price, finance costs, and operating costs is an assumed typical consumer discount rate. The total long-run desired demand for vehicles is assumed to depend partly on the average capitalized cost of vehicle ownership, and the distribution of sales by size class is assumed to depend partly on the relative capitalized costs of cars in different size classes.

Two observations about the capitalized cost variable need to be made. First, the state cross-section observations of vehicle costs do account for state differences in vehicle prices, taxes, and fuel cost due to transportation charges and taxes; repair costs and certain other vehicle costs also vary across states. However, WEFA could not find measures of state-level insurance costs and they are implicitly identical across all states. Because state differences in insurance costs are potentially large, relative to differences in vehicle prices and gasoline prices, there is considerable uncertainty as to whether the WEFA capitalized cost measure fully captures state-to-state differences in vehicle ownership costs.[1] The

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[1]This point is discussed at some greater length in Appendix 3-B. Because there is relatively little state-to-state variation in capitalized costs, it is especially important that the capitalized cost be measured accurately.

second observation about the cost variable is that, as Chapter 6 explains, the WEFA-TSC model assumes that vehicle price/cost characteristics are the only characteristics that influence the vehicle purchase decision. That is, the model does not include other characteristics of vehicles -- weight, acceleration, comfort, styling, etc. -- in specifying the structure of demand for new cars. Because federal fuel economy standards are expected to systematically affect these nonprice variables, and because these nonprice variables are known to affect the consumer vehicle choice, the WEFA-TSC model cannot fully capture the market impacts of "downsizing" or other design change responses to the national energy situation. Insomuch as federal energy policy affects the desirability of cars of different size (seating capacity) classes asymmetrically, the WEFA-TSC model will incorrectly forecast sales by market size class. Insomuch as the nonprice characteristics of new cars change relative to the nonprice characteristics of cars already in the auto stock, the WEFA-TSC model may also inaccurately capture the dynamics of the stock adjustment process.

New Car Purchase Price

As HSRI[1] reports, for 1972 full-sized cars purchase and financing costs were 45.4 percent of the capitalized cost per mile, gasoline costs 20.4 percent, and other operating costs the rest. Although the relative share of fuel costs has risen since 1972, the purchase price is still a very important component of the capitalized cost per mile. Since the purchase price makes up a large portion of the "generalized cost per mile," it is important to understand how this variable is

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[1]University of Michigan Highway Safety Research Institute, Analysis of the WEFA Automobile Demand Model, p. 42.

measured. The new car price is calculated as the sum of base purchase price, purchase taxes, transportation charges, and expenditures for options. Because actual new car transaction prices are not actually the list price, the price measure may not be accurate. Whether this source of "errors in variables" would have biased the coefficients of the "desired" size class share equations depends mainly on whether 1972 discounts offered by car dealers differed systematically across size classes (in a pattern different from that of other years). WEFA fails to explore this issue. A second methodological concern with the WEFA construction of the vehicle price is that price is not quality-adjusted for a standard set of options. WEFA does not discriminate between "real" price changes and price changes that occur because of a change in the option package purchased. Because the price variable is not quality-adjusted and because the market penetration of vehicle options has increased over time, the WEFA data set is bound to understate the real decline in motor vehicle prices over time.

We note that a similar price index methodological problem arises in the "desired" class shares portion of the model. The desired shares of stock by each size class depend on the capitalized cost per mile of the different size classes. The total stock of cars depends on the sales-weighted average cost per mile. However, the sales-weighted capitalized cost per mile is not a quality-adjusted price of real vehicle ownership since it does not hold the size class weightings constant or adjust for changes in the "quality" of cars within each size class. As an example of the illogical forecasting results such a price definition may lead to, imagine that the current choice set was augmented by a line of new expensive luxury cars which prove popular and enjoy substantial sales. This would raise the sales-weighted average cost per mile of all automobiles which the WEFA model would predict would lead to reduced new car sales. However, no previously existing car model is increased in price and a popular car line is marketed. Therefore one would actually expect new car sales to increase. Whether this price index problem causes severe parameter estimation difficulties is difficult to assess without constructing an alternative "quality-adjusted" price index with which to reestimate the model. However, it is certain that the failure to "quality-adjust" prices will lead to large forecasting errors if consumers generally believe that downsizing is leading to changed quality of all or some size classes of motor vehicles.

Mark I Improvements to the Basic Model

In June 1978 WEFA completed a draft report for TSC outlining certain improvements to the original WEFA-TSC model of automobile demand. This Mark I report was a prelude to Mark II work in which a light-duty truck module was added. In the Mark I version of the model those passenger van registrations which had been included as car sales in Mark 0 are removed from the car registration counts to be classified as light-duty trucks. The following additional tasks were later described in the WEFA Mark I report:[1]

1. Behavioral equations were added to forecast the shares of imported passenger cars.
2. An accounting module was added so that scrappage by size class could be exogenously forecast.

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[1]Wharton EFA, Inc., Revisions to the Wharton EFA Automobile Demand Model: The Wharton EFA Motor Vehicle Demand Model (Mark I), submitted to the Transportation Systems Center, June 1978 (Draft).

3. Alternative desired stock equations were estimated in which the behavioral units were licensed drivers and population over 16 rather than family units.
4. An algorithm for combining forecasts of fleet fuel economy and vehicle miles of travel was included so that annual fuel consumption could be estimated. The algorithm for estimating actual "on the road" fuel economy was improved.
5. The model was linked to the Wharton macroeconomic model's expenditure and price components.
6. Output tables were changed to give additional forecasted variables of the auto market model.
7. The data base was updated and improved documentation provided.

Changes in the Model's Forecasting Properties

This section describes actual changes or suggested changes made in the behavioral equations of the WEFA-TSC auto market model. Improvements in the output format or the data documentation are not reviewed here.

Changing the Behavioral Unit

Alternative specifications of the total "desired" auto stock equation of the model were tested with a different choice of behavioral unit. Estimating on the basis of licensed drivers leads to statistical results which are slightly stronger but with only slight changes in the estimated income and cost elasticities. WEFA reports that these "are not likely to substantially change previous behavioral conclusions." Estimating on the basis of a population 16 years old and older leads to income and cost coefficients which are somewhat lower, and a slightly lower level of statistical significance of these coefficients. When the behavioral unit is changed to the percentage of the population between 16 and 64 years old, coefficients are almost identical to those in the original "family unit" equations. The general conclusion is that model results are relatively insensitive to the choice of behavioral unit. Estimated parameters of alternative specifications are given in the table below.

ALTERNATIVE DESIRED AUTO STOCK EQUATIONS

Denominator	Income Coefficient	Cost Coefficient	Income Saturation Coefficient
Family Unit	.56	-.20	-.10
Licensed Driver	.61	-.24	-.11
16+ years old	.48	-.10	-.06
16-64 years old	.56	-.20	-.10

Forecasting Domestic and Foreign Market Shares

In the Mark 0 version of the WEFA-TSC motor vehicle demand model the level of import penetration of the U.S. auto market was forecasted by first predicting the distribution of sales by size class and then predicting the level of import penetration within the size classes in which imports compete. However, WEFA reports that the Mark 0 specification "results yielded extremely high elasticities in many cases, which became explosive in a time-series simulation." For this reason the Mark 0 specification was dropped and import shares were set exogenously.

In the Mark I respecification the registrations shares of imports by size class are defined as a share of total registrations (rather than the total registrations in that size class only). This procedure acts to treat the imports as separate "classes" of cars, recognizing that, for instance, some relatively high-priced imported compacts may compete more closely with domestic larger cars and luxury cars than with domestic compacts. This respecification recognizes the results of marketing research, which shows that imports may compete more actively with the domestic cars of the same price class rather than the same size class.

A second Mark I change in the size class equations is related to the definition of relative costs among size classes. In the Mark 0 version of the model the market share of each size class was assumed to be influenced by the cost per mile of cars in that size class relative to the sales-weighted cost of all cars. In analyzing the market impacts of a size class specific tax or subsidy, the Mark 0 specification leads to the illogical result that all competing classes are affected equally rather than the logical result that the closest competing classes are most severely affected. In the Mark I version of the model, the relative cost terms are redefined to be set equal to the size class cost per mile relative to the cost per mile of the neighboring classes.[1] Then, for each of the eight car classes (five domestic and three import), the size class shares are reestimated. Several alternative specifications for each size class equation were tested, and those with the best statistical and simulation properties were included in the WEFA Mark II model. The size class equations are described in Chapter 4 of this report. WEFA reports that size class share model elasticities are plausible for the chosen specifications of each except for the foreign luxury share equation, for which a higher than reasonable price cross-elasticity are reported. We note that although, as WEFA states, "The desired shares are now very interdependent and

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[1]An exception is the mid-size class equation for which WEFA reports better results when the mid-size cost is measured relative to the costs of all other size classes.

highly simultaneous, due to the relative cost per mile terms,"[1] the equations are estimated with ordinary least square regressions. In Chapter 4 of this report the equations are reestimated in a "seemingly unrelated regression" model.

The Mark I version of the WEFA model also contains significant improvements in the vehicle fuel economy and vehicle price estimators. In addition, there is a respecification of the vehicle miles of travel module in which separate equations forecast urban and rural auto travel. Examining the historic estimates of auto travel WEFA notes that except for the 1974 decline, urban travel has risen continuously since 1963, while rural mileage has actually shown an overall downward trend. WEFA concludes that decomposing travel demand into these two components will provide a more reliable VMT forecasting model. Similar variables are used in both equations, such as income, metropolitan/rural population of licensed drivers, and the real fuel cost of driving. We note that WEFA estimates an elasticity of VMT with respect to the fuel cost of driving about -.35. This estimate seems high in light of the modest VMT response to recent large fuel price increases.

Mark II Improvements to the Basic Model

In December 1978 WEFA submitted a draft report to TSC of a Mark II version of the WEFA-TSC automobile market model.[2] The purpose of the Mark II model enhancements was to expand the

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[1]Wharton EFA, Inc., Revisions to the Wharton EFA Automobile Demand Model.

[2]Wharton EFA, Inc. The Demand for Light-Duty Trucks: The Wharton EFA Motor Vehicle Demand Model (Mark II), submitted to the Transportation Systems Center, December 1978 (Draft).

scope of the model to include projections of demand for light-duty trucks in a manner that integrates the automobile and light-duty truck demand forecasting modules. Such a model would allow federal policy analysts to assess the impacts on both cars and light-duty trucks (LDTs) of policies related to fuel economy standards or other motor vehicle industry rules.

Mark II Model Structure

The structure of the Mark II model was purposefully designed so that the Mark I automobile demand would be a primary self-contained part of the overall motor vehicle demand model. The model first has two separate equations to forecast personal use vehicles (cars and personal LDTs) and commercial use vehicles. Personal use LDTs are defined as "lighter vans and pick-ups, plus old sporty utility vehicles," with the definition determined "primarily by the ready availability of both cross-sectional and time-series data."

Using the 1976 state cross-section data, equations are estimated for the desired stock of all personal use vehicles, the desired stock of automobiles, and the desired stock of commercial use LDTs. Personal LDTs are calculated as the difference between total personal use vehicles and automobiles. Given the estimators of "desired" stocks, equations analogous to those contained in the Mark 0 and Mark I models for new registrations and scrappage are estimated on annual data over the 1958-1976 period.

As one would expect, since automobiles make up the dominant portion of all personal use vehicles, the WEFA equations for "desired" personal vehicles and automobiles are quite similar. Both "desired" stocks increase with real permanent disposable income and suburbanization and decline with increases in the income distribution and capitalized cost per mile measures. The desired stock of commercial light-duty trucks is modeled to depend on a different set of variables. These include the industry mix of the state, the rural porportion of road mileage, and the proportion of population over age 65. Cost and suburbanization variables are common to the auto and commercial LDT equations. WEFA admits in the Mark II report that the treatment of personal use LDT as a residual is the result of their failure to "find a convincing statistical model of personal use LDT demand." We regard this method of forecasting personal use LDT demand as a placeholder within the larger WEFA-TSC auto market model.

Translation to the Time Domain

In the Mark II version of the model, the basic method of translation to the time domain used in earlier model versions is maintained. The desired personal vehicle stock and commercial LDT stock time-series were adjusted so that the desired 1976 stocks exactly equaled the 1976 actual stocks. The automobile actual and desired stocks were set to be exactly equal in 1972. After the desired stock predictors are translated to the time domain, equations to forecast new vehicle sales, scrappage and VMT are estimated in a manner exactly like that used in the Mark 0 version of the model.

Mark II Vehicle Miles of Travel

The VMT equations have been respecified for the Mark II version of the model. Separate equations are specified for urban and for rural auto travel, for personal use LDT travel, and for commercial use LDT travel. The independent variables include demographic, geographic, and economic determinants of vehicle travel.

Appendix II

REVIEW OF EXISTING MOTOR VEHICLE DEMAND MODELS

Statistical models that forecast national motor vehicle demand are used extensively as planning tools by private corporations and public agencies. This appendix provides an overview of the current state of the art of motor vehicle demand modeling. As examples, this appendix uses references from an unpublished annotated bibliography of motor vehicle demand models.[1] That bibliography divides auto demand models into four types: single equation-aggregate models which are primarily sensitive to macrocyclical influences; multiequation size class models for evaluating energy policy; discrete choice models which measure the effects of changes in both price and nonprice vehicle characteristics on vehicle demand; and a miscellaneous set of demand-related studies. To preview the results of this report, a study of existing auto demand research indicates:

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[1]Charles River Associates, *Assessment and Improvement of Motor Vehicle Demand Models: Annotated Bibliography*, prepared for the U.S. Department of Transportation, Transportation Systems Center, June 1979.

- The current reliability of auto demand models depends on the use to which the models are to be applied. The impacts on aggregate car demand of changes in macroeconomic conditions or in auto prices and operating costs are well understood. Models depicting the impact of changes in macroeconomic conditions or in auto prices and operating costs on the distribution of car sales by size class may be less reliable. Models in the public domain which forecast the car/light truck sales split are probably unreliable.
- To say that models of car sales by size class may be less reliable is not to say they are unreliable, but only to say such models have not been adequately tested. Chapter 4 of this report critiques the size class component of the WEFA-TSC model, but the reliability of other leading size class models remains untested.
- Existing auto demand models, including those used by DOT, typically assume that changes in vehicle characteristics other than price and operating cost do not affect car sales or the distribution of sales by size class. Evidence concerning the validity of this assumption and the effect of mandated downsizing on the level and distribution of car sales is currently weak and conflicting.
- Larger scale models of auto demand often contain modules which forecast auto travel and auto scrappage. Although there is reason to suspect that the parameters of these modules are not estimated with precision, the weight of existing evidence indicates that both travel and scrappage are relatively insensitive to changes in exogenous factors other than direct controls, including the limits placed by gasoline supply restrictions on auto travel. Although errors in parameter estimates may be large relative

to the small parameter estimates, this need not seriously impair the use of the vehicle demand models of which these modules are a part.

- Some aspects of the current motor vehicle market are currently not well understood. In particular there seems to be no convincing explanation of the growth of the light truck market over the past decade. There is little understanding of whether that growth is a structural response to long-term geographic and/or cultural change, or a relatively short-lived fad. Neither is there any deep understanding of the degree to which cars and light trucks are personal transportation substitutes or the extent to which the omission of the light truck market from a car demand model biases projections of car demand.

In discussing the state of the art of auto demand models we separately discuss aggregate econometric models, size-class models, discrete choice models, and other models including models of vehicle travel, scrappage, and light truck demand.

Models of Total Car Demand

Most aggregate car demand models are single equation models that seek to explain the relatively short-run year to year variations in car sales. Examples of such models include Eastwood and Anderson (1976), Juster and Wachtel (1972), Suits (1958), Westin (1975), and Wykoff (1973). A second category of aggregate models examine cross-section evidence and can be applied to longer-run forecasting. These include the models of Bennett (1967) and Johnson (1978). Finally, the aggregate components of some of the larger models combine short-run and long-run features. These include the models of Difiglio and Kulash (1977) and Schink and Loxley (1977).

Aggregate auto demand models strongly indicate that, in the short-run, variations in year to year car sales levels have been primarily influenced by changes in levels of consumer confidence. These changes are very highly correlated with changes in objective economic variables such as income or the national unemployment rate. This correlation exists because new cars are an expensive consumer durable, and purchase can usually be easily postposed in the face of economic uncertainty. Juster and Wachtel (1972) indicate that objective and anticipatory (confidence) variables perform about equally well as predictors of car demand. Since objective economic variables are themselves easier to predict than anticipatory variables, economic variables are most often used as predictors of short-run changes in demand. Models typically estimate large one-quarter changes in car sales in response to changes in confidence or economic conditions. For example, Luckey (1978) estimates a short-run income elasticity of 3.25; Juster and Wachtel (1972) and Sweeney (1978) each find that a one percentage point increase in the unemployment rate reduces new car sales by about seven percent. Of course, actual elasticities will depend on the model specification: whether income, the unemployment rate, and other cyclical variables appear together in the model.

Price elasticities also appear to have a relatively strong influence on new car sales in the short run. Typical elasticities estimated include -1.6 by Wykoff (1973) and -1.46 by Schink and Loxley (1977). Because of historical multicollinearity among income, auto price, and fuel price variables, fuel price rarely appears directly in an aggregate new car demand equation. More often it is modeled as either a determinant of auto travel that influences demand via scrappage

(Verleger and Osten, 1976) or as one component of an overall car cost index (Difiglio and Kulash, 1977). Estimates of the short-run effect of changes in fuel price on new car sales generally range from about -.15 to -.75. The value of this elasticity depends on whether changes in fuel prices are regarded as independent of accompanying changes in real income and consumer confidence. In the models that aggregate fuel cost with new car price and other costs into an ownership cost index, the elasticity of auto demand with respect to fuel cost also depends on the aggregation weights employed.

In the long run, car demand is primarily determined by the level of transport infrastructure, geographical considerations, population, and income levels as explained by Smith (1975). Most models hold infrastructure-geographic factors constant and assume that car sales are fundamentally determined by population and income. The better models, such as that of Difiglio and Kulash (1977), carefully consider the possible future saturation of car ownership and reason that car ownership level per family is approaching some upper limit. This limit is most often estimated by examining cross-section household level evidence relating auto ownership to household income. Because auto ownership is approaching some asymptotic limit, we can expect that estimated income elasticities derived from time-series analysis will vary depending on the period over which the model is estimated unless there is an explicit modeling of a saturation effect. Models that omit a saturation effect typically arrive at a long-run income elasticity of about 1.0. More sophisticated models, including those of Difiglio and Kulash (1977) and Schink and Loxley (1977), estimate long-run income elasticities that are much lower and that decline over time.

Just as the long-run income elasticity is lower than the short-run income elasticity, so the long-run price elasticity is lower than the short-run price elasticity. As the Wykoff (1973) and RAND(1974) models emphasize, the effect of price changes on demand diminishes with the passage of time, in part because of the parallel movement of used car prices and new car prices: increases in new car prices are soon translated into increases in used car prices and decreases in new car prices net of trade-in value. Since most new cars are purchased as a replacement for a used car, the relevant new car price to most consumers is really the price net of trade-in value. Although one quarter short-run price elasticities are usually estimated to be about -1.5, typical long-run elasticities, allowing used car prices to adjust, are the -.3 estimated by Wykoff (1973), -.5 by Difiglio and Kulash (1977), and -.1 estimated by Schink and Loxley (1977). Because fuel costs are a smaller share of total auto ownership costs than the new car purchase price, the long-run demand elasticity with respect to fuel price is usually estimated to be lower than the price elasticity. Difiglio and Kulash (1977) estimate a long-run fuel price elasticity for new car demand of -.20, Verleger and Osten (1976) estimate an elasticity of -.01, and Schink and Loxley (1977) estimate a value of -.04.

Sales by Size Class

Many fewer size class models than aggregate sales models have been estimated, and there is much less consensus as to the relevant elasticities. Nevertheless, the prominent models do find that:

- Rising income leads to increases in sales shares of larger, more comfortable cars and of subcompact second cars.[1]

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[1]Luckey (1978) confirms this finding for the long-run, but finds that in the short run income increases lead to larger smaller car shares.

- Rising car prices lead to a market shift downward, so that sales shares of smaller cars increase.
- Increases in gasoline prices also lead to a market shift downward, so that sales shares of smaller cars increase.
- Sales shares of more expensive cars are less price-elastic than sales shares of less expensive cars.
- Short-run impacts of exogenous shocks on the sales distribution of motor vehicles by size class are greater than long-run effects.
- Most models find substantial stability in sales shares by size class due to the importance of demographic/geographic factors to the size class sales choice. Such stability may not be manifest when short run fuel supply uncertainties cause a postponement of large car sales. However, this conclusion of market stability is not universally supported. Sweeney (1978) finds that fleet fuel economy responds dramatically to changes in fuel costs, independent of technological changes in the car stock. International comparisons of auto fleet fuel economy also indicate great sensitivity of auto choice to auto operating costs. Recent evidence from the U.S. confirms that the market may be quite volatile with respect to major changes in fuel prices.

Estimated Elasticities

In this section we omit consensus estimates of size class share elasticities because the estimates in leading models are imprecise. In the Difiglio and Kulash (1977) model, car prices and gasoline cost are aggregated into a "generalized cost." In the size class equations only two of the six variables are significantly different from zero at the 95 percent confidence level. In the Luckey (1978) model, relative car class operating costs do not appear and relative prices are only assumed to influence the shares of imported and small domestic cars. The RAND (1974) model does not explicitly forecast size class shares but does forecast fleet fuel economy, finding an elasticity with respect to the price of gasoline of .17. However, relative car prices or income levels do not appear in the equation. The Schink and Loxley (1977) car size class equations have better statistical properties than do other models, but the size class "desired" stock equations tend to be dominated by geographic dummy variables rather than true determining variables. Rather than report size class share elasticities we describe them as untested.

Use of Equations for Forecasting

The application of size class share models for forecasting purposes is a major methodological question. The models define size classes so as to construct an historic database using size class criteria of vehicle weight or wheelbase. The models are then applied to the auto market in future years in which size classes are defined by seating capacity. Since different definitions of size class are used in past and future vehicle designations, there is reason to believe that the models estimated on past shares may not reliably forecast future market shares. The fundamental issue is whether a new generation of downsized cars is perceived by consumers as being more like the older vintage cars with the same seating capacity or the same exterior size.

The uncertain reliability of forecasting auto size class market shares given a shifting set of characteristics which define "size class" is part of a deeper question concerning the use of traditional models for forecasting market shares. These traditional models implicitly assume that the noncost characteristics of cars, or of cars in a given size class, are homogeneous and constant over time. Of course, a major thrust of fuel economy rules is to induce changes in specific noncost characteristics including vehicle weight. Traditional econometric models, including the Schink and Loxley (1977) model currently used by DOT, simply do not address the effect of downsizing and technological change on the pattern of motor vehicle demand, independent of the effects on price and operating costs.[1]

Discrete Choice Models

The failure of traditional econometric models to address the impacts of changes in noncost, nonprice auto characteristics on auto demand has stimulated the development of discrete choice models. Discrete choice models of the auto market have been constructed by Charles River Associates (1978), Lave and Train (1977), and Manski, Sherman, and Ginn (1978). These models assume that automobiles can be treated as bundles of measurable characteristics, and then estimate the values that consumers place on characteristics. The estimates are made using data on actual sales patterns. The inclusion of both cost and noncost variables in the models makes them particularly relevant to analysis of current regulatory policy, since they do address questions concerning the value to consumers of vehicle weight and other noncost characteristics.

The CRA (1978) model fits a model describing consumer tastes for individual car characteristics to aggregate sales share data. Preliminary results indicate that luxury/comfort characteristics are extremely important to consumers and that the

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[1]NHTSA has sponsored three consumer research studies, each of which finds that a significant minority or a majority of new car buyers believe that downsizing is leading to a deterioration in vehicle quality.

consumer impact of mandated downsizing will depend on the degree to which comfort can be engineered into a lighter car. A major lesson of the CRA (1978) modeling effort is that a high degree of heterogeneity exists in the auto market and that one should be careful in making statements about how "the consumer" will react to auto regulatory policies.

The Lave and Train (1977) model uses disaggregate household-level data to estimate the relationship between household demographic/economic characteristics and the car purchase choice. The estimated model of car choice can then be used to predict sales shares of downsized or otherwise redesigned automobiles. Lave and Train measure the relationship of household size to size of auto purchased, age of household head to weight of car purchased, income of household to price of car purchased, and numerous other household characteristic/auto type choice interactions. The model is estimated with a multinomial logit model specification.

Manski, Sherman, and Ginn (1978) have developed a similar discrete choice model which greatly enlarges the scope of the Lave and Train (1977) model. The Manski, Sherman and Ginn model includes both new and used vehicles, cars and light trucks, and number as well as type of vehicle owned by the household. This model generally reinforces the findings of the Lave and Train (1977) model, while adding a dynamic structure that makes the model more useful for evaluating the long-run impacts of fuel economy rules and other auto-related government policies.

Reliability of Discrete Choice Models

The three discrete choice models mentioned above each add a powerful dimension to econometric modeling of the auto market and provide results which are generally consistent with consumer research evidence about the structure of auto demand. They allow the policy analyst to understand the effect of changes in auto noncost characteristics on the pattern of demand and on the welfare of the consumer.

Despite the analytic power of the discrete choice model, there are several important reasons why they should not be used uncritically for policy analysis purposes:

- There has not yet been an independent evaluation of the predictive power of discrete choice models. The models are estimated using cross-section data and results are applied to time-series projections. No tests have yet been applied to determine whether parameter estimates applied from cross-section evidence are in fact stable over time and whether the models do supply accurate market predictions.
- The models tend to have a large component of unexplained variation in car choice, generally held to be the result of omission of such variables as vehicle styling preferrences, unmeasurable vehicle reputations for "quality" which vary across car types, and vehicle purchase transactions costs which keep the car market from instantaneously adjusting to equilibrium. There has been no critical examination of whether the omission of such variables tends to bias coefficients of included variables.
- The models may ultimately be applied to investigating the effects of changes in the new vehicle choice set on levels of total new car sales. Neither the CRA (1978) nor the Lave and Train (1977) model explicitly addresses this issue since they model sales shares given the size of the new car market. The Manski, Sherman and Ginn (1978) model is developed for use as a dynamic auto market model with new car/used car interaction. While the Manski, Sherman and Ginn (1978) model might be reliable, it is estimated on cross-section data and the results of Smith (1975) regarding

auto ownership indicate that cross-section evidence may be a poor indicator of changes on the size of the auto market over time. Taken in this context, the reliability of the Manski, Sherman and Ginn (1978) estimates of the value of "newness," and of other characteristics which determine the impact of vehicle changes on the size of the total new car and light truck market, really depends on the answer to the larger question mentioned in the first two topics of this section: whether cross-section based parameter estimates are both accurate and stable over time.

- Explicit in the Lave and Train (1977) paper and implicit in the two others is the observation that the models are estimated on cross-section data, within which the auto choice set facing all consumers is nearly identical, and then used to forecast effects on consumer behavior of changes in the auto choice set. There has been no confirmation that this procedure does provide accurate projections. This does not mean that the models are unreliable, but only that they have not been tested for accuracy in forecasting changes in vehicle characteristics.
- The Lave and Train (1977) and Manski, Sherman and Ginn (1978) papers estimate the choice model using some form of a multinomial logit model. The applicability of this model specification requires assumptions about the nature of the auto market, including the Independence of Irrelevant Alternatives (IIA) assumption. IIA states that the ratio of market shares of any two types of cars is independent of other types of cars in the choice set. Since the IIA assumption almost certainly does not apply to the auto market, the discrete choice model parameters are probably biased in some yet unmeasured way.

- None of the discrete choice models of the auto market have yet convincingly answered two fundamental questions of federal auto energy policy: what is the value of fuel economy to the consumer? And what is the value of vehicle weight to the consumer?

  The question regarding fuel economy arises because the models include fuel economy but omit other operating costs, including standard maintenance costs, which are correlated with fuel economy. The models do not make explicit whether fuel economy is a proxy for other costs or not. Furthermore, in the current specification of the CRA (1978) model there is a suggestion that poor fuel economy is correlated with desired streamlined styling, an unobserved variable omitted from the model. This correlation biases the estimated fuel economy coefficient toward zero. Even if the current value of fuel economy to consumers could be settled, the model user would still be forced to determine whether present correlations between fuel economy, other vehicle operating costs, and styling desirability would persist in the future. A parallel question arises with regard to the value of vehicle weight. Weight serves as a proxy for a soft, quiet ride; for perceived safety; for perceived durability; and in most vehicles for perceived luxury. Weight may also be desired for other reasons. None of the discrete choice models have yet definitively separated the value to consumers of the different facets of the characteristic "weight." Nor has it been decided whether weight will continue to be associated with these desirable qualities in future vintages of cars.

Auto Travel and Auto Scrappage

Large-scale models of the auto market often include modules for predicting auto travel and auto scrappage. Auto travel influences energy consumption directly and also influences demand for motor vehicles, which is derived from the demand for travel. A paper by Verleger and Osten (1976) is typical of those that tie auto demand closely to demand for auto travel. Auto scrappage is sometimes modeled as a direct determinant of replacement vehicle demand. In larger scale models scrappage is included in an endogenous used car stock-used car demand-used car price module.

Auto Travel Forecasting Models

A recent paper sponsored by the U.S. Department of Transportation has surveyed the quality of existing data sets measuring national automobile travel.[1] The paper finds that estimates of auto travel are imprecise because VMT is not directly measured, and because methodologies employed for estimating national auto travel from fuel consumption or survey data are currently imprecise. Table 8, reproduced from the paper, compares different estimates of annual auto travel per car and per household. For 1974 the Census survey estimates travel at 11,800 miles per car, and the Federal Highway Administration estimates 9,494 miles per car. As the paper explains, these differences have not yet been resolved.

Given the poor quality of existing VMT data, one must accept the presumption that estimates of VMT elasticities are likely to be inaccurate. However, there are a large number of studies which indicate that in the long run VMT is highly influenced by highway quality and average travel speeds, but relatively insensitive to income and gasoline prices (at constant levels of auto ownership). The message of these studies

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[1]Leon Rudman, "Vehicle Miles Traveled: An Evaluation of Existing Data Sources," presented at the Transportation Research Board Meetings, Washington, January 1979.

TABLE 8. COMPARISON OF ANNUAL MILES DRIVEN

Per Automobile	Per Household	Survey (S) or Estimate (E)	Date	Source
11,600		S	1969	"Annual Miles of Automobile Travel," Report No. 2, Nationwide Personal Transportation Study, U.S. Department of Transportation, Washington, D.C., 1972.
11,800	16,800	S	1974	1973 and 1974 Surveys of Purchases and Ownership, Bureau of the Census, U.S. Department of Commerce, 1976.
9,494		E	1974	Selected Highway Statistics, 1974, Federal Highway Administration, U.S. Department of Transportation, 1976.
9,889	16,828	E	1974	Comprehensive Human Resources Data System (CHRDS), Mathematic Policy Research, Inc.
15,300 (small car) 13,480 (medium car) 14,180 (large car)		S	1976	Study of Automobile Dynamic, Arthur D. Little, Inc. 1976
9,900	16,400	S	1976	The Study of America Markets: Automobile Markets, U.S. News and World Report, 1976.

is that auto travel is integrated into the spatial distribution of employment centers, retail outlets, and residences and that the public is likely to adjust to higher fuel prices by switching to more fuel-efficient cars rather than by severely restricting auto usage. Long-run fuel price elasticities of travel are generally estimated to be between -.1 and -.4. Difiglio and Kulash (1977) estimate it to be -.27, RAND (1974) estimates -.37, Sweeney (1978) estimates an elasticity of -.24, and Verleger and Osten estimate an elasticity of -.10. Given the poor quality of basic auto travel data, it is probably not feasible to provide a more precise estimate of an auto travel price elasticity.

Auto Scrappage

Models of auto scrappage are also affected by data availability problems, including those related to the accuracy of auto travel data. Most models of auto scrappage are estimated on annual time series data constructed as the difference of annual new car registrations and the year to year difference of annual new car registrations. Auto scrappage rates are generally found to depend on the prices of new cars relative to used cars (Difiglio and Kulash, 1977) or on the cost of auto repairs relative to auto prices (Parks, 1977). In addition, scrappage is found to depend on the age structure of the auto fleet and the accumulated mileage in the auto fleet (Schink and Loxley, 1977; Verleger and Osten, 1976). It would be extremely useful to understand the relative effects of age and use on scrappage rates. Unfortunately, the poor quality of auto travel data and the heroic assumptions that must be made in allocating the travel to different vintages of auto preclude putting much confidence in estimates of the relative effects.

The Light Truck Market

Over the past decade the personal light truck market has grown much faster than the car market. Light trucks include pick-up trucks, panel trucks or vans, and utility four-wheel drive vehicles. At this writing there is still no convincing model explaining the growth of the light truck market. That growth is not due to relative price changes, since prices have not shifted to favor trucks, nor are they due to income changes since personal trucks are not owned by higher income groups.[1] The strongest correlation of truck ownership patterns with household characteristics seems to be geographic/cultural. Light truck owners are most often nonurban households with interests in fishing, hunting and camping.

In principle the modeling of the automobile market should depend critically on inclusion of the personal light truck market. To the extent that the two types of vehicles are substitute goods, failure to include the light truck segment of the motor vehicle market may bias estimated auto demand elasticities. In addition, an understanding of car/truck substitution is required for predicting personal motor vehicle fuel consumption and for modeling the effects of automotive regulatory policy. Although modeling the personal light truck market is certainly a research priority, at present there is no well-defined and unambiguous method for testing alternative theories of that market. Judgments as to the effects of emissions rules, car downsizing, geographic population shifts, and the influence of a "rustic chic" fad element on light truck sales remain judgments in the absence of rigorous hypothesis testing.

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[1] Charles River Associates, *Consumer Behavior Towards Fuel Efficient Vehicles*, Chapter 5, prepared for the National Highway Traffic Safety Administration, 1979.

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APPENDIX III

REPORT OF NEW TECHNOLOGY APPENDIX

The work performed under this contract has led to an evaluation of the logical consistency and forecasting accuracy of econometric models of automobile demand. Model evaluation work has lead to suggestions of strategies for better understanding of the automotive market.

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