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Investigation of Variations in Monthly Market Shares of Light-Duty Vehicles

Patricia S. Hu
Russell Lee

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INVESTIGATION OF VARIATIONS IN MONTHLY MARKET SHARES OF LIGHT-DUTY VEHICLES

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EXECUTIVE SUMMARY

The market shares of new, light-duty vehicles sold in the United States have exhibited both long term and monthly patterns. The purpose of this study was to statistically identify these systematic patterns. The time period studied was from October 1977 to May 1986.

The market shares of domestic automobiles have declined steadily from 71.2% of the light-duty vehicles market in October 1977 to a low of 47.2% in November 1985. The market shares of import automobiles were 11.3% in October 1977, and peaked at 25.6% in August 1982 before declining somewhat to 18.6% in May 1986. The market shares of domestic light trucks had a low of 11.3% in March 1981 and subsequently increased to a high of 25.2% in November 1985. The market shares of import light trucks were 1.9% in October 1977, peaked at 6.1% in August 1980, declined thereafter, and peaked again at 7.5% in July 1985.

Time series models were developed to identify the major patterns in the monthly market shares in each of the four light-duty vehicle categories. The transfer function-intervention models were able to capture the long term patterns. Import automobiles, with their complicated pattern, exhibited a high-order autoregressive-moving average behavior. The time series of the other light-duty vehicles were modelled as first-order autoregressive processes, in which market shares were proportional to the previous month's share.

Monthly trends and economic factors were also identified by the models. Lower gasoline prices (0.12% absolute change in market share for a one cent change in gasoline price), and the months of April (1.8%), October (3.9%) and November (1.8%) were associated with higher market

shares for domestic automobiles (numbers in parentheses represent the absolute changes in market shares compared to the share that would otherwise have been expected).

Low-interest financial incentives were introduced by domestic manufacturers in August and September 1985. They intented to stem or reverse the lower than expected market shares in that summer. These incentives led to a market share for domestic automobiles that was 6.3% higher than the share that would otherwise have been expected. Termination of the financial incentives, however, led to an extended decline of 6.9% in the domestic automobile market shares compared to the shares that would otherwise have been expected.

Lower gasoline prices (-0.11%/cent), the months of March (-1.7%), October (-2.8%) and November (-1.8%), and the financial incentive programs offered by domestic auto makers (-3.3%) were associated with declines in the market shares of import automobiles. Perhaps surprisingly, the financial incentive program also resulted in a decline of 3.4% in the market shares of domestic light trucks compared to the shares that would otherwise have been expected, even though the incentives were offered for domestic light trucks, as well as for domestic automobiles. Lower gasoline prices (-0.036%/cent) and the domestic auto makers' financial incentive programs (-1.5%) were associated with lower market shares for import trucks. Shares for import trucks were generally higher in August (0.78%).

The time series models displayed very high correlations between the actual market shares and the predicted historical shares. The modeling procedure allows for additional market-related events to be included as factors affecting market shares. The results indicate that similar models may be developed for the monthly market shares of individual makes and models, and they provide insights to possible enhancements of vehicle choice models.

ABSTRACT

The purpose of the study was to identify systematic patterns in the monthly market shares in each of the four light-duty vehicle categories: domestic automobiles, import automobiles, domestic light trucks, and import light trucks.

Time series models were developed to identify the major patterns in the monthly market shares, using the ARIMA (AutoRegressive Integrated Moving-Average) modeling technique derived by Box and Jenkins. The technique identified temporal lags in monthly market shares and estimated the coefficients of both lagged and economic variables.

In general, monthly trends, gasoline prices, and low-interest financial incentive programs exhibited significant impacts on monthly market shares. Lower gasoline prices, the months of April, October and November, and low-interest financial incentives in August and September 1985 were associated with higher market shares for domestic automobiles. Termination of the financial incentives led to a decline of 6.9% (relative to the market share that was otherwise expected) in the domestic automobile market share. Lower gasoline prices, the months of March, October and November, and the financial incentive programs offered by domestic auto makers were associated with declines in the market shares of import automobiles. Perhaps surprisingly, the incentive programs also resulted in a decline of 3.4% (relative to the market share that was otherwise expected) in domestic light truck market shares.

INVESTIGATION OF VARIATIONS IN MONTHLY MARKET SHARES OF LIGHT-DUTY VEHICLES

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1. INTRODUCTION

This report presents a study of the changes in the monthly market shares of new, light-duty vehicles. The sales of domestic automobiles, import automobiles, domestic light-duty trucks, and import light-duty trucks are expressed in percentage terms relative to the sales of all light-duty vehicles. The emphasis is on market shares, rather than on actual sales, per se. Two interesting questions are addressed: (1) are there systematic monthly variations in the market shares of domestic automobiles, import automobiles, domestic light-duty trucks, or import light-duty trucks? and (2) does gasoline price affect monthly market shares?

These questions are important in many ways. The sales of new light-duty vehicles (as well as the scrappage rates of used vehicles) will affect the average fuel economies of the vehicle fleet in the country in subsequent years, as well as on a seasonal basis. This will have a rather direct impact on gasoline consumption. Also, changes in market shares are important in terms of their seasonal as well as their longer term implications for imports; trade policy; and production, revenues and employment in the automobile industry. Knowledge of systematic patterns in market shares would allow manufacturers to better predict sales and thus plan production. It would also provide a better understanding of the competition between domestic and imported vehicles in terms of logistical (e.g. the time required to ship vehicles from foreign plants to domestic showrooms), political, and economic (e.g. income, vehicle prices, and fuel prices) factors.

The aggregate approach adopted in this study complements the microeconomic models of automobile demand, such as those presented in the August 1985 special issue of Transportation Research (Vol. 19B, No. 4). The changes in monthly market shares that were identified in this study were a reflection of vehicle choices made by individual consumers. The microeconomic approach is typically represented by a nested multinomial logit model (Mannering and Train, 1985). Berkovec and Rust (1985) used this model for the choice of automobile makes and models. The variables that were included in the model were a set of purchase price and operating price variables, passenger carrying and performance variables, and other variables (including dummy variables for foreign-produced vehicles and for the major domestic manufacturers). One of their results was that foreign-produced vehicles had positive valuations. Our study differs from the microeconomic studies in that a statistical explanation was sought for historical changes in the monthly market shares of light-duty vehicles in the United States, rather than for explanations of the specific vehicle characteristics that were valued highly in individuals' discrete choices of vehicles.

Lave and Bradley (1980) have estimated the market share of import cars using geographic and demographic determinants. They estimated a regression model using 1975 State aggregate statistics, as well as other linear and nonlinear models with data from a random sample of 895 households, which was collected by Cambridge Systematics, Inc. The two most important factors were location in coastal parts of the country (which was interpreted as relative marketing effort), and education — both of which had strong positive effects on import market shares. These results were limited to cross-sectional analyses, however, and did not address the time-series changes in monthly market shares which were the subject of this study.

This study focuses on the development of time series models of market shares of light-duty vehicles. These models provide a means of identifying monthly and seasonal trends in market shares in past years, and of forecasting market shares in the future. In classical statistical techniques, the order of the observations is irrelevant. However, it is not true for time series data. A time series is a sequence of measurements ordered by a time parameter. Examples are quarterly car sales, annual average fuel economies, and monthly market shares (the latter being the subject of this study).

There are many problems in analyzing time series data using standard statistical techniques. One of the most severe problems is the autocorrelation observed in the error terms. Since the error terms in these models do not follow a random process, they lead to inconsistent estimates of the standard errors of the parameters. This invalidates the hypothesis tests of the estimates in the model and results in imprecise forecasts. As a result, the correlated error terms provide results from hypothesis tests that lead to misleading conclusions and the forecasts generated from the model tend to exhibit wider confidence intervals.

Many techniques have been developed to analyze time series data. This study used the ARIMA (AutoRegressive Integrated Moving-Average) modeling technique. This technique was devised by Box and Jenkins in a series of articles and in a subsequent book (Box and Jenkins, 1976), and is common and widely accepted in the time series and econometrics literature.

Data for the study were from the Oak Ridge National Laboratory MPG and Market Shares Data System. This data system maintains monthly information on light-duty vehicles since model year 1978. The information includes sales data, fuel economies, and various vehicle characteristics on an individual nameplate basis (Hu and Till, 1986). The development and maintenance of the data base is sponsored by the Office of Transportation Systems, U.S. Department of Energy.

The monthly market shares data of domestic automobiles, import automobiles, domestic light-duty trucks, and import light-duty trucks were each considered in aggregate, and were fitted to separate ARIMA models, one for each of the categories. Included in the models were monthly dummy variables, one for each month of the year, and the gasoline price. Intervention models were also developed in combination with the transfer functions by including a set of dummy variables in an attempt to capture the impact of the 7.5% and 7.7% APR (Annual Percentage Rate) financial incentive programs offered by the domestic auto manufacturers during August and September 1985, as well as the post-incentive impact.

Section 2 of this report briefly describes the monthly market shares data. Section 3 presents the ARIMA models for the market shares of domestic automobiles; Section 4, import automobiles; and Section 5, domestic light-duty trucks and import light-duty trucks. Section 6 summarizes the conclusions from the various models.

2. DATA DESCRIPTION

The monthly market shares data were obtained from the Oak Ridge National Laboratory MPG and Market Shares Data System (Hu and Till, 1986), and the monthly gasoline prices were abstracted from the Survey of Current Statistics compiled by the Bureau of Economic Analysis. The market shares were defined as the sales shares of all new light-duty vehicles. By definition, the market shares of the domestic car, import car, domestic light truck, and import light truck categories sum up to 1 for any given month and year. The gasoline prices were for regular leaded gasoline expressed in 1967 dollars.

Tables 1, 2, 3 and 4 present the monthly market shares of domestic cars, import cars, domestic light trucks, and import light trucks between model years 1978 and 1986 (up to May 1986), respectively. Table 5 lists the gasoline prices during this period. Figures 1 through 4 illustrate the market shares data of the domestic car, import car, domestic light truck, and import light truck categories between model years 1978 and 1986, respectively. Figure 5 illustrates the monthly gasoline prices during this period.

Table 1
MONTHLY MARKET SHARES OF
DOMESTIC AUTOMOBILES
(in %)
Model Years 1978-1986

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**ANN. AVE.**
1977										71.2	68.6	65.7	**68.5**
1978	62.7	63.1	63.8	65.4	65.8	65.6	63.5	61.2	64.0	67.6	65.8	64.5	**64.4**
1979	64.4	63.3	62.2	62.8	61.6	63.1	63.2	62.2	61.0	63.6	61.7	60.5	**62.5**
1980	58.9	59.3	61.4	59.7	58.4	57.7	56.5	57.7	60.1	66.7	63.3	59.8	**60.0**
1981	60.5	59.5	63.3	58.2	58.5	57.3	57.9	61.9	62.6	61.3	59.5	55.1	**58.6**
1982	53.0	55.6	56.0	59.2	60.4	54.2	53.9	53.5	56.6	59.8	59.0	55.2	**56.4**
1983	54.2	55.3	56.1	58.1	57.6	56.3	55.9	54.5	55.8	60.6	57.7	54.5	**56.4**
1984	56.7	58.0	57.5	59.5	56.8	57.0	57.1	55.0	55.7	56.2	54.4	54.1	**56.5**
1985	53.9	54.6	56.7	58.5	55.1	52.3	48.9	56.8	58.9	49.8	47.2	47.9	**53.4**
1986	53.2	52.5	50.4	51.8	51.4								**51.8**
MONTHLY AVERAGE	**57.5**	**57.9**	**58.6**	**59.3**	**58.4**	**57.9**	**57.1**	**57.9**	**59.3**	**61.9**	**59.7**	**57.5**	**58.6**

Table 2
MONTHLY MARKET SHARES OF
IMPORT AUTOMOBILES
(in %)
Model Years 1978-1986

Year	Month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**ANN. AVE.**
1977										11.3	12.8	14.7	**13.0**
1978	15.9	14.5	13.8	13.5	13.1	12.6	13.6	16.3	15.7	11.4	12.0	12.8	**13.8**
1979	13.5	15.1	17.6	17.6	19.3	17.8	17.4	18.1	17.4	14.6	17.0	18.5	**17.0**
1980	21.7	21.9	20.4	22.1	22.9	21.2	23.7	23.3	22.7	17.6	19.4	22.0	**21.6**
1981	22.0	23.4	20.8	22.8	22.5	21.9	23.5	19.8	19.4	19.4	20.4	24.5	**21.7**
1982	23.5	21.0	19.3	19.7	19.1	23.2	24.5	25.6	21.0	20.2	19.0	22.0	**21.5**
1983	23.2	22.7	20.2	18.1	18.6	19.4	20.4	21.1	17.2	17.2	17.8	17.9	**19.5**
1984	18.1	15.8	15.3	13.9	16.5	16.8	16.5	18.5	16.6	16.6	17.3	18.2	**16.7**
1985	17.3	15.8	14.5	14.8	17.9	18.6	19.5	18.9	15.4	20.9	21.8	21.2	**18.0**
1986	19.6	18.6	19.3	18.1	18.6								**18.9**
MONTHLY AVERAGE	**19.4**	**18.8**	**17.9**	**17.8**	**18.7**	**18.9**	**19.9**	**20.2**	**18.2**	**16.6**	**17.5**	**19.1**	**18.6**

Table 3
MONTHLY MARKET SHARES OF
DOMESTIC LIGHT TRUCKS
(in %)
Model Years 1978-1986

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**ANN. AVE.**
1977										15.5	16.5	17.4	**16.5**
1978	18.6	19.8	19.8	19.1	19.0	19.8	20.7	19.7	17.2	18.2	19.4	19.4	**19.2**
1979	19.2	18.1	16.4	15.6	14.9	15.4	15.4	16.2	18.1	18.7	17.3	16.9	**16.8**
1980	14.5	13.5	13.6	13.4	14.0	16.6	14.5	12.9	11.5	12.0	13.6	14.5	**13.7**
1981	13.1	12.3	11.3	14.2	14.4	15.9	14.0	13.5	12.9	15.1	15.7	15.0	**13.9**
1982	19.1	19.1	20.4	17.6	17.1	18.8	17.1	15.8	18.0	14.9	17.5	18.1	**17.8**
1983	18.1	18.2	19.6	20.4	20.0	20.5	19.4	18.4	21.7	18.9	20.6	22.8	**19.9**
1984	20.8	21.5	22.6	22.6	21.9	21.5	21.7	19.8	22.8	22.6	23.1	21.8	**21.9**
1985	23.2	24.0	23.6	21.5	21.6	24.0	24.2	19.2	20.6	23.9	25.2	24.5	**23.0**
1986	21.5	22.5	23.1	23.8	24.0								**23.0**
MONTHLY AVERAGE	**18.7**	**18.8**	**19.0**	**18.7**	**18.5**	**19.1**	**18.4**	**16.9**	**17.9**	**17.8**	**18.8**	**18.9**	**18.5**

Table 4
MONTHLY MARKET SHARES OF
IMPORT LIGHT TRUCKS
(in %)
Model Years 1978-1986

Year	Month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**ANN. AVE.**
1977										1.9	2.0	2.2	**2.0**
1978	2.8	2.6	2.6	2.1	2.1	2.1	2.3	2.8	3.1	2.8	2.7	3.2	**2.6**
1979	2.8	3.5	3.8	4.0	4.1	3.7	3.9	3.6	3.4	3.1	4.0	4.1	**3.7**
1980	5.0	5.3	4.6	4.8	4.8	4.6	5.3	6.1	5.6	3.7	3.6	3.8	**4.8**
1981	4.4	4.8	4.6	4.8	4.6	4.8	4.6	4.8	5.1	4.2	4.4	5.5	**4.7**
1982	4.4	4.3	4.3	3.5	3.4	3.8	4.5	5.2	4.4	5.0	4.4	4.8	**4.3**
1983	4.5	3.7	4.1	3.3	3.8	3.7	4.4	5.9	5.3	3.3	3.9	4.8	**4.2**
1984	4.4	4.6	4.6	4.0	4.8	4.7	4.8	6.6	4.9	4.6	5.2	6.0	**4.9**
1985	5.6	5.6	5.2	5.3	5.4	5.1	7.5	5.1	5.0	5.5	5.7	6.5	**5.6**
1986	5.7	6.4	7.2	6.3	6.0								**6.3**
MONTHLY AVERAGE	**4.4**	**4.5**	**4.6**	**4.2**	**4.3**	**4.1**	**4.7**	**5.0**	**4.6**	**3.8**	**4.0**	**4.6**	**4.4**

Table 5
MONTHLY GASOLINE PRICES
REGULAR LEADED
(in 1967 $)
October 1977 - May 1986

Year	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1977										.403	.399	.397
1978	.398	.397	.397	.398	.402	.407	.414	.421	.424	.425	.431	.439
1979	.532	.544	.569	.600	.633	.683	.724	.753	.770	.776	.786	.817
1980	.876	.925	.953	.956	.960	.962	.960	.959	.949	.946	.949	.959
1981	.963	1.03	1.05	1.05	1.04	1.03	1.02	1.02	1.02	1.01	1.01	1.01
1982	.999	.980	.938	.893	.907	.966	.982	.975	.961	.948	.939	.918
1983	.891	.855	.827	.879	.915	.931	.939	.935	.925	.911	.899	.891
1984	.879	.875	.875	.890	.897	.892	.878	.868	.871	.876	.874	.862
1985	.824	.809	.833	.870	.890	.897	.897	.889	.878	.869	.873	.873
1986	.861	.804	.695	.634	.663							

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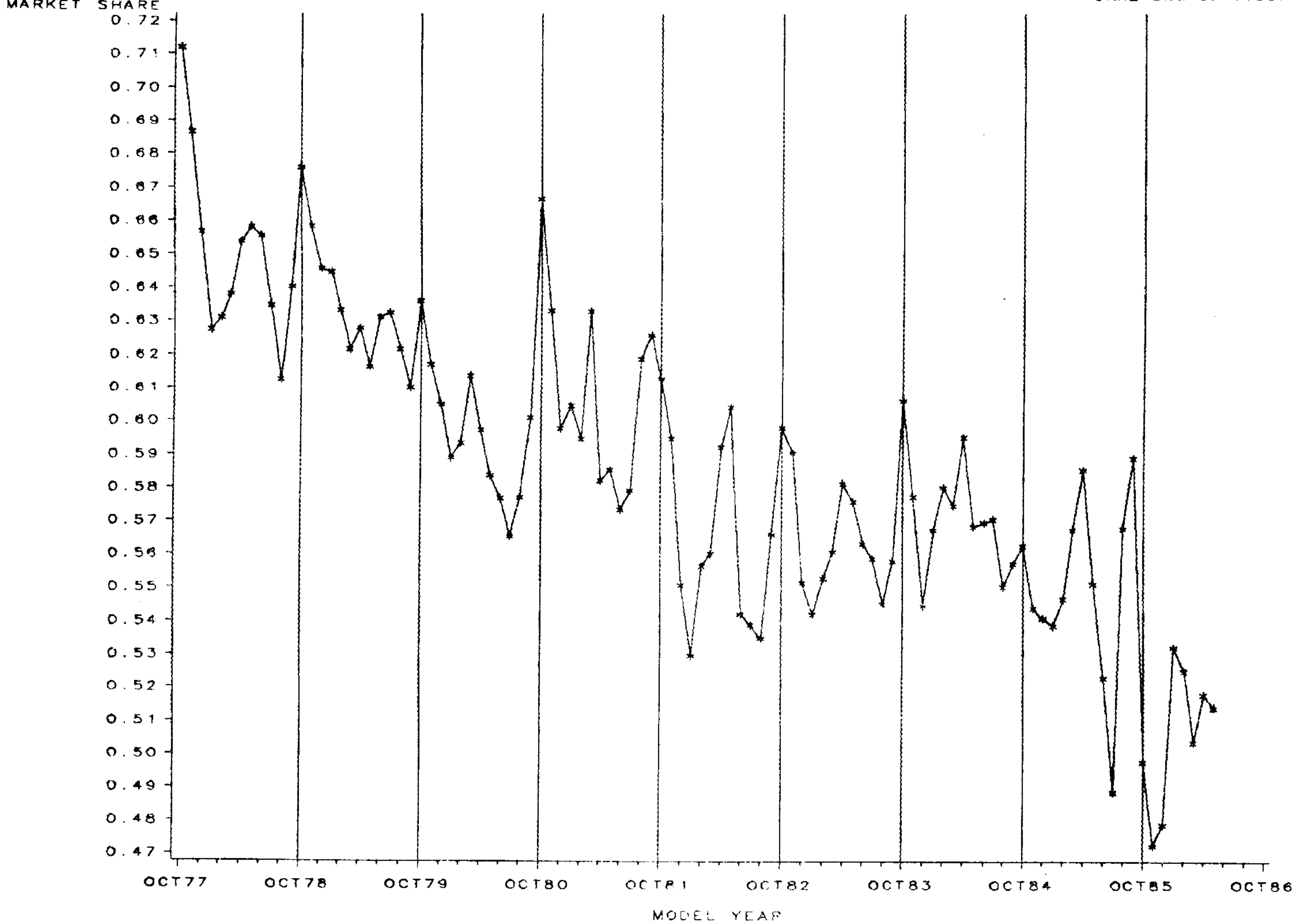

Figure 1. Monthly Market Shares of Domestic Automobiles.

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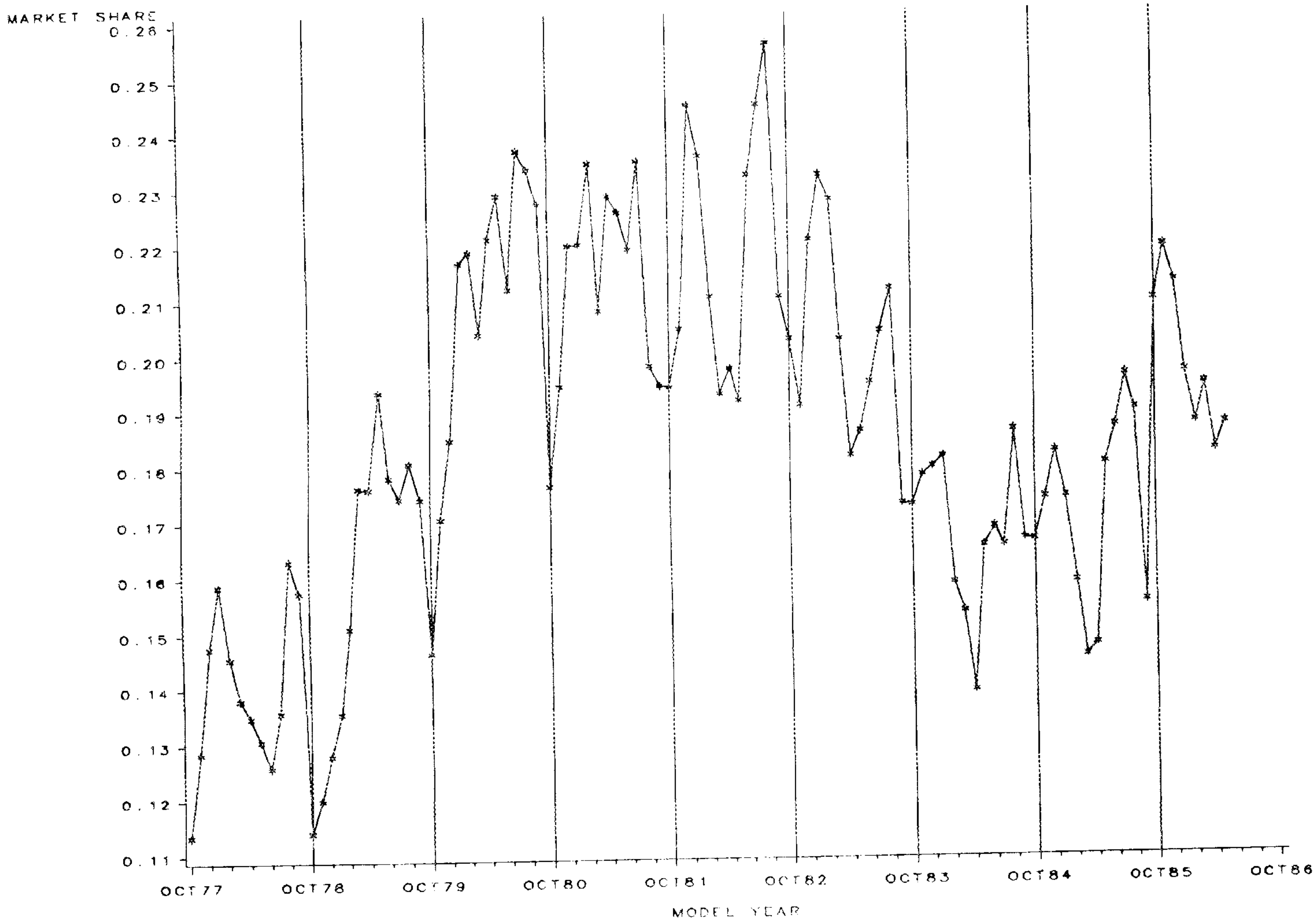

Figure 2. Monthly Market Shares of Import Automobiles.

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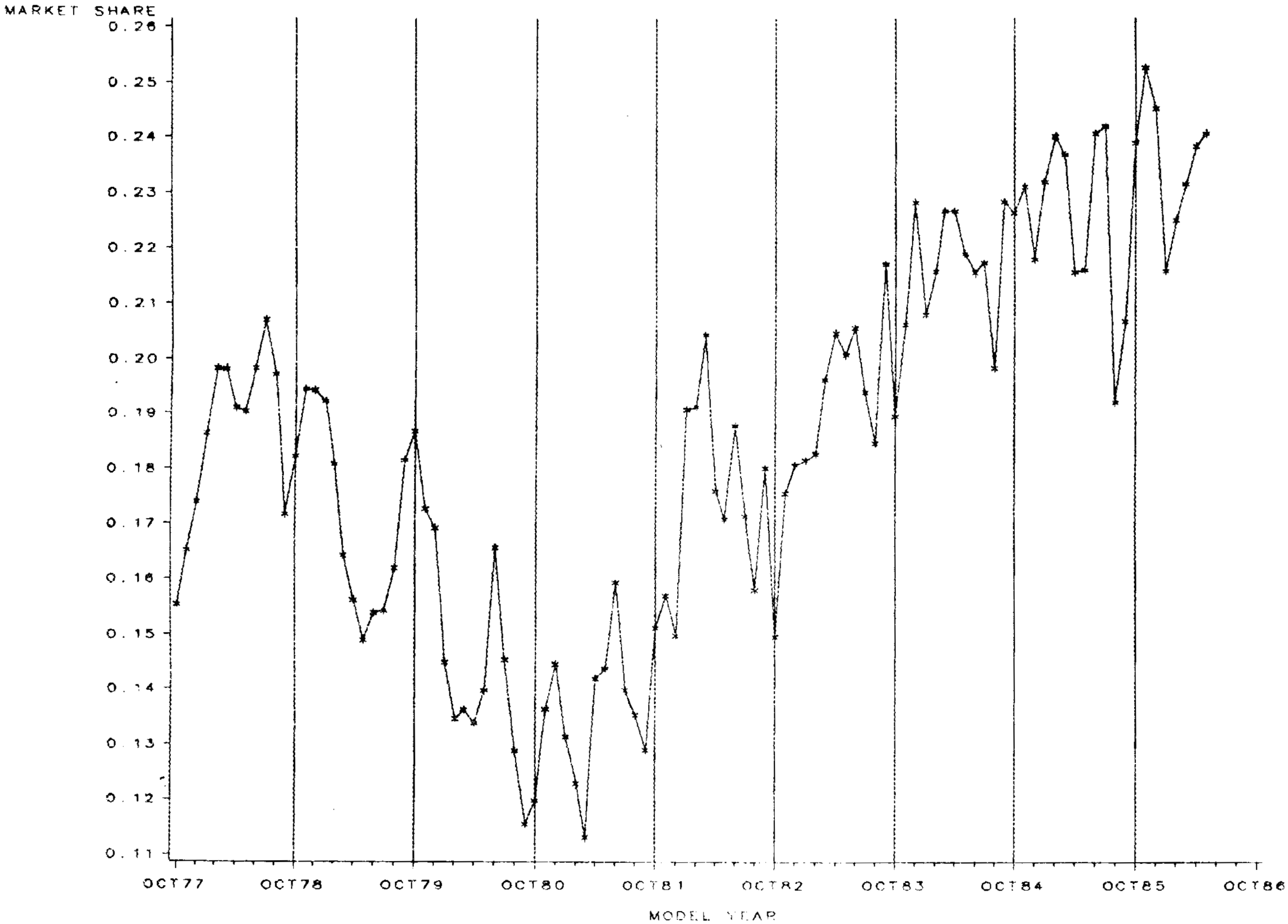

Figure 3. Monthly Market Shares of Domestic Light Trucks.

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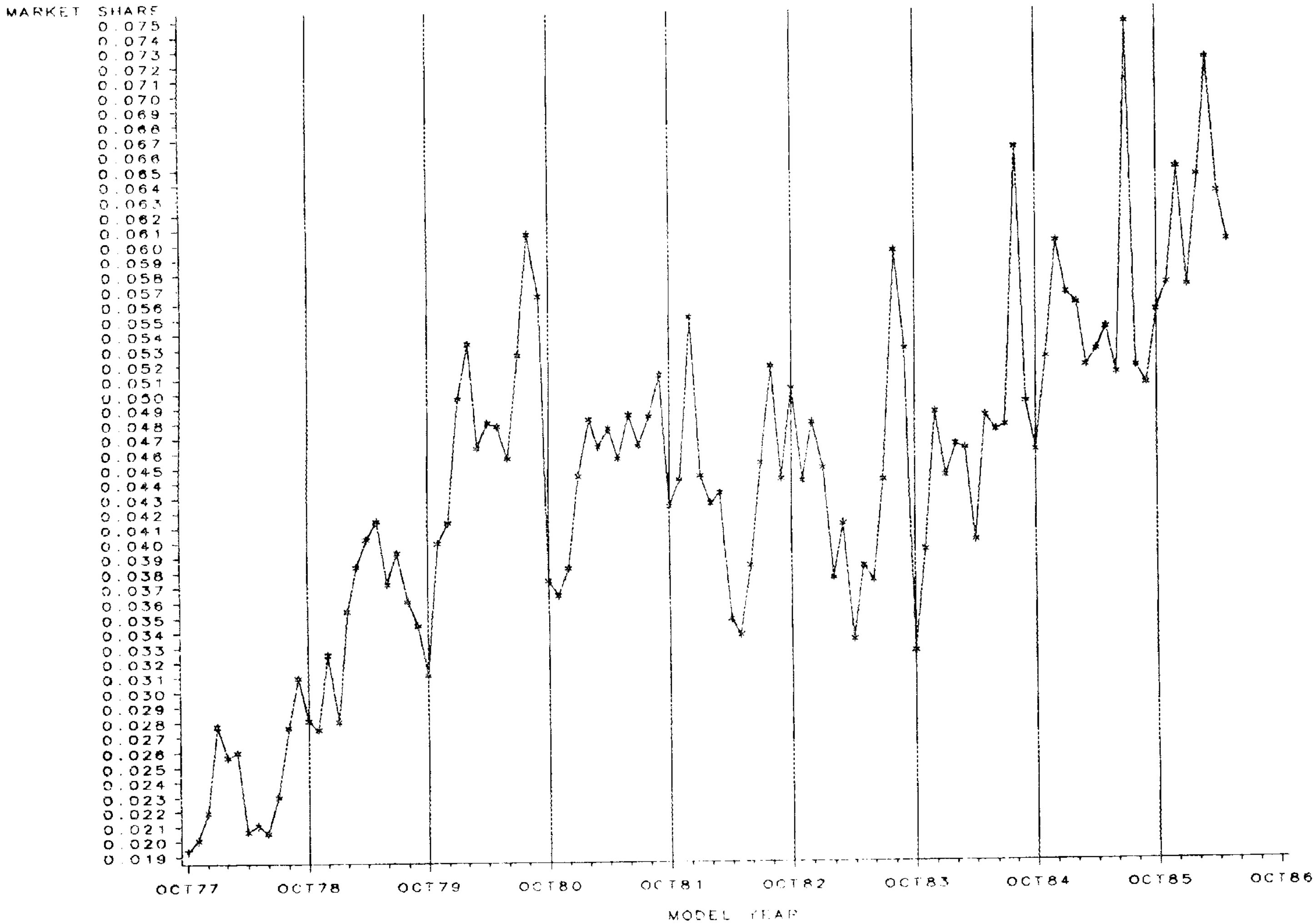

Figure 4. Monthly Market Shares of Import Light Trucks.

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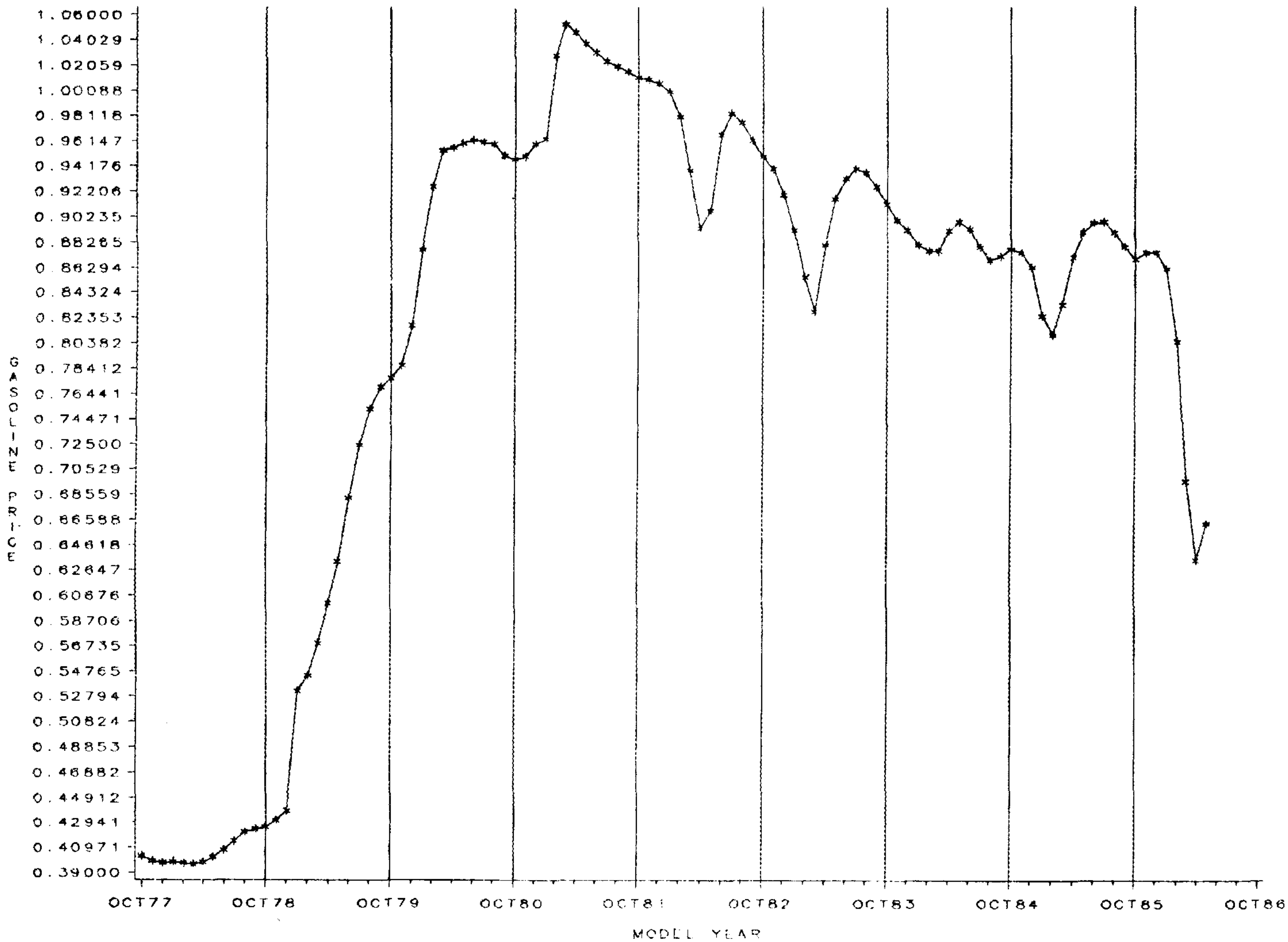

Figure 5. Monthly Gasoline Prices.

3. ARIMA MODELS FOR MARKET SHARES OF DOMESTIC AUTOMOBILES

3.1 TRANSFER FUNCTION MODEL

In this model, the monthly market shares of domestic automobiles are structured as a function of the monthly dummy variables and the monthly gasoline prices. The effect of gasoline price P at time t, P_t, on the market share Y_t is not assumed to be contemporaneous, but rather spread over a period of time. This implies that the current market share does not depend on the current gasoline price but rather on recent past gasoline prices. However, by including the gasoline prices for the period from time (t-k) to time (t-1) in the model, one would encounter two major problems. First, one loses (k-1) degrees of freedom because the model can be estimated from only (n-k+1) observations, provided that there are no other parameters in the model. If k is relatively large, this results in a considerable decrease in the number of observations that can be used for the estimation procedure. Second, frequently there is high multicollinearity among the gasoline prices during the period from time (t-k) to time (t-1), and this results in imprecise estimates for the parameter coefficients.

One of the many suggestions presented in the literature is to put some "structure" on the coefficients of gasoline prices from time (t-k) to time (t-1) (Maddala, 1977). The inverted V distributed lag model was used to build the structure of the coefficients in this study. This approach was first proposed by F. DeLeeuw in 1962. The effect of gasoline prices on the market share is considered to be most influential at the middle of the previous time period, and to decrease linearly toward the two ends of the period. The gasoline price effect was estimated by regressing the market share on the constructed variable Z_t, where

$$Z_t = \sum_{i=0}^{k/2} iP_{t-i} + \sum_{(k/2)+1}^{k} (k-i)P_{t-i}$$

$$= \sum_{i=0}^{2} iP_{t-i} + \sum_{3}^{4} (4-i)P_{t-i}$$

$$= P_{t-1} + 2P_{t-2} + P_{t-3} ,$$

where P_t is the price of regular leaded gasoline at time t (expressed in 1967 dollars). This implies that the current market share does not depend on the current gasoline price but on the gasoline price from one month ago, two months ago, and three months ago; and the gasoline price two months ago has the heaviest weight. This argument is intuitively reasonable in that it assumes that consumers do not respond instantaneously to changes in gasoline prices in their car purchase decisions. If there is any influence at all, it is assumed that it depends on gasoline prices from the previous few months. Future research on this topic will extend the influence of gasoline price to a period beyond the three previous months.

Let Y_t represent the observed market share of domestic automobiles in time period t; let Z_t be the constructed price variable for the time period t-1, t-2, and t-3; and let D_i be the dummy variable for month i. The month of January was used as the norm, and is captured in the constant term. In the first step of the analysis, a general linear model was built:

$$Y_t = \mu_0 + \beta Z_t + \sum_{i=2}^{12} \tau_i D_i + a_t \;, \tag{1}$$

where a_t is of ARIMA model structure (i.e., exhibits autocorrelation).

As mentioned earlier, the problem in building a time series model using the standard regression technique is the autocorrelation in the residual series a_t. Consequently, the next step in the analysis was to build the structure of the residual series a_t by using the iterative model-building philosophy of Box and Jenkins (1976). From an examination of the sample autocorrelations at lag k, where k=1,2, ..., 24, the initial model for a_t was identified to be

$$(1-\varphi B)a_t = (1-\Theta_5 B^5)\varepsilon_t$$

$$a_t = [(1-\Theta_5 B^5)/(1-\varphi B)]\varepsilon_t \;, \tag{2}$$

where φ is the "autoregressive" parameter of lag 1, Θ_5 is the "moving average" parameter of lag 5, and B is the backshift operator such that $B^5 a_t = a_{t-5}$. ε_t is a white noise series distributed normally with mean 0 and standard error σ^2.

A transfer function model can be derived by substituting (2) into (1):

$$Y_t = \mu_0 + \beta Z_t + \sum_{i=2}^{12} \tau_i D_i + [(1-\Theta_5 B^5)/(1-\varphi B)]\varepsilon_t \;. \tag{3}$$

The estimation of the parameters in Equation (3) was accomplished by conditional least squares estimation methods as described by Box and Jenkins (1976). The parameters μ_0, β, Θ_5, and φ were statistically significant at α=0.05 level. Equation (3) with the estimated parameters is

$$Y_t = \mathbf{0.0675} + (\mathbf{-0.032})Z_t + 0.0048D_2 + 0.0124D_3 + 0.0193D_4 + 0.0103D_5 + 0.0011D_6 + (-0.0048)D_7 + 0.0057D_8 + \mathbf{0.0226}D_9 + \mathbf{0.0362}D_{10} + 0.0161D_{11} + (-0.0049)D_{12} + [(1+\mathbf{0.4218}B^5)/(1-\mathbf{0.7360}B)]\varepsilon_t \quad (4)$$

The estimated parameters in **bold** are statistically significant at the α=0.05 level. A portmanteau lack of fit test of the residuals indicated a white noise process. The residual standard error was 0.020. The mean square error of the sample forecast was 0.0004.

The monthly variations in domestic automobile market shares are illustrated by standardizing them relative to January's market share (Figure 6). However, these monthly coefficients should only be used in qualitative comparisons of monthly market shares. They should not be used to draw any statistical inferences regarding the comparisons between any two months. For statistical inferences, one must consider the standard errors of the estimated parameters as well as their estimated values.

The observed market shares and the market shares predicted by the model are plotted in Figure 7. The model is able to follow the trend and the monthly pattern closely. However, the model tends to overestimate the shares for the later months of the series, i.e., months in early model-year 1986. This suggested that some peculiar events occurred during that period that affected the market share pattern. A series of

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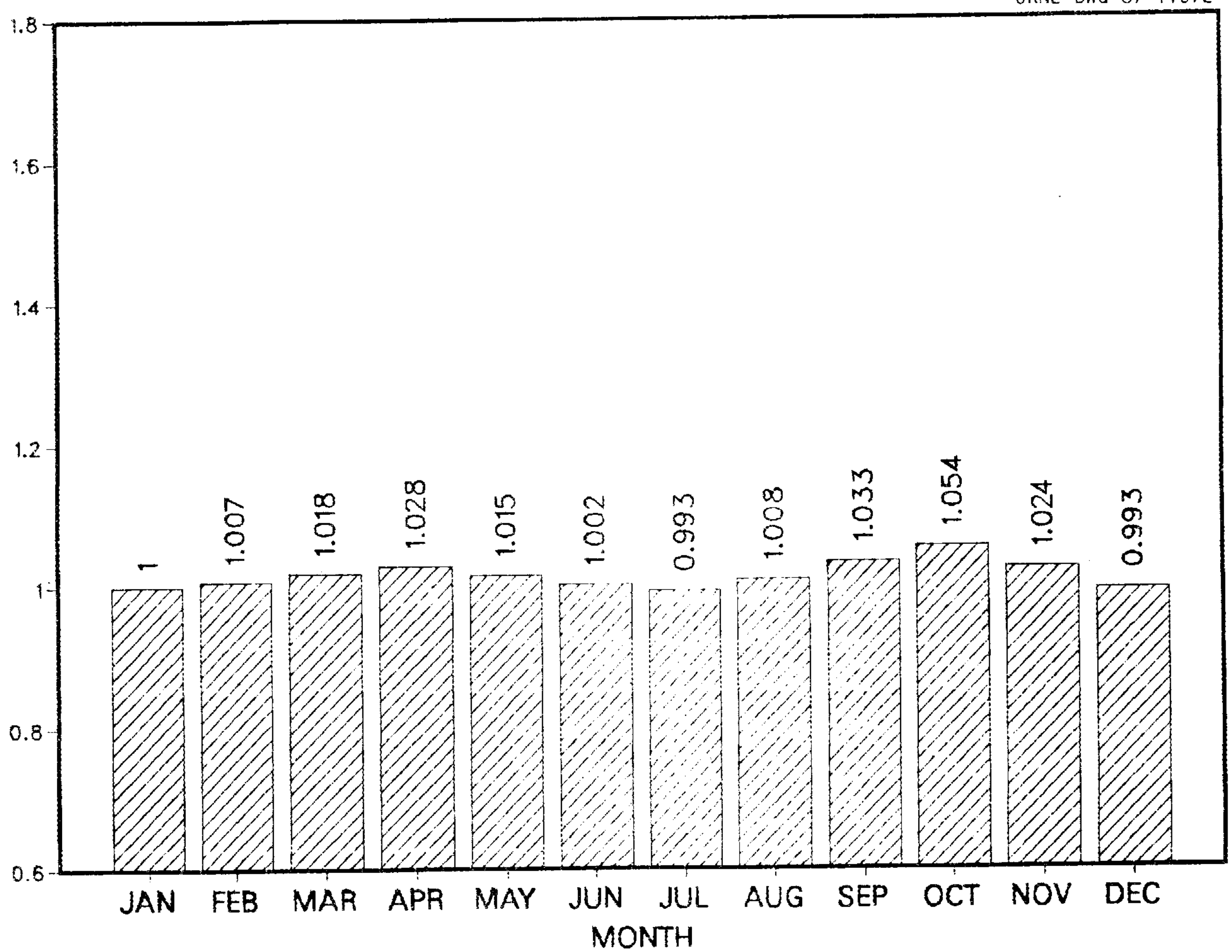

Figure 6. Standardized Monthly Coefficients of Domestic Automobile Market Shares, Transfer Function Model.

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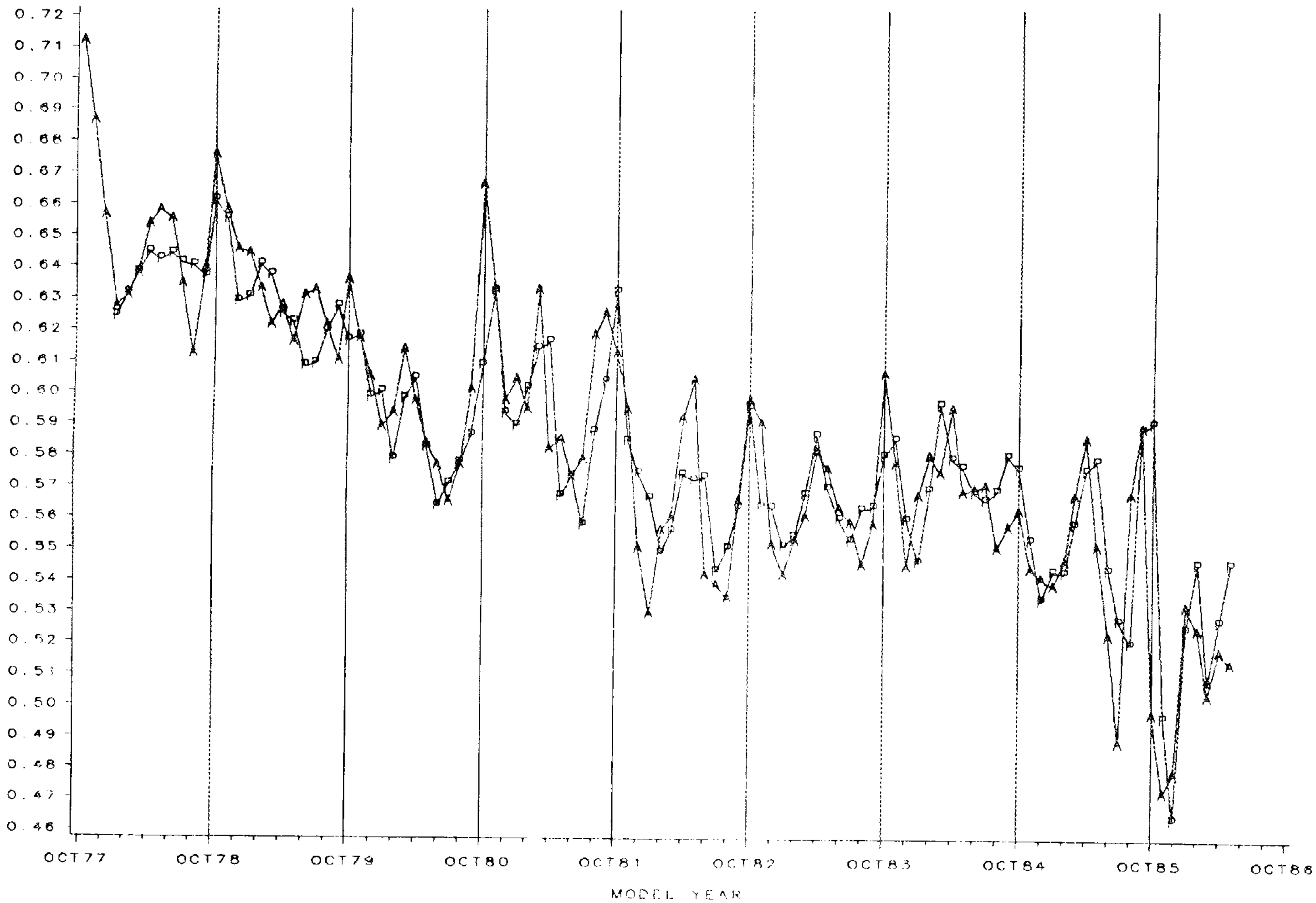

Figure 7. Actual vs. Predicted Domestic Automobile Market Shares, Transfer Function Model.

events that may have altered the usual pattern of market shares were the financial incentive programs offered by the auto makers in August and September 1985. This is addressed in the next section.

3.2 COMBINED TRANSFER FUNCTION-INTERVENTION MODEL

During August and September 1985, the three major domestic manufacturers (Ford, GM, and Chrysler) implemented 7.5% and 7.7% annual percentage rate (APR) financial incentive programs. These cut-rate financial programs dramatically increased the sales in domestic automobiles during these two months. Consequently, the market shares of domestic automobiles and import automobiles were affected. Because of their apparent impacts, these financial programs were included in the model structure to capture their effects on the changes observed in market shares.

Time series models that explicitly include the effects of identifiable isolated events in their structures are referred to as <u>intervention models</u> by Box and Jenkins. The effects of the identifiable isolated events in the intervention model are represented in a binary way as the occurrence or nonoccurrence of certain events over the time span. One of the common patterns used in the statistical literature is the step effect. In this pattern, the effect of the event is observed not only during the occurrence time span, but also throughout the period beyond it. Another common pattern is the pulse effect, in which the event has an effect only during the time span in which the event occurred. Since the cut-rate financial incentive program only occurred during the months of August and September 1985, it was felt that the financial program affected domestic vehicle sales for only those two months, and the effect was not continued throughout the remaining period of the time series. Financial incentives were offered on limited number of months throughout 1986, but it was felt that these were sporadic and minor in impact. Based on these arguments, the financial incentive program can be represented as

$$I_t = \begin{cases} 1, & \text{if } t\text{=August or September 1985} \\ 0, & \text{otherwise.} \end{cases}$$

Once the financial incentive program was terminated in October 1985, import sales exhibited a record high in spite of the new model year introduction of automobiles by the domestic manufacturers. This drop in the share of domestic car sales after the financial incentive programs might be attributed to a saturation of built-up demand for domestic automobiles or to a decrease in domestic car inventories. A second binary variable was included in the model to represent the post-financial-program effects on the market shares of light-duty vehicles. This binary variable was defined as:

$$J_t = \begin{cases} 1, & \text{if } t \geq \text{October 1985} \\ 0, & \text{otherwise.} \end{cases}$$

The monthly market shares of domestic automobiles, Y_t, can be modeled as a combined transfer function-intervention model by expanding Equation (1) to include the two binary variables that relate to the financial incentive program:

$$Y_t = \mu_0 + \beta_1 Z_t + \beta_2 I_t + \beta_3 J_t + \sum_{i=2}^{12} \tau_i D_i + n_t , \qquad (5)$$

where Z_t, D_i are the same as defined in Equation (1), and n_t is the residual series from fitting the model (5).

As mentioned earlier, the estimated residuals from the classical regression environment are not independent and identically distributed with zero mean and variance σ^2. Hence, it would be possible to have misleading inferences from the hypothesis tests on the estimated coefficients. To avoid this problem, the residual series n_t was structured in such a manner that the resulting residual series exhibited the desired white noise behavior.

Using the model-building philosophy of Box and Jenkins, the residual series from Equation (5) can be modeled as

$$(1-\varphi B)n_t = \varepsilon_t$$
$$n_t = [1/(1-\varphi B)]\varepsilon_t \ , \tag{6}$$

where ε_t is a white noise process.

After substituting (6) into (5), the combined transfer function-intervention model can be written as

$$Y_t = \mu_0 + \beta_1 Z_t + \beta_2 I_t + \beta_3 J_t + \sum_{i=2}^{12} \tau_i D_i + [1/(1-\varphi B)]\varepsilon_t \ . \tag{7}$$

Estimation of this model gave the final model equation,

$$\begin{aligned} Y_t = \mathbf{0.6778} &+ (\mathbf{-0.0302})Z_t + \mathbf{0.0631}I_t + (\mathbf{-0.0692})J_t \\ &+ 0.0046D_2 + 0.0117D_3 + 0.0184D_4 + 0.0096D_5 \\ &+ (-0.0022)D_6 + (-0.0085)D_7 + (-0.0071)D_8 \\ &+ 0.0089D_9 + \mathbf{0.0392}D_{10} + \mathbf{0.0179}D_{11} \\ &+ (-0.0040)D_{12} + [1/(1-\mathbf{0.7950}B)]\varepsilon_t \ . \end{aligned} \qquad (8)$$

Estimated parameters in **bold** are statistically significant at the α=0.05 level. The standard deviation of the model's residuals was 0.0166, and there was no significant autocorrelation in the estimated model residuals. The mean square error of the sample forecast was 0.00027.

The results in Equation (8) indicate that higher gasoline prices led to a lower market share for domestic automobiles in the following months. An "inverted V" effect - with the gasoline price two months ago having double the influence of the prices one and three months ago - was an appropriate representation of the lag in the price effect. The 7.5% and 7.7% APR financial programs boosted the domestic automobile market shares by an additional 6.3% from what would have been expected; but the termination of the financial program reduced the domestic automobile market share by 6.9% from what would have been expected.

The monthly variation in domestic automobile market shares can be illustrated as a function of January's market shares (Figure 8). The only significant monthly variations were for April, October, and November, which were significantly greater than January market share (other things being equal). Although statistically insignificant, the

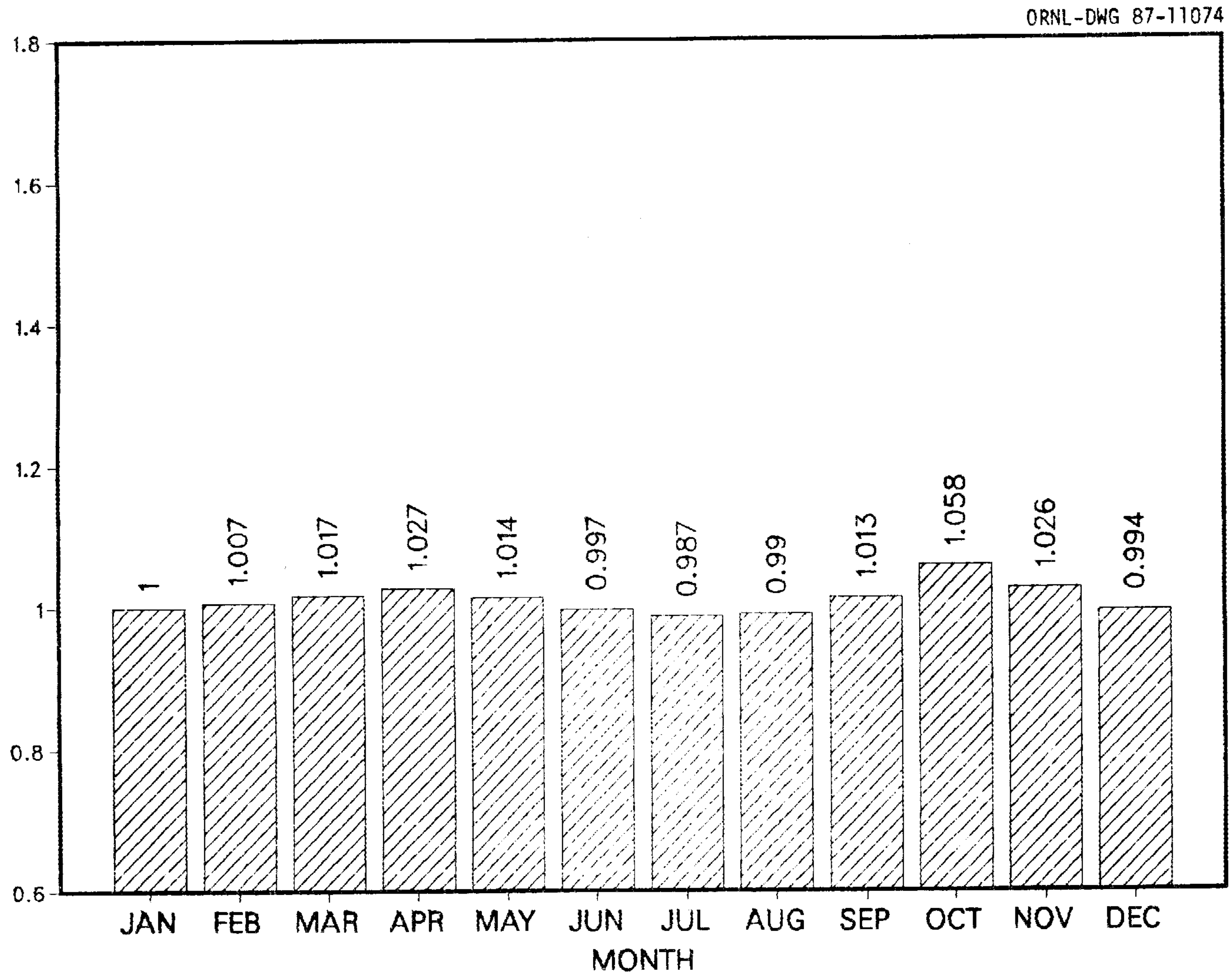

Figure 8. Standardized Monthly Coefficients of Domestic Automobile Market Shares, Combined Model.

three summer months -- June, July, and August -- exhibited decreases in market share relative to January. The actual market shares versus those predicted from model (8) are plotted in Figure 9. This combined transfer function-intervention model gave better predictions for the post-financial-program period than the transfer function model stated in Equation (3).

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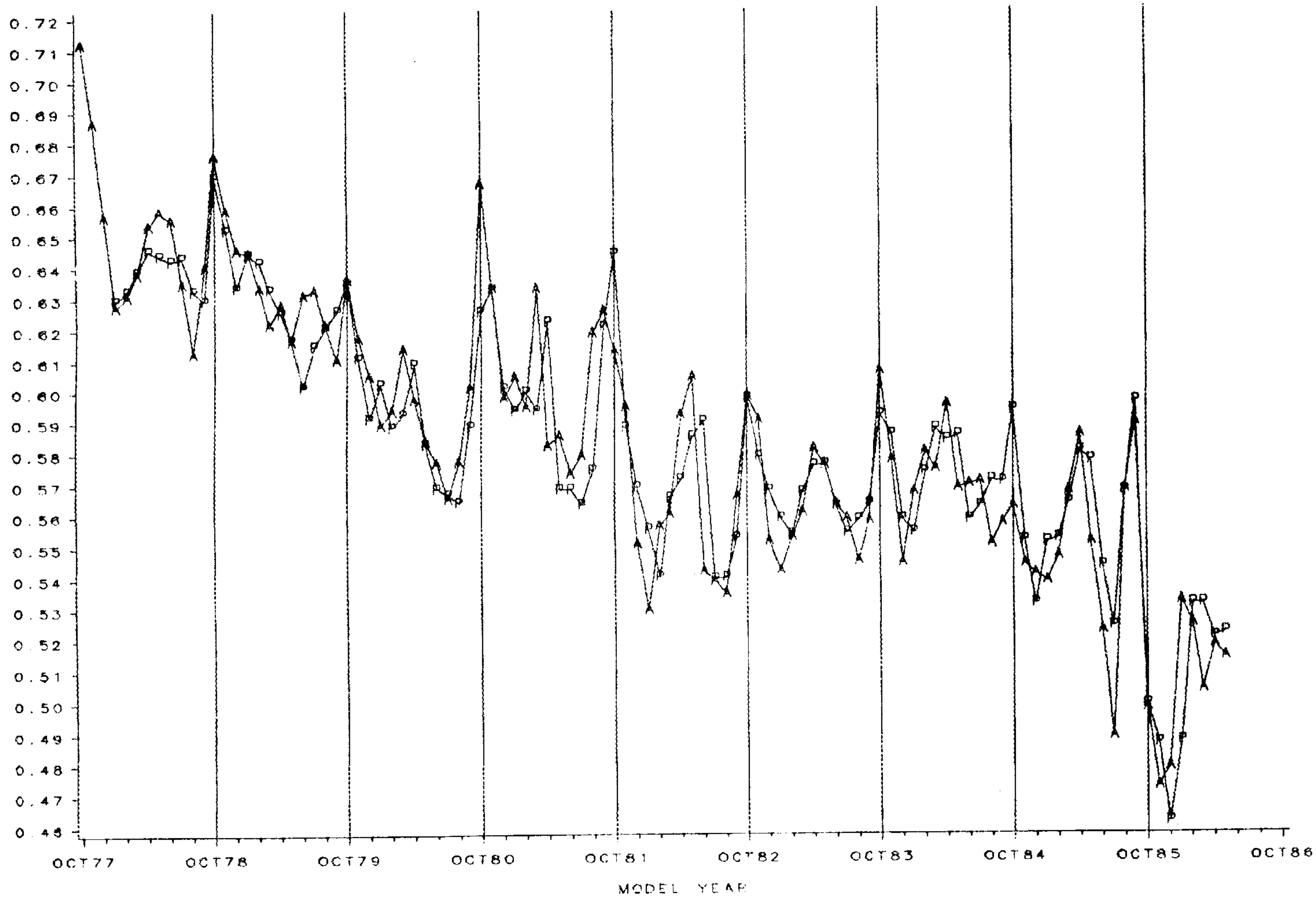

Figure 9. Actual vs. Predicted Domestic Automobile Market Shares, Combined Model.

4. ARIMA MODELS FOR MARKET SHARES OF IMPORT AUTOMOBILES

4.1 TRANSFER FUNCTION MODEL

Very similar arguments that were presented in Section 3 were applied to the analyses of market share data of import automobiles. The transfer function model was constructed to relate the monthly market shares to recent past gasoline prices controlling for consistent monthly variations in market shares:

$$Y_t = \mu_0 + \beta Z_t + \sum_{i=2}^{12} \tau_i D_i + a_t , \qquad (9)$$

where a_t is of ARIMA model structure. By examining the patterns of the sample autocorrelations and the sample partial autocorrelations, the initial model for a_t was identified to be

$$(1-\varphi B)a_t = \varepsilon_t . \qquad (10)$$

After substituting (10) into (9), the transfer function model of import automobile market shares was

$$Y_t = \mu_0 + \beta Z_t + \sum_{i=2}^{12} \tau_i D_i + [1/(1-\varphi B)]\varepsilon_t . \qquad (11)$$

With parameters estimated using the conditional least squares estimation method, the transfer function model was

$$
\begin{aligned}
Y_t = \mathbf{0.106} &+ \mathbf{0.0280}Z_t + (-0.0069)D_2 + (\mathbf{-0.0161})D_3 \\
&+ (\mathbf{-0.0169})D_4 + (-0.0076)D_5 + (-0.0071)D_6 \\
&+ 0.0006D_7 + 0.0023D_8 + (\mathbf{-0.0186})D_9 \\
&+ (\mathbf{-0.0281})D_{10} + (\mathbf{-0.0189})D_{11} + (-0.0031)D_{12} \\
&+ [1/(1-\mathbf{0.6943}B)]\varepsilon_t \; . \qquad (12)
\end{aligned}
$$

The estimated parameters in **bold** were statistically significant at the α=0.05 level. The residuals from model (12) were normally distributed with mean 0 and standard deviation 0.0148, and there was no autocorrelation in the estimated model residuals. The mean square error of the sample forecast was 0.00022.

In this model, increases in the weighted composite variable for past gasoline prices, Z_t, resulted in increases in import automobile market shares. As expected, this is just the opposite phenomenon observed in the market shares of domestic automobiles where past increases in gasoline prices decreased the market shares. Figure 10 shows that the market shares observed from September through November tended to be significantly smaller than January's. Controlling for the effects of variations in gasoline price, the import automobile market share had its lowest level at the beginning of the model years.

4.2 COMBINED TRANSFER FUNCTION-INTERVENTION MODEL

A combined transfer function-intervention model of the import car market shares was built to capture the effects of not only gasoline prices but also of the two identifiable isolated events: (1) 7.5% and 7.7% APR financial incentive programs offered by the domestic automobile

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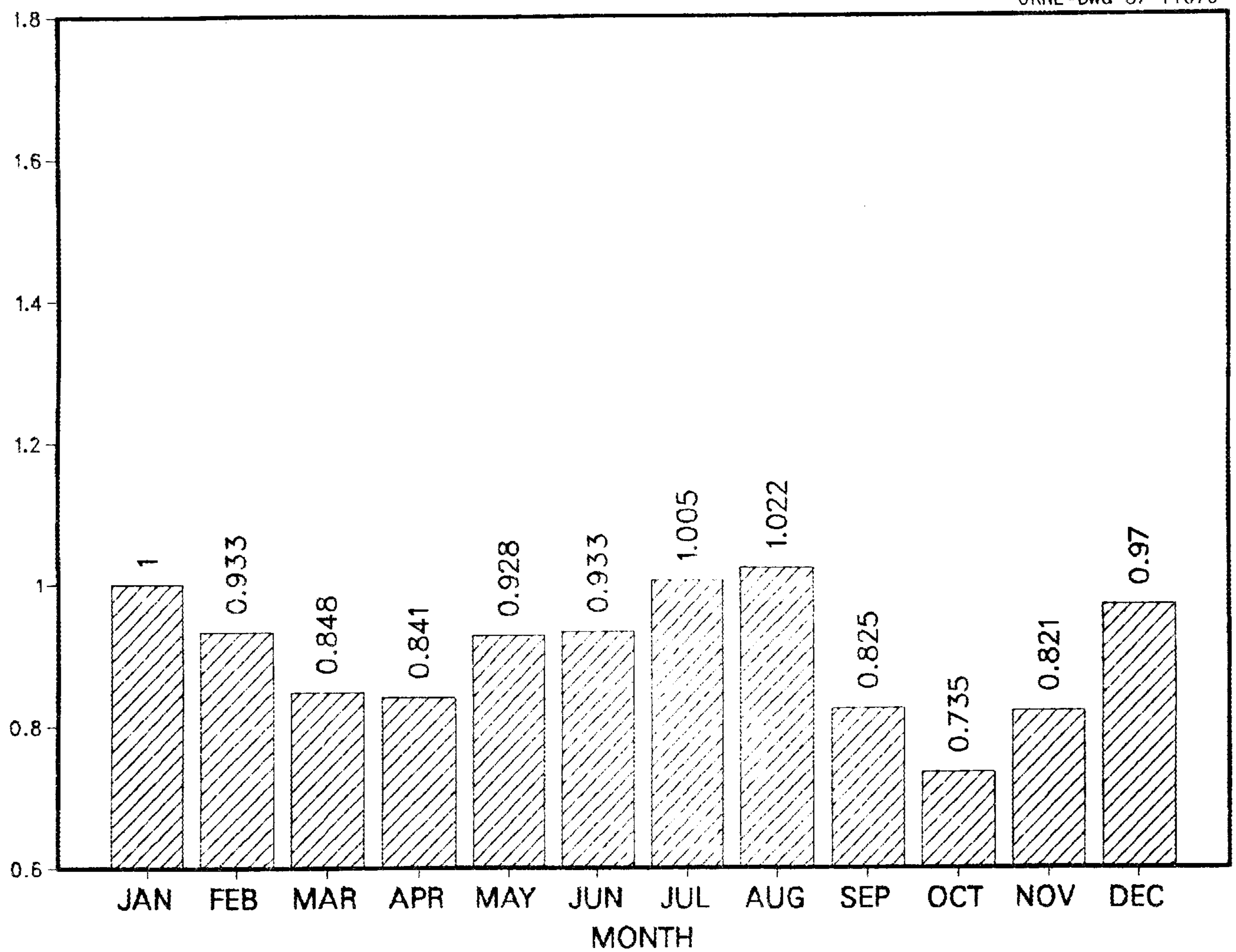

Figure 10. Standardized Monthly Coefficients of Import Automobile Market Shares, Transfer Function Model.

manufacturers, and (2) the termination of these financial programs. The model was identified to be

$$Y_t = \mu_0 + \beta_1 Z_t + \beta_2 I_t + \beta_3 J_t + \sum_{i=2}^{12} \tau_i D_i$$

$$+ [(1-\Theta_4 B^4)(1-\Theta_{12} B^{12})/(1-\varphi B)]\varepsilon_t \ . \qquad (13)$$

With parameters estimated by the conditional least squares estimation method, the combined transfer function-intervention model (13) became

$$Y_t = 0.104 + 0.0278 Z_t + (-0.0325) I_t + 0.0258 J_t$$

$$+ (-0.0074) D_2 + (-0.0165) D_3 + (-0.0176) D_4$$

$$+ (-0.0088) D_5 + (-0.0074) D_6 + 0.0007 D_7$$

$$+ 0.0087 D_8 + (-0.0116) D_9 + (-0.0281) D_{10}$$

$$+ (-0.0184) D_{11} + (-0.0031) D_{12}$$

$$+ [(1-0.2205 B^4)(1+0.2488 B^{12})/(1-0.7884 B)]\varepsilon_t \ . \qquad (14)$$

The residuals from this model were normally distributed with mean 0 and standard deviation 0.0134. The check for autocorrelation in the residuals indicated a white noise process. The mean square error of the sample forecast was 0.00018.

This combined transfer function-intervention model of import car market shares revealed that the weighted, past gasoline prices had a positive impact on the market shares. Higher gasoline prices generally led to higher market shares for import automobiles. Financial programs offered by the domestic auto makers significantly decreased the market shares of import automobiles by 3.25%. However, once the programs were terminated, the import cars recaptured their share of the market to a large degree.

The monthly variation in import car market shares is shown in Figure 11. Similar to the transfer function model in Equation (12), the market shares in March, October and November tended to be the smallest during the year.

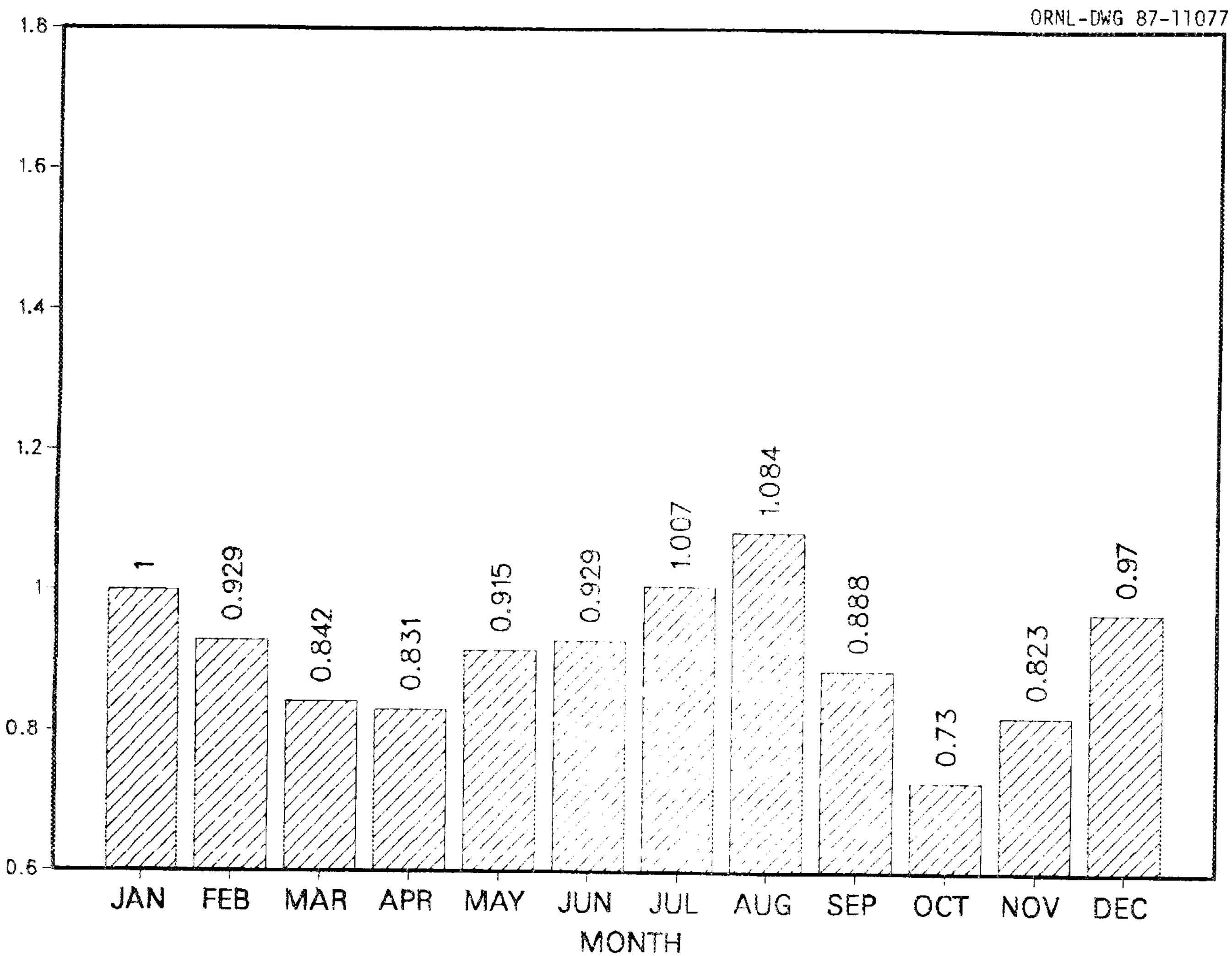

Figure 11. Standardized Monthly Coefficients of Import Automobile Market Shares, Combined Model.

5. ARIMA MODELS FOR LIGHT-DUTY TRUCK MARKET SHARES

5.1 MODELS FOR DOMESTIC LIGHT TRUCK MARKET SHARES

Similar procedures were applied to the market share data of domestic light-duty trucks. Refer to Sections 3 and 4 for more detailed descriptions of the modeling procedures. Two separate ARIMA models were built to measure: (1) the monthly variation and the effect of gasoline prices, and (2) in addition to those trends, the impacts of financial programs offered by manufacturers.

The transfer function model, which relates the monthly market share behavior to the movements in gasoline prices, was

$$\begin{aligned} Y_t &= \mu_0 + \beta Z_t + \sum_{i=2}^{12} \tau_i D_i + a_t \\ &= \mathbf{0.1957} + (-0.0032)Z_t + 0.0007D_2 + 0.0023D_3 \\ &\quad + (-0.0006)D_4 + (-0.0025)D_5 + 0.0090D_6 \\ &\quad + 0.0014D_7 + (-0.0136)D_8 + (-0.0050)D_9 \\ &\quad + (-0.0040)D_{10} + 0.0053D_{11} + 0.0050D_{12} \\ &\quad + [1/(1-\mathbf{0.9282}B)]\varepsilon_t \ . \end{aligned} \tag{15}$$

The residuals from model (15) were distributed normally with mean 0 and standard deviation 0.0138. The autocorrelation check indicated that the residual series ε_t was of a white noise process. The mean square error of the sample forecast was 0.00019.

This transfer function model of domestic light truck market shares shows that weighted, past gasoline prices did not significantly affect the market shares of domestic light trucks. Holding the effect of gasoline prices constant, the model also shows that the market shares of domestic light trucks tended to be somewhat higher (though not statistically significant) in the months of November, December, January, February, and March (Figure 12).

In order to determine whether the financial incentive program offered by the domestic auto makers had any impacts on the market shares of domestic light trucks, the combined transfer function-intervention model was developed. With the estimated parameters, the model was

$$\begin{aligned} Y_t = \mathbf{0.1949} &+ (-0.0032)Z_t + (\mathbf{-0.0340})I_t + 0.0066J_t \\ &+ 0.0007D_2 + 0.0023D_3 + (-0.0006)D_4 \\ &+ (-0.0025)D_5 + 0.0091D_6 + 0.0017D_7 \\ &+ (-0.0090)D_8 + (-0.0003)D_9 + (-0.0043)D_{10} \\ &+ 0.0051D_{11} + 0.0050D_{12} \\ &+ [1/(1-\mathbf{0.9370}B)]\varepsilon_t \ . \end{aligned} \tag{16}$$

The residual ε_t was normally distributed with mean 0 and standard deviation 0.0130, and exhibited no significant autocorrelation. The mean square error of the sample forecast was 0.00017.

Similar conclusions can be drawn about the effects of gasoline prices and about the monthly variations as in the transfer function model (15). The 7.5% and 7.7% APR financial incentive programs caused a reduction of 3.4% in the domestic light truck market share. Even though the program was applied to both automobiles and light trucks, the domestic automobiles were clearly the major beneficiaries of the program

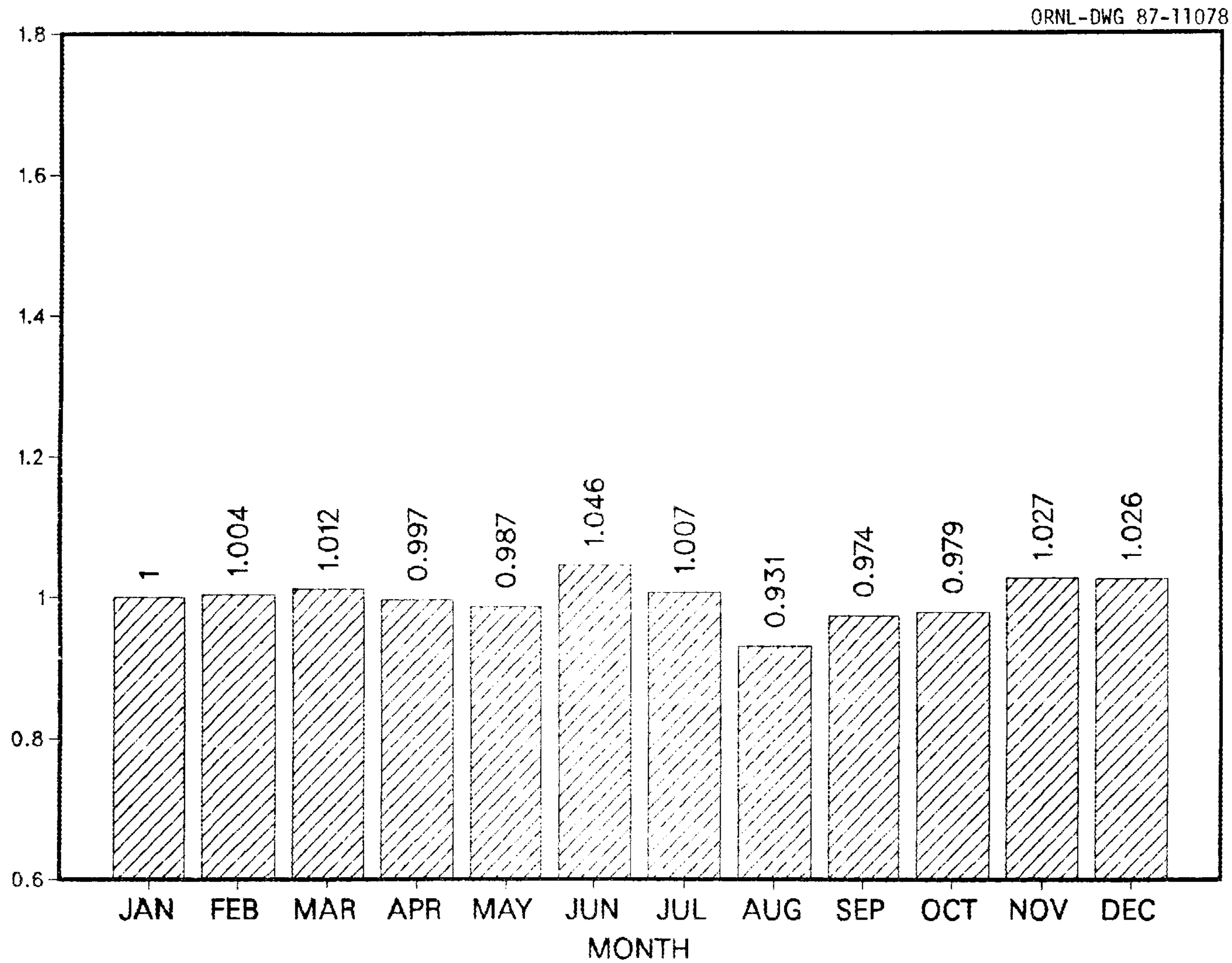

Figure 12. Standardized Monthly Coefficients of Domestic Light Truck Market Shares, Transfer Function Model.

and the market shares of domestic light trucks in fact suffered. Although the termination of the program was followed by a gain in domestic light truck market share, the gain was not significant at the $\alpha=0.05$ level. The monthly variations of the market shares are illustrated in Figure 13.

5.2 MODELS FOR IMPORT LIGHT TRUCK MARKET SHARES

The transfer function model of import light truck market shares was estimated to be

$$\begin{aligned} Y_t = {} & 0.0148 + 0.0092Z_t + 0.0013D_2 + 0.0014D_3 + (-0.0020)D_4 \\ & + (-0.0008)D_5 + (-0.0021)D_6 + 0.0027D_7 \\ & + 0.0055D_8 + 0.0009D_9 + (-0.0053)D_{10} \\ & + (-0.0033)D_{11} + 0.0026D_{12} \\ & + [1/(1-0.6660B)(1-0.2637B^3)]\varepsilon_t \ . \end{aligned} \qquad (17)$$

The mean of the residual from this model was not significantly different from 0, and the standard deviation was 0.0056. The check of residuals showed no significant autocorrelation. The mean square error of the sample forecast was 0.000031.

When the weighted composite gasoline prices of the previous three months increased, the market shares of import light trucks increased. The market share of import light trucks was the lowest in the month of October. The trend of the monthly variation is illustrated in Figure 14.

The combined transfer function-intervention model of import light trucks was estimated to be,

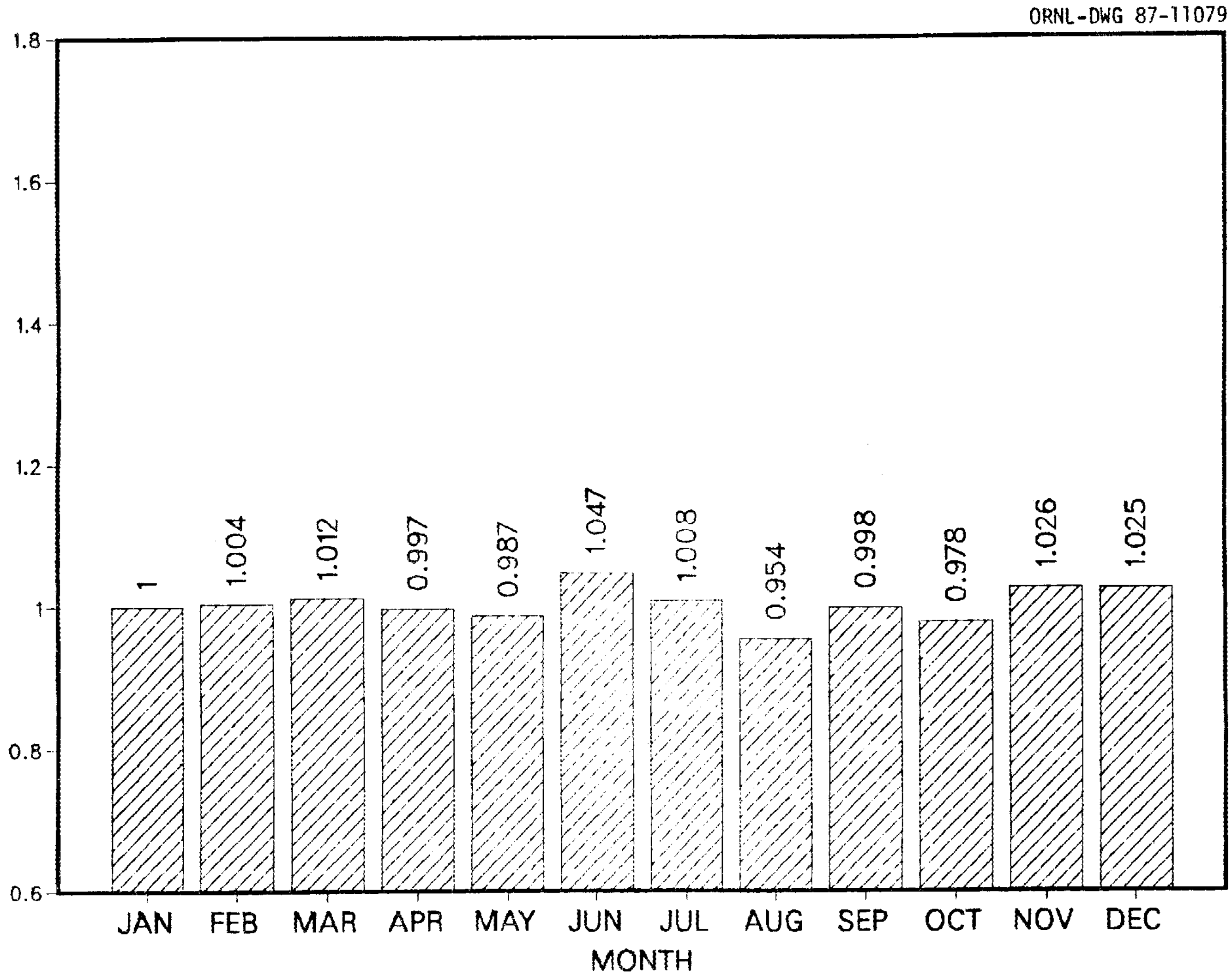

Figure 13. Standardized Monthly Coefficients of Domestic Light Truck Market Shares, Combined Model.

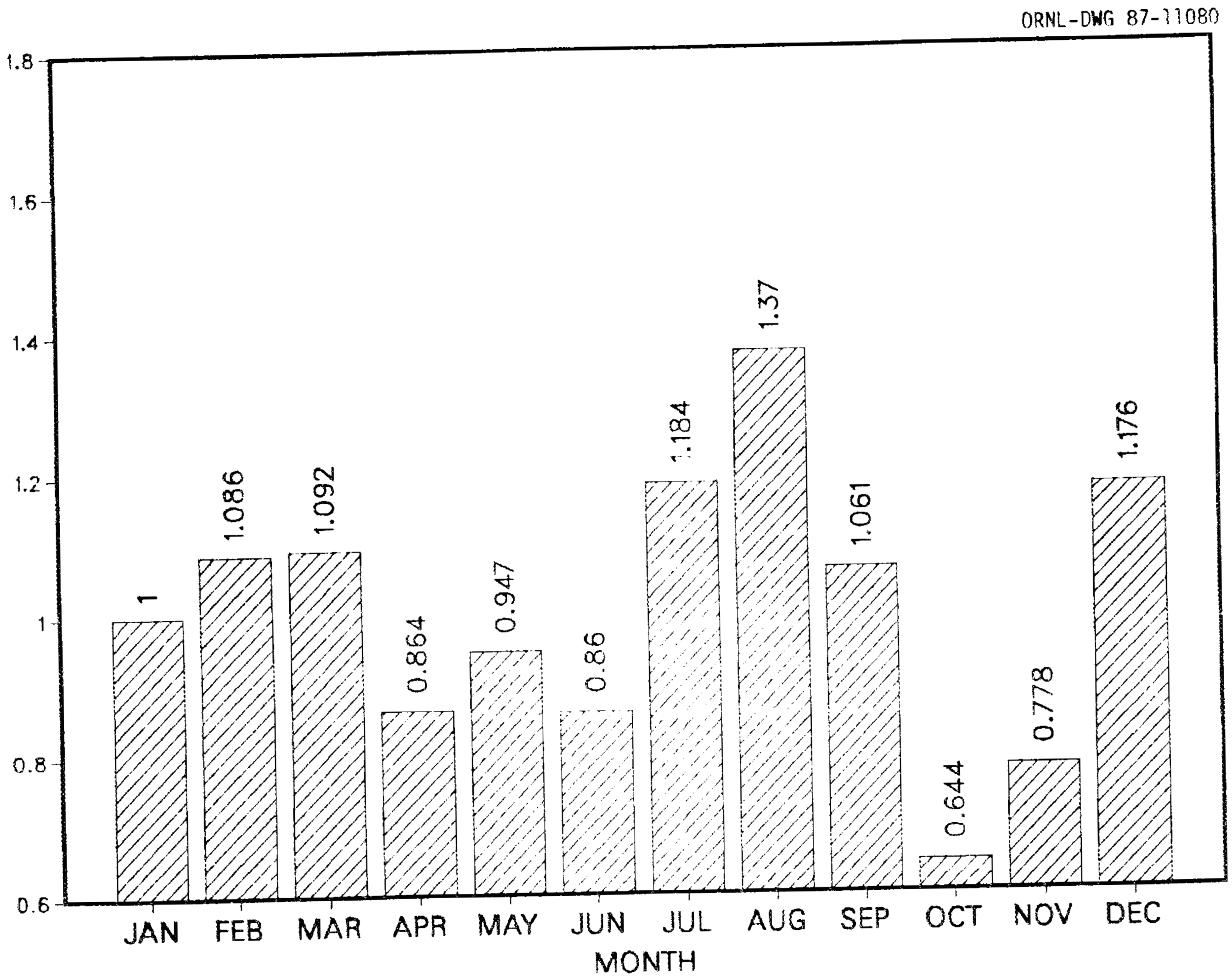

Figure 14. Standardized Monthly Coefficients of Import Light Truck Market Shares, Transfer Function Model.

$$Y_t = 0.0144 + 0.0090Z_t + (-0.0147)I_t + 0.0097J_t + 0.0013D_2 + 0.0014D_3 + (-0.0020)D_4 + (-0.0007)D_5 + (-0.0020)D_6 + 0.0030D_7 + 0.0078D_8 + 0.0033D_9 + (-0.0056)D_{10} + (-0.0035)D_{11} + 0.0025D_{12} + [1/(1-0.7178B)]\varepsilon_t \; . \quad (18)$$

The mean and the standard deviation of the residual series ε_t were 0 and 0.0052, respectively; and there was no autocorrelation in the residual series. The mean square error of the sample forecast was 0.000027.

Increases in the weighted composite past gasoline prices were followed by gains in import light truck market shares. The financial programs offered by the domestic automobile manufacturers resulted in a drop in the import light truck market share. The import light trucks gained more of the light-duty vehicle market after the financial incentive program, though the gain was not statistically significant. In terms of monthly patterns, the market share reached its peaks during the month of August, and dropped to the lowest level in October (Figure 15).

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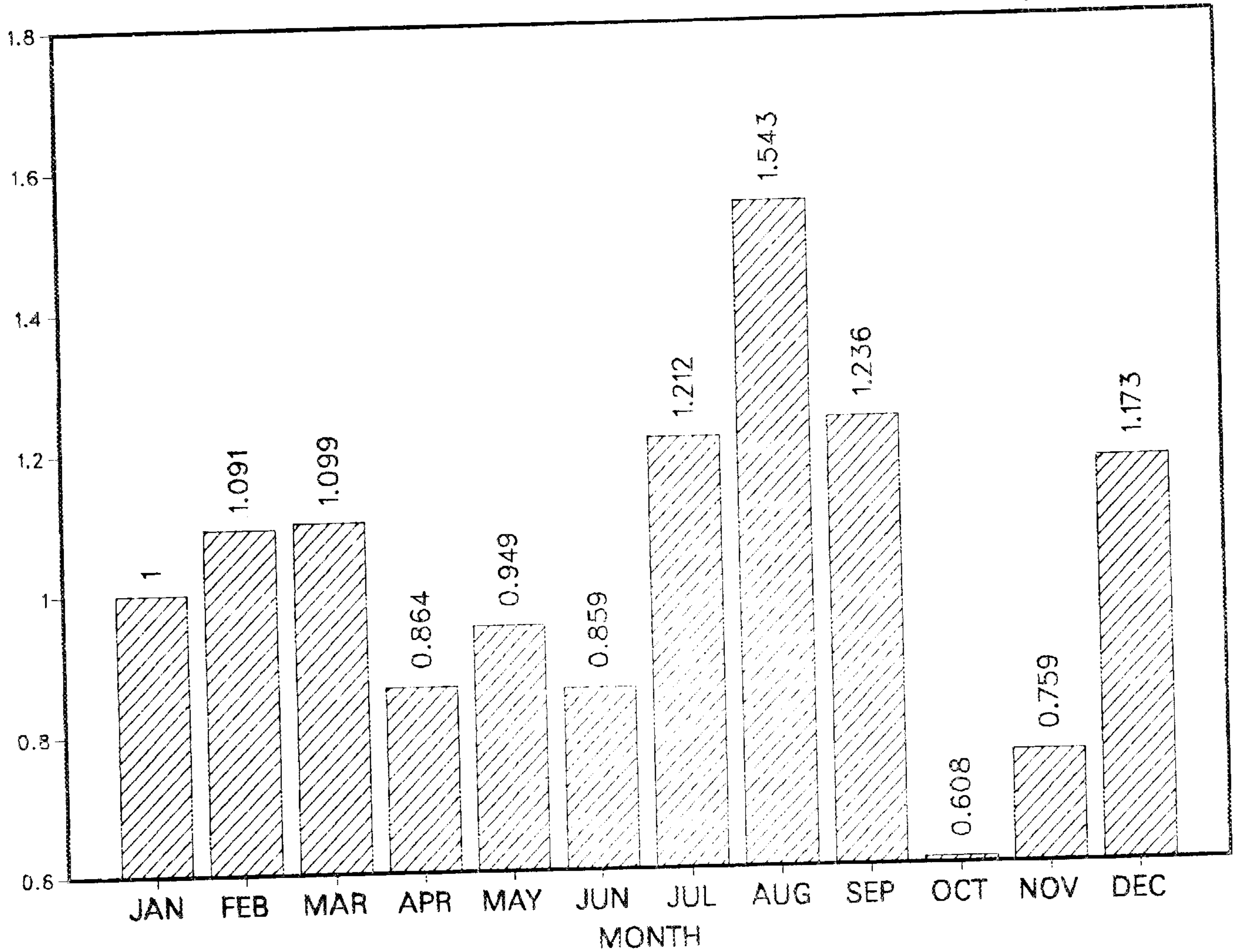

Figure 15. Standardized Monthly Coefficients of Import Light Truck Market Shares, Combined Model.

6. CONCLUSION

A transfer function model and a combined transfer function-intervention model were developed for monthly market shares data in the United States for each of the four light-duty vehicle categories: domestic automobiles, import automobiles, domestic light trucks, and import light trucks. The transfer function model included the monthly variation in market shares and the effect of recent, past gasoline prices. The combined transfer function-intervention model included the monthly variation and the gasoline price, and also the impacts of the cut-rate financial incentive programs which were offered by the domestic auto makers in August and September 1985. Conclusions are drawn from the transfer function-intervention models, which included more of the significant variables.

The transfer function-intervention models were able to capture the long term patterns. Import automobiles, with their complicated pattern, exhibited a higher-order autoregressive-moving average. Light-duty vehicles were modelled as first-order autoregressive processes in which market shares were proportional to previous month's share.

Monthly trends and economic factors were also identified by the models. Comparisons of the monthly patterns were illustrated in Figures 6, 8, and 10 through 15. The impacts of gasoline prices and of the financial incentive programs are summarized in Table 6. The monthly market shares of domestic cars were inversely proportional to prior gasoline prices. The effect of prior gasoline prices was measured by

Table 6
SELECTED COEFFICIENTS OF
COMBINED TRANSFER FUNCTION-INTERVENTION MODELS

	Weighted Composite Gasoline Price	Financial Incentive Program	Post-Financial Incentive Program
Domestic automobiles	-0.03016[a]	0.06306[a]	-0.06921[a]
Import automobiles	0.02784[a]	-0.03255[a]	0.02579
Domestic light trucks	-0.00324	-0.03402[a]	0.00659
Import light trucks	0.00897[a]	-0.01471[a]	0.00975

[a]Indicates the coefficient is statistically significant at the $\alpha = 0.05$ level.

taking a weighted composite of the past three months' prices. In the weighting scheme, the price two months ago was twice as important as the previous month's price and as the price three months ago. The underlying behavioral assumption was that consumers' expectations of future gasoline prices, to the extent that these expectations affect choices of domestic versus import automobiles and light trucks, were from impressions based on gasoline prices two months ago and to a lesser extent on gasoline prices one and three months ago. It was estimated that a one cent increase in the previous months' gasoline price led to a 0.0302% decline (in absolute rather than relative terms) in the domestic automobile share of the light-duty vehicle market, other things being equal. A one cent increase in the previous three month period led to a total of 0.1208% decrease in domestic automobile market share. Although the percentage decrease may seem small, a twenty cent increase in gasoline price for one year (e.g., from $1.00 to $1.20 in all months) would lead to an estimated 367,000 decrease in annual sales, based on sales of 15,203,880 light-duty vehicles during model year 1985 (Hu, 1986).

The 7.5% and 7.7% APR financial incentive programs were a successful short term promotion which boosted the domestic car market shares by 6.3% above the otherwise expected levels. However, once the program was terminated, domestic car market shares decreased 6.9% more than otherwise expected. One explanation of this decline is that the inventories of new, model year 1985 cars were depleted as a result of the financial incentives. Consequently, fewer 1985 domestic cars were available after the introduction of the 1986 cars than would have otherwise been expected. Another explanation is that the high sales that were prompted by the financial incentive programs saturated much of the consumer demand for new domestic automobiles. Buyers of new cars decided to purchase the 1985 cars at low interest rates rather than wait for the 1986 cars. A third possible explanation is that the relaxation of the voluntary import quotas in 1986 led to greater sales of import vehicles and a reduced market share for domestic automobiles.

Controlling for other factors, April, October and November were the months in which domestic cars gained a larger share of the market. October and November are traditionally the first two months of the model year. Consumer interest in the new models, which was heightened by heavy advertising by the domestic auto makers, resulted in higher sales during these two months. October and November market shares were respectively 3.9% and 1.8% greater, using January as a norm. The month of April, with its share greater by 1.8% compared to the January norm, is more diffcult to explain, and is the subject of ongoing research.

The changes in the market shares of import automobiles were generally the converse of those of the domestic automobiles. This is because automobiles comprise about three-quarters of the total light-duty vehicles market (Hu, 1986). In contrast to their domestic counterparts, the market shares of import cars reacted positively to increases in gasoline price. A one cent increase in the previous month's gasoline price was estimated to result in an increased market share of 0.0278% for import automobiles. A one cent increase in the previous three month period would lead to an estimated increase of 0.1112%.

The cut-rate financial program of the domestic auto makers had a significant impact on the import car market shares: a drop of 3.3%. Thus, about half of the 6.3% gain in domestic automobile market share during this program was at the expense of import automobiles. The end of the program appeared to help the import cars regain their market shares to their otherwise expected levels. The variable that was used to denote the period after the financial incentive programs was not statistically significant in both of the light truck models as well. Thus, the market shares of import automobiles, domestic light trucks, and import light trucks rebounded after the program to approximately their expected levels, taking into account gasoline prices and monthly trends. By comparison, the financial incentive programs had a "yo-yo" effect on domestic automobiles in terms of an increased market share followed by an approximately equal decreased share after the program.

In the months of March, October and November, market shares of import automobiles were significantly below the January norm: -1.7%, -2.8% and -1.8%, respectively. The March pattern is not yet explained. The October and November patterns might be associated with the traditional beginning-of-model-year strength in domestic automobile sales. Part of the reason for the relatively weaker sales of import automobiles during this period may be due to delays in distributing some vehicles to car dealers in the United States because of the greater transportation distances from foreign manufacturing plants.

The market shares of domestic light trucks were the least sensitive to any changes in gasoline price. The gasoline price coefficient was not statistically significant.

Interestingly, the market shares of domestic light trucks suffered together with import cars and import light trucks during the period of cut-rate financial programs offered in August and September 1985. Even though financial incentives were offered for domestic trucks as well as for automobiles, domestic light truck market shares declined compared to what was otherwise expected. In fact, about half of the market share gain by domestic automobiles was at the expense of domestic light trucks. With the termination of the financial incentive programs, the domestic light truck market share rebounded to an otherwise expected level.

There were no statistically significant monthly trends in domestic light truck market shares. This stable behavior with regard to both seasonal changes and gasoline prices suggests that domestic light trucks were a somewhat different type of good compared to automobiles in that domestic light trucks were used for rather different purposes. Hence, the demand for domestic light trucks was generally invariant to gasoline prices or seasonal factors.

Similar to their car counterparts, market shares of import light trucks reacted positively to increases in gasoline price. The coefficient was 0.0090. The financial incentive program of domestic auto makers also put a significant dent in the shares of import light trucks. There was a -1.47% impact on the import light truck market share. The termination of the program helped the import light trucks to gain approximately 1% more than expected of the market, but this estimate was not statistically significant. The market shares of import light trucks peaked during the period from July through September, with August being the only statistically significant month (with a coefficient of 0.0078). Winter months were also somewhat better for import light trucks, though there was no statistically significant pattern.

The time series models displayed very high correlations between the predicted historical market shares and the actual market shares. Nevertheless, there may be other major factors, which affect market shares, that were omitted from the models. The possibility of this omitted-variable bias is always a concern in statistical models, and it serves to warn that the numerical estimates of the various coefficients are not "final." The modeling procedure allows for additional market-related events to be included as factors affecting market shares. The results indicate that similar models may be developed for the monthly market shares of individual makes and models, and they may provide insights to possible enhancements of vehicle choice models.

REFERENCES

(1) Berkovec, J. and J. Rust (1985). A nested logit model of automobile holdings for one vehicle households. Transportation Research, 19B, 275-285.

(2) Box, G. E. and G. M. Jenkins (1976). Time Series Analysis: Forecasting and Control. Holden-Day Inc., San Francisco, California.

(3) Hu, P. S. (1986). Motor Vehicle MPG and Market Share Report: Model Year 1985. ORNL/TM-9909. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

(4) Hu, P. S. and L. E. Till (1986). User's Manual: Oak Ridge National Laboratory MPG and Market Shares Data System, ORNL-6903. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

(5) Lave, C. and J. Bradley (1980). Market share of imported cars: a model of geographic and demographic determinants. Transportation Research, 14A, 379-387.

(6) Maddala, G. S. (1977). Econometrics. McGraw-Hill Book Company, New York, New York.

(7) Mannering, F. and K. Train (1985). Recent directions in automobile demand modeling. Transportation Research, 19B, 265-274.

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