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# THE RELATIONSHIP OF AUTOMOBILE CHARACTERISTICS TO LIST PRICES AND PROFIT MARGINS -- A PRELIMINARY ANALYSIS

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AUGUST 1978

FINAL REPORT

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16. Abstract

This report describes research on potential impacts of fuel economy regulations on the U.S. automobile industry. The study focused on the possible effects of auto "down-sizing" on manufacture profit margins. Historical price data were used to estimate variable profit margins. Estimated margins were strongly correlated with vehicle inertia weight and the price of the average options packages and, to a lesser extent, were negatively correlated with production volume. Regression analyses were also performed to relate list prices to vehicle characteristics believed to represent valuable attributes to consumers. The results, although ambiguous, suggest that vehicle roominess, fuel economy, and power-to-weight ratio are positive influences on prices. However, the extent and quality of the data employed in the analyses were too limited to support firm general conclusions. Further study is required to anticipate the long term effects of the fuel economy regulations on price.



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# PREFACE

When the Energy Policy and Conservation Act of 1975 mandated automotive fuel economy standards starting with the 1978 model year, an urgent need was created for information on the implications of the standards for U.S. automobile manufacturers. A major area of concern was the potential effects of vehicle redesign and weight reduction programs on automobile prices and manufacturer profitability. The research reported here represents a preliminary evaluation of this complex issue.

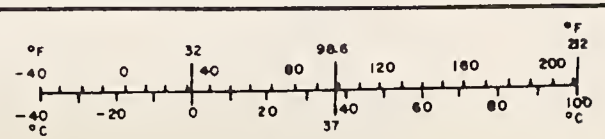
# METRIC CONVERSION FACTORS

## Approximate Conversions to Metric Measures

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


## Approximate Conversions from Metric Measures

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



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# 1. INTRODUCTION

The Energy Policy and Conservation Act of 1975[1] imposes mandatory fuel economy standards on automobile manufacturers selling new cars in the United States. These standards will be increased incrementally from an average of 18.0 miles per gallon (mpg) in 1978 to 27.5 mpg in 1985.

Several major studies[2,3,4] have analyzed the probable aggregate impact of these fuel economy standards on auto technology and on the finances of the automobile industry. There is a broad consensus that the majority of the required fuel economy improvements must be derived through substantial reductions in the weight of new automobiles. Manufacturers have agreed[5] that their primary strategy is one of "down-sizing", that is, of reducing the overall size and weight of their new cars within the larger market segments while retaining interior roominess and appointments.

Down-sizing alone, however, appears insufficient to meet the later standards, and manufacturers must combine technology changes (principally engine and drive-train improvements) with reduced performance (i.e., lower horsepower-to-weight ratios) to achieve the mandated 1985 fuel economy averages.

While such design modifications are within the current capabilities of the manufacturers, their impacts on production costs and consumer demand are highly uncertain. There is concern that modifications associated with weight reductions may reduce the prices consumers are willing to pay for new cars. At the same time, design modifications may increase vehicle production costs beyond any offsetting reductions in materials costs. It is possible, on the other hand, that such modifications could increase the value of cars to consumers and hence offset potential cost increases.

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[1]Public Law 94-163.

[2]The Report by the Federal Task Force on Motor Vehicle Goals Beyond 1980, U.S. Department of Transportation, September 2, 1976.

[3]Jet Propulsion Laboratory, Should We Have a New Engine, California Institute of Technology, JPL SP 43-17, August 1975.

[4]Rulemaking Support Paper Concerning the 1981-1984 Passenger Auto Average Fuel Economy Standards, U.S. Department of Transportation, National Highway Traffic Safety Administration, July 1977.

[5]See Chapter 5, Reference 4 above.

This study examines such potential impact of the fuel economy standards. It focuses on an empirical quantification of recent variable profit margins for General Motors Corporation and a statistical assessment of how these margins are likely to change as a result of downsizing. The results suggest that variable margins can be maintained despite major weight reductions.

The following sections present detailed findings and conclusions. Section 2 evaluates the variable costs of GM car lines in 1972 and 1975 and estimates the margins obtained on wholesale prices. The relationship between these margins and several other characteristics of the vehicles are also evaluated.

Section 3 analyzes the effects of specific vehicle characteristics on the list prices of new automobiles. It reviews the findings and previous analyses and interprets the statistical results of this study.

Section 4 summarizes the conclusions of the study. Detailed statistical results are provided in Appendix A.

## 2. ASSESSMENT OF COSTS AND MARGINS

Some insight has been gained into total corporate fixed costs and variable labor and material costs through analysis of corporate financial statements at TSC. Unfortunately, these total costs provide no information on variations in profitability for different market classes of vehicles. One major difficulty, corporate allocation of overhead costs to different production units, may be avoided by focusing on variable profit margins, that is, unit price minus unit variable costs. However, there is insufficient information at this time to permit detailed differentiation of labor inputs and material costs variations for individual models or market classes produced by each manufacturer.

Crude estimates of variable margins for different classes of vehicles may be obtained by assuming equal labor input to all classes of vehicles and by allocating material costs based on the average weight of vehicles within each market class. Such a procedure will overestimate costs of vehicles with lower than average labor inputs (e.g., subcompacts) and underestimate those of vehicles with higher than average amounts of purchased components.

This procedure was applied to 1972 and 1975 General Motors vehicles, the only group for which adequate data were available. Data on average labor costs per vehicle and material costs per pound were obtained from General Motors' Form 10-K reports to the Securities and Exchange Commission for the years in question. Reported corporate values for purchased production materials and components were divided by the total weight of vehicles produced in each year to determine material costs per pound. Values for total corporate production labor were similarly divided by vehicle production figures to determine labor costs per unit. A final class of variable costs, comprising such items as maintenance and warranties, was estimated by determining 1972 and 1975 values as a proportion of variable material and labor costs.

In 1972, the average cost of purchased production material and components for GMC was $0.33 per pound, while the average production labor input was $686 per vehicle. Corresponding 1975 values were $0.47 per pound and $951 per vehicle. "Other" variable costs (e.g., maintenance, warranties, etc.) amounted to 12 percent of material and labor costs in 1972 and 14 percent in 1975. It should be noted that material costs include purchased components fabricated by supply industries and are therefore considerably higher than raw material prices.

To account for variations in the sales of optional equipment and labor inputs from model to model, variable costs and margins were calculated for GMC body lines rather than individual models. Most body lines represent many models, ranging from basic Chevrolets to luxury Buicks. Table 1 identifies the nameplates within each body line. Averaging the price, weight, and value of optional equipment across such models creates a more representative unit for calculating variable costs and margins from corporate-wide financial data.

Variable margins were defined as the difference between wholesale prices and labor, materials, and other variable costs per unit. Wholesale prices are equal to manufacturers suggested list prices (less delivery and handling charges) minus the dealer discount.[6] Delivery and handling charges and dealer discounts vary by size class as shown in Table 2. It should be noted that dealers often receive rebates on the wholesale price, and hence the calculated values should overestimate actual wholesale prices.

The results of this variable margin analysis are summarized in Table 3. Estimated variable margins range from 17 percent to 55 percent of wholesale prices. Relationships between variable margins and weight, sales volume, and wholesale price of sold optional equipment are graphed in Figures 1-8. Variable margins as a percent of wholesale price show no clear relationship to sales volume (see Figures 1 and 2). Luxury and specialty vehicles have higher margins while compacts and subcompacts have lower margins. For specialty compacts, intermediate and full size cars, this ratio is independent of the level of sales.

The distinct positive relationship between percent variable margin and weight is illustrated in Figure 3. Percent variable margins and wholesale price of options, graphed in Figure 4, exhibit a similar positive relationship. However, weight and the wholesale price of installed options are also positively correlated (see Figure 5).

It appears then that larger, heavier cars have more optional equipment while smaller cars have less. Consequently, it is impossible to determine whether weight, options, or both have a positive effect on variable margins.

The same analysis of variable margins holds true for General Motors in 1975. These results are presented in Figures 6-8. It should be noted that curb weights are not available for 1975 so 1974 weights were used. Therefore, the effect of any change in curb weight on 1975 for individual body styles is not captured in these estimates.

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[6] Pioneer Engineering & Manufacturing Company, Development of a Motor Vehicle Materials Historical High-Volume Industrial Processing Rates Cost Data Bank, prepared for U.S. Department of Transportation, National Highway Traffic Safety Administration, Contract No. DOT-HS-6-01081, February 1976.

TABLE 1. GM NAMEPLATES BY BODY STYLE

| H | X | F |
|---|---|---|
| Vega | Nova | Camero |
| Astre | Ventura | Firebird |
| | Omega | |
| | Apollo | |
| A | $A_s$ | |
| Chevelle | Monte Carlo | |
| Malibu | Grand Prix | |
| LeMans | | |
| Olds F-85 | | |
| Cutlass | | |
| Skylark | | |
| Buick GS | | |
| Century | | |
| B | C | E |
| Biscayne | Olds 98 | Riviera |
| Bel Air | Electra | Toronado |
| Impala | Calais | Eldorado |
| Caprice | Deville | |
| Catalina | Cadillac 60 | |
| Bonneville | Cadillac 75 | |
| Grandville | | |
| Delta 88 | | |
| LeSabre | | |
| Centurion | | |
| V | | |
| Corvette | | |

Source: Footnote 6.

TABLE 2. DEALER DISCOUNTS AND DELIVERY AND HANDLING CHARGES

| Class | Body Style | Delivery & Handling ($ per vehicle) 1972 | 1975 | Dealer Discount (% of list price) |
|---|---|---|---|---|
| Subcompacts | H | 9 | 9 | 17% |
| Compact | X, F | 12 | 14 | 17% |
| Intermediate | A | 12 | 15 | 21% |
| Full Size | B | 14 | 16 | 25% |
| Luxury | C, E, V | 16 | 17 | 25% |

Source: Footnote 6.

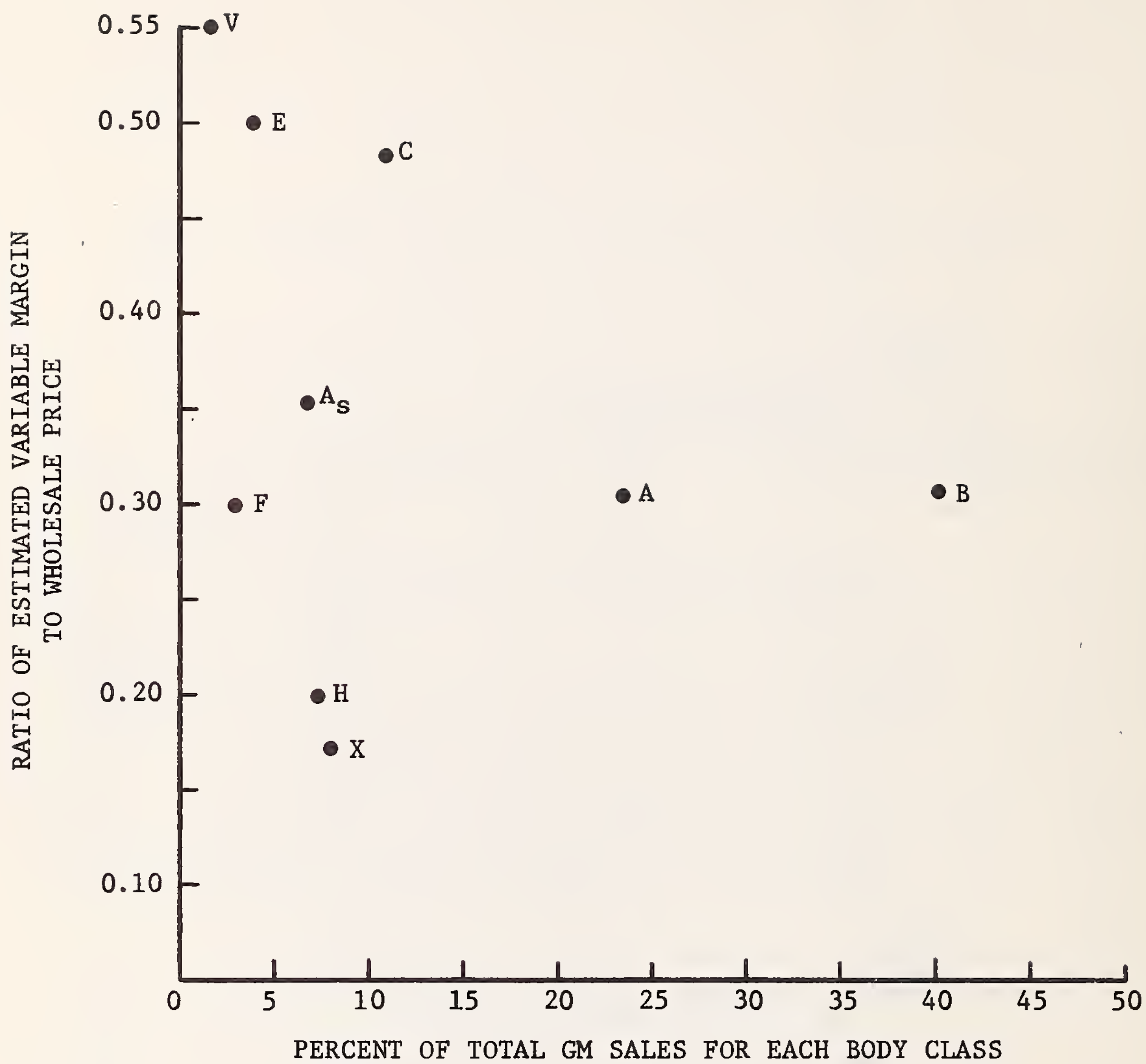
TABLE 3. VARIABLE MARGIN ANALYSIS[a] GMC 1972 and 1975

| Style[b] | Average Weight | | Variable Margin ($) | | Margin-Price Ratio | | Average Cost[c] of Option ($) | | Percent of Sales | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1972 | 1974 | 1972 | 1975 | 1972 | 1975 | 1972 | 1975 | 1972 | 1975 |
| H | 2247 | 2481 | 401 | 625 | 0.20 | 0.21 | 234 | 394 | 7.1 | 9.1 |
| X | 3143 | 3360 | 391 | 799 | 0.17 | 0.22 | 352 | 612 | 8.0 | 12.6 |
| F | 3378 | 3551 | 890 | 971 | 0.30 | 0.25 | 491 | 611 | 2.4 | 6.1 |
| A | 3602 | 3995 | 915 | 953 | 0.30 | 0.23 | 609 | 772 | 23.0 | 23.2 |
| $A_s$ | 3724 | 4084 | 1219 | 1261 | 0.36 | 0.28 | 563 | 817 | 5.9 | 9.2 |
| B | 4363 | 4495 | 1023 | 1021 | 0.30 | 0.23 | 449 | 703 | 39.7 | 20.9 |
| C | 4667 | 5003 | 2297 | 2778 | 0.48 | 0.43 | 648 | 641 | 10.8 | 10.4 |
| E | 4670 | 4930 | 2581 | 3410 | 0.50 | 0.48 | 680 | 643 | 2.6 | 2.3 |
| V | 3305 | 3390 | 2517 | 2897 | 0.55 | 0.50 | 490 | 649 | 0.6 | 1.3 |

[a]All margins and cost figures are measured in current dollars.

[b]H Subcompact
X,F Compact
A Intermediate
B Full Size
C,E,V = Luxury

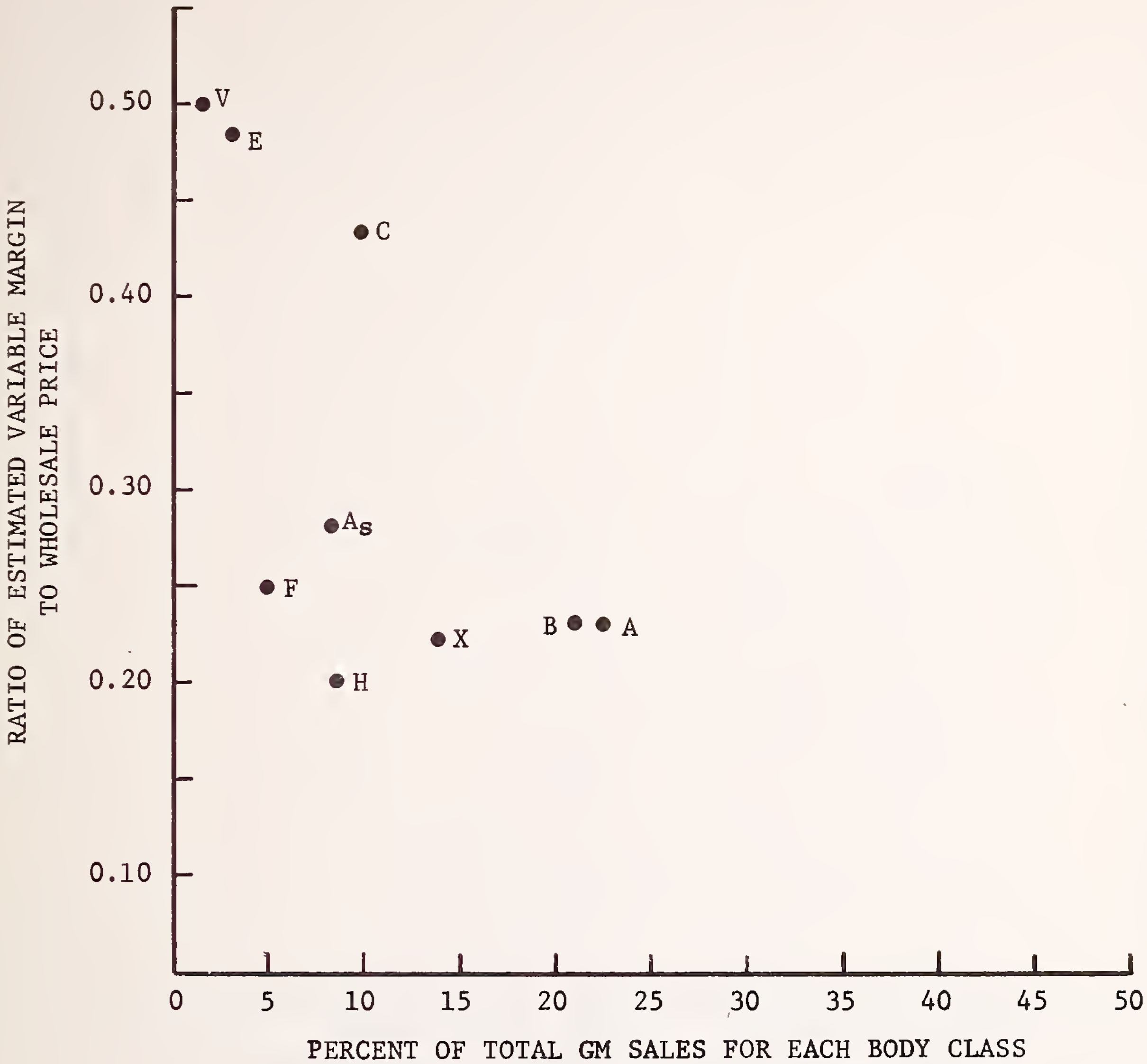
[c]Wholesale, weighted average price of optional equipment.




Key

| | |
|---|---|
| H: | subcompact |
| X,F: | compact |
| A: | intermediate |
| B: | full size |
| C,E,V: | luxury |

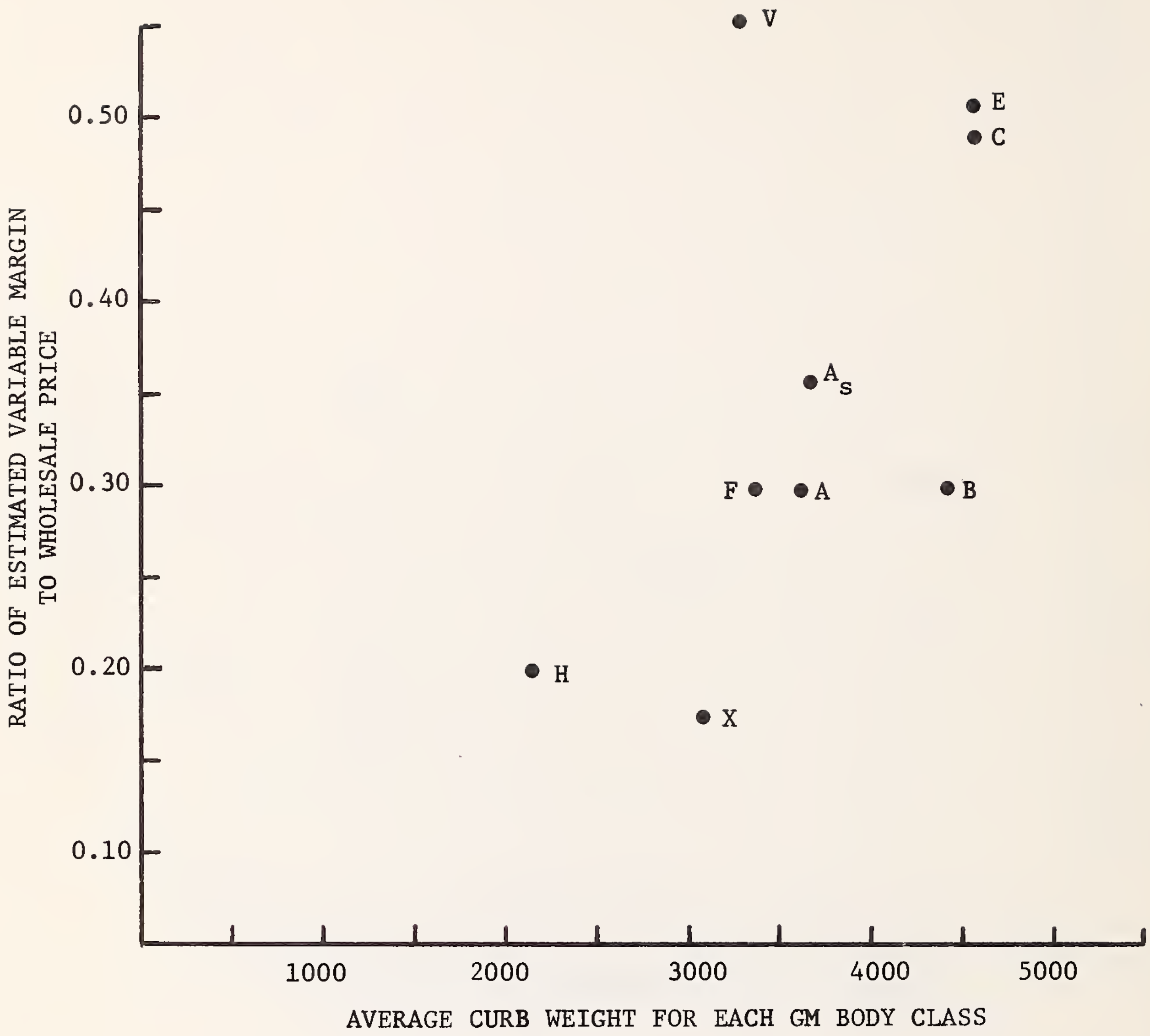
FIGURE 1. RELATIONSHIP OF VARIABLE MARGIN AND SALES VOLUME FOR 1972 GENERAL MOTORS CARS.




Key

H: subcompact
X,F: compact
A: intermediate
B: full size
C,E,V: luxury

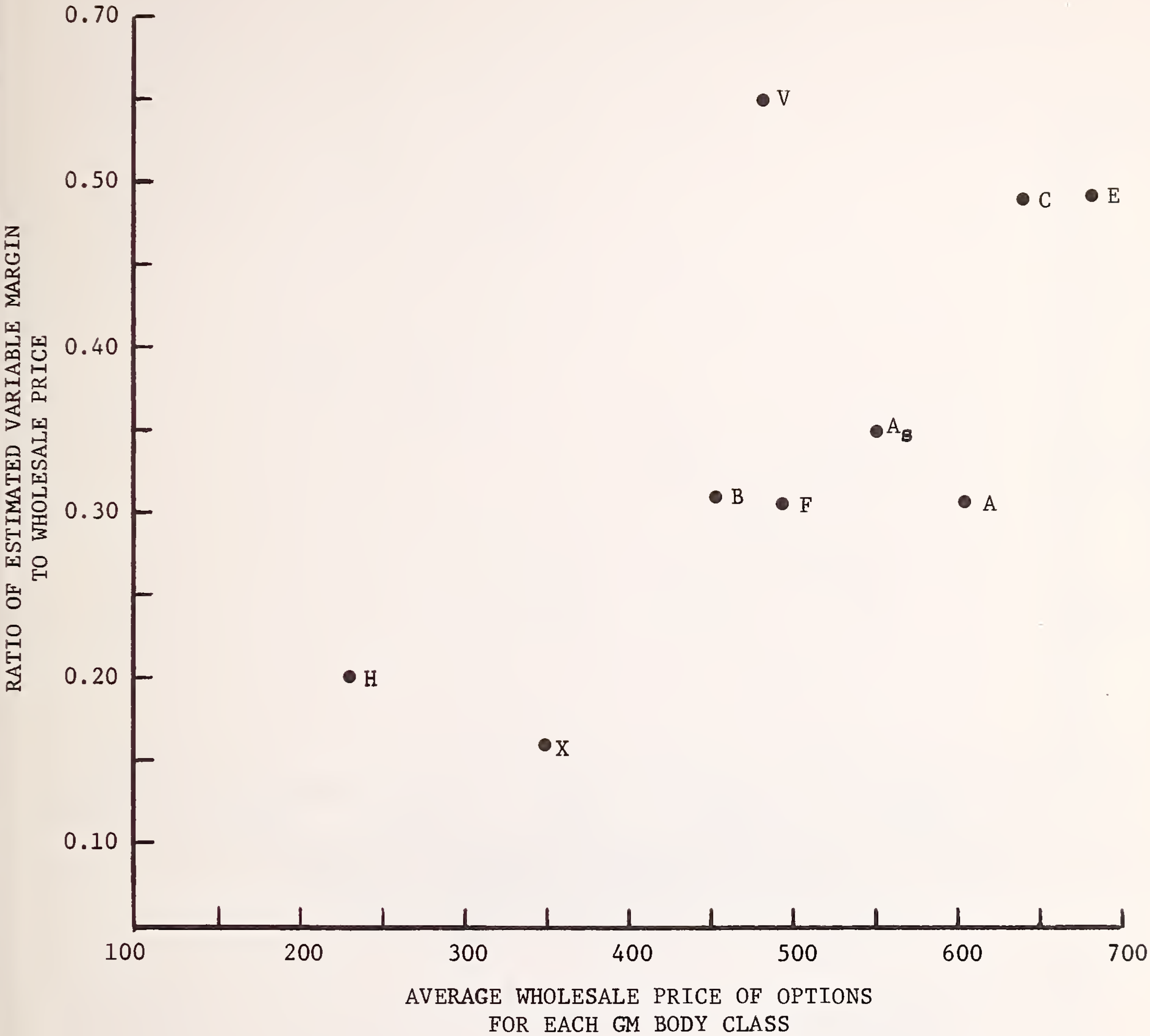
FIGURE 2. RELATIONSHIP OF VARIABLE MARGIN TO SALES VOLUME FOR 1975 GENERAL MOTORS CARS.




<u>Key</u>

| | |
|---|---|
| H: | subcompact |
| X,F: | compact |
| A: | intermediate |
| B: | full size |
| C,E,V: | luxury |

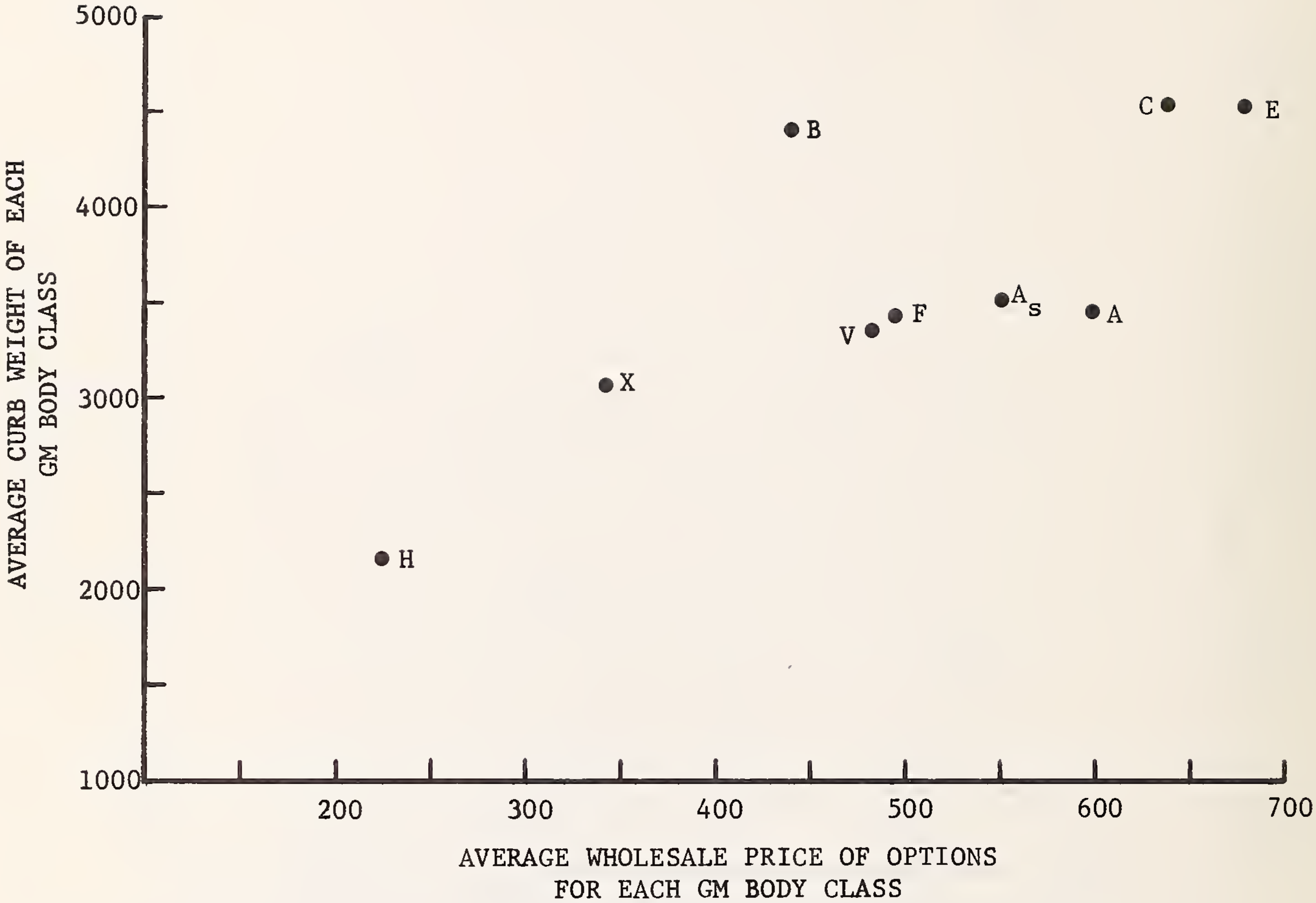
FIGURE 3. RELATIONSHIP OF VARIABLE MARGIN AND CURB WEIGHT FOR 1972 GENERAL MOTORS CARS




Key

| | |
|---|---|
| H: | subcompact |
| X,F: | compact |
| A: | intermediate |
| B: | full size |
| C,E,V: | luxury |

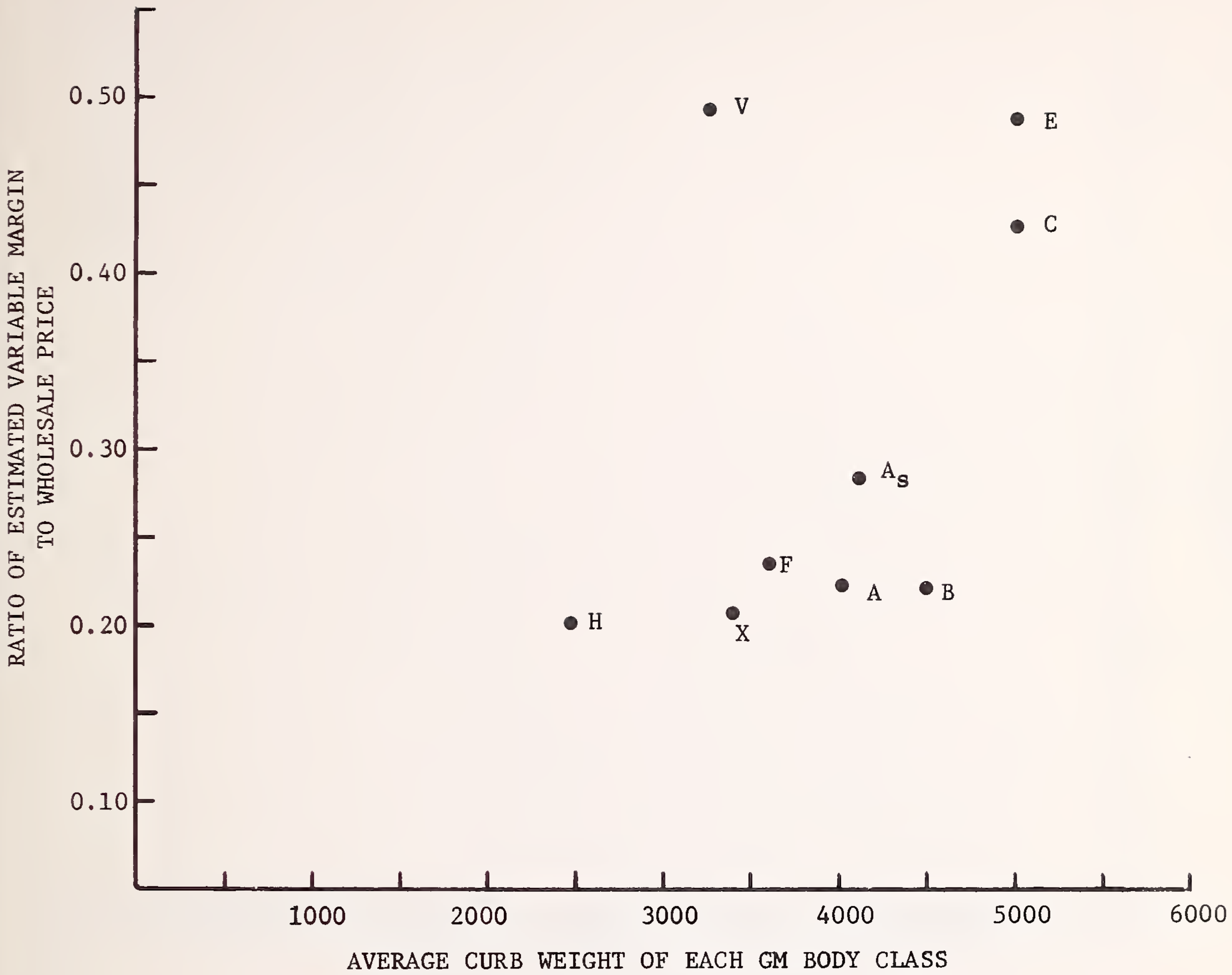
FIGURE 4. RELATIONSHIP OF VARIABLE MARGIN AND PRICE OF OPTIONAL EQUIPMENT FOR 1972 GENERAL MOTORS CARS.




<u>Key</u>

| | |
|---|---|
| H: | subcompact |
| X,F: | compact |
| A: | intermediate |
| B: | full size |
| C,E,V: | luxury |

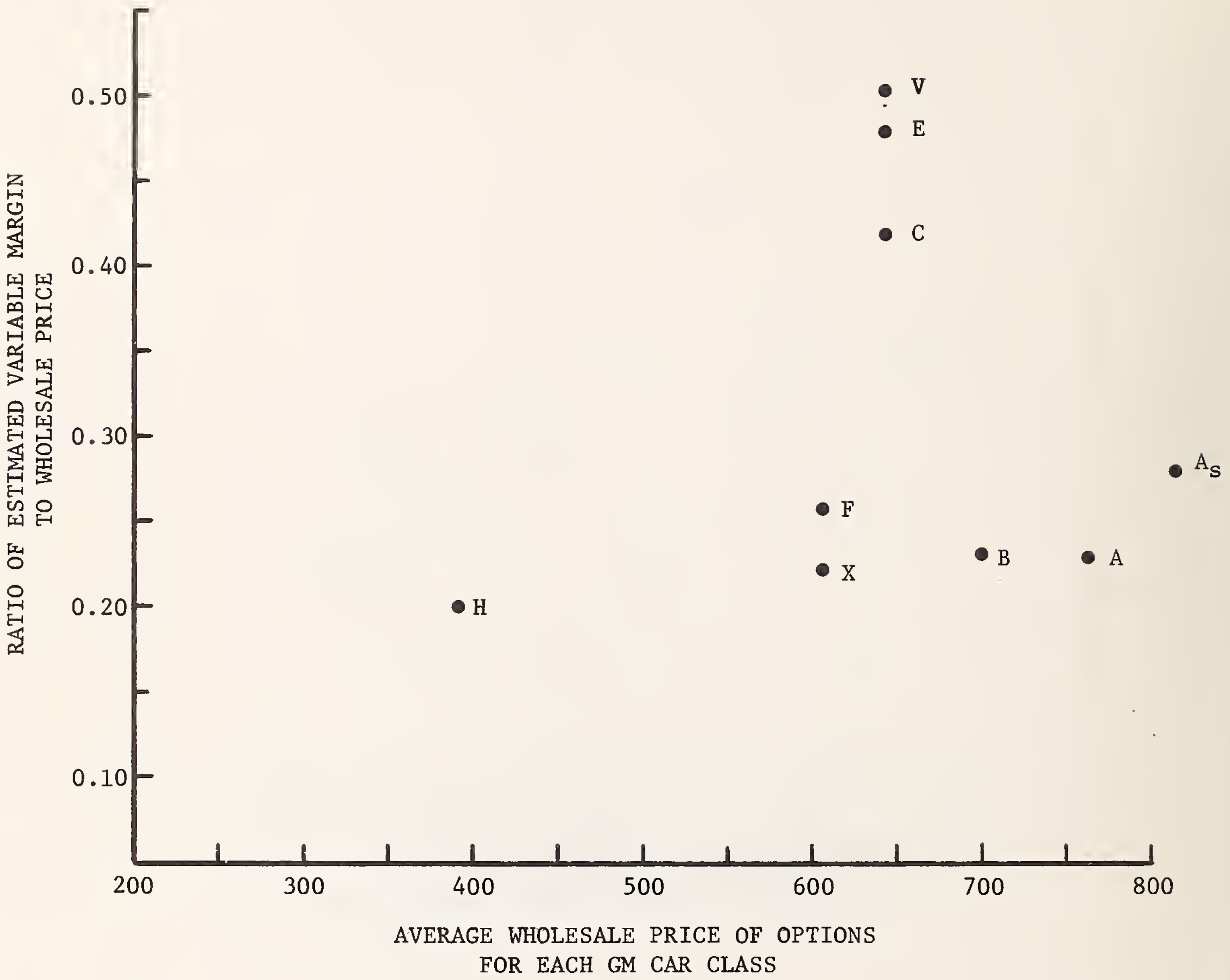
FIGURE 5. RELATIONSHIP OF CURB WEIGHT AND PRICE OF OPTIONAL EQUIPMENT FOR 1972 GENERAL MOTORS CARS.




Key

| | |
|---|---|
| H: | subcompact |
| X,F: | compact |
| A: | intermediate |
| B: | full size |
| C,E,V: | luxury |

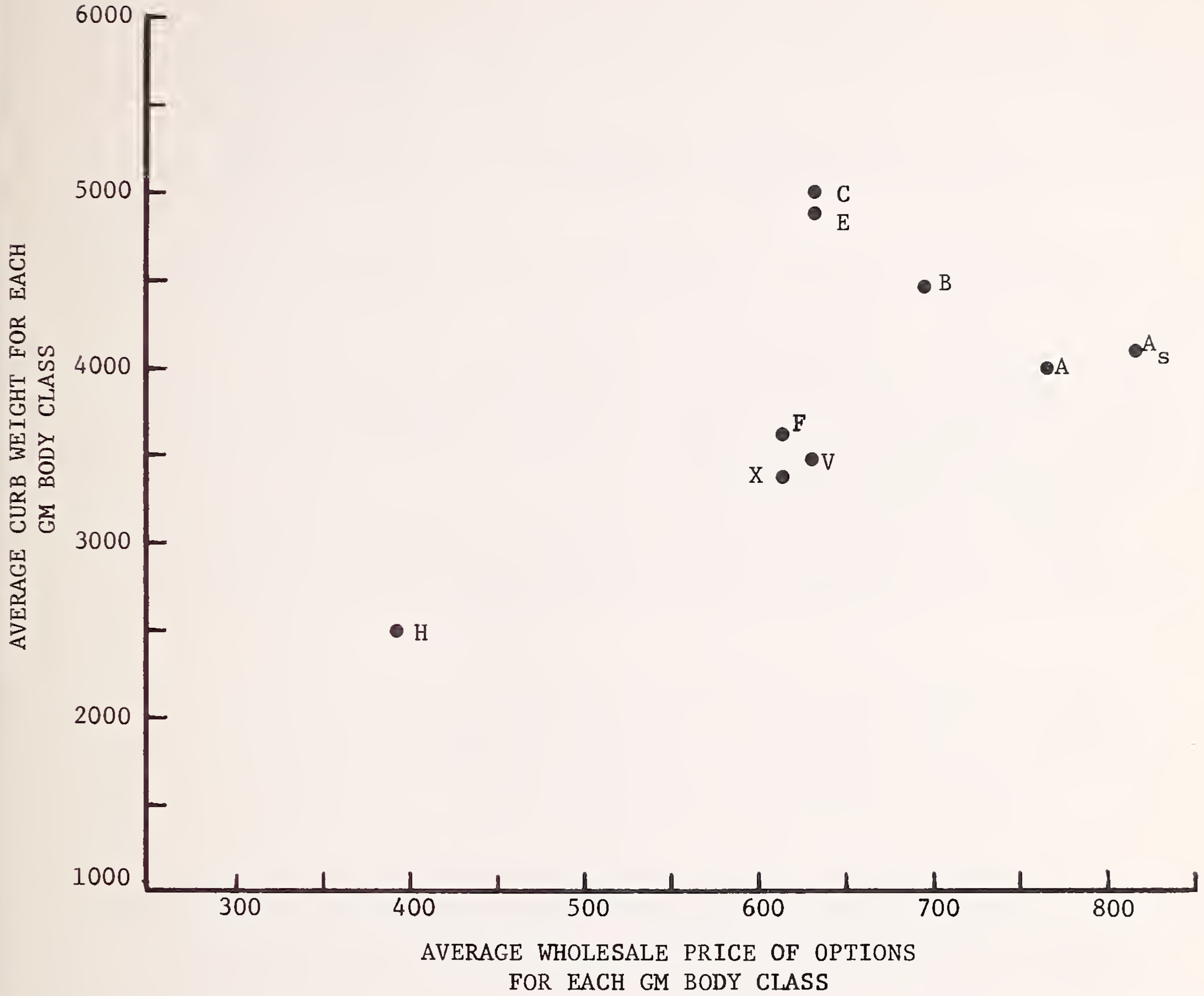
FIGURE 6. RELATIONSHIP OF VARIABLE MARGIN AND CURB WEIGHT FOR 1975 GENERAL MOTORS CARS.




Key

| | |
|---|---|
| H: | subcompact |
| X,F: | compact |
| A: | intermediate |
| B: | full size |
| C,E,V: | luxury |

FIGURE 7. RELATIONSHIP OF VARIABLE MARGIN AND PRICE OF OPTIONAL EQUIPMENT FOR 1975 GENERAL MOTORS CARS.




Key

| | |
|---|---|
| H: | subcompact |
| X,F: | compact |
| A: | intermediate |
| B: | full size |
| C,E,V: | luxury |

FIGURE 8. RELATIONSHIP OF CURB WEIGHT AND PRICE OF OPTIONAL EQUIPMENT FOR 1975 GENERAL MOTORS CARS.

These data support several hypotheses concerning variable profit margins in the auto industry. As expected, variable margins tend to be smaller for larger sales volumes since the manufacturer can spread fixed costs across more vehicles. However, this sales volume effect appears much less important than the combination of curb weight and optional equipment in influencing variable margins.

Unfortunately, as noted above, the data do not support any inference as to the relative importance of weight and optional equipment. It is impossible to tell to what extent higher margins for larger cars may be the result of highly profitable options packages associated with such vehicles rather than any intrinsically higher value attributable to weight or size. Moreover, there is no reason to expect that weight, in itself, is a vehicle characteristic of value to consumers. Rather, weight may be an indirect indication of other vehicle characteristics such as roominess or safety that consumers value directly.

To further investigate these issues, a more extensive set of statistical analyses was conducted. Results are discussed in the following section.

## 3. PRICE-QUALITY RELATION FOR AUTOMOBILES

The effect of fuel economy standards on profitability in the auto industry can be approached in another way by estimating the influence of design modifications necessary to meet the standards on the prices consumers are willing to pay for new cars. This requires quantification of the monetary value consumers place on specific vehicle attributes that are likely to be affected by fuel economy improvements.

Such an analysis is based on hedonic price theory, which assumes that consumers will serve their self-interest by paying higher prices for goods embodying higher quality or value. The theory asserts that complex products comprise a bundle of valuable characteristics and that the price consumers are willing to pay for the product is implicitly represented by the sum of the values of the individual characteristics. Economists, therefore, have attempted to determine the "implicit" price of a variety of durable goods by estimating empirically the marginal value of individual product characteristics. Multiple regression analysis has been used to isolate the value of each characteristic.

The literature on price-quality relations for consumer durables can be divided into two broad categories. The first, dating back to 1939 (for example, Court[7], Griliches[8], Tripplet[9], Dhrymes[10]), uses the hedonic approach to correct price indices for changes in quality of the good over time. More recently, the work of Lancaster[11] and Muth[12] related to

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[7]A. T. Court, "Hedonic Price Indexes with Automotive Examples" in General Motors, The Dynamics of Automobile Demand, New York, 1939.

[8]Zvi Griliches, "Hedonic Price Indexes Revisited," in Price Indexes and Quality Change, Griliches (Editor), Harvard University Press, 1971.

[9]Jack Tripplet, "Consumer Demand and Characteristics of Consumption Goods," U.S. Department of Labor, Working Paper No. 22, Washington, 1974.

[10]Phoebus J. Dhrymes, "Price and Quality Changes in Consumer Capital Goods: An Empirical Study," in Prices Indexes and Quality Change, Zvi Griliches (Editor), Harvard University Press, Cambridge, 1971.

[11]Kevin Lancaster, "A New Approach to Consumer Theory," Journal of Political Economy, Vol. 74, April, 1966.

[12]Richard F. Muth, "Household Production and Consumer Demand Functions," Econometrica, Vol. 34, July, 1966.

household production models has revived interest in price-quality relations by providing a better theoretical basis for hedonic studies.

Price-quality relations for automobiles have been used primarily to isolate "pure" price changes by removing the influence of quality changes on price. The effect of quality changes on price is usually estimated by regressing price on quality attributes for a cross section of vehicles at different points in time:

$$P_{it} = a_0 + ax_{1t} + a_2x_{2t} + \dots a_nx_{nt} + u_{it} \qquad (1)$$

The coefficients of the $x_i$'s are the average implicit prices of the characteristics; u is the random disturbance term. Such equations are then used to define the relative quality of the new model's characteristics based on the implicit prices of the attributes in some base period:

$$P_{io} = a_0 + a_1x_{1t} + a_2x_{2t} + \dots a_nx_{nt} \qquad (2)$$

The hedonic approach was used in this study to estimate implicit prices for such vehicle attributes as roominess, fuel economy, and performance in order to examine the impact of improved fuel economy on automobile prices. The following pages first describe the results and problems of previous efforts and then document our results.

Previous Empirical Results

The empirical results obtained for such price-quality relationships as equation 1 reflect the sensitivity of the model to the quality characteristics included and the sampling technique used (i.e., weighted or unweighted). The apparent instability of the implicit prices has been attributed to the severe multicollinearity among vehicle characteristics and the use of proxy variables whose relationship to the actual qualities they represent changes over time. While these problems have biased the implicit price estimates, there is clear evidence that most of the variation in automobile prices over time reflects the improved quality of the vehicles.

The variables most frequently included in the estimation of price-quality relations for the construction of price indices have been weight, length or wheelbase and some measure of performance (usually, horsepower or displacement). Some of these models are summarized in Table 4.

The experience of this previous research suggests some guidelines for choosing the quality characteristics to be included.

TABLE 4. VARIABLES INCLUDED IN PREVIOUS HEDONIC MODELS OF NEW CAR PRICES

| Variables Tested | Griliches | Dhrymes | Court | Cowling & Cubbins | Hogarty & Boyle |
|---|---|---|---|---|---|
| Weight | √ | √ | √ | | |
| Length | √ | √ | √ | √ | |
| Horsepower | √ | √ | √ | √ | √ |
| Displacement | | √ | | | |
| Roominess | | | | √ | √ |
| Fuel Economy | | | | √ | √ |
| Durability | | | | | √ |
| Maneuverability | | | | | √ |
| Cylinders | √ | √ | | | |
| Hard Top | √ | | | | |
| Automatic | √ | √ | | | √ |
| Power Steering | √ | √ | | | √ |
| Power Brakes | √ | | | | |
| Compact | √ | | | | √ |
| Two-Door | | √ | | | √ |

a. The explanatory variables should measure qualities which determine consumers utility (see Hogarty[13]). Consequently, vehicle performance characteristics, when available, are preferable to more general specifications (see Tripplet[9]).

b. When physical characteristics are used as proxy variables for utility characteristics for which data is not available, they must be carefully selected. There should be a stable relationship between the physical attributes and the services which they provide (see Cowling and Cubbins[14] and Hogarty and Boyle[15]).

Two of the most frequently used proxy variables of the earlier studies are weight and length. Neither has a clear relationship to consumer utility. Weight is highly correlated with several utility characteristics such as comfort, safety, performance, and fuel economy; length is correlated with style, luxury and maneuverability. One problem with weight as a proxy variable is that its relationship to the attributes it represents has been unstable over time. One obvious example is the relationsip between weight and roominess, which has been decreasing with the introduction of more spacious lightweight models. Therefore, the coefficients estimated for this variable are also unstable over time. Another difficulty is best exemplified by the length variable. Length is positively correlated with style but negatively correlated with maneuverability. While style and maneuverability can be expected to have a positive influence on price since they add to the consumers utility, the expected sign for the proxy variable length is indeterminant because of the trade-off involved. The net result of using one physical characteristic for two or more conflicting attributes can limit the significance of the proxy variable.

A third problem is that weight as a proxy variable often dominates the other independent qualities. This is a statistical problem caused by the high correlation between weight and several other potentially valuable characteristics such as performance, roominess and fuel economy. The

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[13]Thomas F. Hogarty, "Price-Quality Relations for Automobiles: A New Approach," Applied Economics, Vol. 7, No. 1, March, 1975.

[9]Tripplet, op. cit.

[14]Keith Cowlings and John Cubbin, "Hedonic Price Indexes for United Kingdom Cars," The Economic Journal, September, 1972.

[15]Stanley E. Boyle and Thomas F. Hogarty, "Pricing Behavior in the American Automobile Industry 1957-71," Journal of Industrial Economics, Vol. XXIV, No. 2, December, 1975.

multiple regression procedure cannot distinguish the relative importance of such intercorrelated variables, and weight consequently appears as statistically significant while the other attributes do not.

The usual "solution" to this problem has been to omit these other characteristics if they fail to meet statistical tests of significance or fail to produce the theoretically expected sign. Yet both these effects may be caused by the intercorrelation alone. As a result, the implicit price estimates are biased. Although this does not affect the use of the price equation for the purpose of constructing price indices for consecutive years, it eliminates the possibility of determining the effect of those dominated characteristics on price. When the main interest in price-quality relations is the identification of structural relations, the bundle of characteristics for which weight is a proxy should be introduced as separate characteristics in place of a single weight variable. This is preferable from a theoretical point of view as well, since vehicle weight has no intrinsic value to the consumer.

The fact that ".... car weight per se is undesirable and in a complete analysis would have a negative net regression" (Court[7]) has long been recognized. However, the lack of more specific data on vehicle attributes has led to a reliance on weight as a proxy for nonquantifiable utility characteristics.

Since some of these data, such as fuel economy and roominess, are now available, this study has attempted to reestimate the implicit prices of vehicle attributes. In particular, we have specified directly several of the utility variables formerly represented by weight to avoid the above-mentioned difficulties.

A New Model of Price-Quality Relationships

The variation in automobile prices across models and over time was studied by examining the available data for most domestically produced models for 1972 to 1974. For the dependent variable, several choices have been considered:

1. Actual transaction prices for the vehicles. Although such transaction prices are preferable from a theoretical point of view, there is no available data on transaction prices.

2. Manufacturers Suggested List Price (MSLP) for the base vehicle. These prices make comparisons difficult because of the variation in what is included as standard equipment over time and across models.

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[7]Court, op. cit.

3. MSLP plus sales weighted options package. By using the available data on the price of options and the percent of vehicles so equipped, the average nominal price for each model can be determined. This is preferable to including only stripped down (or fully loaded) models which would bias the measurement of list price to the minimum (or maximum). The use of such price plus options required several additional variables on the right-hand-side of the equation to capture the price of the options. These additional variables are the degree of market penetration for options such as:

- automatic transmission
- power steering
- power brakes
- AM radio
- FM radio
- air conditioning
- power seats
- power windows

The other independent variables tested were the quality characteristics for which implicit prices were desired. The most important quality characteristics in terms of consumers utility are likely to be comfort, performance, safety, operating and repair costs, maneuverability and style. As with previous efforts to study price-quality relations, not all of these qualities are quantifiable. Comfort includes many factors but the most important and most easily measured appears to be roominess. This study utilized the roominess index defined by the EPA. This roominess index is the sum of seven interior measurements: head room, leg room, and shoulder room for both the front and rear passenger areas as well as front seat height. Performance is best measured by the ability to accelerate. In lieu of test data on acceleration, most studies have used brake horsepower or brake horsepower-to-weight ratio. Horsepower to weight ratio was selected as the more appropriate measure of performance for the purposes of this study. Operating cost could not be included, since this includes cost for which data was not available (e.g., maintenance schedules and frequency of repair records), but fuel economy was incorporated as one measure of variable cost. Maneuverability should be represented by turning radius, but this data was not available. The problem of using wheelbase as a proxy for ease of handling due to its correlation with style and luxury has already been noted.

Problems in Estimating the Model

The initial specification of the price-quality relationship for examining the impact of down-sizing on manufacturers pricing decisions is listed below:

$$PBPO = a_0 + a_1\ MPG + a_2\ RF + a_3\ TS + a_4\ HPWT + a_5\ AUTO + a_6\ AIR + a_7\ PS + a_8\ PB + a_9\ PDB + a_{10}\ FM + a_{11}\ AM + a_{12}\ PSEAT + a_{13}\ PW \quad (3)$$

where:

PBPO = manufacturers suggested list price for the base car plus options. The options were sales weighted to reflect their degree of market penetration.

MPG = fuel economy based on EPA estimates for the most popular vehicle configuration.

RF = roominess factor as defined by the EPA index.

TS = truck space measured as cubic feet of luggage capacity with the spare tire and tools in place.

HPWT = horsepower to weight ratio. The measures used reflect net horsepower and curb weight.

AUTO = percentage of vehicles equipped with automotic transmission.

AIR = percentage of vehicles equipped with air conditioning.

PS = percentage of vehicles equipped with power steering.

PB = percentage of vehicles equipped with power brakes.

PDB = percentage of vehicles equipped with power disc brakes.

FM = percentage of vehicles equipped with FM radios.

AM = percentage of vehicles equipped with AM radios.

PSEAT = percentage of vehicles equipped with power seats.

PW = percentage of vehicles equipped with power windows.

Given the high degree of intercorrelation among many of these independent variables (particularly among the options), a much larger sample would be necessary if unbiased and consistent parameter estimates were to be obtained from the resulting estimates.

Since the options were very highly correlated with each other but not with the other vehicle attributes, some of these options were dropped from the specification of the model. As a result, the coefficient for the remaining options are biased upward by the omitted options and cannot be interpreted as implicit prices for any specific option. Rather, these coefficients reflect the prices of some "bundles" of options. Roominess and trunk space also presented severe multicollinearity problems and were therefore combined into a single measure of interior room.

Although the Wharton and Chilton data bases used for this study each contain a large number of observations, major differences in the data bases limited the number of usable observations. The Wharton data base which uses the model as the unit of observation contains information on base price, option prices, and percent of sales equipped with each of the options for each model. The Chilton data base provided the necessary information on fuel economy, horsepower roominess, trunk space, and wheelbase. The Chilton data is organized on the basis of vehicle configurations identified by manufacturer but not by division. There was not a one-to-one correspondence between the two data sources. Of the original 318 models listed in the Wharton data base for the three years 1972-1974, only 173 could be matched with the Chilton data base. Although the Wharton data contains information on models from 1947 to 1974, reliable fuel economy and roominess data in the Chilton data are only available from 1972. Data for 1975 and 1976 are available in the Chilton source, but the necessary data comparable to the Wharton data was not readily available. The addition of these last two years could have improved the analysis not only by providing additional observations, but also by introducing more variability in roominess and fuel economy.

Table 5 shows the breakdown of the combined data set by manufacturer and size class. There are not enough observations for American Motors, subcompacts or specialty vehicles to support a statistical investigation of price-quality relations for these groups. The lack of data also precluded the inclusion of station wagons and vans in the sample.

The final specification, therefore, was as follows:

$$\begin{aligned} PBPO = {} & a_0 + a_1\, MPG + a_2\, RT + a_3\, HPWT + a_4\, AUTO + a_5\, AIR \\ & + a_6\, PS + a_7\, RADIO + a_8\, BRAKE + a_9\, P\ SEAT + a_{10}\, PW \end{aligned} \quad (4)$$

TABLE 5. NUMBER OF SAMPLE OBSERVATIONS BY VEHICLE CLASS AND MANUFACTURER

| Size Class | Manufacturer | | | | Total |
|---|---|---|---|---|---|
| | GM | Ford | Chrysler | AMC | |
| Subcompact | 2 | 3 | - | 2 | 7 |
| Compact | 11 | 6 | 5 | 3 | 25 |
| Intermediate | 12 | 9 | 7 | 3 | 31 |
| Full | 34 | 16 | 21 | 3 | 74 |
| Special Subcompact | - | 1 | - | - | 1 |
| Special Compact | 4 | 3 | 3 | 3 | 13 |
| Special Intermediate | 4 | 2 | - | - | 6 |
| Special Full | 8 | 6 | - | - | 14 |
| Corvette | 2 | - | - | - | 2 |
| Total | 77 | 46 | 36 | 14 | 173 |

where:

RT = combined roominess and trunk space index

BRAKE = percentage of vehicles with either power brakes or power disc brakes

RADIO = percent of vehicles with radios (AM or FM)

and the other variables are as previously defined. This specification was tested for:

1. all non-specialty vehicles of each manufacturer (excluding subcompacts);

2. compacts, intermediate, and full-sized vehicles, each class separately for each manufacturer;

3. all non-specialty vehicles pooled for all manufacturers (Big Three); and

4. compacts, intermediates, and full-sized vehicles, each class combined for all manufacturers.

These results were compared using standard statistical tests to determine if the same price-quality relationships held for different manufacturers and across different market classes of vehicles. A detailed description of the procedures used and results is contained in Appendix A. Results of regressions using data pooled across vehicle classes are shown in Table 6.

The above specification is comparable in overall explanatory power to previous hedonic analyses despite the absence of a weight variable. The coefficient of variation ($R^2$) for the regressions indicates that some 89 to 94 percent of the total variation in vehicle prices was explained by the variables included. The coefficients for fuel economy (MPG), roominess (RT), and performance (HPWT) generally have the expected positive effect on price, but are consistently significant only for GM. The coefficients for optional equipment, however, are unstable and far from their expected magnitudes. This is probably the result of the high level of intercorrelation among the option variables. Attempts at combining these variables to avoid the problem provided no better results.

Greater difficulties were encountered in the detailed regressions by vehicle class. The coefficients for all variables were highly unstable across vehicle classes and manufacturers. Statistical tests indicated that price-quality relationships vary significantly across both vehicle

TABLE 6. MULTIPLE REGRESSION RESULTS BY MANUFACTURER-POOLED OVER SIZE CLASSES

| | GM | | Ford | | Chrysler | | Big 3 | |
|---|---|---|---|---|---|---|---|---|
| | Coeff. | t | Coeff. | t | Coeff. | t | Coeff. | t |
| Constant | -8461. | (-1.9) | +5285. | (+1.2) | -8705. | (-1.0) | -676. | (-0.3) |
| MPG | +63.5 | (+2.3) | -59.2 | (-1.6) | -10.0 | (-0.2) | +11.0 | (+0.7) |
| RT | +12.0 | (+1.5) | +2.1 | (+0.1) | +32.9 | (+2.3) | +4.8 | (+1.1) |
| HPWT | +33962. | (+3.4) | +20086. | (+1.0) | +2701. | (+0.3) | +10386. | (+2.0) |
| AUTO | +4611. | (+0.9) | -7667. | (-1.2) | +840. | (+0.2) | +177. | (+0.1) |
| AIR | -1.3 | (-0.01) | +267. | (+0.8) | -1860. | (-0.9) | +435. | (+1.2) |
| PS | -81.0 | (-0.2) | +2465. | (+1.0) | +174. | (+0.04) | +536. | (+1.3) |
| RADIO | -121. | (-0.1) | +1575. | (+0.7) | -866. | (-1.0) | -83. | (-0.1) |
| BRAKE | +472. | (+1.4) | +478. | (+2.8) | +272. | (+0.9) | +334. | (+2.7) |
| PSEAT | +2086. | (+2.4) | +2976. | (+3.6) | +2488. | (+1.3) | +2394. | (+4.9) |
| PW | -40. | (-0.04) | -633. | (-0.5) | +454. | (+0.2) | -11. | (-0.02) |
| N | 57 | | 31 | | 33 | | 121 | |
| $R^2$ | 0.89 | | 0.94 | | 0.91 | | 0.87 | |
| F | 37.8 | | 31.8 | | 23.0 | | 73.0 | |
| SER | 329 | | 255 | | 292 | | 327 | |

Note: Coeff. = estimated coefficient of variable
t = student's t-static value
N = number of observations
$R^2$ = coefficient of determination
F = F-statistic value
SER = standard error of the estimate
Other variables as previously defined.

classes and manufacturers. Unfortunately, no inferences were possible concerning which relationships differ, and the result may have been caused simply by the small number of observations available in most of the vehicle classes analyzed separately.

One extremely interesting aspect of these results is the superior performance of the specification when applied to GM vehicles. The coefficients for roominess, fuel economy and weight are all statistically significant for GM, whereas they vary in sign and significance for the other manufacturers. This may be a natural consequence of the larger size for GM vis a vis the other manufacturers. However, it is also consistent with the theory that GM, as the industry price leader, can set prices consistent, in some sense, with vehicle characteristics, while the remaining firms must adjust their prices to match GM's despite the potential inconsistency with their own vehicle attributes. A much more thorough study would be required to investigate this interpretation.

On the whole, these findings are encouraging. They provide evidence that the influence of attributes directly valued by consumers on auto prices can be isolated without using weight as a proxy. The results, however, are too inconsistent to allow forecasts of the probable list prices of future automobile configurations. In fact, they signify that a much larger data base comprising a more recent and longer time period is needed to sort out important price-quality relationships in detail.

While price forecasts are beyond the validity of the regression equations, the results allow a tentative quantification of the marginal price impacts of changing those vehicle characteristics most closely associated with down-sizing. Assuming that the pooled GM regression coefficients (Table 6) approximate average company-wide pricing policies, the following relationships obtain:

TABLE 7. MARGINAL EFFECT OF VEHICLE ATTRIBUTES ON VEHICLE PRICES AS ESTIMATED FOR GENERAL MOTORS, 1972-1974.

| Change of | Change in Price ($) |
|---|---|
| +1 mpg | +64 |
| +12 inches roominess | +144 |
| -0.01 horsepower/weight | -340 |

Thus, for example, reducing horsepower to weight ratio by 0.01, a frequently recommended technique for improving fuel economy would cause an estimated decrease in car value of some $340. This would require a simultaneous increase in fuel economy of more than 5 mpg to offset the loss in value.

These figures, however, assume that all other vehicle characteristics remain constant, and thus represent an approximation at best. Nevertheless, to the extent that this and the above assumptions hold, the findings have important implications. In particular, they suggest that down-sizing need not have negative impacts on the prices manufacturers can command so long as roominess and performance are sustained. This topic is explored more fully in the following section.

## 4. SUMMARY AND CONCLUSIONS

The preceding sections have described factual empirical findings concerning the relationships between prices, variable costs, and vehicle characteristics of automobiles. The findings, it should be stressed, are restricted in scope and crude in precision, since both the quantity and quality of the available data were quite limited. Nevertheless, the results provide interesting insights into probable effects of fuel economy standards on profit margins in the auto industry.

As Section 2 indicated, variable profit margins by car line appear, historically, to be strongly correlated with sheer dimensions of the vehicles. This, together with previous hedonic studies showing weight as a key explanatory variable for auto prices, creates the impression that down-sizing programs by the auto manufacturers will inevitably squeeze margins and create major financial difficulties for the industry.

The data also clearly show, however, that variable margins are strongly correlated with the quantity and price of optional equipment sold on each car line, which in turn are positively related to vehicle size. Thus, higher margins for larger cars may be the result of highly profitable option packages associated with such vehicles rather than any intrinsically higher value attributable to size.

The findings of Section 3 provide empirical evidence that down-sizing need not create downward pressure on prices. The results suggest that so long as down-sized vehicles retain their earlier interior roominess and performance, they can be priced at levels equivalent to their heavier counterparts. The analyses also suggest, however, that decreases in performance, as measured by horsepower-to-weight ratio, or interior roominess could have a severe negative impact on prices that may not be counterbalanced by fuel economy increases.

Unfortunately, these conclusions must be viewed as quite tentative. Because roominess and weight are so strongly correlated in historical data, one cannot confidently assume that roominess is an important determinant of price while weight is not. The hypothesis that roominess represents the attribute of importance to consumers is more pleasing theoretically, but weight is certainly a better proxy for such attributes as safety which cannot be measured directly. Moreover, our results, like those of previous hedonic studies, leave hanging the question of how optional equipment influence auto prices, an issue of some importance in view of the previously mentioned relation between variable margins and option packages. Lastly, the failure of the pooling tests indicates that our findings reflect a crude average of relationships which actually differ across vehicle classes and manufacturers.

For all these reasons, the results have more qualitative than quantitative significance. Only an evaluation of more recent data in which roominess and weight show increasing co-variation, and using a much larger set of observations, could help clarify these issues.

With these caveats in mind, however, the results still suggest that variable margin in the industry can be maintained despite down-sizing if roominess and performance are maintained and if manufacturers can continue to sell substantial option packages on their lighter vehicles. Increased fixed costs, on the other hand, could still reduce profit margin over full costs depending on extraordinary investments actually incurred during down-sizing.

APPENDIX A

STATISTICAL DATA

This appendix presents the regression results by manufacturer and size class. The best results were generally obtained for General Motors and the pooled samples for which there were additional degrees of freedom. The instability of the coefficient among samples is due to the multicollinearity among the independent variables and the small sample sizes. Table A-1 shows the intercorrelation among these variables for the Big Three sample pooled over compact, intermediate and full size vehicles.

Most of the variables listed in these tables were defined in Section 3. Those that require further explanation are the combined roominess variable and the choice of options to be included in the equation. The high level of intercorrelation between roominess and trunk space suggested that some combined measure of interior room would both reduce the number of coefficients to be estimated and some of the instability among the coefficients. Since the EPA roominess factor is the sum of seven interior dimensions in inches, while trunk space was measured as a volume in cubic feet, the two could not simply be added. Instead, the new variable combining roominess and trunk space was defined as:

$$RT = ROOM + (12)(3)(TRUNK)^{1/3} \qquad (A\text{-}1)$$

Of the nine options initially specified only two appear in the equations estimated for the individual subsamples. Tables A-2 through A-4 show that for many of these options, market penetration is almost one hundred percent. This is particularly true for automatic transmission, power steering, and power brakes on intermediate and full size vehicles. This lack of variation among these options causes singularities in the matrix when these variables are included in the regressions for these subsamples. In addition, many of the options are available as options packages. For example, power steering and power brakes, and on the more luxurious cars, power seats and power windows. Other options are mutually exclusive such as AM and FM radios and if combined as would yield almost one hundred percent market penetration. For these reasons, in one of the specifications tested, the only options included are air conditioning and power windows. It should be noted that the estimated coefficients for these options reflect not only the price of these options but also the price of the excluded options with which they are highly correlated. Power windows and power seats are highly correlated as are air conditioning, automatic transmission, and power brakes.

The full specification of the price-quality relation included seven options and was tested on subsamples for each of the "Big Three"

TABLE A-1. INTERCORRELATIONS AMONG THE VARIABLES*

| | PBPO | MPG | ROOM | TS | HPWT | AUTO | AIR | PS | PB | FM | AM | P Seats | PW | PDB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PBPO | 1.0 | -.43 | +.68 | +.52 | +.20 | +.59 | +.70 | +.49 | +.64 | +.24 | -.13 | +.87 | .90 | -.09 |
| MPG | | 1.0 | -.58 | -.50 | -.31 | -.57 | -.63 | -.32 | -.61 | -.38 | +.36 | -.34 | -.45 | +.25 |
| ROOM | | | 1.0 | +.86 | +.20 | +.80 | +.84 | +.58 | +.83 | +.60 | -.54 | +.51 | +.69 | -.10 |
| TS | | | | 1.0 | +.29 | +.69 | +.72 | +.50 | +.70 | +.56 | -.54 | +.36 | +.52 | -.07 |
| HPWT | | | | | 1.0 | +.14 | +.18 | +.04 | +.15 | +.10 | -.07 | +.08 | +.09 | +.12 |
| AUTO | | | | | | 1.0 | +.87 | +.79 | +.91 | +.53 | -.41 | +.37 | +.58 | -.04 |
| AIR | | | | | | | 1.0 | +.66 | +.86 | +.56 | -.48 | +.55 | +.71 | -.20 |
| PS | | | | | | | | 1.0 | +.80 | +.42 | -.31 | +.27 | +.43 | +.04 |
| PB | | | | | | | | | 1.0 | +.55 | -.46 | +.40 | +.60 | -.04 |
| FM | | | | | | | | | | 1.0 | -.93 | +.19 | +.31 | -.14 |
| AM | | | | | | | | | | | 1.0 | -.08 | -.20 | +.14 |
| P Seats | | | | | | | | | | | | 1.0 | +.94 | -.21 |
| PW | | | | | | | | | | | | | 1.0 | -.14 |
| PDB | | | | | | | | | | | | | | 1.0 |

*See notes on following page for variable definitions.

NOTES FOR TABLE A-1

PBPO = manufacturers suggested list price for the base car plus options. The options were sales weighted to reflect their degree of market penetration.

MPG = fuel economy based on EPA estimates for the most popular vehicle configuration.

ROOM = combined interior and trunk space roominess index.

HPWT = horsepower to weight ratio. The measures used reflect net horsepower and curb weight.

AUTO = percentage of vehicles equipped with automatic transmission.

AIR = percentage of vehicles equipped with air conditioning

PS = percentage of vehicles equipped with power steering.

PB = percentage of vehicles equipped with power brakes.

PDB = percentage of vehicles equipped with power disc brakes.

FM = percentage of vehicles equipped with FM radios.

AM = percentage of vehicles equipped with AM radios.

PSEAT = percentage of vehicles equipped with power seats.

PW = percentage of vehicles equipped with power windows.

TABLE A-2. VARIABLE MEANS AND STANDARD DEVIATIONS BY SIZE CLASS, POOLED FOR GM, FORD AND CHRYSLER

| | N=11 Compacts | | N=6 Intermediates | | N=5 Full | |
|---|---|---|---|---|---|---|
| | $\bar{X}$ | S | $\bar{X}$ | S | $\bar{X}$ | S |
| PBPO | 2386. | 312.2 | 2963. | 219.3 | 3850. | 789.1 |
| HP | 124. | 27.9 | 164. | 28.8 | 187. | 27.8 |
| MPG | 15.4 | 3.1 | 12.9 | 2.1 | 11.5 | 1.6 |
| ROOM | 272. | 3.8 | 281. | 2.7 | 292. | 2.6 |
| TS | 13.3 | 1.6 | 15.6 | 1.3 | 19.7 | 1.8 |
| HPWT | 0.389 | 0.00575 | 0.0437 | 0.00879 | 0.0424 | 0.0539 |
| AUTO | 0.90 | 0.03 | 0.98 | 0.02 | 1.0 | 0.0 |
| AIR | 0.39 | 0.07 | 0.74 | 0.08 | 0.90 | 0.11 |
| PS | 0.75 | 0.20 | 0.97 | 0.02 | 1.0 | 0.0 |
| PB | 0.23 | 0.20 | 0.81 | 0.14 | 0.99 | 0.04 |
| FM | 0.04 | 0.02 | 0.17 | 0.09 | 0.28 | 0.17 |
| AM | 0.83 | 0.07 | 0.75 | 0.09 | 0.64 | 0.17 |
| PSEATS | 0.0 | 0.0 | 0.02 | 0.02 | 0.29 | 0.29 |
| PW | 0.0 | 0.0 | 0.13 | 0.04 | 0.45 | 0.23 |
| PDB | 0.10 | 0.12 | 0.11 | 0.21 | 0.09 | 0.28 |

Note: Means and standard deviations are not sales weighted.

TABLE A-3. VARIABLE MEANS AND STANDARD DEVIATIONS FOR INTERMEDIATE VEHICLES BY MANUFACTURER

| | N=12 GM | | N=9 Ford | | N=7 Chrysler | |
|---|---|---|---|---|---|---|
| | $\bar{X}$ | S | $\bar{X}$ | S | $\bar{X}$ | S |
| PBPO | 3052. | 200.7 | 2935. | 172.4 | 2848. | 239.2 |
| HP | 158. | 11.6 | 156. | 13.6 | 185. | 47.4 |
| MPG | 12.6 | 1.4 | 12.1 | 1.8 | 14.6 | 2.5 |
| ROOM | 280. | 3.4 | 281. | 0.5 | 280. | 3.1 |
| TS | 14.9 | 0.7 | 15.4 | 0.8 | 17.2 | 1.2 |
| HPWT | 0.0415 | 0.00372 | 0.0399 | 0.00400 | 0.0521 | 0.0129 |
| AUTO | 0.98 | 0.02 | 0.99 | 0.01 | 0.97 | 0.02 |
| AIR | 0.76 | 0.07 | 0.77 | 0.06 | 0.66 | 0.07 |
| PS | 0.98 | 0.02 | 0.98 | 0.01 | 0.95 | 0.02 |
| PB | 0.88 | 0.11 | 0.80 | 0.10 | 0.72 | 0.19 |
| FM | 0.22 | 0.10 | 0.15 | 0.07 | 0.12 | 0.06 |
| AM | 0.69 | 0.10 | 0.77 | 0.07 | 0.80 | 0.06 |
| PSEATS | 0.03 | 0.02 | 0.03 | 0.02 | 0.0 | 0.0 |
| PW | 0.10 | 0.04 | 0.17 | 0.03 | 0.13 | 0.03 |
| PDB | 0.14 | 0.21 | 0.0 | 0.0 | 0.18 | 0.28 |

Note: Means and standard deviations are not sales weighted.

TABLE A-4. VARIABLE MEANS AND STANDARD DEVIATIONS FOR FULL SIZE VEHICLES BY MANUFACTURER

| | N=34 GM | | N=16 Ford | | N=21 Chrysler | |
|---|---|---|---|---|---|---|
| | $\bar{X}$ | S | $\bar{X}$ | S | $\bar{X}$ | S |
| PBPO | 3950. | 733.7 | 3728. | 900.6 | 3783. | 764.0 |
| HP | 186. | 29.4 | 173. | 20.1 | 198. | 25.0 |
| MPG | 11.6 | 1.7 | 11.5 | 1.8 | 11.3 | 1.4 |
| ROOM | 294. | 0.9 | 289. | 1.6 | 292. | 2.5 |
| TS | 19.1 | 1.6 | 18.6 | 1.2 | 21.5 | 1.2 |
| HPWT | 0.0412 | 0.00519 | 0.0396 | 0.00247 | 0.0465 | 0.00495 |
| AUTO | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 |
| AIR | 0.92 | 0.04 | 0.85 | 0.21 | 0.90 | 0.04 |
| PS | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 |
| PB | 1.0 | 0.0 | 0.98 | 0.03 | 0.99 | 0.06 |
| FM | 0.34 | 0.19 | 0.19 | 0.13 | 0.25 | 0.11 |
| AM | 0.60 | 0.19 | 0.74 | 0.13 | 0.64 | 0.11 |
| PSEATS | 0.36 | 0.28 | 0.24 | 0.31 | 0.23 | 0.27 |
| PW | 0.49 | 0.23 | 0.46 | 0.23 | 0.37 | 0.22 |
| PDB | 0.0 | 0.0 | 0.30 | 0.44 | 0.08 | 0.25 |

Note: Means and standard deviations are not sales weighted.

manufacturers pooled over three sizes - compact, intermediate, and full-sized vehicles. These results are presented in Table A-5.

For the GM subsample, the estimated coefficients for fuel economy, roominess, and performance are statistically significant and of the theoretically expected sign. Since the results for Ford and Chrysler were rather poor, pooling across manufacturers failed to improve the regression results. The coefficients of the options variables were also disappointing. Most of these coefficients are not statistically different from zero and many have the wrong sign. This appears to be due to the high level of multicollinearity among the options. As a result, an alternative specification was tested with only two of the options included. Table A-6 demonstrates that while this increased the significance of the option variables, it reduced the significance of the roominess variable. The fuel economy and performance variables exhibited greater stability and were not greatly affected by this change in the model's specification. The superiority of the results for the GM samples, under both specifications, is consistent with General Motors' price leadership role, yet also suggest that manufacturers differ in their pricing strategies with respect to individual quality attributes.

This alternative specification was also estimated for samples grouped by vehicle size to test if pricing strategies differ among size classes. The results for compact, intermediate, and full size vehicles are presented in Tables A-7, A-8 and A-9. Most of these subsamples contained too few observations to provide stability to the estimated coefficients. The largest subsample was the GM full-sized group; for this sample, the estimated coefficients are comparable to those obtained for GM pooled over size classes.

The subsamples were also pooled across manufacturers within a size class to provide additional degress of freedom. The pooled results proved no better than those obtained from GM alone.

The homogeneity test used to determine the appropriateness of pooling was the Chow test which follows the F distribution and is defined below:

$$F = \frac{\left[ SSR_a - \sum_{t=1}^{T} SSR_t \Big/ (T-1)(K+1) \right]}{\sum_{t=1}^{T} SSR_t \Big/ [N-T(K+1)]} \qquad \text{(A-2)}$$

where:

$SSR_a$ = the sum of the squared residuals for the pooled regression

TABLE A-5. MULTIPLE REGRESSION RESULTS BY MANUFACTURER-POOLED OVER SIZE CLASSES

| | GM | | Ford | | Chrysler | | Big 3 | |
|---|---|---|---|---|---|---|---|---|
| | Coeff. | t | Coeff. | t | Coeff. | t | Coeff. | t |
| Constant | -8461. | (-1.9) | +5285. | (+1.2) | -8705. | (-1.0) | -676. | (-0.3) |
| MPG | +63.5 | (+2.3) | -59.2 | (-1.6) | -10.0 | (-0.2) | +11.0 | (+0.7) |
| RT | +12.0 | (+1.5) | +2.1 | (+0.1) | +32.9 | (+2.3) | +4.8 | (+1.1) |
| HPWT | +33962. | (+3.4) | +20086. | (+1.0) | +2701. | (+0.3) | +10386. | (+2.0) |
| AUTO | +4611. | (+0.9) | -7667. | (-1.2) | +840. | (+0.2) | +177. | (+0.1) |
| AIR | -1.3 | (-0.01) | +267. | (+0.8) | -1860. | (-0.9) | +435. | (+1.2) |
| PS | -81.0 | (-0.2) | +2465. | (+1.0) | +174. | (+0.04) | +536. | (+1.3) |
| RADIO | -121. | (-0.1) | +1575. | (+0.7) | -866. | (-1.0) | -83. | (-0.1) |
| BRAKE | +472. | (+1.4) | +478. | (+2.8) | +272. | (+0.9) | +334. | (+2.7) |
| PSEAT | +2086. | (+2.4) | +2976. | (+3.6) | +2488. | (+1.3) | +2394. | (+4.9) |
| PW | -40. | (-0.04) | -633. | (-0.5) | +454. | (+0.2) | -11. | (-0.02) |
| N | 57 | | 31 | | 33 | | 121 | |
| $R^2$ | 0.89 | | 0.94 | | 0.91 | | 0.87 | |
| F | 37.8 | | 31.8 | | 23.0 | | 73.0 | |
| SER | 329 | | 255 | | 292 | | 327 | |

Note: Coeff. = estimated coefficient of variable
t = student's t-static value
N = number of observations
$R^2$ = coefficient of determination
F = F-statistic value
SER = standard error of the estimate
Other variables as previously defined.

TABLE A-6. MULTIPLE REGRESSION RESULTS BY MANUFACTURER-POOLED OVER SIZE CLASSES

| | GM | | Ford | | Chrysler | | Big 3 | |
|---|---|---|---|---|---|---|---|---|
| | Coeff. | t | Coeff. | t | Coeff. | t | Coeff. | t |
| Constant | -430. | (-0.2) | +8388. | (+2.8) | -8502. | (-2.0) | +1209. | (+0.8) |
| MPG | +59.8 | (+2.1) | -39.7 | (-1.0) | -14.1 | (-0.4) | +23.7 | (+1.4) |
| RT | -1.1 | (-0.2) | -16.6 | (-2.2) | +33.3 | (+2.6) | -0.2 | (-0.04) |
| HPWT | +37304. | (+3.6) | +15362. | (+0.7) | +58.37 | (+1.0) | +15797. | (+3.0) |
| AIR | +1727. | (+3.5) | -14.3 | (-0.03) | -2422. | (-2.0) | +622. | (+2.0) |
| PW | +2029. | (+7.7) | +3457. | (+9.2) | +3585. | (+9.4) | +2689. | (+14.8) |
| N | 57 | | 31 | | 33 | | 121 | |
| $R^2$ | 0.86 | | 0.87 | | 0.89 | | 0.83 | |
| F | 65.6 | | 34.9 | | 44.7 | | 114.9 | |
| SER | 348 | | 332 | | 292 | | 361 | |

Note: Coeff. = estimated coefficient of variable
t = student's t-static value
N = number of observations
$R^2$ = coefficient of determination
F = F-statistic value
SER = standard error of the estimate
Other variables as previously defined.

TABLE A-7. REGRESSION RESULTS - COMPACTS ONLY

| | GM | | Chrysler & Ford | | Big 3 | |
|---|---|---|---|---|---|---|
| | Coeff. | t | Coeff. | t | Coeff. | t |
| Constant | +86894. | (+1.0) | -814. | (-0.2) | +6018. | (+1.6) |
| MPG | +45.3 | (+0.6) | -107. | (-1.5) | +0.2 | (+0.01) |
| RT | -237.7 | (-1.0) | +14.4 | (+0.9) | -8.6 | (-0.6) |
| HPWT | +392. | (+0.01) | +20915. | (+0.6) | -16031. | (-0.7) |
| AIR | +1325. | (+0.6) | -1520. | (-1.0) | +134. | (+0.1) |
| PW | - | - | - | - | - | - |
| N | 11 | | 11 | | 22 | |
| $R^2$ | 0.34 | | 0.40 | | 0.18 | |
| F | 0.8 | | 1.0 | | 0.9 | |
| SER | 307 | | 292 | | 321 | |

Note: Coeff. = estimated coefficient of variable
t = student's t-static value
N = number of observations
$R^2$ = coefficient of determination
F = F-statistic value
SER = standard error of the estimate
Other variables as previously defined.

TABLE A-8. REGRESSION RESULTS - INTERMEDIATES ONLY

| | GM | | Ford & Chrysler | | Big 3 | |
|---|---|---|---|---|---|---|
| | Coeff. | t | Coeff. | t | Coeff. | t |
| Constant | -137874. | (-1.2) | +12032. | (+1.4) | +8472. | (+2.2) |
| MPG | +91.1 | (+2.0) | -16.1 | (-0.5) | +3.9 | (+0.2) |
| RT | +42.4 | (+1.3) | -27.8 | (-1.2) | -19.4 | (-1.8) |
| HPWT | +6776. | (+0.4) | +10288. | (+1.6) | +8222. | (+1.7) |
| AIR | -836. | (-0.4) | +1207. | (+1.2) | +1775. | (+2.8) |
| PW | +4602. | (+1.2) | +580. | (+0.3) | -286. | (-0.3) |
| N | 12 | | 16 | | 0.28 | |
| $R^2$ | 0.60 | | 0.38 | | 0.35 | |
| F | 1.8 | | 1.2 | | 2.4 | |
| SER | 181 | | 208 | | 200 | |

Note: Coeff. = estimated coefficient of variable
t = student's t-static value
N = number of observations
$R^2$ = coefficient of determination
F = F-statistic value
SER = standard error of the estimate
Other variables as previously defined.

TABLE A-9. REGRESSION RESULTS - FULL SIZE ONLY

| | GM | | Ford | | Chrysler | | Big 3 | |
|---|---|---|---|---|---|---|---|---|
| | Coeff. | t | Coeff. | t | Coeff. | t | Coeff. | t |
| Constant | -959. | (-0.1) | -32753. | (-1.4) | -18530. | (-3.1) | -7874. | (-1.9) |
| MPG | +74.7 | (+2.0) | -61.6 | (-0.8) | -14.3 | (-0.2) | +29.5 | (+1.0) |
| RT | +22.9 | (+1.0) | +87.4 | (+1.4) | +48.6 | (+2.6) | +21.7 | (+2.0) |
| HPWT | +60173. | (+5.2) | +62212. | (+1.2) | +14657. | (+1.1) | +35043. | (+4.0) |
| AIR | -10233. | (-3.4) | +54. | (+1.0) | +1793. | (+0.4) | +156. | (+0.3) |
| PW | +4225. | (+6.7) | +2221. | (+2.5) | +3026. | (+3.9) | +2889. | (+13.7) |
| N | 34 | | 16 | | 21 | | 71 | |
| $R^2$ | 0.84 | | 0.87 | | 0.91 | | 0.80 | |
| F | 29.0 | | 13.6 | | 31.4 | | 52.2 | |
| SER | 325 | | 408 | | 267 | | 368 | |

Note: Coeff. = estimated coefficient of variable
t = student's t-static value
N = number of observations
$R^2$ = coefficient of determination
F = F-statistic value
SER = standard error of the estimate
Other variables as previously defined.

TABLE A-10. RESULTS OF CHOW TEST

| | Calculated F | Critical F | Can Samples be Pooled |
|---|---|---|---|
| Compacts across manufacturers | 0.12 | 3.11 | Yes |
| Intermediate across manufacturers | 1.06 | 2.74 | Yes |
| Full across manufacturers | 2.43 | 1.94 | No |
| GM over size classes | 2.14 | 2.01 | No |

$SSR_t$ = the sum of the squared residuals for each of the subsamples to be pooled

T = the number of subsamples

K = the number of independent variables

N = the pooled sample size

If the value of F calculated above is greater than the critical value of $F[(T-1)(K + 1), N-T(K + 1)]$, then the hypothesis that the two sets of estimated coefficients are the same and that they refer to the same structure should be rejected.

This F test was used to test whether for a particular class of vehicles the Big Three manufacturers could be pooled in the estimation of a single price-quality relation. The same test was applied to individual manufacturers over different size classes. These test results are presented in Table A-10. For the compact and intermediate classes, vehicles can be pooled across manufacturers, but such pooling for full size vehicles was rejected. The test for pooling over size classes within a single manufacturer (GM) was also rejected.

## APPENDIX B

## REFERENCES


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## APPENDIX C

## REPORT OF INVENTIONS

The contract, DOT-TSC-1311, required the contractor, EIC Corporation, to evaluate relationships between automobile characteristics, list prices, and profit margins using data supplied by TSC. Conclusions appear on pages 30-31.

A review of work performed under this contract has revealed no discoveries, improvements, or innovations to existing inventions or technology.

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