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Author(s): F. Owen Irvine, Jr.

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Demand Equations for Individual New Car Models Estimated Using Transaction Prices with Implications for Regulatory Issues*

F. OWEN IRVINE, JR.
Michigan State University
East Lansing, Michigan

I. Introduction

The economic impact of the automobile industry on the U.S. economy hardly needs to be emphasized.[1] Taking into account related and "feeder" industries (such as rubber, steel, zinc) it has been estimated that one business in six is automobile related. Over the last 20 years, the auto industry has been subject to increasing regulation. Laws have been passed which require manufacturers to install certain safety equipment and pollution control equipment, and recently have mandated that fuel efficiency (CAFE) standards be met on average by the fleet of cars sold by each manufacturer.[2] The impact of these CAFE standards is enormous. Currently, the domestic auto manufacturers have plans to spend over 40 billion dollars to essentially redesign all of their models.[3]

The effects all these regulations have had and will have on the health and structure of the U.S. automobile industry has been the subject of much debate. Auto manufacturers have argued that (1) consumers do not value the safety and pollution control equipment and that therefore the expense of such equipment merely hurts their sales,[4] and (2) due to the differential ability of the four major auto companies to meet any given standard, the imposition of them disrupts the competitive market relationships which exist between the companies.[5] Advocates of these regulations, on the other hand, view the U.S. auto industry as resisting change in order to protect its profits.

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1. Turley [15] estimated that in 1972 nearly 10 percent of GNP and 26 percent of retail sales were automotive related.

2. Safety standards were imposed under the National Traffic and Motor Vehicles Safety Act of 1966, as amended. Automobile exhaust standards were prescribed under the Clean Air Act of 1963, as amended. See White [19] Chapter 4, for a history of this regulatory effort. Mandatory average fuel economy standards were required of U.S. manufacturers and importers beginning with the 1978 models under the Motor Vehicle Information and Cost Savings Act as amended by the Energy Policy and Conservation Act.

3. The dramatic increase in gasoline prices in 1979-80 due to the Iranian situation, of course, added additional market incentive to produce more fuel-efficient cars.

4. See White [19], Chapter 4 "Air Pollution and Auto Safety Issues."

5. See, for example, the article "GM Juggernaut" in the March 26, 1979 *Business Week*. According to this

Because of the importance of the auto industry and because of its volatility, the estimation of the demand for automobiles has been and continues to be an important topic in applied econometrics.[6] Nearly all previous studies of automobile demand have been at the aggregate level. A sample of the price elasticities estimated in these studies, reported in Table I, suggests that overall price elasticity of demand is between -1.0 and -1.5. These aggregate results, however, do not help very much in evaluating the arguments surrounding the effects of the various regulations. What is needed are (1) estimates of the influence that model characteristics have on automobile demand and (2) estimates of the cross-price elasticities between different models, classified by size-class and manufacturer. These cross-price elasticities are especially needed to evaluate both the impact regulations have had on inter-manufacturer competition and the potential of various tax or subsidy plans to induce consumers to switch to smaller more gas-efficient models from larger models. The literature to date is almost void of such estimates.[7]

This paper begins to fill this void by estimating on monthly data time series demand equations for seven popular domestic models which together accounted for one-third of domestic car sales on average over the 1968-75 sample period. The estimated coefficients suggest that the demand for a particular model is influenced by the model's relative need for repairs. This finding helps explain the current popularity of Japanese models which nearly uniformly have excellent repair records. Also a model's relative safety in a crash is shown to be positively valued by new automobile buyers; this contrasts with Detroit's traditional view that "safety doesn't sell." Each model's demand is shown to be influenced by variations in the prices of other models as well as by fluctuations in its own price. The estimated own-price and cross-price elasticities are very large. The pattern of cross-price elasticities suggests that the substitutability of models diminishes the greater the disparity there is in their size. The large size of these price elasticities helps explain the resistance of the manufacturers to regulations and supports their contention that the imposition of regulations has disrupted the competitive relationships that exist between the major producers. On the other hand, the size of these price elasticities also suggests that the relative mix of car sales by size-class could be altered substantially by a tax or subsidy which favored fuel-efficient cars.

In the next section the theoretical specification of the estimated demand equations is discussed. In Section III, the time series data base used is reviewed. It is unique in that it includes unpublished retail transaction price indices for each of the models, model wholesale price indices constructed by the author, and many other series tabulated from original sources. In Section IV, the estimation results are presented. In Section V, a table of point-of-mean elasticity values is utilized to help evaluate the implications of these results. The question of whether market incentives can be utilized to replace or compliment the CAFE standards is addressed. Finally, Section VI consists of a brief summary.

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article "Some competitors are irate because they think federal regulations have unfairly helped GM garner more and more of the domestic market. They argue that GM can spread the fixed costs of engineering and development work over a much larger sales base than other companies. 'I'd say the root of General Motors strength is the government and regulation,' observes Harold K. Sperlich, group Vice President of engineering and product development at Chrysler."

6. See White [19] and Smith [13] for recent surveys of this literature.

7. Recently Blomqvist and Haessel [1] did estimate the cross-price elasticity between subcompact sales and the aggregate sales of all other size classes to be between (.86) and (1.73) in the Canadian new car market.

Table I. Estimated Price Elasticity of Auto Sales

Study Name	Range Over Which Equation Estimated	Auto Price Index Used	Estimated Price Elasticity[a]
Dyckman [6]	1929-1962	Chow's Newspaper price index	−1.7
		Deflated BLS New Car price index	−1.2
Hamburger [9]	1954:1-1964:4	Implicit Price Deflators IPD (Autos)/IPD(Cons)	−1.17
Evans [8]	1948:1-1964:4	IPD (Autos)/IPD(Cons)	−3.1 −1.5[b]
Hymans [10]	1954:1-1968:4	IPD (Autos)/IPD(Cons)	−1.07 − .36[b]
Rippe and Feldman [12]	1958:7-1973:3	IPD (Autos)/IPD (Cons)	−1.14 − .60[b]
Carlson [3]	1965:1-1975:4	Constructed Size Class Price Indexes for	
		Subcompacts	− .82
		Compacts	−1.21
		Intermediates	−1.30
		Full-Sized	−1.54
		Luxury	−2.07
Blomqvist and Haessel [1]	1971-1975 and cross-sectional	Manufacturers' suggested retail prices (adjusted for Canadian province differentials)	
		Subcompacts	−2.30
		Larger Cars	−1.26

a. Earlier studies surveyed by Dyckman [6] and White [19] report similar sized price elasticities.
b. This is a long-run price elasticity.

II. Equation Specification

As the dependent variable of each model's demand equation we utilized the share of that model's sales in total domestic automobile sales, $SHR_i(t)$. A particular ith model's share was hypothesized to depend on that ith model's price, $P_i(t)$, the prices of substitute models, $P_j(t)$, and the characteristics of the ith model relative to the characteristics of other models. A priori, we expected the coefficient of the own price to be negatively signed and the coefficients of the other model prices to be positively signed. Presumably the closer the substitute, the larger will be the cross-price elasticity estimate. A priori, we expected the closest substitutes for a particular model to be models of the same size-class and models of similar size classes produced by the same company. Model characteristics thought a priori to be important included the model's relative riding comfort, $C_i(t)$, relative frequency of need for repairs, $RF_i(t)$, relative safety in a crash, $S_i(t)$, and its gas mileage relative to other models, $MPG_i(t)$. A priori, a particular model's market share should be larger, the more comfortable its ride, the less frequently it needs repair, the higher its safety in a crash, and the higher its relative gas mileage, ceteris paribus.

It is also clear that the domestic auto manufacturers choose to change the style of each model every few years presumably in an effort to increase sales.[8] To capture any effect major style changes have had on a model's sales share, a variable measuring the number of years since a major style change, $STYLE_i(t)$, was included in the specification. Also a model's share may be temporarily affected by exogenous events like auto strikes and the OPEC embargo gasoline shortage. Dummy variables were included to pick up these effects. Writing the basic model as a linear functional form, we obtain (omitting time subscripts) for each model:[9]

$$SHR_i = \alpha_0 + \alpha_1 P_i + \alpha_j P_j + \ldots + \beta_1 C_i + \beta_2 RF_i + \beta_3 S_i + \beta_4 MPG_i + \beta_5 STYLE_i + \beta_6 OPEC + \beta_7 GMSTR + \beta_8 CHRSTR + \beta_9 AMCSTR + \epsilon \quad (1)$$

where:

P_i = Own price of ith model

P_j = Price of jth substitute model ($j \neq i$)

RF_i = Relative repair frequency of ith model

C_i = Relative riding comfort of the ith model

S_i = Relative safety in a crash of ith model

MPG_i = Relative gas mileage obtained by ith model

$STYLE_i$ = Number of years since major change in styling of ith model

$OPEC$ = Dummy for OPEC oil embargo period

$GMSTR$ = Dummy for period of General Motors strike

$CHRSTR$ = Dummy for period of Chrysler strike

$AMCSTR$ = Dummy for period of AMC strike.

In estimating equation (1), we are implicity assuming that the α_is and β_is are constant over the sample period. Since our sample period (1968-1975) is relatively short, this is a reasonable assumption for all the independent variables except perhaps the relative gasoline mileage. Between May 1973 and May 1974 real gasoline prices rose 29.6 percent.[10] This should have caused consumers to put more weight on the MPG_i attribute in the last two years of the sample. To test this possibility, alternative versions of equation (1) were estimated with $MPG_i(t)$ unweighted and with $MPG_i(t)$ weighted by the real price of gasoline.

8. See White [19], Chapter 12.

9. The stock-adjustment model is typically employed to model aggregate auto demand. It assumes that at any given time there exists a desired stock of automobiles and that aggregate automobile sales will reflect an attempt to adjust the actual stock, partially toward the target stock. The stock adjustment framework is not practical for modelling the demand for individual new models, however. This is because it would be ridiculous to assume that there exist desired stocks of each particular model since for nearly all models there are several other models that are very good substitutes. Applying the stock adjustment model to disaggregated segments of a market requires that the desired stock of each segment to have some practical significance. The greater the degree of substitutability between the goods in the market segments, the less reasonable it is to assume that there exist distinct target stocks. Our modelling of the proportion of aggregate sales accounted for by each model as a function of the factors listed in equation (1) is consistent with aggregate sales being influenced by stock-adjustment considerations.

10. The real price of gasoline is defined as the C.P.I for gasoline divided by the overall C.P.I.

Since the market share of a particular model in a particular month clearly ranges from zero to one, equation (1) falls into the class of limited dependent variable models. The dependent variable, $SHR_i(t)$, can be interpreted as an estimate of the probability that a particular period's new car buyers will choose to purchase the ith model conditional upon information regarding the model's relative price and relative characteristics. Rather than estimate equation (1) directly, a logit probability model was utilized.[11] This simply required the transformation of the dependent varible into the "logarithm of the odds" form, i.e., the dependent variable was made to be:

$$LSHR_i(t) = \log[SHR_i(t)/(1.0 - SHR_i(t))]. \tag{2}$$

This transformation avoids the problem sometimes encountered in a linear probability model of forecasting shares outside the (0, 1) interval.[12]

III. Data Utilized

Time series equations like equation (1) (with the dependent variable in log-odds form) were estimated for the seven domestic models listed in Table II. Data availability limitations restricted us to these seven popular models.[13] Nearly all the data had to be collected from raw data sources. The exact definition and source of each variable is listed in Appendix A. The monthly sales (not registrations) of each model were divided by total domestic sales in the same month to calculate the model's monthly market share, $SHR_i(t)$.

Auto demand studies have been plagued by one major data problem, the unavailability of good data on transactions prices. Unpublished data allowed us to overcome this problem. In each model's equation we initially included the model's price index, the price indexes of each of the other six models, and a price index for Volkswagens. Fluctuations in these price indexes measure changes in the average transactions price actually paid by purchasers of the model on average across the United States. They are based on unpublished data which the U.S. Bureau of Labor Statistics collected as part of its monthly Consumer Price Index (CPI) survey and are constructed in a manner identical to published CPI subindices.[14] Thus they reflect monthly variations in the discount given customers from the list price and also the quality adjustments made by B.L.S. to reflect changes in the model's specification. Each model's price index was divided by the overall CPI before being entered in the model demand equations.

11. See Pindyck and Rubinfeld [11, 248-51] for a discussion of the Berkson-Thiel technique for estimation of logit models on frequency data.

12. Using this logit model transforms the problem of predicting market shares within a (0,1) interval to the problem of predicting the odds of an event occurring within the range of the entire real line.

13. These were the only domestic models for which B.L.S. collected C.P.I. transaction price data over this 1968-1975 sample period. Prior to the 1968 model year, even fewer models were priced by B.L.S. In 1975, several new models were added to the B.L.S. sample, however, in December 1977, when the B.L.S. started basing the C.P.I. on a probability sample, it ceased collecting data on particular specifications of automobile models. Hence, since 1978 no unpublished C.P.I. data are available to construct model price indices.

14. In obtaining this unpublished data from the B.L.S., the author agreed not to publish or otherwise release the model price indices. However, B.L.S. will supply the data to other researchers on an individual request basis.

Table II

Model Name	Average Percentage Share of Total Domestic Sales	Model's Size Class
Chevrolet Impala	10.47	Full Size
Pontiac Catalina	3.69	Full Size
Ford Galaxy/LTD	8.82	Full Size
Chrysler-Plymouth/Fury	3.05	Full Size
AMC Rebel/Matador	.66	Intermediate
Chevrolet Chevelle	4.58	Intermediate
Ford Mustang	2.66	Compact

Many of the model characteristics were taken from road tests of the model done by and reported in *Consumer Reports* (hereafter *CR*). As a measure of riding comfort, *CR's* measures of relative riding comfort with a light load, RRL_i, and full load, RRF_i, were utilized. These ratings range from 1.0 for a poor ride to 5.0 for good ride. As a measure of the expected frequency with which a model will probably need to be repaired, *CR* frequency of repair data for the model in previous years were used. These ratings range from 1.0 for models needing "much greater frequency of repair than average" to 3.0 for average to 5.0 for models needing "much less frequency of repair than average." To calculate the expected repair frequency of the *i*th model, RF_i, the repair frequency ratings of the *i*th model produced the previous year, the year before that, 3 years previously, and 4 years previously were averaged.[15] Gas usage for city and highway driving taken from *CR* were divided by the average miles per gallon for all cars in the U.S. to give two measures of relative fuel economy for each model, $RMPGT_i$ and $RMPGH_i$. As a measure of the safety of a model in an accident, an index of the relative frequency of serious and fatal injuries associated with crashes of the model was obtained from a cross-sectional study conducted by the Highway Safety Research Center at the University of North Carolina. The lower the value of this index, S_i, the lower the relative frequency of serious injuries or death in actual crashes of the model. To construct the index giving the number of years since a major style change, $STYLE_i(t)$, yearly pictures of each model were examined to determine the years of major restyling.

A number of variables were constructed for use as instrumental variables. For each model an index of the wholesale price charged new car dealers by the automobile manufacturer was constructed. The exact model specification (including options, etc.) for which B.L.S. collected retail prices was priced using the *Edmund's New Car Prices* publication. The October values of each index were corrected by the average quality change applied to the wholesale price index for new cars by B.L.S.[16] Also for each model an inventory to expected sales ratio was constructed as a measure of the condition of dealer inventories of the model.

15. Three year and two year averages of repair frequency ratings were also tried.

16. B.L.S. would not release individual model wholesale price indexes nor the quality change correction applied to individual models as this would have violated disclosure agreements.

IV. Estimation Results

Substituting the empirically available measures of the independent variables discussed in the previous section into equation (1), we obtain the specification which we initially estimated for each model:

$$LSHR_i(t) = \alpha_0 + \alpha_1 P_i(t) + \alpha_j P_j + \ldots + \alpha_8 P_{VOLK} + \beta_1 RRL_i(t) + \beta_2 RRF_i(t)$$
$$+ \beta_3 RF_i(t) + \beta_4 RMPGT_i(t) + \beta_5 RMPGH_i(t) + \beta_6 S_i(t)$$
$$+ \beta_7 STYLE_i(t) + \beta_8 OPEC + \beta_9 GMSTR + \beta_{10} CHRSTR$$
$$+ \beta_{11} AMCSTR + \epsilon(t) \quad (3)$$

where:

$i = 1, \ldots, 7$ and $j \neq i$

P_i = ith model's own price index divided by the CPI

P_j = jth substitute model's price index divided by the CPI.

Since these are demand equations they must be estimated by a simultaneous equations technique to avoid simultaneous equations bias. An instrumental variables technique was employed, treating the own price, $P_i(t)$, as endogenous. As excluded instruments we utilized a manufacturer's price index for the ith model, an inventory to expected sales ratio for the model, the prime bank interest rate, and the average hourly earnings of employees at auto dealerships.[17] The limited availability of the unpublished consumer price index data on individual models restricted the sample period to 1968 through 1975.[18] Thus for most of the equations (except the one for Mustang) we had around 80 monthly observations.

An examination of plots against time of the model consumer price indices revealed, as one would expect, that they generally moved together. As one can see from Table III, the simple correlations between them are quite high. Thus a priori we expected that we would encounter multicollinearity. Multicollinearity does not cause coefficient bias. However, serious multicollinearity can cause the estimated standard errors of the collinear variables to "blow-up" reflecting the inability of the regression to precisely estimate the individual effects of the explanatory variables. Our approach to dealing with the multicollinearity was to first estimate each equation with all of the independent variables included. Then for a particular model's equation, the variable with the lowest asymptotic t-statistic was dropped, and the equation reestimated.[19] In general, if dropping the variable improved the fit of the equation (as judged by the estimated standard error adjusted) and did not substantially affect the coefficients of the remaining variables, it was dropped. Then another insignificant variable was dropped, etc. Chow tests (F-tests) were done to

17. The submarket for each auto model is being viewed here as consisting of a model demand equation representing the behavior of new car buyers and a model supply equation representing the average new car dealership's willingness to supply various quantities of the model at a set of corresponding prices. The quantity sold and the average transaction price in the model submarket are endogenously determined. The excluded instruments are exogenous factors which shift the average new car dealership's supply curve of the ith model. A standard two-stage least squares estimating procedure like that utilized in the "TSP" package was used to estimate each demand equation.

18. The sample period for several of the models was shorter than this because of the B.L.S. discontinuing collection of data on the particular models.

19. Only variables whose estimated t-statistics were less than one were ever considered for omission from the specification. If dropped, the variable was generally added to the equation's instruments.

Table III. Correlation Matrix

	Impala CPI	Catalina CPI	Ford CPI	Plymouth CPI	AMC CPI	Chevelle CPI	Volkswagen CPI	Mustang CPI
Impala/CPI	1.000							
Catalina/CPI	.997	1.00						
Ford/CPI	.994	.993	1.00					
Plymouth/CPI	.971	.996	.978	1.00				
AMC/CPI	.991	.987	.990	.985	1.00			
Chevelle/CPI	.994	.989	.988	.969	.991	1.00		
Volkswagen/CPI	−.751	−.782	−.768	−.720	−.735	−.726	1.00	
Mustang/CPI	.963	.955	.964	.936	.974	.971	−.615	1.00

Note: All correlations calculated over April 1968 through September 1974 sample period except those with Mustang are for a April 1968 through October 1973 sample period.

test the null hypothesis that the dropped variables' coefficients were not statistically different from zero. The resulting final equations' estimated coefficients are reported in Table IV.

As one can observe from Table IV, the estimated coefficient signs conform closely to the a priori expected pattern. For all models, the estimated coefficient on the own price is negatively signed and in six of the seven equations tests to be statistically different from zero by an asymptotic one-tailed t-test at the 2.5 percent level. Twenty out of twenty-three cross-price coefficients are positively signed and about two-thirds of them test to be statistically significant. Among the relative model characteristics, the repair frequency and crash injury frequency entered significantly in the most equations. The two relative gas mileage measures were generally quite colinear (both with each other and other equation variables). Entering the average of the city and highway gas mileage measures, $RMPGA_i(t)$, improved the fit in the Impala and Fury equations. The equations reported in Table IV are for the alternative specification which allowed the coefficients on the relative gas mileage measures to be larger in the post-OPEC portion of the sample. This alternative specification generally had tighter fits, implying that consumers assigned more weight to the relative gas mileage attribute after the real price of gasoline increased.[20]

20. An attempt was first made to estimate separate slope coefficients on the relative gasoline mileage variable, i.e. the following equation:

$$\text{Share}\ (t) = \alpha + \beta_{pre\text{-}OPEC}[RMPG_1(t)] + \beta_{post\text{-}OPEC}[RMPG_2(t)] + \ldots$$

was estimated where $RMPG_1(t)$ equals the appropriate relative gas mileage variable through Nov. 1973 (zero afterwards) and where $RMPG_2(t)$ is zero through Nov. 1973 and equal to the gas mileage variable afterwards. However, the facts (1) that there are only 10 to 19 months in the post-OPEC portion of the samples and (2) that the $RMPG(t)$ variables only change when a model is altered (usually once a year), meant that the post-OPEC coefficient could not be accurately estimated (in two equations the multicollinearity was so great as to prevent the estimation altogether). As an alternative, it was assumed that coefficient on the RMPG attribute is proportional to the average real price of gasoline, i.e., we made the assumption that

$$\frac{\beta\ \text{post-OPEC}}{\beta\ \text{pre-OPEC}} = \frac{\text{Post-OPEC Avg. Real Gas Price}}{\text{Pre-OPEC Avg. Real Gas Price}}$$

From December 1973, through mid-1975 (the end of our sample) the average real price of gasoline was 17.024 percent higher than in the 1968-Nov. 1973 portion of the sample. Hence, to implement the above assumption, each post-OPEC observation in each RMPG series was multiplied 1.17024. When this weighting was done, the fits of the equations improved which indicates that this assumption is better than the alternative one which assumes a constant $RMPG(t)$ coefficient for the entire sample period. Note that the coefficient estimates reported in Table IV for the gas mileage measures are the pre-OPEC coefficients. The post-OPEC coefficient estimates are 17.02 percent larger.

Table IV. Equations Explaining Model Market Share in Log-Odds Form

Independent Variables	A Priori Expected Sign	GM Chevrolet Impala	GM Pontiac Catalina	Ford Galaxy LTD	Chrysler Plymouth Fury	AMC Rebel/ Matador	GM Chevrolet Chevelle	Ford Mustang
Relative Prices								
Impala/CPI		−19.30	23.12		−8.29		14.13	
		(6.78)	(11.18)		(3.32)		(7.21)	
Catalina/CPI		6.49	−20.15					
		(3.46)	(8.00)					
Ford/CPI		4.45		−6.63	7.33			
		(2.71)		(2.72)	(2.66)			
Plymouth/CPI		5.45	.58	8.66	−5.42	7.38	2.07	
		(2.08)	(3.18)	(2.64)	(2.28)	(2.98)	(3.03)	
AMC/CPI		−10.83	−10.13		10.32	−6.91		6.53
		(4.38)	(4.69)		(3.04)	(3.08)		(4.18)
Chevelle/CPI		14.66	6.36				−20.78	4.47
		(5.03)	(6.21)				(7.00)	(6.62)
Mustang/CPI		.58	.32	1.04				−9.52
		(.18)	(.28)	(.26)				(6.86)
Volkswagen/CPI						1.14		4.66
						(1.11)		(3.50)
Relative Model Characteristics								
Repair Frequency	+		.57	.51			3.30	127.3
			(.34)	(.15)			(.92)	(28.3)
Crash Injury Frequency	−		−.031		−.0028		−.043	−.33
			(.014)		(.0027)		(.009)	(.07)
Ride Rating - Full Load	+					.063	−2.34	
						(.071)	(.62)	
Ride Rating - Light Load	+		.22		.28		1.22	
			(.18)		(.06)		(.27)	
Gas Mileage (weighted) - City	+		−5.80	.50			−33.26	−1152.0
			(3.54)	(.54)			(8.25)	(258.5)
Gas Mileage (weighted) - Highway	+		1.54			1.45	17.76	603.0
			(1.24)			(.27)	(4.26)	(134.5)

Gas Mileage - Avg. of above	+	.951			1.12			
		(.543)			(.33)			
Years Since Model Style Altered	?						−.62	85.81
							(.14)	(19.17)
Other Factors								
GM Strike Dummy		−.61	−.33	.45	.090	.41	−.13	.18
		(.08)	(.09)	(.08)	(.041)	(.11)	(.06)	(.06)
Chrysler Strike Dummy					−.23			
					(.15)			
OPEC Dummy						.35		
						(.14)		
Intercept		−4.24	−2.23	6.79	−9.22	−8.90	−4.13	−362.7
		(.61)	(1.04)	(.73)	(.53)	(1.53)	(1.48)	(78.3)
Summary Statistics								
R-Square Adjusted		.800	.748	.831	.861	.485	.477	.895
Standard-Error Adjusted		.155	.156	.150	.137	.217	.168	.115
Sum-of-Squared-Residuals		1.848	1.579	1.787	1.277	3.300	2.125	.410
Durbin-Watson Statistic		1.71	1.87	1.30	1.67	1.28	1.43	2.29
Sample Period		68/4-75/6	68/4-74/9	68/4-75/6	68/4-74/9	68/4-74/9	68/4-75/6	68/4-71/9
Mean Market Share Over Sample (percent)		10.47	3.69	8.82	3.05	.66	4.58	2.66

Note: Asymptotic standard errors reported in parenthesis below each coefficient. Each equation estimated by an instrumental variables technique, which treated the own price as endogenous. Excluded instruments used include $MPIB_i$, *FYPR*, *AHECAR*, IES_i, and generally the independent variables omitted from each equation.

Statistically the coefficients on the relative gas mileage measures in the Impala, Fury, and AMC equations all test by a one-tailed t-test to be different from zero at the five percent level. Likewise, F-tests reject at the five percent level the hypothesis that the coefficients on the city and highway gas mileage variables are both zero in the Mustang and Chevelle equations. Hence, despite the collinearity, the relative gas mileage attribute is statistically important to the explanation of these model market shares. Of the riding comfort measures, the light load measure dominated. This is reasonable because most new car buyers test-drive models which are lightly loaded. The style change variable entered significantly in only two equations and had opposite signs in these. This suggests that style changes do not always have the desired effect of increasing a model's sales. The large strike against GM in late 1970 had a pronounced effect on all model market shares as indicated by the significant coefficients on the GM strike dummy variable. On the other hand, the short strike against Chrysler in September 1973, significantly influenced only the Plymouth Fury's market share.

Generally as the reported coefficients of determination suggest, the fit of these equations is quite good considering that monthly data were utilized. An examination of plots of the fitted model shares versus the actual model shares confirms that these equations capture most major movements in the model market shares.[21]

V. Implications Of Empirical Results

From the estimated coefficients in Table IV, the estimated point-of-means elasticities of each model's share, $SHR_i(t)$, with respect to each independent variable were derived. These are given in Table V. Upon examining these, one is immediately impressed by the large size of the price elasticities. The own-price elasticities range from -4.59 to -16.99 and average -10.42. The size of these own-price elasticities supports the view that each model has a number of close substitutes. The estimated cross-price elasticities are also generally quite large.[22]

White [19, 100] has suggested that "overall, the market for new cars appears to be a somewhat segmented one, with the segments overlapping." The cross-elasticity estimates support this view with the segments (or submarkets) being defined by size-class and automobile manufacturer. The estimated cross-price elasticities among the four full-size models (Impala, Galaxy, Fury and Catalina) suggest that they all are substitutes. However,

21. These plots are reported in a statistical appendix available from the author. The relatively poor fit of the AMC equation can be explained by the fact that the AMC model had by far the smallest market share and the fact that the AMC consumer price index is probably the least accurate because (1) the model priced was altered several times over the sample period requiring links to be made and (2) not all cities have AMC dealers. In this case, B.L.S. priced a non-AMC substitute car (generally it was the Plymouth Valiant) and linked in this observation. The relatively poor fit of the Chevelle equation is explained by the fact that its market share displays considerable seasonal variation. However, since the market share of every other model displayed little seasonal variation, seasonal adjustment of these model demand equations was judged not worth the loss of degrees of freedom such procedures entail.

22. These price elasticities are considerably larger than those obtained in most previous auto demand studies. This finding, however, is consistent with (1) the fact that previous studies utilized considerably worse price data and (2) the fact that previous equations were estimated on aggregate data. On a priori grounds, we would expect individual models to have many more substitutes than an entire size-class of autos or automobiles as a whole. The fact that the coefficient standard errors are quite small relative to the estimated own-price coefficients rules out the possibility that these coefficients are seriously affected by multicollinearity. Two-thirds of the cross-price elasticities are also based on coefficients which test to be statistically different from zero by a one-tailed t-test at the 5 percent level.

these elasticities also show that the higher priced Pontiac Catalina is in a somewhat different market segment. The estimated same company cross-elasticity between the Impala and Pontiac is high while the cross elasticity estimates between both the Plymouth and Ford and the Pontiac are quite low.[23] The substantial cross elasticity estimates between these full-size models and the two intermediate size models (Chevelle and Rebel/ Matador) confirm that they are good substitutes. Notice that the cross-elasticity between the full-sized Impala and intermediate Chevelle is around 11.0 as estimated in both model's equations. On the other hand hand, the small cross elasticity estimates between the full-sized models and the compact sized Mustang suggest that full-sized and compact models are relatively poor substitutes. The failure to find any cross-price effect of the price of the subcompact Volkswagen in the full-sized model equations, lends further support to the hypothesis that the degree of substitutability decreases the further apart the models are in size. The substantial cross elasticity estimates in the compact Mustang's equation suggest it to be a good substitute for both the subcompact Volkswagen and the two intermediates.

Thus the cross-price elasticity estimates suggest that the degree of substitutability between two models is a function of the closeness in their sizes and the identity of their manufacturer(s). The fact that models made by the same manufacturer are better substitutes, ceteris paribus, is explained by the importance of brand loyalty. White [19] quotes survey data which show the repeat buying ranged from 40 to 70 percent for different makes in different years.[24] In discussing the pricing policies of the automobile companies, White [19, 121] speculated that General Motors as the price leader faces a price elasticity which is a "good deal in excess of -1.0." This paper's estimated price elasticities certainly confirm his speculation. The large size of these estimated elasticities implies that the automobile companies have to be quite competitive in pricing each model, being particularly sensitive to the prices of substitute models within the model's market segment. Failure to be competitive can cause a substantial reduction in the model's market share.[25]

Given that other researchers have documented that there exist substantial economies of scale in auto production, our finding of large cross-price elasticities between similar models lends support to those who argue that the smaller scale producers (AMC and Chrysler in particuar) have been put at a competitive disadvantage by the increasing number of government regulations imposed on the auto industry over the last 20 years.[26] For example, if manufacturing and installing a certain pollution control device costs one company less per unit than it costs the others (say because of differences in research facilities, production volumes, etc.), then a regulation requiring that the device be put on all cars gives the low cost company a cost advantage. In turn, the higher cost companies will either lose sales to the lower cost company, or if they charge the same as the lower cost company for the device, their profits will be adversely affected. These large price elasticities also help explain why individual companies have been reluctant to introduce design innovations which they thought would not increase the model's relative sales appeal.

23. This is a very reasonable pattern since it is customary in the new car market for Chevrolet buyers to "move up in quality" to Pontiacs while Ford buyers "move up in quality" to Mercurys.

24. White [19, 103] notes this brand loyalty may also be influenced by customers returning to dealerships who sold them their present car and satisfactorily serviced it.

25. This is in accordance with White's observation that positioning of a model's price relative to its rivals is important in setting a model's price [19, 115].

26. See Eric Toder [14], Chapter 4, and footnote 5.

Table V. Point-of-Mean Elasticity Values of Model Shares W.R.T. Independent Variables

Independent Variables	GM Chevrolet Impala	GM Pontiac Catalina	Ford Galaxy/ LTD	Chrysler Plymouth Fury	AMC Rebel Matador	GM Chrevolet Chevelle	Ford Mustang
Relative Prices							
Impala/CPI	−14.79*	19.30*		−6.97*		11.54*	
Catalina/CPI	5.09*	−16.99*					
Ford/CPI	3.48*		−5.16*	6.16*			
Plymouth/CPI	4.22*	.49	6.82*	−4.59*	6.40*	1.71	
AMC/CPI	−8.51*	−8.56*		8.78*	−6.02*		5.86
Chevelle/CPI	11.23*	5.30				−16.96*	3.96
Mustang/CPI	.34*	.23	.63*				−8.42
Volkswagen/CPI					1.12		4.30
Relative Model Characteristics							
Repair Frequency		1.70*	1.39*			6.95*	341.0*
Crash Injury Frequency		−2.17*		−0.21		−3.59*	−26.38*
Ride Rating-Full Load					.14	−2.77*	
Ride Rating-Light Load		−.88	1.24*			4.04*	
Gas Mileage-City							
Pre-OPEC		−3.02	.29			−22.60*	−862.9*
Post-OPEC		−3.53	.34			−26.45*	
Gas Mileage-Highway							
Pre-OPEC		1.86			2.09*	23.23*	854.6*
Post-OPEC		2.17			2.45*	27.18*	
Gas Mileage-Avg. of Above							
Pre-OPEC	.51*			1.08*			
Post-OPEC	.59*			1.26*			

*asterisks indicate that the coefficient used to calculate the elasticity value tested to be statistically different from zero by the appropriate t-test at the 5% level.

Historically, despite the fact that theoretically consumers should value safety and be willing to pay for design changes which make cars safer, the U.S. auto manufacturers have acted as if they believed extra safety equipment would not be valued by consumers.[27] Even in recent years, after many safety features have been required by regulation, the automobile manufacturers continue to resist the installation of a proven safety device, air-bags. The estimation results, however, contradict this traditional view. In four of the equations, an index of the relative frequency of death and serious injury (given that an accident occurs) entered with a negatively signed coefficient. The size of the elasticity values with respect to this safety index, as reported in Table V, are quite substantial, indicating that changes in a model's safety (relative to other models) will have a large impact on the model's demand curve.[28] In Table VI the average relative gas mileage, $RMPGA_i(t)$, is given for each of our models for each model year in our sample.[29] The pre-OPEC coefficient estimates on the respective gas mileage measures from the Impala, Fury, Ford, and AMC equations average 1.0. Assuming a 1.0 coefficient, then for a model whose market share is initially five percent, an increase of 0.1 in $RMPGA_i(t)$ would cause the model's sales share to increase by .475 per cent (i.e. 47,500 cars if domestic sales are 10 million a year). After 1973 the shift would be even larger (about .556 percent). This example and the size of the elasticities on the gas mileage variables make it clear that shifts in a model's relative gas mileage can have an important impact on its market share. Obviously, the increased market share of imports in the late 1970s is partially explained by their high relative gas mileages and the increased weight consumers are putting on this attribute.[30]

The estimated elasticity values show that demanders are quite sensitive to each model's expected repair needs as judged by their experience with the model in previous years. Models which need less repair are in higher demand. This finding also helps explain the current popularity of Japanese models which nearly uniformly have excellent repair records. The fact that a four-year average of *Consumer Reports* repair frequencies was more significant than 2 or 3 year averages suggests that it takes several years for a model's repair reputation to change. This suggests that U.S. manufacturers must increase the quality of their cars and maintain the quality for several years in order to again become competitive along this dimension with the Japanese models. As expected, the estimation results show that riding comfort also seems to have a moderately important influence on the demand for individual models. Domestically manufactured cars typically have had better comfort ratings. To maintain their share of the market, U.S. manufacturers need to

27. There is an externality problem, however, in that some of the benefits of less accidents go to individuals other than the purchaser of the safety equipment. According to White [19, 239] until 1965, the auto companies ". . . dragged their feet, behaving as if safety did not enter the preferences of consumers and as if the mention of safety considerations might well deter consumers." As a result of the failure of a 1956 effort by Ford to stress safety features (the "Lifeguard design" which was dropped in mid-year due to poor sales) "safety doesn't sell" became the accepted byword in the auto industry.

28. The success of SAAB in marketing safety features is also evidence that some subsegment of new car buyers value safety features.

29. Each of the $RMPGA_i(t)$ can be converted to mpg by multiplying by the average fleet mpg ($AVMFC$) also given in Table VI. A model year runs from October through September.

30. As we have seen, the data supported the assumption that the weight on the relative gas mileage increases in proportion to the real price of gasoline. If this continues to hold, then in comparing two models whose initial market shares are five percent each, a doubling of the real gas price would cause the more fuel efficient model to gain about one-half of a percent market share for each 0.1 its $RMPGA_i(t)$ exceeded the other model's $RMPGA_i(t)$

Table VI. Average Relative Gasoline Mileage, $RMPGA_i(t)$

Model	Model Year								Average Over Sample
	1968	1969	1970	1971	1972	1973	1974	1975	
Pontiac Catalina	1.007	.909	.884	.910	.914	.865	.842	.910	.915
Chevrolet Impala	1.007	.982	.884	.874	.914	.903	.879	.946	.935
Ford Galaxy/LTD	1.007	1.018	.920	.947	.951	.903	.879	.910	.947
Plymouth Fury	1.078	1.164	.920	.874	1.061	1.016	.879	.983	.996
Chevrolet Chevelle	1.042	.945	1.105	1.093	1.097	.941	1.062	1.005	1.045
AMC Rebel/Matador	1.258	1.200	1.068	1.093	1.097	1.053	1.026	.946	1.121
Ford Mustang	1.150	1.164	.957	1.202	NP	NP	NP	NP	1.114
VW Beetle	1.725	1.855	1.878	1.675	1.609	1.655	1.612	NP	1.728
Fleet Average mpg (AVMFC)	13.91	13.75	13.58	13.73	13.67	13.29	13.65	13.74	13.67
Real Price Gasoline	.982	.960	.916	.882	.862	.874	1.054	1.050	.9395

Note: Average relative gasoline mileage, $RMPGA_i(t)$, equals $[RMPGT_i(t) + RMPGH_i(t)] / 2$. Data based on *Consumer Reports* road tests (See Data Appendix). "NP" means model not produced in particular year.

maintain these comfort levels. This, however, may be difficult given the current downsizing of domestic models in order to make them more fuel efficient while imports appear to be growing more luxurious. Because of their size, domestically produced models also historically have been relatively safer than imports; this advantage may also be impaired by downsizing.

This downsizing of domestic models is required by an act of Congress. In 1978 Congress mandated that each manufacturer redesign its cars so that its fleet of cars sold obtain on average a certain miles-per-gallon (mpg) standard or face stiff penalties. These CAFE standards required 18 mpg (EPA test) in 1978 and rise to 27.5 mpg in 1985. Wharton EFA in their March 1979 forecast, using their "Wharton EFA Motor Vehicle Model" [17], projects that this downsizing program will increase mpg enough to meet these CAFE standards through reducing the 1985 curb weights of new autos (relative to 1975 weights) by from 18 percent for subcompacts to 30 percent for full-size and luxury classes and through the widespread use of diesel engines in the early 1980s.[31] These technological improvements will, according to the Wharton predictions, increase the average actual mpg of the fleet of new cars from 15.13 mpg in 1980 to 19.36 mpg in 1985 (a 28 percent improvement). Making the technological changes necessary to meet these CAFE mpg standards has been both very expensive and very disruptive to the automobile industry.

An alternative to (or perhaps compliment to) this forced technological change strategy would be a program which encouraged the substitution of smaller, more gas efficient cars for larger, less energy efficient models. The potential gasoline savings by this approach is large. This is because first, under existing technology switching from a

31. Wharton [17, A1 85-87] bases actual mileage estimates on *Consumer Reports* road test data related by regression analysis to the model's characteristics.

domestic full-size model to a domestic compact increases actual gasoline mileage by 23 percent (or 2.8 mpg) and switching to a domestic subcompact increases gasoline mileage by 49 percent (or 6.0 mpg). Secondly, there are a large number of new car buyers who potentially can make these switches—the larger sized luxury, full-sized, and intermediate models still accounted for 45 percent of U.S. auto sales in 1979. Lastly, as we discussed earlier, because the cross-price elasticities between models of different size-classes are quite large, the mix of new car sales by size class can be substantially altered by taxing or subsidizing models in certain classes. In turn, substantial amounts of gasoline can be saved. Given a commitment to reducing gasoline consumption by automobiles, it does not seem economically rational to rely solely on the expensive technological change approach as the U.S. has been doing.[32]

VI. Summary

As the first study to report statistically estimated demand equations for individual models of new automobiles, this paper has provided many new insights. Individual model characteristics such as relative safety, relative gasoline mileage, and relative maintenance requirements were shown to significantly influence the individual model demands. The large estimated price elasticities imply that the degree of substitutability between new models is quite high. As we have discussed, this helps explain why manufacturers have been resistant to regulatory efforts such as those requiring the installation of new safety devices. As we examined in the last section, these large price elasticity values also imply that an excise tax on gas-guzzler cars could successfully encourage substitution toward smaller, more fuel-efficient cars. These findings resulted from the use of the unique data base assembled for this study.

This study's sample was limited to the models for which B.L.S. collected transaction prices. Hence, the Mustang and the Volkswagen were the only small cars included in the sample. With the 1979-80 increase in the price of gasoline, sales of such compact and subcompact models have grown rapidly at the expense of full-sized and luxury models. In this paper we found that the estimated cross-price elasticities between the full-sized models and (1) the subcompact Volkswagen were insignificant and close to zero, and (2) the compact Mustang were statistically significant, but relatively small-sized, and (3) the intermediate models were statistically significant and quite large in size. From this pattern we concluded that the cross-price elasticities are substantial between models of adjacent size-class, but diminish the more the models differ in size. It seems reasonable that such a pattern of cross-price elasticities would continue to exist in the new car market today. Increased "energy awareness" should, if anything, increase the willingness of consumers to substitute smaller models for larger ones. The current process of downsizing, to the extent it reduces the size differentials between the models of different size-class, should also increase the degree of substitutability that exists. These changes imply even larger cross-price elasticities between models of adjacent size-class than those estimated in this paper.

32. Unfortunately, the gas-guzzler tax passed as part of the 1978 Energy Act is too weak to be anything more than a backup to the CAFE standards. Comparisons of the E.P.A. mpg projections made by Wharton with the gas-guzzler tax minimum mpg show that few if any models will actually be taxed under the present law.

Appendix A. Description of Data Utilized

NAME	DESCRIPTION	SOURCE
i = Impala, Catalina, Plymouth, Ford, Chevelle, Matador, Mustang		
$SALES_i$	Sales of model i in units.	*Automotive News*
$LSHR_i$	Log odds form of the market share for model i: $log[SHR/(1.0 - SHR_i)] = LSHR_i$ where $SHR_i = SALES_i / \text{total domestic sales}$.	
CPI_i	Consumer Price Index for model i. (1967 = 100)	BLS (unpublished data)
MNT_{it}	Measure of relative frequency of repair for model i, t years old: 1 = Much greater freq. of repair than avg. 2 = Greater freq. of repair than avg. 3 = Average freq. of repair 4 = Less freq. of repair than avg. 5 = Much less freq. of repair than avg.	*Consumer Reports*
RF_i	Measure of expected relative frequency of repair for model i. $RF_i = (MNT_{i1} + MNT_{i2} + MNT_{i3} + MNT_{i4})/4$	
RRF_i	Measure of relative ride rating of model i with a full load. 1 = Poor; 2 = Poor to Fair; 3 = Fair; 4 = Fair to Good; 5 = Good	*Consumer Reports*
RRL_i	Measure of relative ride rating of model i with a light load. Numerical valuation as for RRF_i.	*Consumer Reports*
$MPGT_i$	Miles per gallon in city driving for model i.	*Consumer Reports*
$MPGH_i$	Miles per gallon in highway driving for model i.	*Consumer Reports*
$AVMFC$	Average miles per gallon for all cars.	*Statistical Abstract of the United States*
$RMPGT_i$	$MPGT_i / AVMFC$.	
$RMPGH_i$	$MPGH_i / AVMFC$.	
S_i	Index of number of serious and fatal injuries in a crash for Model i compared to a standard reference group (Average = 100). Safer cars have lower index ratings.	Study by Campbell at the Highway Safety Research Center at the U. of North Carolina [2]
	Supplemented by data from the	Highway Loss Data Institute
INV_i	Inventories of model i in units. Raw data was inventories expressed in days of sale which were then multiplied by the selling rate of the previous month to arrive at units.	*Automotive News*
$EXPLS_i(t)$	$SALES_i(t-12)[1/3]\{[SALES_i(t-1)/SALES_i(t-13)] + [SALES_i(t-2)/SALES_i(t-14)] + [SALES_i(t-3)/SALES_i(t-15)]\}$	

Appendix A. Continued

NAME	DESCRIPTION	SOURCE
IES_i	Ratio of inventory to expected sales for model *i*. $IES_i(t) = INV_i(t)/EXPLS_i(t)$	
$STYLE_i$	Number of years elapsed since a major style change in model *i*.	*Automotive News* Almanac Issues
$MPIB_i$	Wholesale price index, with BLS average quality changes taken into account, for model *i*.	BLS Pricing Specifications; Edmund's *New Car Prices*; BLS Average Quality Changes
CPI	Consumer Price Index: All Items	NBER Tape "PC"
FYPR	Prime Rate, Loans of Leading City Banks	NBER Tape "FYPR"
AHECAR	Avg. hourly earnings of automobile dealer employees	BLS *Employment and Earnings, 1909-1975*
BENZIN	CPI for gasoline.	BLS, CPI Tape: Code No: 04 4112 1001
OPEC	= 1 Nov. 1973 to Mar. 1974, = 0 otherwise.	
CHRSTR	= 1 in months of large strikes against Chrysler Motor Corp., = 0 otherwise.	
AMCSTR	= 1 in months of large strikes against American Motors Corp., = 0 otherwise.	BLS *Analysis of Work Stoppages*
GMSTR	= 1 in months of large strikes against the General Motors Corp., = 0 otherwise.	
D_j	= 1 in month j; = 0 otherwise.	

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