**Rodney L. Carlson**
*Tennessee Tech University*

**M. Michael Umble**
*Baylor University*

# Statistical Demand Functions for Automobiles and Their Use for Forecasting in an Energy Crisis

## Introduction and Model

A research study in 1976 by one of the authors (Carlson 1978) investigated automobile demand over the period 1965–75 using a disaggregate approach. Previous studies by Chow (1957), Nerlove (1957), Suits (1958), Smith (1975)[1] and others had explained auto purchase by aggregating all sizes and classes of automobile into one demand function. The 1976 study suggested that as little aggregation as possible is desirable in a model of the new car market and that automobile demand segmented into the five automobile classifications—subcompact, compact, intermediate, standard, and luxury—revealed much additional information.

While the purpose of this earlier study was model building (with emphasis on computing elasticities and demonstrating a practical application of "seemingly unrelated regression") and not forecasting, the implications for future demand were discussed, and the tentative forecasts made were quite accurate. The model forecast 1977 sales at 10.3 million, 1978 sales at 10.7 million, and 1979 sales at less than 11.0 million. Actual new car sales for 1977 and 1978 were 10.7 and 10.9 million cars, respectively, with 1979 sales projected around 11 million. One test for model validity is its ultimate forecasting ability,

This research is an addendum to "Seemingly Unrelated Regression and the Demand for Automobiles of Different Sizes, 1965–75: A Disaggregate Approach," published by the *Journal of Business* in April 1978. The purpose of this additional study on automobile demand is (1) to point out the forecasting accuracy of the market segmentation approach and (2) to estimate the effects of the energy crisis on automobile demand for the years 1979–83. While this paper presents no additional theory on the topic, it is felt that these forecasts are of considerable interest in light of the importance of the auto industry to the nation's economy.

1. See Smith (1975) for a good summary of other approaches to modeling the automobile market.

(*Journal of Business*, 1980, vol. 53, no. 2)

0021-9398/80/5302-0001$01.09

and the 1976 model has projected very accurately.[2] This suggests that the model does reflect consumer purchase behavior in the automobile market and can be used to forecast the effects of a prolonged energy crisis on new car sales.

The automobile industry has already experienced temporary effects of the energy crisis on new car sales. These effects caused a change in consumer buying patterns in 1974 and 1975 and are described in detail in the earlier study. In 1976, however, consumer buying habits largely reverted to preembargo patterns because (1) the American public in general did not believe the energy crisis was real when gasoline prices stabilized, and (2) the redistribution to smaller cars slowed because of the "American love affair with larger automobiles." Now, after 3 years of ominous silence, the energy crisis has again become a clear threat to economic stability. The price of gasoline is certain to continue to increase, especially if all government regulations are removed from the oil industry, and continued gasoline shortage is a definite possibility.

This paper is an addendum to the 1976 research and attempts to forecast automobile demand over the next 5 years. This research will (1) update the 1976 model using quarterly data from 1967 to 1978; (2) develop various forecasting scenarios requiring assumptions about the economy, automobile prices, gasoline price, and gasoline shortage; and (3) interpret these projections as to their implications for the automobile industry.

The theoretical model is basically the same as that used in the previous study. The only differences are in (1) the procedure used to account for population change and (2) the deleting of the variable "auto stock" from the model. The revised model uses an index of population change (1967 = 100) to adjust auto sales and disposable income, while auto stock was not significant in preliminary research. The revised model can be written as

$$D_t^i = B_0 + B_1 Y_t^D + B_2 P_t^i + B_3 G_t + B_4 Z_t^E + B_5 Z_t + E_t \qquad (1)$$

where

$D_t^i$ = demand for car size $i$, $i$ = 1 (subcompact), 2 (compact), 3 (intermediate), 4 (standard), and 5 (luxury), seasonally adjusted and adjusted for population size;
$Y_t^D$ = disposable income, seasonally adjusted and adjusted for population size and to constant dollars (1967 = 100);
$P_t^i$ = an average of car prices for size $i$, $i$ = 1, 2, 3, 4, 5; adjusted to constant dollars (1967 = 100);
$G_t$ = gasoline price in current dollars;

2. While forecast accuracy is a value judgment, forecast errors of 3.9 and 1.9% are small in the projection of demand for any durable good.

$Z_t^E$ = 1, first and second quarter, 1974; gasoline shortage; and 0, otherwise;
$Z_t$ = 1, fourth quarter, 1970; UAW strike; and 0, otherwise; and
$E_t$ = the disturbance term.

Table 1 shows the results of estimating demand functions for each of the automobile classifications and suggests the following observations: (1) All variables seem to have correct signs, which is important since economic theory dictates certain relationships, *ceteris paribus,* in demand functions. (2) Disposable income is the variable of greatest impact in the model, which is to be expected, and is a result reported in all previous studies on automobile demand.[3] (3) Price is significant (at the .10 level) in all equations, which suggests it could be a significant factor in the depressed levels of auto sales. (4) Gasoline price is significant and positive in the subcompact and compact equations, significant and negative in the standard equation, not significant in the luxury equation (as expected), and absent from the intermediate equation. (5) The energy dummy indicates that in times of gasoline shortage the demand for subcompacts will increase, the demand for compacts will not significantly change, and that all other automobiles will decrease in sales. The implication is that consumers view subcompacts as the only true gasoline economy car and that shortage coupled with high gas prices will greatly increase the demand for this small car. Through 1978, however, these changes in demand had not occurred, as sales of intermediate sized cars led all others in 1977 and 1978 (see fig. 1 or 2). (6) The demand function for standard sized cars was modified because income ($Y^D$) had improper sign and was dropped from the equation. (Sales of standard sized cars have been decreasing since the late 1960s while income has been increasing.) A polynomial trend variable ($T$ = 1, 1967) was added to the model in order that secular trend could be used as a proxy for income.

## Forecasting Automobile Demand, 1979–83

Two assumptions are made about each predictor variable in the next 5 years which can be labeled as optimistic and pessimistic. These different assumptions generate forecasts for each size of automobile which are aggregated into total automobile demand.

### *Disposable Income*

From 1966 to 1978, 1974–76 excluded, disposable income in constant dollars, population adjusted, grew at an average rate of 2.7%. How-

3. If the regression coefficients are transformed into $\beta$-coefficients which reflect the relative importance of the variables, the income variable is of greatest magnitude.

**TABLE 1 Demand Functions for the Different Sizes of Automobiles, 1967–78**

| Dependent Variable | Constant | $P_t^i$ | $Y_t^D$ | $G_t$ | $Z_t^E$ | $Z_t$ | $T_t$ | $T_t^a$ |
|---|---|---|---|---|---|---|---|---|
| Subcompact, $D_t^1$ | −709,190 | −275 | 2570 | 3470* | 101000* | ... | ... | ... |
| | | (−3.37) | (3.95) | (1.67) | (1.82) | | | |
| | | | $R^2 = .91$ | D-W = 2.16 | | | | |
| Compact, $D_t^2$ | 209,010 | −158 | 760 | 2575 | ... | ... | ... | ... |
| | | (−3.34) | (2.12) | (2.48) | | | | |
| | | | $R^2 = .88$ | D-W = 2.10 | | | | |
| Intermediate, $D_t^3$ | 289,400 | −161* | 1136 | ... | −170100 | −82700 | ... | ... |
| | | (−1.68) | (2.74) | | (−4.84) | (−2.15) | | |
| | | | $R^2 = .72$ | D-W = 2.24 | | | | |
| Standard, $D_t^4$ | 3,565,600 | −342* | ... | −28030 | −171500 | −230100 | −42370 | 636 |
| | | (−1.80) | | (−5.01) | (−2.48) | (−4.62) | (−7.02) | (5.72) |
| | | | $R^2 = .91$ | D-W = 1.41 | | | | |
| Luxury, $D_t^5$ | 234,600 | −53.1 | 694 | ... | −56010 | −61900 | ... | ... |
| | | (−4.13) | (6.16) | | (−2.68) | (−3.54) | | |
| | | | $R^2 = .83$ | D-W = 2.08 | | | | |

NOTE.—Values in parenthesis are *t*-values; all coefficients are significant at .05 level except those with one asterisk, which are significant at .10; D-W is the Durbin-Watson statistic.

ever, in the period 1974–76 average growth was around 1%, and forecasts of future growth vary considerably.

1. *Optimistic.* Income growth to average 2.7% annually, which assumes minimal energy effects.

2. *Pessimistic.* Income growth to average 1.0% annually, which assumes major energy effects.

*Sales Price*

While automobiles are certain to get smaller, they will probably become more expensive. In real terms, however, the automobile has usually been a bargain. The constant dollar price decreased from the early 1960s until 1974, when it increased dramatically through 1975. Since 1976 the constant dollar price of automobiles has decreased for some cars while increasing slightly for others.

1. *Optimistic.* Price to remain constant (at 1978–79 new car levels) assuming that prices and inflation will stalemate, possibly due to government persuasion or outright control.

2. *Pessimistic.* Price to remain constant during 1979 and then to increase at 2.0% annually plus another 10% for "gas guzzlers"—standard and luxury cars.

*Gasoline Prices*

The price of gasoline in the next 5 years will be a function of (1) pricing decisions of the Organizations of Petroleum Exporting Countries (OPEC) and (2) the degree of deregulation of the oil industry in the United States.

1. *Optimistic.* Prices to climb to an average of $0.90 per gallon by late 1979 and then to increase at the rate of 5% per year. This should place the price of gasoline around $1.25 per gallon by 1983 and assumes partial stability in the Middle East and some government controls on price.[4]

2. *Pessimistic.* Prices to climb to an average of $1.00 per gallon by late 1979 and then increase at the rate of 20% per year. (This assumes that gasoline could reach $2.00 levels before government controls are enacted. It is likely that the government would institute gasoline rationing at a price lower than $2.00 and that gasoline price may not reach this level.)

*Gasoline Shortage*

A gasoline shortage is hard to define since industry analysts often disagree on (1) whether gasoline is in short "supply" or (2) whether the "quantity supplied" is being artificially restricted. This research

4. According to the *Oil and Gas Journal* the average price of gasoline was around $0.70 in early 1979. It was projected that prices could reach $0.90–$1.00 as an average around the United States by late 1979.

TABLE 2 A Catalog of Forecasting Scenarios Given Different Marketing Assumptions

| | Income Change | | Gas Price Change | | Sales Price Change | | Shortage | |
|---|---|---|---|---|---|---|---|---|
| Case | 2.7% | +1% | +5% | +20% | None | +2% | Yes | No |
| 1*a* | X | | X | | X | | | X |
| 1*b* | X | | X | | X | | X | |
| 2*a* | X | | | X | X | | | X |
| 2*b* | X | | | X | X | | X | |
| 3*a* | | X | X | | X | | | X |
| 3*b* | | X | X | | X | | X | |
| 4*a* | | X | | X | X | | | X |
| 4*b* | | X | | X | X | | X | |
| 5*a* | X | | X | | | X | | X |
| 5*b* | X | | X | | | X | X | |
| 6*a* | X | | | X | | X | | X |
| 6*b* | X | | | X | | X | X | |
| 7*a* | | X | X | | | X | | X |
| 7*b* | | X | X | | | X | X | |
| 8*a* | | X | | X | | X | | X |
| 8*b* | | X | | X | | X | X | |

defines shortage as any type of significant nationwide curtailment of gasoline supplies. Thus, significant weekend or weekday gasoline station closings, as happened in 1974 and in 1979, is assumed to have the same effect on automobile sales as actual rationing by allotment.

1. *Optimistic.* No shortage as defined will occur.

2. *Pessimistic.* Shortage to occur which would cause the annual demand for new automobiles (population adjusted) to change as estimated by the energy dummy in the five-equation model.

| *Subcompact* | *Compact* | *Intermediate* | *Standard* | *Luxury* |
|---|---|---|---|---|
| +404,000 | . . . | −680,000 | −686,000 | −224,000 |

While these figures reflect an increase in demand for subcompact cars in the advent of a shortage, they reveal a more definite tendency to refrain from purchasing larger cars during such a period.

The assumptions made in this section on income, sales price, and energy will generate 16 possible forecasts for automobile demand. These 16 scenarios are summarized in table 2. Case 1*a* is strictly optimistic while case 8*b* is strictly pessimistic.

### *Forecasting Results and Conclusions*

Figures 1–4 summarize graphically the different forecasts. All projections show high and low levels which are simply the high and low values for the 16 scenarios for that year. It should be noted that the high forecast levels are not all products of strictly optimistic assump-

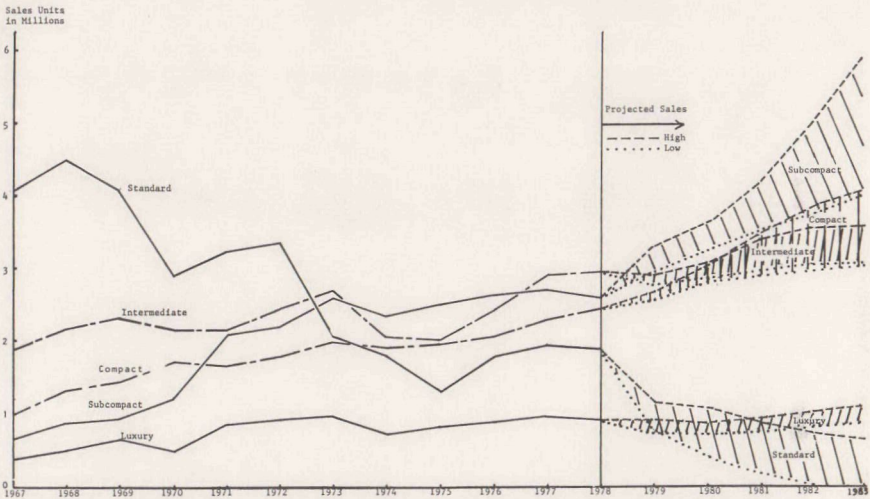


FIG. 1.—Automobile sales, classified by size, actual and projected, yearly aggregates, 1967–83 (projections under no gasoline shortage assumption).

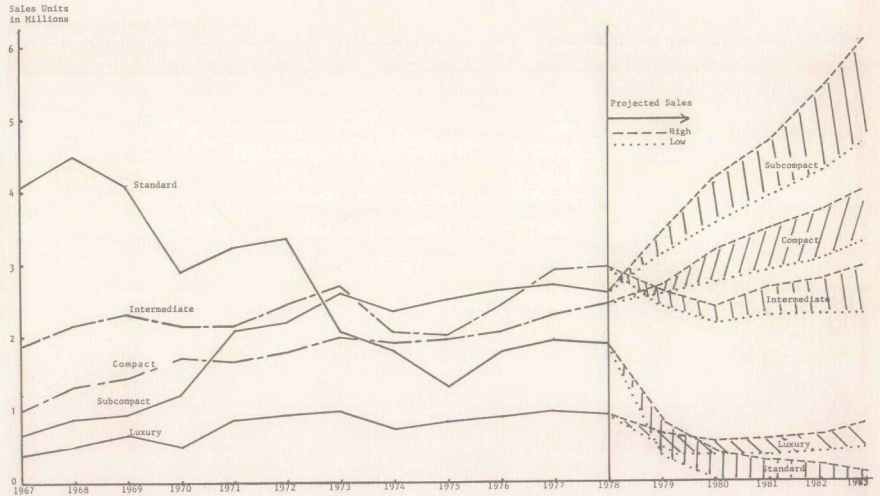


FIG. 2.—Automobile sales, classified by size, actual and projected, yearly aggregates, 1967–83 (projections under gasoline shortage assumption).

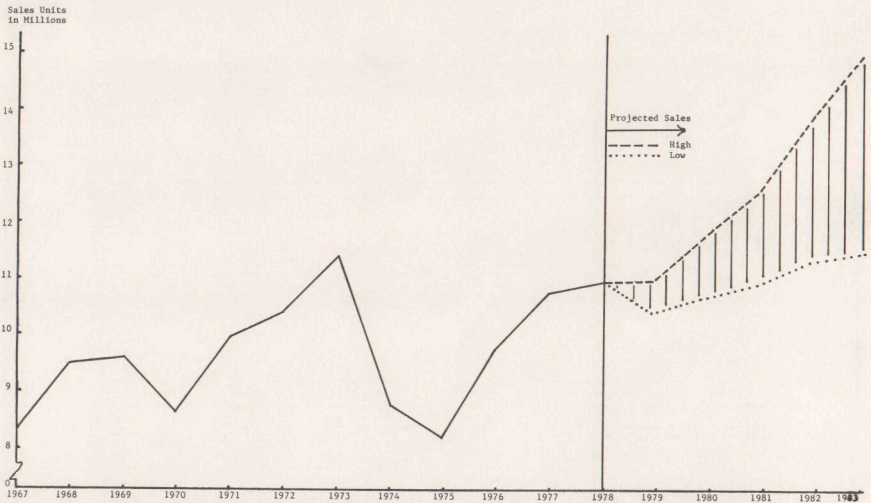


FIG. 3.—Automobile sales, actual and projected, yearly aggregates, 1967–83 (projections under no gasoline shortage assumption).

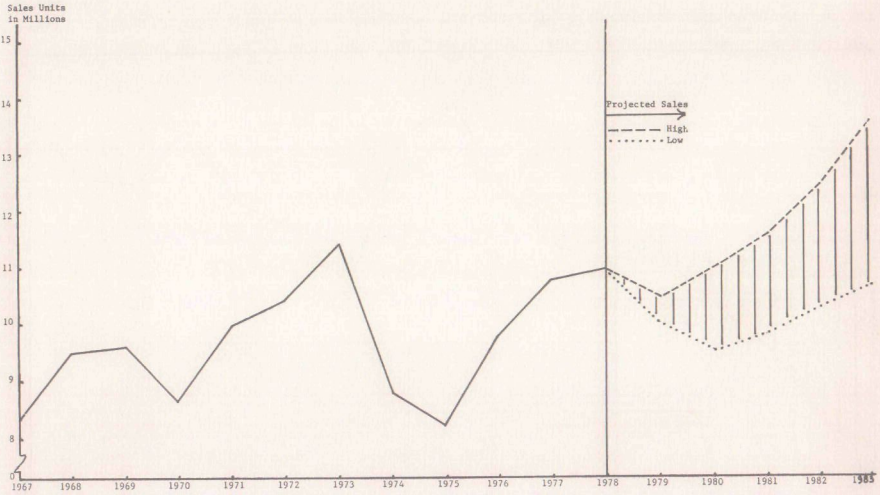


FIG. 4.—Automobile sales, actual and projected, yearly aggregates, 1967–83 (projections under gasoline shortage assumption).

tions. Subcompact demand is greatest, for example, when gasoline prices are the highest.[5]

*Comparing forecasts for each car size.* What is most apparent from these forecasts is the dominance of the subcompact automobile regardless of the assumptions used in the projections. If these estimates are correct, subcompact demand can be expected to average 35%–45% of total demand by 1983. This is not surprising considering the energy crisis assumptions in this research; however, in 1978 subcompact sales totaled less than 25% of the market while the larger automobiles—intermediate, standard, and luxury—totaled 52.3%.

The forecasts for the other small car, the compact, are lower than expected. In general, compact demand shows projected increases of 5%–7% by 1983. This supports the view that the compact automobile is in many cases a luxury subcompact, possessing significantly inferior fuel economy. Even though compact demand may not increase as much as subcompact demand, these projections do indicate that small car demand could make up 75% of the market in five years.[6]

In addition, these forecasts show that the demand for larger automobiles could be very unstable, particularly if gasoline prices rise dramatically and gasoline shortage is serious. The projected demand for intermediates shows a small increase (1%–2%) except in the case of gasoline shortage. In 1977 and 1978 intermediate automobiles led all others in sales because of (1) industry downsizing and (2) many new intermediates on the market designed to capture consumers "moving down" to small cars. If there is no gasoline shortage the intermediate could hold on to 25% of the market; however, if shortage does occur, their market share could drop to 18% or less.

The luxury automobile will, most probably, hold on to a 7.5%–9% market share unless there is extreme gasoline shortage. Luxury sales have been very stable (except for 1974–75) since the late fifties. Projections show that this will continue, unless shortage occurs, which could cut luxury sales to under 6%.

As for the standard sized car, projections indicate little demand for this car by 1983. Only under strictly optimistic assumptions does the standard model retain any significant market share—5%. It is also possible that the automobile manufacturers will not retain this size classification through 1983, thus, little or no demand may not be unreasonable.[7]

*Comparing forecasts of total sales.* That the economy is the prime

5. Tabular results of the 16 forecasting scenarios are available on request.

6. Small cars can be expected to remain defined as subcompacts and compacts until at least 1983. Intermediates may fall into this category in the near future; however, many cars in this size classification are already downsized standard models.

7. Some assumptions under shortage conditions lead to negative demand for standard sized cars by 1983. In these cases projected demand is assumed zero.

determinant of future automobile demand is certain. If gasoline shortage occurs, the two factors are certain to interact and produce a low level of consumer demand. The projections show that under these conditions automobile demand could drop as low as 9.4 million in 1980 before increasing to 10.9 million in 1983, the same level of sales as in 1978. However, if income growth is 2.7% or more (the optimistic assumption), then record levels of automobile sales are possible. Projections under the most favorable assumptions indicate that sales could increase to over 14 million. This is possible, as consumer demand for new cars has been depressed for some time. It is far more likely, however, that gasoline and automobile prices will continue to increase (at rates close to the pessimistic assumptions) and that total automobile demand will only reach 12–13 million by 1983.

This study suggests that unless disposable income increases at rates equal to pre-1974 levels the demand for automobiles could stagnate around 12.5 million even under favorable assumptions about energy and price levels. This is far short of the sales levels that auto makers anticipate by 1983. If the more realistic assumptions of high gasoline prices and gasoline shortages are made, total demand may not reach 11 million in a recessionary economy. This is not reassuring news for the auto industry.

## References

Carlson, Rodney L. 1978. Seemingly unrelated regression and the demand for automobiles of different sizes, 1965–75: a disaggregate approach. *Journal of Business* 51 (April): 243–62.

Chow, Gregory C. 1957. *Demand for Automobiles in the United States*. Amsterdam: North-Holland.

Nerlove, Marc. 1957. A note on long-run automobile demand. *Journal of Marketing* 22, no. 1 (July): 57–64.

Smith, Ronald. 1975. *Consumer Demand for Cars in the USA*. Cambridge: Cambridge University Press.

Suits, D. B. 1958. The demand for new automobiles in the United States, 1926–1956. *Review of Economics and Statistics* 40, no. 3 (August): 273–80.

Zellner, Arnold. 1962. An efficient method of estimating seemingly unrelated regression equations and tests for aggregation bias. *Journal of the American Statistical Association* 57 (June): 348–68.