ANALYSIS OF FUEL ECONOMY EXCISE TAXES AND REBATES

Carmen Difiglio, Office of Transportation Research, Federal Energy Administration

Excise taxes on fuel-inefficient automobiles and rebates for fuel-efficient automobiles have been proposed to reduce gasoline consumption by encouraging a more fuel-efficient automobile fleet. This paper presents a methodology for estimating the impact that various automobile excise tax and rebate proposals will have on fuel consumption, fuel economy of the new automobile fleet, and total automobile sales. This analysis explicitly considers the cost to improve the technical efficiency of automobiles and the potential for shifting consumers to smaller automobiles. The results of the analysis are displayed graphically for a prototypical excise tax proposal.

A frequently proposed approach to improve automobile fuel economy is to place a heavy excise tax on new automobiles that have poor fuel economy. This tax is reduced step by step as the fuel economy of new automobiles improves until, eventually, there is no tax at all on automobiles that have good fuel economy. Several proposals go farther and, in addition to fuel economy taxes, provide rebates to purchasers of automobiles that have high fuel economy. These taxes and rebates will precipitate changes in gasoline consumption in the following ways:

1. Induce manufacturers to improve the fuel efficiency of their automobiles so as to reduce specific tax rates on those models,
2. Encourage consumers to purchase automobiles with better fuel economy,
3. Change the total level of automobiles sold,
4. Reduce the operating costs of new automobiles, and
5. Change the use and scrappage of used automobiles.

Impacts 1 and 2 both clearly reduce gasoline consumption. The third impact will also reduce gasoline consumption for an excise tax system. However, if both excise taxes and rebates are provided, it is possible for total automobile sales to increase. Impacts 4 and 5, however, increase gasoline consumption. The improved fuel economy of new automobiles reduces their operating costs and thereby mitigates the fuel efficiency improvement in additional travel per vehicle. Also, the impacts of this fuel economy policy on scrappage and the use of the existing fleet tend to reduce gasoline savings from what they would otherwise be. The increased cost of new large automobile increases the value of similar used automobiles. Thus, these large used automobiles will be maintained longer and driven more than if no policy were implemented. Similarly, if new small vehicles are subsidized, their decreased cost will drive down the value and increase the scrappage of small used automobiles. These two effects combined result in a lower fleet efficiency for existing automobiles.

The net result of all five impacts should be to reduce overall fuel consumption. To determine the extent of that reduction and also to estimate associated impacts on automobile sales, market shifts, scrappage, and other variables, the Federal Energy Administration (FEA) initiated research to evaluate automobile fuel economy tax policy. This research is still under development, and the material presented in this paper represents interim results. Future research will improve some of the data that have been used and provide a more elaborate model to analyze behavioral impacts.

ANALYTICAL STRUCTURE

The impact analysis of excise taxes on new automobiles includes both supply and demand of new automobiles. Figure 1 shows a schematic of the impact on new automobile supply.

The excise tax and rebate program provides an incentive to each automobile manufacturer to improve the fuel economy of each model produced that is, or is potentially, affected by the tax and rebate program. For example, if a model is produced that delivers 6.8 km/liter (16 mpg) and the tax and rebate schedule specifies a $300 tax for 6.8-km/liter (16-mpg) automobiles and a $150 tax for 7.2-km/liter (17-mpg) automobiles, an incentive to the manufacturer exists to improve the fuel economy of that model to 7.2 km/liter (17 mpg). This incentive should induce a cost analysis for that model to determine what in terms of engine and chassis design, performance, and other characteristics might be changed on that model to deliver 7.2 km/liter (17 mpg). Further, if the tax incentive program provides that no tax be levied for automobiles that deliver 7.6 km/liter (18 mpg)

Figure 1. Automobile supply impact.

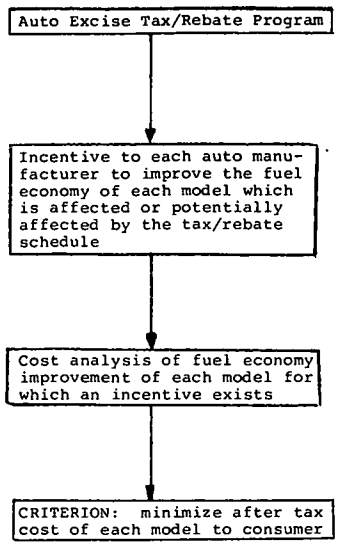
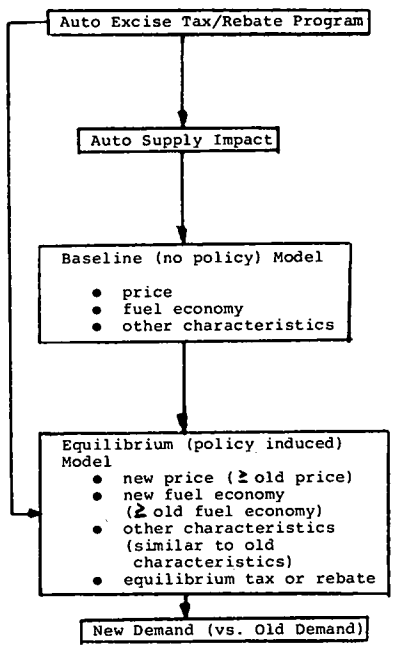


Figure 2. Automobile demand impact.



or better, then this cost analysis could conceivably be extended to that goal as well. For another model, which already delivers 7.6 km/liter (18 mpg) or better, the tax table, which begins at 7.2 km/liter (17 mpg) and extends downward, would provide no incentive to further improve the fuel economy of that model.

After performing a cost analysis for each model affected, the manufacturer would use, explicitly or implicitly, some criterion for actually implementing fuel economy improvements. The criterion shown in Figure 1 is: Minimize the after-tax cost of each model to the consumer. This criterion is subject to various constraints regarding the nonprice characteristics of that model, for example, acceleration performance. Although this is a complex area, it is probably accurate to say that the important marketing characteristics will be maintained so as to ensure continued demand for that model.

Figure 2 shows the factors that will affect automobile demand. If the manufacturer minimizes the after-tax cost of each model produced, these automobiles will likely have different prices, fuel economies, and other hedonic characteristics from those that existed in the base case (no policy). To simplify the analysis, we assumed that the other nonprice, nonfuel economy characteristics do not change significantly. Thus, price and fuel economy are potentially affected in a significant way.

Both of these may increase from the base case model. In addition, a tax or rebate may exist for that model that faces the consumer with a different after-tax cost of purchasing the automobile. This after-tax cost will tend to be higher, relative to the base-line case, if the equilibrium fuel economy of a model is low. Alternately, the after-tax cost relative to the base case will be lower if the base-line fuel economy is high. An ambiguous middle ground exists if the base-line fuel economy is low and the equilibrium fuel economy is high. Cost increases to achieve the improved fuel economy can potentially be offset by rebates. A continuum of possibilities exist over all affected models.

The influence of the new automobile market supply and demand changes on total gasoline consumption is schematically shown in Figure 3. As indicated in Figures 1 and 2, the tax and rebate table (top of Figure 3) generates new automobile sales, model mix, and sales-weighted fuel economy. Also, the change in the cost of new automobiles impacts used automobile scrappage and the fleet fuel economy of used automobiles. Given the operating cost characteristics of new and used automobiles, total travel demand can be estimated. Gasoline consumption is then determined in response to the policy option (i.e., the tax and rebate program). Figure 3 shows basically what our analysis will attempt to simulate.

For the purpose of providing some interim results for specific tax and rebate proposals, our analysis has temporarily concentrated on the new automobile market and given less attention to the secondary impacts on the used automobile fleet. To replicate the process shown in Figure 3 would obviously be impractical for each automobile provided. Instead, a set of market classes was used in which each market class represented an average response for all automobiles in that market class. The more heterogeneous these market classes are, the more inaccurate such a representation becomes. Ideally, each market class only includes a tightly homogeneous group of automobiles. Therefore, the market class system chosen should define as homogeneous submarkets as feasible. In this study we adopted 5 marked classes: subcompact, compact, intermediate, standard, and luxury.

To simulate the typical manufacturer's treatment of each market class in response to the tax and rebate policy required a base-line fuel economy for each market class over time. This base-line fuel economy corresponds to no government intervention in either the automobile or the gasoline markets under the expected regulatory environment regarding emissions and safety. To rigorously derive such a base line, however, involves difficulties that surpass the policy impact analysis itself. Therefore, based on the manufacturer's announced intentions to improve fuel economy in response to market pressure (as opposed to government pressure), a conservative estimate of fuel economy improvements was selected that would yield a 40 percent improvement by 1985 with no market shifts to smaller automobiles. This base-line forecast is given in Table 1.

Data required to simulate the manufacturer's response to the tax and rebate policy also include a fuel economy improvement cost curve for each market class

Figure 3. Influence of new automobile supply and demand charges on gasoline consumption.

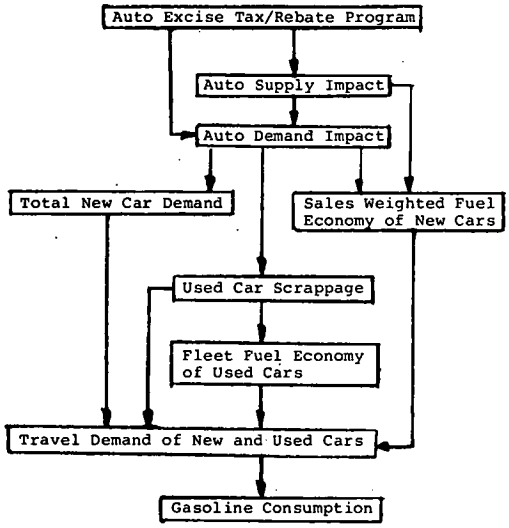


Table 1. Base-line fuel economy of automobile forecast by market class.

Year	Sub-Compact	Compact	Intermediate	Standard	Luxury
1976	11.6	8.0	6.7	5.6	5.4
1977	11.7	8.2	6.8	5.7	5.6
1978	11.9	8.3	7.0	5.9	5.8
1979	12.2	8.5	7.2	6.0	6.0
1980	12.3	8.6	7.4	6.4	6.3
1981	12.5	8.7	7.5	6.7	6.6
1982	12.7	8.9	7.7	6.8	6.7
1983	12.9	9.0	7.9	7.0	6.9
1984	13.2	9.2	8.0	7.0	6.9
1985	13.3	9.3	8.2	7.0	6.9

Note: Values are in kilometers per liter, where 1 km/liter = 2.35 mpg.

Figure 4. Part 1 of simulation process.

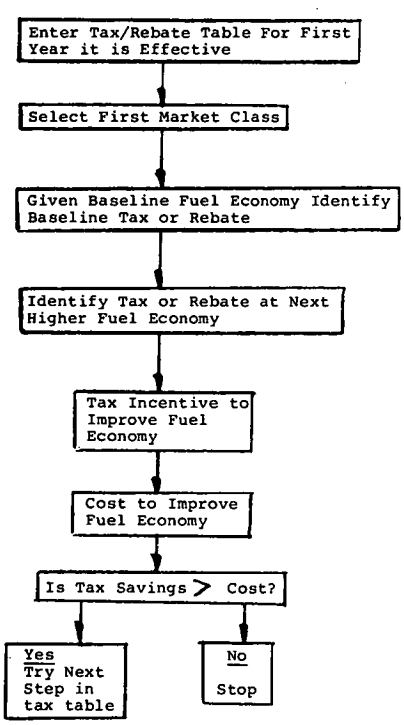
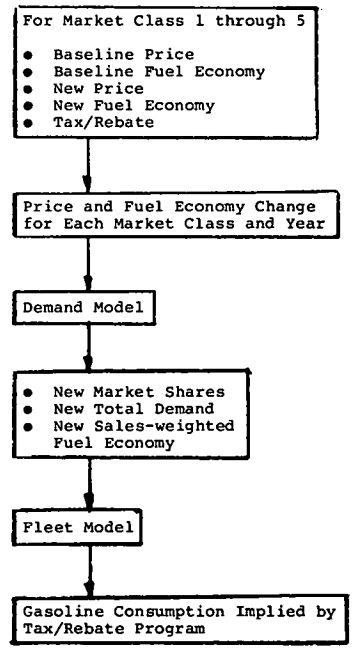


Figure 5. Part 2 of simulation process.



over time. This cost curve provides, within each market class for a given future year, the cost to improve the fuel economy of the automobile over and above the base-line fuel economy. By analyzing each market class as if it were an individual model, one need only apply the suggested manufacturer's criterion five times for each model year. In each case, the after-tax cost of a market class can be minimized as long as the cost curves are well behaved. That is, the cost curves should indicate that each additional kilometer per liter improvement costs more. If they do not, multiple or indeterminate equilibrium may exist.

Figure 4 shows the simulation process employed. The tax and rebate table is entered into a program that contains the base-line fuel economies and cost of improvement curves. It selects the first year for which a tax is applicable and determines for the first market class what its base-line tax or rebate is. It then moves up to the next tax class (or the next higher kilometer per liter) and calculates the potential tax savings that would be realized if the market class were improved to achieve that fuel economy. The cost of improvement curves (including expected markup to represent retail cost) are used to determine whether the tax savings is greater than the cost. If so, the next step in the tax table is evaluated in the same manner until the cost to improve the fuel economy exceeds the tax savings. When this happens, the final market class fuel economy, price, and tax are calculated for that year. The program goes on to the next year, repeats the process, and continues for the next four market classes. In each market class and year, equilibrium fuel economies, prices, and taxes or rebates are determined. These outputs are shown at the top of Figure 5. An automobile demand model that estimates the demand for each market share generates these new fuel economies and prices new market shares, new total automobile demand, and new sales-weighted fuel economy. The automobile demand model currently being used is a logarithmic-linear function for each market class.

$$A_i = a \prod_k X_k^{c_k} P_i^{e_i} \prod_j P_j^{ce_{ij}} \qquad i \neq j \tag{1}$$

where

A_i = demand for automobiles of market class i;
P_i = price of automobiles in market class i;
P_j = price of automobiles in other market classes j, $j \neq i$;
X_k = all other variables that affect the demand for A_i;
a = constant;
e_i = price elasticity of demand for market class i;
ce_{ij} = cross-price elasticity of demand for market class i with respect to the price of market class j, $j \neq i$; and
c_k = elasticities of demand for market class i with respect to variables X_k.

Equation 1 was selected to model total automobile demand in each class because it is a constant elasticity model with within-class elasticity estimates that do not depend on the base-line level of automobile demand. The cross-price elasticities interconnect the price of one market class to each of the other market classes. In equation 1, these were partly derived from the following a priori criteria:

1. Lower (higher) prices for a market class should increase (decrease) demand for that market class while not increasing (decreasing) demand for competing market classes;
2. Lower (higher) prices for a market class should increase (decrease) total demand for all market classes; and
3. The shift in demand among similar market classes should be higher than that among less similar market classes.

To satisfy criterion 1 above,

$$e_i < 0 \tag{2}$$

$$ce_{ij} > 0 \tag{3}$$

These parameter constraints can be demonstrated by differentiating automobile demand for each mode with respect to P_i and P_j. Constraints in equations 2 and 3 are the familiar conditions on price elasticities (must be negative) and cross-price elasticities (must be positive or zero) for substitute goods. Criterion 2 requires a somewhat more complex constraint. Since total demand must decrease given a price increase in a market class, the constraint in equation 4 guarantees that the total increase in the demand for other market classes (other than market class j) is smaller than the decrease in the demand for the market class that has a price increase (market class j).

$$\frac{\partial A}{\partial P} < 0$$

$$\sum_{i \neq j} \frac{\partial A_i}{\partial P_j} + \frac{\partial A_j}{\partial P_j} < 0$$

$$\sum_{i \neq j} ce_{ij} P_j^{ce_{ij}-1} A_i P_j^{-ce_{ij}} < -e_j P_j^{e_j-1} A_j P_j^{-e_j}$$

$$\sum_{i \neq j} ce_{ij} A_i < -e_j A_j \tag{4}$$

This constraint can be used as the basis for an exact relation between e_j and each ce_{ij} by using criterion 3. Criterion 3 requires that the shift should be higher between similar market classes than between less similar market classes. If, as a starting point, it is assumed that the absolute market share shifts induced by a price change are equal, then

$$ce_{ij} = -e_j \left(\frac{A_j'}{A_i'}\right) F(0.25) \qquad 0 < F < 1 \tag{5}$$

where A_j', A_i' = base period automobile demand for market class i, j. The factor 0.25 is based on the definition of five market classes, which implies four cross elasticities in each market class in equation 1.

In equation 5, the absolute shift between market classes is dependent on e_j and F but, regardless of their values, the shift to other market classes A_i (i = 1, . . . , 5; $i \neq j$) is equal. To satisfy criterion 3, a weighting system can be introduced that alters the distribution of shift from that specified in equation 5.

$$ce_{ij} = -e_j \left(\frac{A_j'}{A_i'}\right) F\, d_{ij} \qquad \sum_{i \neq j} d_{ij} = 1 \tag{6}$$

The factor 0.25 is replaced in equation 6 by a more general weighting factor d_{ij}. This factor is larger when i and j are adjacent and is smaller as i and j represent more dissimilar market classes. For example, if i = 1, then d_{ij} is largest when j = 2, smaller when j = 3, still smaller when j = 4, and smallest when j = 5. The constraint that the sum of d_{ij} over each $i \neq j$ = 1 preserves the property that when F = 1 the entire decline of demand for market class j is distributed over all other market classes with no net change in total automobile sales.

Thus, the factor F represents the proportion of reduced sales in one market class (induced by a price increase) that is shifted to increased sales in other market classes. This is a particularly important parameter regarding the cost-effectiveness of excise taxes and rebates based on automobile fuel economy. As F approaches one, a tax on fuel-inefficient automobiles will have less impact on total automobile sales while precipitating more of a shift in the sales-weighted fuel economy than would be the case as F approaches zero. A relatively large value of F would mitigate the need for rebates on fuel-efficient automobiles to maintain total automobile sales. Also, since it is difficult to restrict tax rebates to domestic automobiles, tax rebates on fuel-efficient automobiles are likely to subsidize foreign automobile sales in the United States.

Equation 6 reduces the number of price parameters to be estimated from 25 to 6. There are 25 price parameters for five market classes since there is a direct elasticity of demand between each market class and all others. Equation 6 reduces as many as 20 cross-elasticity estimates to one, depending only on the value of F and each direct elasticity estimate.

Although these a priori considerations help simplify the problem of identifying the parameter values required for equation 1, they still do not eliminate the need for empirical observation. Up to now, equations 1 and 6 have served as a test-bed for sensitivity analysis of tax policy under various assumptions. Recently, however, an FEA consultant developed a three-market-class shares (small, medium, and large) and total automobile demand model in the context of FEA's participation in the Interagency Task Force for Motor Vehicle Goals Beyond 1980 (1).

Since our currently available cost data are in the

Figure 6. Tax and rebate tables by year.

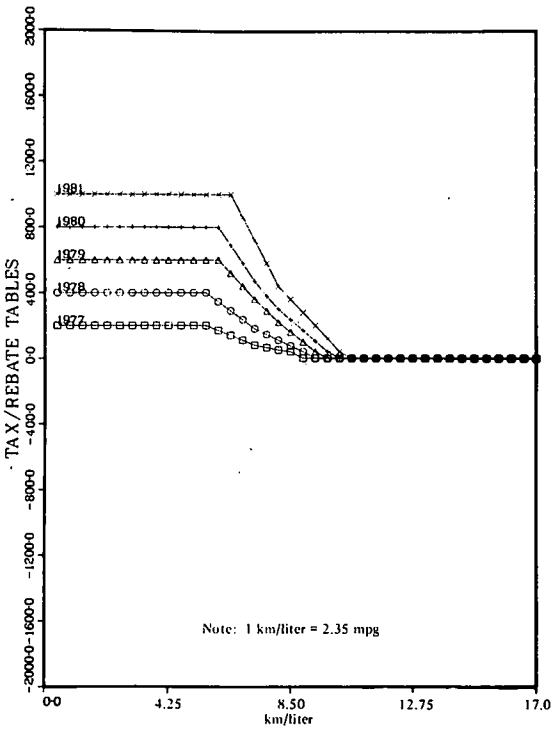
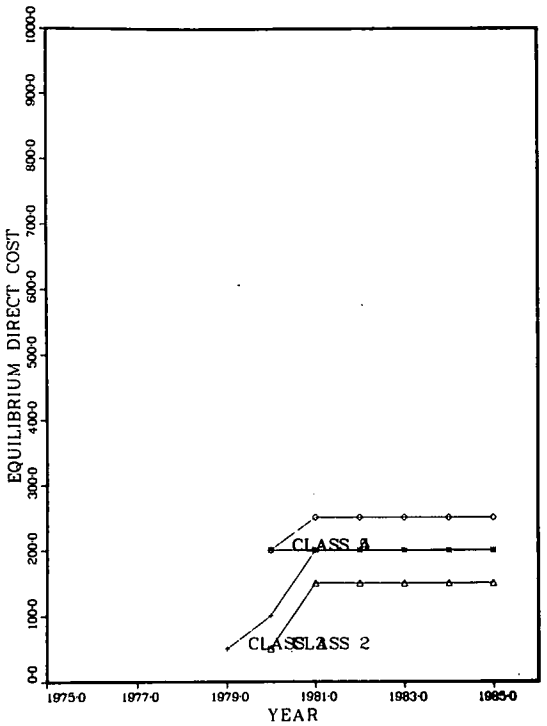


Figure 7. Direct cost by market class.



context of five market classes, this model was not used. However, the results of the marketing and mobility model were used to estimate the in-class elasticities and the F-value required for equations 2 and 6. When the cost data are reestimated in the context of a three-market-class framework, the marketing and mobility model will be used to derive policy impacts. Similarly, the consultant will provide more accurate and well-documented cost curves (2); the current cost curves are based on preliminary results of this contract. The range of uncertainty associated with the current estimates is high, and the number of technological steps on which the curves are based is too few.

Despite these disclaimers and the substantial amount of work required to complete our intended improvements, the currently available cost curves and behavioral models can still be used to produce sample results.

PRELIMINARY RESULTS

The analytical procedure described above has been applied to analyze several legislative proposals that were introduced in Congress during 1975. The early tax proposal of the House Ways and Means Committee was considered to illustrate the types of output provided by the tax and rebate model.

Figure 6 shows the selected tax schedule. The tax program begins in 1977 at $200 for automobiles that deliver 5.5 km/liter (13 mpg) or less, indicated by boxes on the 1977 line from 0.4 to 5.5 km/liter (1 to 13 mpg) on the y-axis and $200 on the x-axis. At 6.0 km/liter (14 mpg) in 1977, the tax drops by $30 and continues to drop by similar amounts until at 8.42 km/liter (20 mpg) there is no tax; the sloped portion of 1977 line levels off at 0 tax from 8.5 km/liter (20 mpg) and above. In 1978 the tax begins at $400 and also begins to drop off at 6.0 km/liter (14 mpg) and reaches zero by 8.9 km/liter (21 mpg). This progression continues through 1981 at a maximum tax of $1000, dropping off at 6.8 km/liter (16 mpg) and becoming zero at 10.6 km/liter (25 mpg). In each successive year, the slope of the falling portion of the tax and rebate schedule is progressively steeper. This indicates a more substantial financial incentive to the manufacturers to improve the fuel economy of their automobiles. Also, the cost curves to improve automobile fuel economy indicate higher fuel economy for improvements (for a given cost) in each successive year through 1981.

In the first 2 years of the tax program, the financial incentive is too small to induce manufacturers to improve the fuel economy of any automobiles beyond what they would otherwise be (base-line fuel economy). In Figure 7, this is shown by no direct cost for any of the five market classes in 1977 or 1978. In 1979, however, the tax incentive is sufficient to induce a $50 improvement in market class 3 (intermediates). By 1980 all market classes except class 1 incur cost increases. In 1981, the maximum direct cost incurred is in market class 5 (luxury) at $250 (indicated by diamonds in Figure 7). Market classes 4 (standards) and 3 (intermediates) both level off at $200 direct cost (shown in Figure 7 by + for class 3 and X for class 4). Class 2 (compacts) incurs a $150 direct cost by 1981 (triangles in Figure 7), and class 1 (subcompacts) incurs no cost changes at all. The average base-line fuel economy of subcompacts is always above the point at which no tax incentive exists. Because of the homogeneity of class assumption, all subcompacts experience no fuel economy improvements above base line.

From 1981 through 1985, the direct costs incurred in 1981 are assumed to hold, despite the lack of any tax incentive beyond 1981. This is an extreme assumption that is not likely to be realized. It is more likely to hold if manufacturers are locked in to given technologies because of capital commitments made in response to tax incentives of earlier years. The other extreme would be to drop the direct cost to zero for all market classes in 1982. Because of the capital required to realize improved technologies to deliver better fuel economy, this assumption too is not likely to be realized.

Figure 8. Base versus imputed fuel economy.

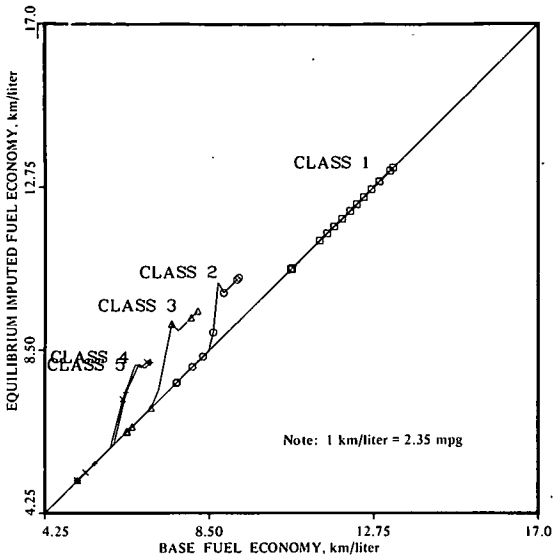
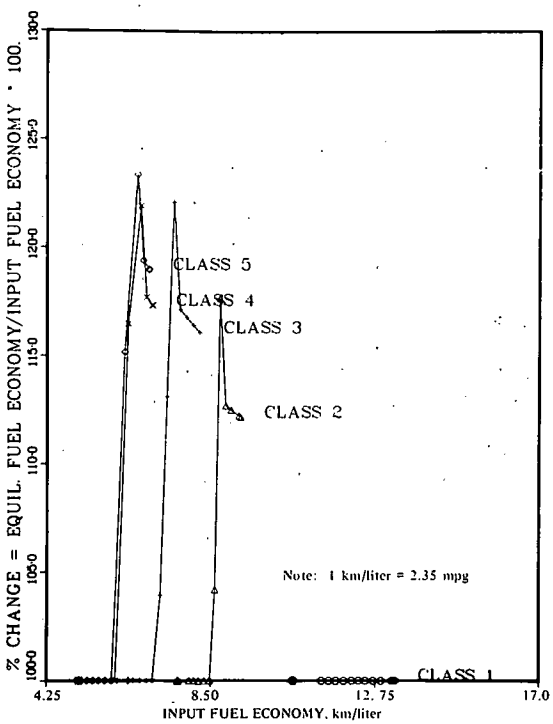
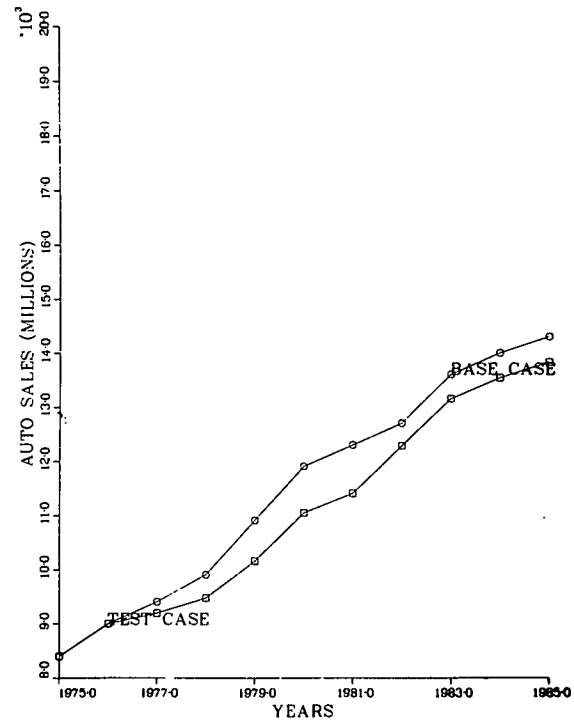


Figure 9. Percentage change from base fuel economy.



This issue also introduces a more fundamental problem associated with the cost curves. They only indicate the cost of fuel economy improvements for a given year independent of any other year. Also, since they are derived as an envelope of alternate technologies, there is no indication that by moving from one fuel economy level to another substantially different technologies and associated capital investments would be required. Obviously, manufacturers must view a set of taxes and rebates as an interdependent set of incentives. The tax incentive in a single year will not be so strong in each year as a set of tax incentives during several years. The analysis, at this point, does not simultaneously consider the tax incentives of all years. Rather, a recursive system

Figure 10. Automobile sales by year.



is used in which a tax and rebate incentive for a given year only impacts the fuel economy of automobiles in that year and succeeding years. Although a simultaneous analytical structure could be designed, it would require a more sophisticated cost function than we currently have. This will be an important area for future research.

The cost increases in market classes 2 through 5 paid for technical improvements of fuel economy above and beyond the base-line fuel economy. Figure 8 shows the base-line fuel economy (x-axis) versus the improved fuel economy (y-axis). For market class 1, which was unaffected by the House committee tax schedule, the fuel economy for 1975 through 1985 lies along the diagonal. However, market class 3 departs upward from the diagonal in 1979, and market classes 2, 4, and 5 also diverge in 1980. The percentage improvements of fuel economy for market classes 2 through 5 are shown in Figure 9. Maximum percentage improvements occur in either 1980 or 1981. After 1981, despite maintenance of technical improvements, the base-line fuel economy rises and thereby reduces the fuel economy impact measured as a percentage.

The impact of both the cost changes and taxes on total automobile sales is shown in Figure 10. The maximum impact occurs in 1981 (demand down by 7.3 percent). After 1981 the taxes cease, and only cost changes cause the test case demand to be lower than the base case. This point is especially evident in Figure 11, which shows the gross revenue represented by the sales in Figure 10. The test case revenue is lower only in years for which taxes exist. After 1981, the test case and base case revenue are essentially equal, reflecting the estimated price elasticity (near unity) of the marketing and mobility model.

The tax revenue generated by the House committee program, shown in Figure 12, reaches a maximum of $3.34 billion in 1979. Despite the substantial increase of the taxes at given fuel economies in 1980 and 1981, tax revenues are substantially reduced (to $2.53 billion in 1981) because of the substantial fuel economy im-

Figure 11. Gross revenues by year.

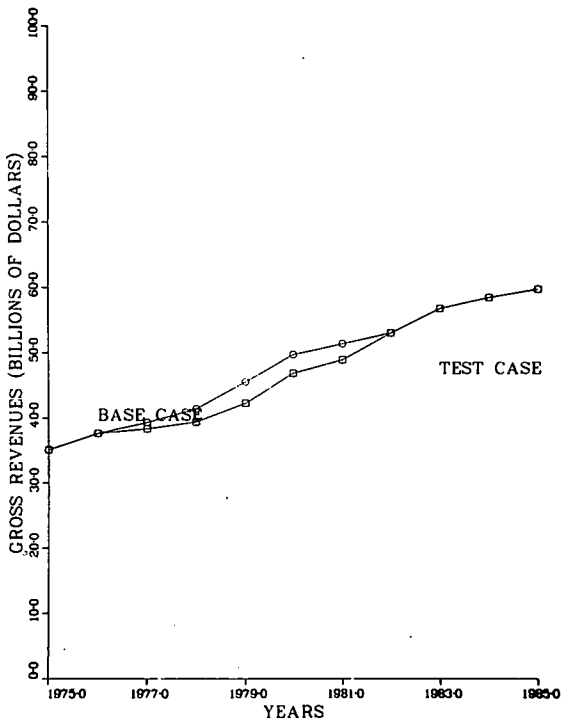
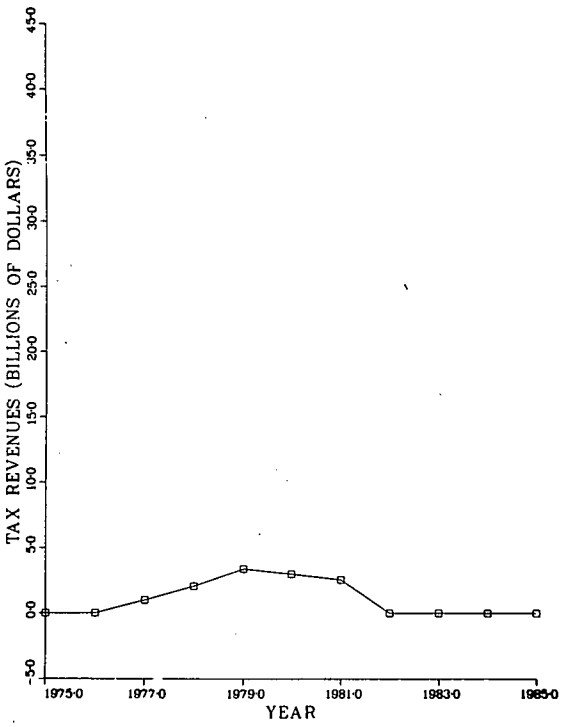


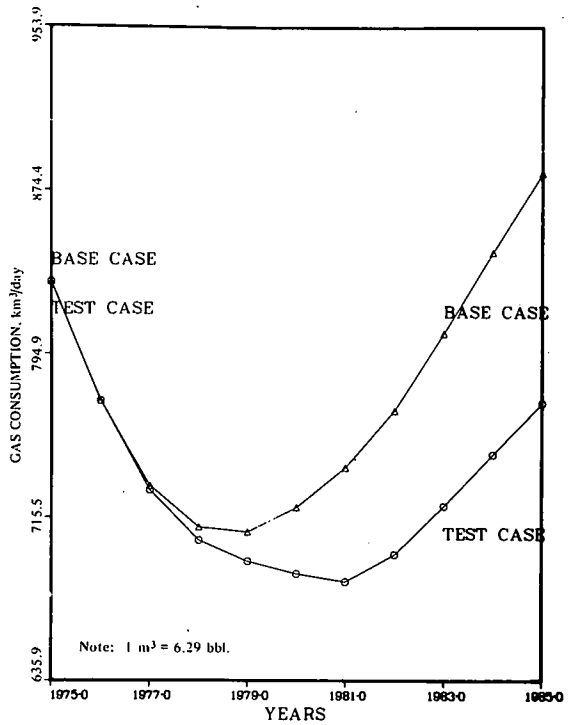
Figure 12. Tax revenues by year.



provements in market classes 2 through 5 during 1980 and 1981.

The most important impact is on fuel consumption (Figure 13). Since the existing automobiles must be retired and replaced with new automobiles at a fairly gradual rate, the maximum fuel economy impacts are in the long term. In 1985, a 112.9-km^3/day (0.71

Figure 13. Gas consumption by year.



million-bbl/day) reduction in gasoline consumption is indicated for the House committee tax program [882.4 km^3/day (5.55 million bbl/day) in the base case versus 771.1 km^3/day (4.85 million bbl/day) in the test case]. This represents a substantial energy savings, although substantial economic costs are required to achieve it.

REFERENCES

1. C. Difiglio and D. Kulash. Marketing and Mobility. Prepared for the Interagency Task Force for Motor Vehicle Goals Beyond 1980, March 1, 1976.
2. Fuel Economy/Cost Relationships for Future Automobiles. Hittman Associates, Jan. 1976.