The Impact of the Electric Car on the U.S. Economy: 1998 to 2005

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ABSTRACT *This paper presents an exercise in using the INFORUM LIFT macroeconomic interindustry model of the United States to analyze the industry and macroeconomic impacts of structural change in the Motor vehicles industry. This structural change is the result of 3.6% of U.S. automobiles sold assumed to be electric vehicles by 2005, as a result of California legislation expected to be adopted by thirteen states, which will take affect starting in 1998. In this study, alternative input-output coefficients for the Motor vehicles and the Auto repair industries are derived for this mix of electric car production, and assumptions about fuel consumption and maintenance expenditures are also developed. The results of the study show that although macroeconomic effects are minimal, impacts on particular industries are significant, given the small level of market penetration assumed.*

KEYWORDS: *Macroeconomic interindustry model, structural change, electric vehicles*

1. Introduction

Almost 25 years since the passage of the Clean Air Act of 1970, air pollution continues to be a major environmental problem in U.S. cities. In 1993, 91 cities, comprising over 60% of the U.S. population, did not meet federal clean air standards. Of this pollution, it is estimated that 60% of hydrocarbons, carbon monoxide, nitrogen dioxide, and other pollutants that combine to produce smog are due to automobile emissions (EPA, 1992). Automobile emissions also contribute to acid rain and global warming. The cost due to property damage and respiratory ailments has been estimated at hundreds of billions of dollars per year.[1]

In an effort to comply with legislative requirements in the Clean Air Act, the California Air Resources Board in September of 1990 put forth its new standards that automobile manufacturers will have to follow starting in 1998, if they are to then sell cars in the state of California. This legislation, adopted by the California legislature, calls for 2% of all new cars sold to be Zero Emission Vehicles (ZEVs) by 1998, 5% by 2001, and 10% by 2003. At present, the only type of vehicle that qualifies as a ZEV is the electric car. Some observers believe that technological advancements foreseeable in the next 3 to 5 years will enable the production of an efficient, economical electric car that will be competitive with conventional gasoline fueled internal combustion autos in terms of purchase price, maintenance cost, and fuel expense. Since then, New York and Massachusetts have also voted to adopt the California legislation, but are being challenged in court by the Big Three auto producers. Maryland and Virginia are among the other 10 states considering adopting the requirements. The other states are all in the northeast where automobile pollution is a serious problem.

California was probably encouraged to go ahead with the adoption of these requirements by the announcement, in early 1990, of GM's plans to produce the *Impact*, a sporty, high-tech electric car with powerful acceleration and reasonable range.[2] Within another year, both Ford and Chrysler had announced their own electric car programs although they were focusing on more expensive minivans, targeted to electric utilities and state and local governments. However, in the last year the Big Three auto producers have been fighting the standards in court, stating that the technology will not be ready in time to produce an efficient electric car, with acceptable range, at a cost consumers can afford. The biggest obstacle appears to be batteries, although the producers also cite the high cost of redesigning automobile chassis and frames to be lighter and provide less wind resistance. In the meantime, foreign producers such as Nissan, Toyota, BMW, and even Swatch, the Swiss watch maker, are charging ahead with their own plans to produce electric cars. Battery development is ongoing, with about forty different battery technologies in the race. The most likely choice is probably a more efficient version of the familiar lead-acid battery used in conventional cars, but other more exotic contenders, such as nickel metal-hydride, lithium polymer, and flywheel batteries may usurp the place of the common lead-acid battery, due to longer range or lower weight.[3]

In addition to the beneficial environmental impacts from the introduction of the electric car, economic impacts are also of great interest. Will the introduction of the electric car have positive or negative effects on the overall level of GNP and employment?[4] Will the switch from fossil fuels to electricity help the United States to reduce its dependence on petroleum imports, and how will it affect the overall trade balance? What will be the economic impacts on the specific states involved in the program?

This study is an attempt to address the economic impacts of the electric car on the economy at a national level, if the California standards are in fact adopted by the thirteen states who either have already adopted the standards, or are considering adoption. The study is performed with the INFORUM LIFT model, which is an interindustry model forecasting results for 85 industries comprising the U.S. economy. This model is particularly well-suited to a study of this kind, because it tracks not only the macroeconomy, but also industry output and employment and the interdependence among industries brought about by the fact that every industry relies on other industries for its production inputs.[5] Using the *LIFT* model, one can look at how the changing input requirements of electric versus conventional vehicles affect the demands for automobile inputs, and one can also trace the impacts of different fuel and maintenance requirements of electric vehicles. In addition, the investment requirements for charging stations or new electrical generation capacity can be analyzed. If sufficient information were available on the input requirements of the new types of batteries, the impacts of using these batteries on metals and chemicals industries could be examined as well.

The results of the model are ultimately dependent on the assumptions used, and the study of the electric car poses questions which can only be answered with uncertainty. How much will a production version of an electric car cost compared with a similar conventional car? How much will the batteries cost, and how often will they need to be replaced? How energy efficient will electric cars be, and what will be the total operating cost? The next section will present the development of the assumptions used in running the *LIFT* model. Finally, the last section will present macroeconomic and industry impacts suggested by the simulation.

2. Development of Model Assumptions

Given the technological and legislative questions associated with the electric car, the results of this study are subject to great uncertainty. The assumptions used for the current simulation using the LIFT model are presented as the best projection, given current knowledge. Wherever possible, assumptions were derived from published projections in newspaper and magazine articles, price lists of companies converting conventional cars into electric cars, and consultations with the Chrysler/Westinghouse consortium for which an earlier version of this study was performed.

2.1 Market Penetration of Electric Vehicles

Perhaps the most basic assumption underlying this study is the degree of market penetration of the electric vehicle over time as a percentage of new auto sales. This assumption influences the output mix of electric and conventional gasoline vehicles in new auto production. Over time, this assumption also influences the calculated shares of electric vehicles in the total auto stock. Production of charging stations in the study is also determined by how many electric vehicles are sold.

The legislated penetration rates in the 13 participating states are projected to be 2% by 1998, 5% by 2001, and 10% by 2003.[6] In 1991, according to the federal Highway Administration, these 13 states comprised 36% of all new vehicle registrations (Federal Highway Administration, 1992). Assuming that the share of autos sold by state remains roughly constant, this would imply that 3.6% of all vehicles sold nationally in 2003 will be electric if the emissions standards are adopted and state legislatures are able to persuade enough consumers to buy electric vehicles.[7]

FIGURE 1 HERE

The graph in Figure 1 shows new car sales to personal consumption from 1959 to 2005. The years shown after 1991 are projections from the *LIFT* model base forecast. Even though the auto market was particularly volatile in the 1980s, there has been a clear long-term upward trend in auto sales, based on corresponding trends in population and income. The *LIFT* forecast follows this general trend, although it is not projected to reach the peak level of auto sales of 1986 until the year 2000. The *LIFT* base forecast for total auto sales was taken as given, and electric vehicle sales were estimated as a percentage of this number. These calculations indicate that the number of electric vehicles sold by 2003 would be 656.6 thousand units, given these assumptions. The graph in Figure 2 is a stacked bar graph, showing the proportions of total auto sales comprised by conventional and electric vehicles. Table 1 shows the unit forecasts underlying the graph. Table 2 shows the estimated number of electric vehicles sold by the participating states, assuming that their shares of the national market remain at the 1991 level[8].

FIGURE 2, TABLES 1 AND 2 HERE

2.2 Input Coefficients

Given these projections of market penetration, the next step in the development of the model assumptions is to determine the relative input structure of gasoline and electric cars and to weight the forecast input structure by the output mix of the two types of vehicles. If electric vehicles constitute a higher proportion of all new cars produced over time, average input coefficients will change in the auto industry, thus affecting the demand for other industries that supply to the industry.

Much of the input requirements of electric cars are similar to conventional gasoline cars. An electric car must still have a body, a chassis, passenger compartment, steering mechanism, tires and windows. However, many of the auto parts that a typical car owner is familiar with needing to replace are simply missing in an electric car. (The claims of low operating costs for the electric car are in part based on the small number of moving and wearable parts.) These include the auto parts and systems shown in Table 3. The SIC code and corresponding *LIFT* sector are shown in the columns to the right.

TABLE 3 HERE

In the electric car *one* battery is removed and perhaps *twenty to thirty* are put back in. A computer-controlled converter is used to transform direct current electricity from the batteries into alternating current that most modern electric motors can use more efficiently. An electric motor is added, which is a surprisingly small component of the product cost. A controller module controls the power supplied to the motor and controls its speed. Finally, sophisticated electronics are needed to monitor the power demands of the motor and handle charging and power from regenerative braking. Table 4 summarizes the new components that must be considered in an electric car that are not found in the conventional car.

TABLE 4 HERE

Figure 3 shows the differences in key inputs between gasoline and electric vehicles, based on data provided by the Chysler/Westinghouse consortium, as well as auxiliary information obtained from companies doing gasoline to electric vehicle conversions.[9] The coefficients were formed as follows:

1. Starting with a current dollar vector of input requirements in the U.S. Motor vehicle industry, costs were separated into production and non-production costs. Non-production costs were taken to include trade and transportation margins, and some services. Production costs included all materials, some services, and the costs associated with payments to labor and return to capital. The goal was to try to identify those costs which make up the producer price of an average car as it leaves the factory.

2. Available data showed additions and deletions of input requirements with respect to a vehicle with a production price of $15,000, in 1992 dollars.[10] These additions and deletions were then converted to production price coefficients.

3. The coefficients were used to change the vector of input requirements into Motor vehicles in 1992 dollars.

4. The output total in 1992 dollars was also adjusted upward to sum to the new calculated flows.

5. Constant price coefficients were then recalculated by dividing constant dollar input flows by constant dollar output. Note that this procedure will force some coefficients to be smaller, for industries which were unaffected by the assumed changes in input structure, since the total cost of producing the car is larger.

FIGURE 3 HERE

One of the biggest unknown factors is the cost of batteries. No one knows at this point which will be the type of battery ultimately in common use, nor how much it will cost. Although some of the more exotic batteries under development promise higher power, longer life, and lower weight, they are as yet relatively untested, and many can only be produced at a much higher cost. For example, the sodium-sulphur batteries used by Ford in the *Ecostar* van currently cost a whopping $45,000, bringing the total cost of the van to $100,000. Clearly, such a vehicle, while perhaps affordable by an electric utility trying to heighten public awareness, will not be purchased by the average consumer.[11] For this study, high-quality lead-acid batteries were assumed to be the most likely choice, and the input cost of the battery pack was assumed to be $5000, which accords roughly with estimates by GM, Solectria, and other electric manufacturers or converters. Batteries are the largest factor in increasing the price of an electric car.

In addition to the other coefficient assumptions affected by the list of components in tables 3 and 4, it was also assumed that electric vehicles would be constructed for lighter weight to make the most use of scarce battery power. With current designs, such as the GM *Impact* or the *Sunrise* produced by Electricar, this entails the use of an aluminum chassis and more plastic and composite body parts. These assumptions were incorporated by reducing the coefficient of Ferrous metals and increasing that of Plastics and Non-ferrous metals.[12]

TABLE 5 HERE

The relative numeric values for the final calculated 1977 dollar coefficients are shown in Table 5. The biggest differences for the electric vehicle are of course in the increased use of Miscellaneous electrical equipment (41), Communication equipment and electronic components (38), and Electrical industrial equipment (39). The single largest difference in input coefficients is due to the increased use of batteries, which is part of industry 41, as batteries are expected to comprise almost one-third of the total production cost of the electric vehicle. The electric vehicle uses roughly 3 times as much Copper (26) as the gasoline vehicle but less Ferrous metals (25). Finally, the size of the diagonal coefficient for Motor vehicles (43) is significantly reduced in the electric vehicle. This includes many of the items listed in Table 3, such as mufflers, radiators, exhaust pipes, manifolds, fuel tanks, carburetors, etc.

TABLE 6 HERE

Although the differences between some of the coefficients in conventional gasoline and electric vehicle production are striking, when we take into account the small penetration ratios, the impacts on the coefficient structure of the national industry as a whole are not great. By 2003, the year of greatest penetration, the electric vehicle proportion is still only 3.6%. Table 6 provides an indication of how the coefficients are projected to change over time due to electric vehicle penetration.[13]

The largest changes are again to be seen in industries 38, 39, and especially industry 41. The coefficients of industries 38, 39, and 41 increase by 50%. The diagonal coefficient for Motor vehicles (43) decreases only slightly, despite the dramatic differences shown in Table 4. Most of the other coefficients do not show dramatic changes. Nevertheless, small changes in coefficients can result in measurable differences in output and employment demands. Furthermore, larger assumed penetration ratios *would* result in dramatic differences in average national coefficients.

2.3 Differences in Fuel Requirements

Perhaps one of the most significant impacts of the introduction of the electric car at the national level is the impact on the consumption of petroleum fuels and electricity. In order to develop reasonable assumptions about how consumption of fuels and electricity would change, auxiliary calculations needed to be made for total miles traveled, the proportions of miles traveled by conventional gasoline and electric vehicles, and the relative fuel efficiency of the two types of vehicles.

Table A-1, at the end of this paper, shows the data used in the calculations that were made to obtain assumptions about differences in fuel and electricity requirements from the base case. For reference, numbers in parentheses in the text that follows refer to columns of that table. First, a projection of total miles traveled was made indirectly (3), based on the LIFT forecast of gasoline consumption (1), and a projection of trends in miles per gallon (2)[14]. Stocks of gasoline vehicles (5) and electric vehicles (4) were estimated using perpetual inventory methods, with an average depreciation rate of .20 for gasoline vehicles and .15 for electric vehicles, with no depreciation occurring in the first year. The new gasoline consumption forecast was obtained by reducing the previous gasoline forecast by the share of gasoline vehicles. The difference that resulted is in column (8), and was one of the assumptions used in the model. Assuming a mileage achievement of 3.3 miles per kilowatt hour (MpKwh) for electric vehicles[15], the kilowatt hours required for total miles traveled was derived in (9). The cost of this electricity was then calculated in current dollars (11) and constant dollars (13) and then adjusted by the share of electric vehicles in total stock of cars (6) to obtain the additional electricity consumption requirements (14), which was the other main assumption provided to the model. These assumptions are summarized in Table 7.

TABLE 7 HERE

Note that by 2003 automobile drivers are saving $876.8 million in 1977 dollars for gasoline, but only spending $326.2 million more in electricity. This suggests that electric vehicles should be extremely favorable over gasoline vehicles in terms of fuel requirements. Of course, this result is entirely sensitive to the 3.3 MpKwh assumption mentioned above. A more or less efficient value for this assumption would correspondingly result in a different projection for electricity consumption requirements.

Another issue, not dealt with in this study, is that vehicle charging may occur mostly at nights, at off-peak rates. Furthermore, users of electric vehicles may enjoy a subsidy on electricity purchased through the charger, making electricity even cheaper. The reason that this would be economical for the power companies is that they have a large amount of underutilized capacity at night.[16] .

2.4 Investment in Charging Stations

Table 8 highlights the assumptions used in determining the dollar investment in charging stations required. According to estimates provided by the Chrysler/Westinghouse consortium, an average of 2.1 charging stations per electric vehicle will be required at a cost of $1000 each in 1998 dollars. Deflating this to 1977 dollars using the forecast price for electric utility investment for 1998 yields the figure in the last column of table 8, which is the assumption used in LIFT. The cost of charging stations was split into two components. Two thirds was assumed to be invested by electric utilities, and one third was assumed to be in the personal consumption of durable appliances.

TABLE 8 HERE

2.5 Maintenance Cost of Electric Vehicles

There is little agreement on the likely maintenance cost of electric cars. On the one hand, there are less moving and wearable parts to replace; such as fan belts, spark plugs, radiator hoses, mufflers, and radiators. An electric motor requires only a relatively inexpensive replacement of bushings every few years at a cost of perhaps $100. On the other hand, batteries must be replaced, and the batteries are expensive. Data on the average cost of maintenance expenditures per vehicle were taken from the *LIFT* consumption series for Auto repair, divided by the estimated number of vehicles. Battery replacement cost was calculated by assuming that a full battery pack lasts an average of 5 years. At a cost of $5,000 for the full set of batteries, this implies an annual cost of $1000 of battery replacement per vehicle in current dollars. There would still be other maintenance costs such as tires and electrical maintenance. The net result of the calculations resulted in an estimate of electric vehicle maintenance costs that were 50% higher than that of conventional vehicles. Table 9 shows how this calculation was then implemented to obtain an assumption as to how total auto repair expenditures would change with the assumed penetration rates of the electric car.

Column (1) shows the forecast by LIFT of Auto repair expenditures in the base run. Column (2) shows the unit cost obtained by dividing by the estimated number of gasoline vehicles in operation. Column (3) shows the gasoline vehicle repair cost obtained by reducing column (1) by the new share of gasoline vehicles in the total stock. Columns (4) and (5) show the unit cost of auto repair for electric cars per year in 1977 dollars, and the total cost, obtained as unit cost times stock. Finally, column (6) shows the total of gasoline and electric repair cost, and column (7) shows the difference which was used as an input to the model.

TABLE 9 HERE

Not only will the level of maintenance cost for electric cars change. The composition of maintenance expenditures will also change. As mentioned above, batteries, included in LIFT industry 41, will rise to become a large portion of total maintenance requirements. Conventional auto parts will become a relatively small part. Relative differences in input coefficients between gasoline and electric cars are shown in Figure 4. These differences were combined according to the weights of gasoline and electric vehicles in the total vehicle stock and input to the LIFT model as coefficient changes for the Auto Repair industry.

FIGURE 4 HERE

3. Macroeconomic and industry results

In the context of the national economy, most of the macroeconomic impacts of the introduction of the electric car can be expected to be small. The penetration assumed for electric cars is small (3.6% by 2003), and this is a scenario where a similar good is being substituted for another. One would expect neither a dramatic disruption nor a strong stimulus to economic activity .

However, although the impacts are small they are indicative of what may be expected from the introduction of the electric car on a small scale, and the impacts of a larger-scale switch to electric cars could be extrapolated from the results presented in this paper.

The graphs included as Figure 5 summarize the main assumptions used in implementing the electric car scenario. Note that all of these numbers are displayed in 1977 constant dollars, which can be interpreted more or less as quantity measures. Consumption of gasoline is reduced by 877 million dollars by 2003 and by 1.295 billion dollars by 2005, relative to the base. Consumption of electricity, due to electric cars, is up by 326 million in 2003 and by 526 million in 2005. Therefore, total fuel expenditures are reduced by roughly 551 million in constant dollars by 2003. Expenditures on auto repair, however, are increased by 371 million by 2003, due to the increased costs of replacing batteries in the electric car compared to the standard maintenance of a typical gasoline car. Finally, investment in charging stations by electric utilities is up about .5 billion by 2003. In addition to these assumptions, the calculations of coefficient change in the Motor vehicles and Auto repair industries developed above were implemented.

FIGURE 5 HERE

Table 10 summarizes some of the important macroeconomic variables in the base run without the zero emission standards with respect to the electric car scenario in which the emission standards are adopted by the thirteen states under consideration. The values for the base run are on the first line for each variable, and the second line shows the difference of the alternate from the base. As the table shows, the differences at the macroeconomic level are tiny. GNP is down by $0.8 billion in the alternate case by 2003 (in constant 1977 dollars), the federal deficit is increased slightly, and the trade surplus is also somewhat smaller. The unemployment rate seems to be virtually unaffected. The largest impact is a $1.1 billion increase in imports in current dollars along with a 0.5 billion increase in exports, worsening the trade balance by about 1.5%.

TABLE 10 HERE

Industry output impacts, though also small, are more interesting. Table 11 shows changes from the base case to the alternate case for a few industries where differences are noticeable. As expected, Crude petroleum (6) and Petroleum refining (17) both experience declines in output, whereas Electric utilities (56) enjoys higher output with respect to the base. It is useful to compare the final output effects with the assumptions shown in Table 7. Although the assumptions were applied to personal consumption, they relate directly to assumptions about changes in industry final demand for Petroleum refining and Electric utilities. By the year 2000, changes in direct requirements for Petroleum refining are -$275 million, whereas changes in total requirements are -$160 million. The difference of $115 million of course represents increases in indirect requirements for Petroleum refining, some of it arising from increased production in Electric utilities. By 2005, whereas changes in direct requirements are -$1295 million, changes in total requirements are only -$760 million, implying a change of

$535 million in indirect requirements.[17] For the Electric utility industry, on the other hand, total requirements are essentially changed only by the differences in final demand, implying little change in indirect demand.

Among the other industries, Communication equipment and electronic components (38) and Electrical industrial appliances and distribution equipment (39) both are stimulated, due to increased demand as inputs into electric cars directly, as well as into electricity generation. Electric lighting and wiring equipment (41), which includes batteries, is the most positively affected industry, with a gain of $1.58 billion in 2003, an increase of 4.7%. The Motor vehicles (43) industry is the biggest loser, with output lower in the alternate case by $1.14 billion by 2003, both because the new electric cars require less inputs that are classified in this industry, as well as because Auto repair (67) inputs are shifted away from Motor vehicles inputs and into batteries (in 41). Auto repair output is also larger in the alternate case which is a direct result about the assumptions relating to higher personal consumption expenditures on Auto repair.

TABLE 11 HERE

Table 12 summarizes the larger important employment impacts by industry. Industries shown all have a change of at least 1.5 thousand employees by the year 2005. The changes in these employment forecasts is due almost exclusively to differences in the output forecasts between the base and alternate case.[18] Since employment in LIFT is estimated by a labor productivity function unless labor productivity changes much between two scenarios, employment changes are caused primarily by differences in the output forecasts. However, the size of employment impacts will also be proportional to the labor intensity of each industry. Important industries in the ranking of output differences (Petroleum refining in Table 11) may not be as important in terms of employment impacts, because they do not hire as much labor per unit of output. Other industries, (Wholesale trade, Electric lighting and wiring equipment) are more labor intensive and so display more dramatic relative changes in employment.

TABLE 12 HERE

The largest employment gainers are Electric lighting and wiring (+17.1 thousand by 2003), Automobile repairs (+5.8), Communication equipment (+3.1), Electric utilities (+2.2) and Electrical industrial apparatus and distribution equipment (+1.8). The biggest employment losers are Motor vehicles (-5.3), Wholesale trade (-1.8), Crude petroleum and natural gas (-2.0), and Ferrous metals (-1.7). Overall, there is a net gain of 21 thousand jobs by 2003.

It would appear that much of this job gain comes about because electric cars require more resources to produce and to maintain. The analysis in this study suggests a higher initial purchase price in addition to significant costs of battery replacement as each car ages. Therefore, the increase in employment is similar to that caused by a reduction in productivity. Directly and indirectly, it requires more labor services to produce an electric car than a conventional gasoline car.

This particular study does not attempt to allocate the job gains and losses across states, but the earlier study commissioned by the California consortium CalStart found an increase of 55 thousand jobs in California attributable to electric car production. These results are not inconsistent with the current study, but if true, they would imply that some other states, such as Michigan, would be suffering job losses.[19]

Table 13 shows the only industries for which price impacts were noticeable. The largest price impacts were found in Motor vehicles and Automobile repairs. These price increases were driven mostly by the higher coefficient of batteries in both electric car production and repair. The slightly higher price of Electric lighting and wiring equipment was induced by higher demand for this industry.[20]

TABLE 13 HERE

The net impact on imports, shown in Table 14, is small but positive. Imports of goods in industries 38, 39, 41, and 43 increase somewhat. This is not counteracted by the reductions in imports of industries 6, 17, and 43. This increase in imports worsens the trade balance only slightly, as discussed above. Imports in the LIFT model are determined by the level of domestic demand and the ratio of domestic to foreign prices, estimated with a lag. Since price ratios did not change much between these two scenarios, differences in imports can be attributed primarily to differences in domestic demand by industry.

TABLE 14 HERE

4. Summary

This paper has presented an analysis of the macroeconomic and industry impacts of a small level of penetration (3.6% by 2003) of the electric car into the national automobile market. Assumptions made in developing this study could well be criticized. For instance, the actual degree of penetration could well be different, the electricity consumption of the electric fleet could be higher or lower, or the actually realized production coefficients could be much different from what has been derived here. However, the nature of the impacts would probably be similar to those presented here, so that this study provides a qualitative idea of which industries would be affected and in what direction.

Notes

To summarize the results, from a macroeconomic standpoint the long-run impacts on the U.S. economy of the introduction and penetration of the electric car at this level are small , but they are more important for individual industries. However, if the electric car were to achieve, say, a 20% national penetration rate, the industrial impacts would be much larger than those presented here.

The analysis of impacts at the state level would be an important accompaniment to this study. Since the factories producing autos as well as those producing electric motors and batteries are concentrated in particular areas, the state and local impacts of the rise of the electric car are likely to be more significant. Therefore, it is no coincidence that Detroit is fighting the emissions standards legislation in court. A more widespread adoption of the electric car will be detrimental to the Motor vehicle industry, even if large U.S. auto makers ultimately are the main producers, since most of the intermediate inputs to electric cars will be electrical systems, not traditional motor vehicle parts and equipment.

[1] Estimated by the American Lung Association.

[2] For more information on the *Impact*, see Cogan (1994) and McCosh (1994).

[3] Bishop, 1992.

[4] A study commissioned by Calstart, the California technology consortium, estimated an additional 55,000 jobs in California alone from electric car production. Another study, conducted by the UCLA Lewis Center for Regional Policy Studies, predicted that electric car industries would generate 24,000 new jobs in Southern California.

[5] The structure of the LIFT model is outlined in the Appendix, and is more fully described in McCarthy (1991). Projections of full input-output matrices and across-the-row coefficient change are discussed in Almon et al (1974).

[6] A more stringent version of the standards calls for the percentage to be increased to 17% by 2010.

[7] It is not clear that there will be enough incentives in place for 2% of all buyers to decide on electric vehicles even with the 10% tax break announced in July, 1993. Given the current high cost of electric vehicles, the subsidies may need to be much larger. However, this study starts with the degree of market penetration as an exogenous assumption.

[8] This assumption of constant consumption shares by state is admittedly unrealistic, but this assumption is only used to obtain a rough estimate of likely national penetration, given that the proposed legislation is adopted and effective in the 13 states in question.

[9] Actual dollar estimates per vehicle of the cost of removed and added items could not be published in this paper, due to confidentiality restrictions from the consortium.

[10] This is almost twice the average production cost of a conventional gasoline car.

[11] This is, however, the electric vehicle covered in the May 31, 1994 *Business Week* article.

[12] The calculation of the coefficients for these inputs was *ad hoc*, but based on reports on the GM *Impact*, which has a body weight less than half of a conventional car, and uses roughly 35% of the steel in a conventional car (Cogan, 1994).

[13] No attempt was made to account for coefficient change in electric vehicles due to scale effects or to account for changes in gasoline vehicle production technology due to innovations in electric vehicle production.

[14] This trend in average fleet Mpg was calculated using a simple time trend regression, but accords well with EPA projections.

[15] The much publicized GM *Impact* prototype has a fuel efficiency of 9 MpKwh. However, less exotic (and cheaper) cars experience mileage more on the order of 2 to 5 MpKwh. In fact, later production versions of the *Impact* are heavier and are reported to have lower energy efficiency. The value of 3.3 MpKwh was provided by Westinghouse.

[16] The Electric Power Research Institute has reported that U.S. electric utilities have enough capacity to support up to 20 million electric vehicles on nighttime charging, without having to construct new power plants. The net result of using this capacity would be lower electricity prices, higher utility profits, or both.

[17] To make a complete analysis of the changes in total requirements and indirect requirements, one can create a *matrix listing* with LIFT which shows demand by all other intermediate industries and by final demand categories. In this table, import requirements are subtracted so that the total is domestic requirements.

[18] LIFT does not model changes in labor/output ratios in response to changes in either relative wages or output price. However, relative wages are determined partially by labor productivity.

[19] An earlier study, performed by INFORUM and the Maryland Department of Economic and Employment Development (DEED), found an increase in jobs in Maryland of about 2,000 by 2003, due mostly to electric drive train production in the State of Maryland.

[20] The profit equations in LIFT, which contribute to the calculation of prices, respond positively to faster output growth.

References

Almon, C., Buckler, M., Horwitz, L. and Reimbold, T. (1974) *1985: Interindustry Forecasts of the American Economy* (Lexington, MA, D.C. Heath).

American Lung Association (1990) *The Health Costs of Air Pollution*, prepared by James S. Cannon for the American Lung Association.

Brown, Michael and Prange, Shari (1993) *Convert It* (Felton, Ca. Electro Automotive).

Bishop, Jerry E. (1992) New Generation of Electric Car Batteries to Be Unveiled, *Wall Street Journal*, May 15, p. B3.

Burgess, John (1992) Jump Starting a New Electric Car Battery, *Washington Post*, May 20, p. F1.

Cogan, Ron (1994) Redefining the Electric Vehicle State-of-the-Art: GM *Impact*, *Motor Trend*, January, p. 80.

Cushman, John (1993) Big Breaks for Buying Alternative-Energy Car, *New York Times*, June 12, p. L34.

Electro Automotive (1994) *Price List*.

Environmental Protection Agency (1992) Air Pollutant Emissions, by Pollutant and by Source, *National Air Pollution Trends, 1990-1991*, (Washington, D.C., U.S. Govt. Printing Office).

Fischetti, Mark (1992) Here Comes the Electric Car, It's Sporty, Aggressive and Clean, *Smithsonian*, April, p. 34.

Gromer, Cliff (1994) New Age of the Electric Car, *Popular Mechanics*, February, p. 38.

Federal Highway Administration (1992) Motor Vehicle Registrations by State: 1980-1991, *Highway Statistics* (Washington, D.C., U.S. Govt. Printing Office).

Hayden, Tom (1993) Here's a Way to Get Jobs and Clean Air, *Los Angeles Times*, March 25, p. B7.

Markus, Frank (1994) The Flywheel Battery Car, *Car and Driver*, June, p. 90.

McCarthy, Margaret (1991) LIFT: INFORUM's Model of the U.S. Economy, *Economic Systems Research*, Vol. 3, No. 1, pp. 15-48.

McCosh, Dan (1994) We Drive the World's Best Electric Car, *Popular Science*, January, p. 52.

Parrish, Michael (1993) State is Driving Force Behind Emission-Free Cars, *Los Angeles Times*, August 9, p. A2.

Perrin, Noel (1992) *Solo: Life With An Electric Car*, (New York, W.W. Norton & Co.).

Plotkin, A.S. (1993) Solectria Charges Ahead with Electric Car Plan, *Automotive News*, November 8, p. 27(1).

Scott, Allen (1993) Electrical Vehicle Manufacturing in Southern California: Current Developments, Future Prospects, UCLA Lewis Center Working Paper #5, June.

Solar Car Corporation (1994) *Price List*.

Solectria (1994) *Price List.*

Suris, Oscar (1994) Californians Collide With Folks in Detroit Over the Electric Car, *Wall Street Journal*, January 24, p. A1.

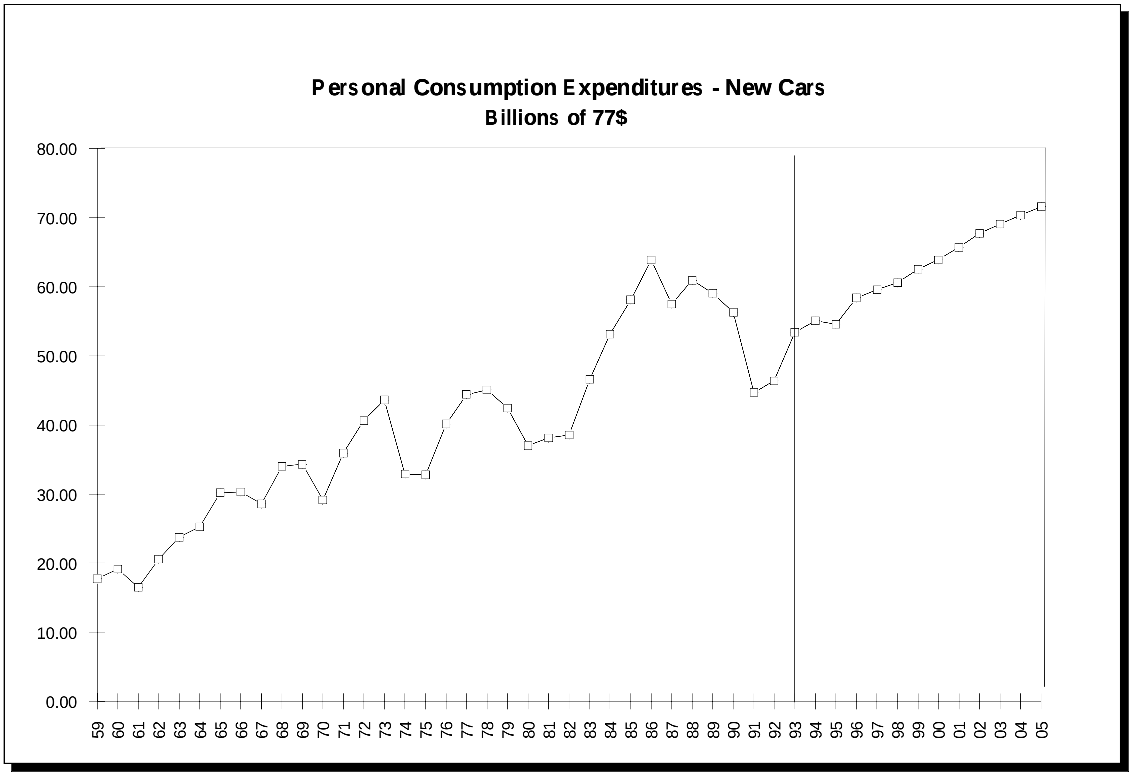
Wald, Matthew (1992) Cars That Whirr and Burn Rubber, *New York Times*, Feb 2, p. 10.

Woodruff, David and Carey, John (1994) Electric Cars: Will They Work? And Who Will Buy Them? , *Business Week*, May 30, p. 104.

Woodruff, David (1993) Assault on Batteries: Detroit Wages War on Legislation Promoting Electric Cars, *Business Week*, November 29, p. 39.

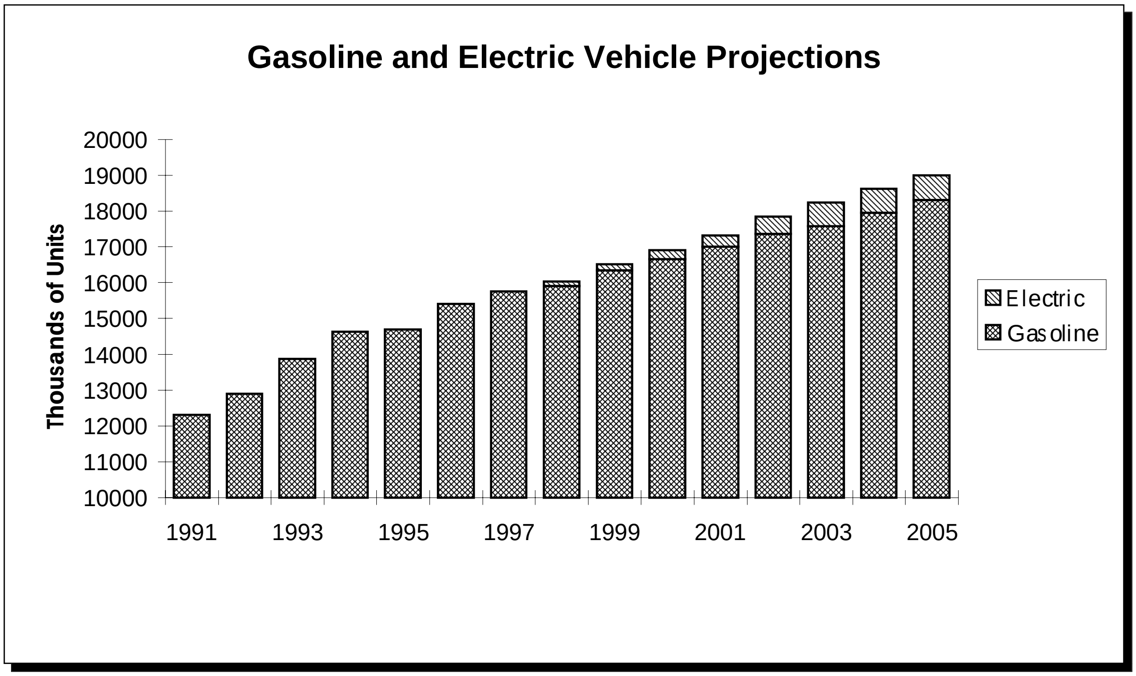
Woutat, Donald (1994) Committee Vote on Electric Car Mandate Rebuffs Auto Industry, *Los Angeles Times*, March 22, p. D6.

Figure 1 - Personal Consumption Expenditures of New Cars



Source: Historical data for Personal Consumption Expenditures for "New cars" from the U.S. National Income and Product Accounts, converted to constant 1977 dollars using industry deflators. Projection is from the base forecast of the

Figure 2 - Electric Vehicle Market Penetration in the U.S.



Source: See Table 1.

Table 1 - Electric Vehicle Penetration

Projected Sales, Thousands of Units

	Gasoline	*Electric*
1993	13870	0
1994	14637	0
1995	14690	0
1996	15410	0
1997	15755	0
1998	15918	115
1999	16345	179
2000	16666	244
2001	17011	312
2002	17359	482
2003	17583	657
2004	17950	670
2005	18322	684

Source: Estimates of units of cars sold in the base were made by calibrating total constant dollar sales of autos with unit auto sales, as published in *Ward's Automotive Statistics*. The share of electric cars in the total was determined as described

Table 2 - Total Auto Sales by State in 1991 and Electric Vehicle Penetration by State

Projected Sales, in Units

State	1991 (Actual)	1998 (2%)	2001 (5%)	2003 (10%)
California	1005896	36210	97837	206029
Connecticut	116458	4192	11327	23853
Delaware	30282	1090	2945	6202
Maine	27284	982	2654	5588
Maryland	236620	8518	23014	48465
Massachusetts	194630	7006	18930	39864
New Hampshire	38162	1374	3712	7816
New Jersey	327711	11797	31874	67122
New York	496029	17856	48246	101597
Pennsylvania	369831	13313	35971	75749
Rhode Island	25876	931	2517	5300
Virginia	214727	7730	20885	43981
Washington	122218	4400	11887	25033
Total	3205724	115400	311800	656600

Source: Units sold by state derived by distributing national total by data for 1991 for new motor vehicle registrations by state, from FHA *Highway Statistics*. Each state is assumed to have the same proportion of total new motor vehicle purchases

Table 3 - Automobile System Components Not Used in Electric Car

Automobile System Components	*SIC*	*LIFT*
Exhaust System: Manifold, muffler and tailpipe.	37145	43
Cooling System: Radiator, hoses, heater assembly.	37149	43
Fuel System: Gas tank, carburator, fuel lines, air cleaner.	37142	43
Engine: Engine block, pistons, valves, head, timing chain, oilpan, fan belts.	37142	43
Electrical System: Battery, alternator, voltage regulator, coil, spark plugs, distributor.	36913, 36941 to 36947	41
Transmission and Drive Train: Gearbox and clutch assembly, or automatic transmission, rear differential.	37146	43
Pollution Control System: Catalytic converter, PCV valve, etc.	37149	43

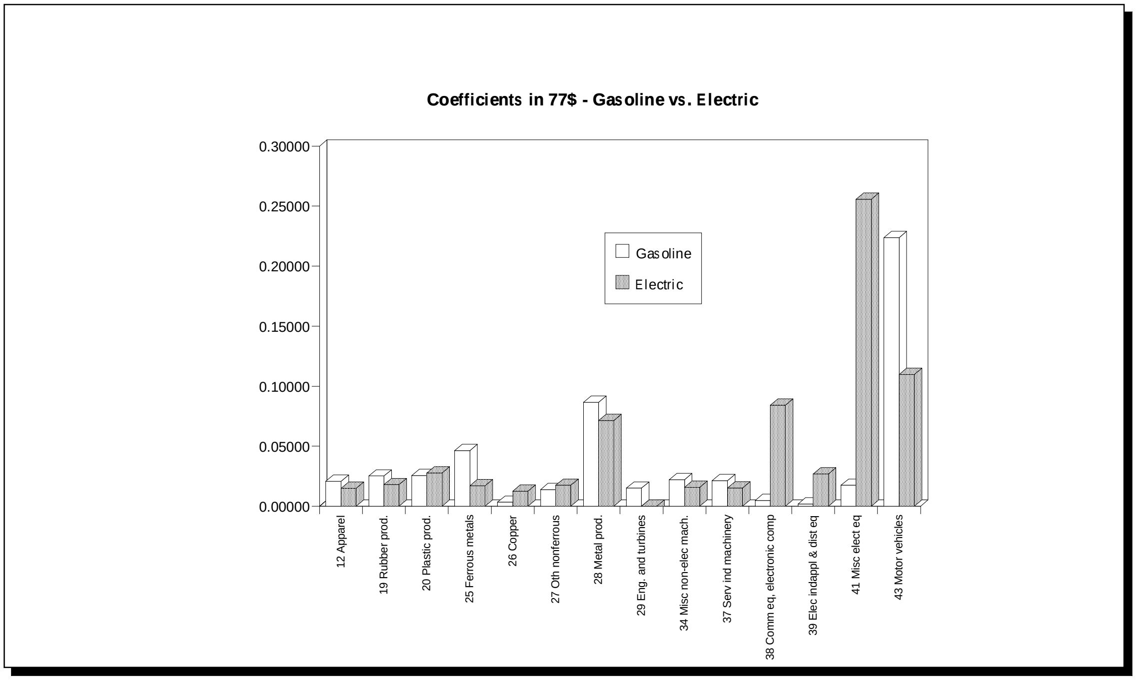
Source: Information provided by Chrysler/Westinghouse consortium, to develop assumptions for these simulation

Table 4 - New System Components in Electric Car

Automobile System Components	*SIC*	*LIFT*
Batteries (20 to 30)	36913 or 36915	41
Controller module	36250	39
DC/AC converter	36210	39
Electric motor	36211	39
Regenerative braking alternators	36942	41
Miscellaneous electronics	36134, 3672, 3673	38,39
On board charger (optional)	36290	39

Source: Information provided by Chrysler/Westinghouse consortium, to develop assumptions for these simulation exercises.

Figure 3. - Differences in Input Coefficients for Motor Vehicles



Source: Calculations as described in the text, starting with 1992 coefficients from the Inforum projected input-output table.

Table 5. Differences in Motor Vehicles Input Coefficients
Coefficients for 1992

(Coefficients are based in 1977$)

Inforum Industry	*Gasoline*	*Electric*
12 Apparel, household textiles	0.02090	0.01497
19 Rubber products	0.02520	0.01803
20 Plastic products	0.02560	0.02771
25 Ferrous metals	0.04640	0.01703
26 Copper	0.00340	0.01260
27 Other nonferrous metals	0.01380	0.01753
28 Metal products	0.08660	0.07135
29 Engines and turbines	0.01510	0.00000
34 Miscellaneous non-electrical mach.	0.02210	0.01585
37 Service industry machinery	0.02140	0.01534
38 Communic equipment, electronic comp	0.00490	0.08426
39 Electrical industrial appliances & distribution equipment	0.00180	0.02694
41 Miscellaneous electrical equipment (includes batteries)	0.01750	0.25570
43 Motor vehicles	0.22370	0.10986

Source: Calculations as described in the text, starting with 1992 coefficients from the Inforum projected input-output table.

Table 6. - Projected coefficients, based on penetration projections

	1992 (0%)	1998 (.72%)	2001 (1.8%)	2003 (3.6%)
12 Apparel, household textiles	0.0209	0.0209	0.0208	0.0207
19 Rubber products	0.0252	0.0251	0.0251	0.0249
20 Plastic products	0.0256	0.0256	0.0256	0.0257
25 Ferrous metals	0.0464	0.0462	0.0459	0.0453
26 Copper	0.0034	0.0035	0.0036	0.0037
27 Other nonferrous metals	0.0138	0.0138	0.0139	0.0139
28 Metal products	0.0866	0.0865	0.0863	0.0861
29 Engines and turbines	0.0151	0.0150	0.0148	0.0146
34 Miscellaneous non-electrical mach.	0.0221	0.0221	0.0220	0.0219
37 Service industry machinery	0.0214	0.0214	0.0213	0.0212
38 Communic equipment, electronic comp	0.0049	0.0055	0.0063	0.0078
39 Electrical industrial appliances & distribution equipment	0.0018	0.0020	0.0023	0.0027
41 Miscellaneous electrical equipment (includes batteries)	0.0175	0.0192	0.0218	0.0261
43 Motor vehicles	0.2237	0.2229	0.2217	0.2196

Source: Weighted coefficients of electric and conventional cars, using assumed penetration ratios.

Table 7 - Changes in Gasoline and Electricity Consumption

Millions of 77$

	1998	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*
Gasoline	-66.3	-159.7	-275.3	-410.0	-614.3	-876.8	-1103.2	-1295.7
Electricity	17.9	48.8	90.2	141.9	220.3	326.2	429.0	526.6

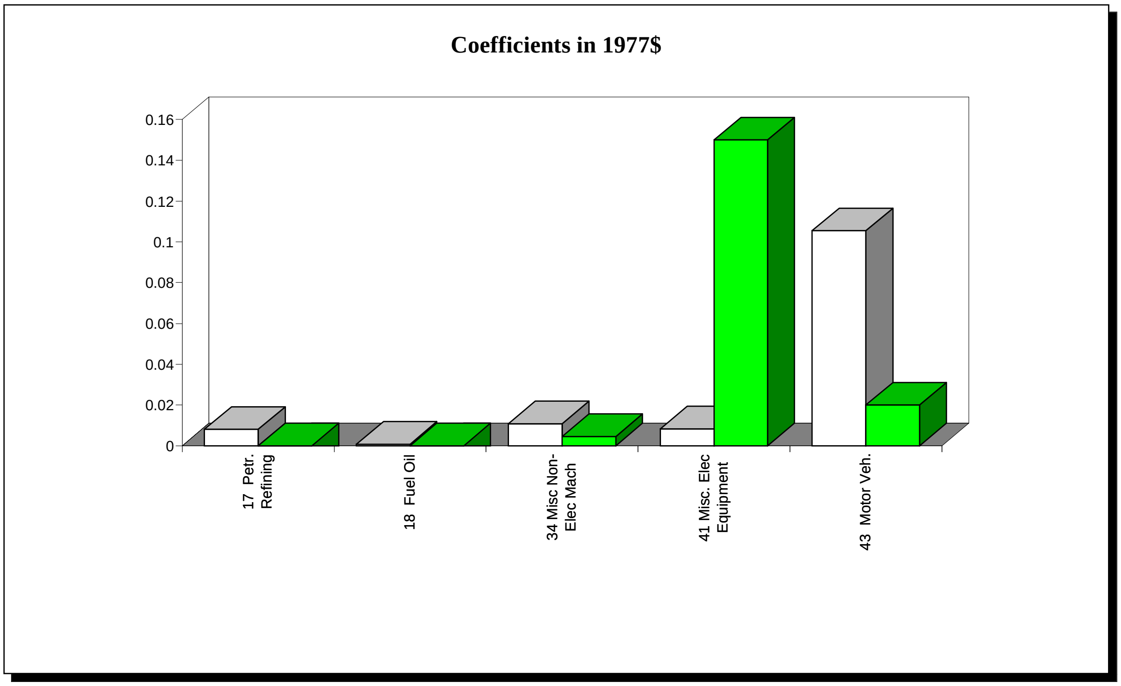
Table 8. - Charging Station Calculations

	Projected Electric Car Sales **(1000's)**	*Charging Stations Required* **(1000's)**	*Cost of Station Investment* **(1998$)**	*Cost of Station Investment* **(Mil 1977$)**
1998	115.4	242.4	242428	123.4
1999	178.5	374.8	374758	190.7
2000	243.5	511.4	511355	260.2
2001	311.8	654.8	654809	333.2
2002	481.7	1011.6	1011572	514.8
2003	656.6	1378.9	1378886	701.7
2004	670.3	1407.7	1407697	716.4
2005	684.2	1436.9	1436887	731.2

Table 9. Changes in Maintenance Expenditures

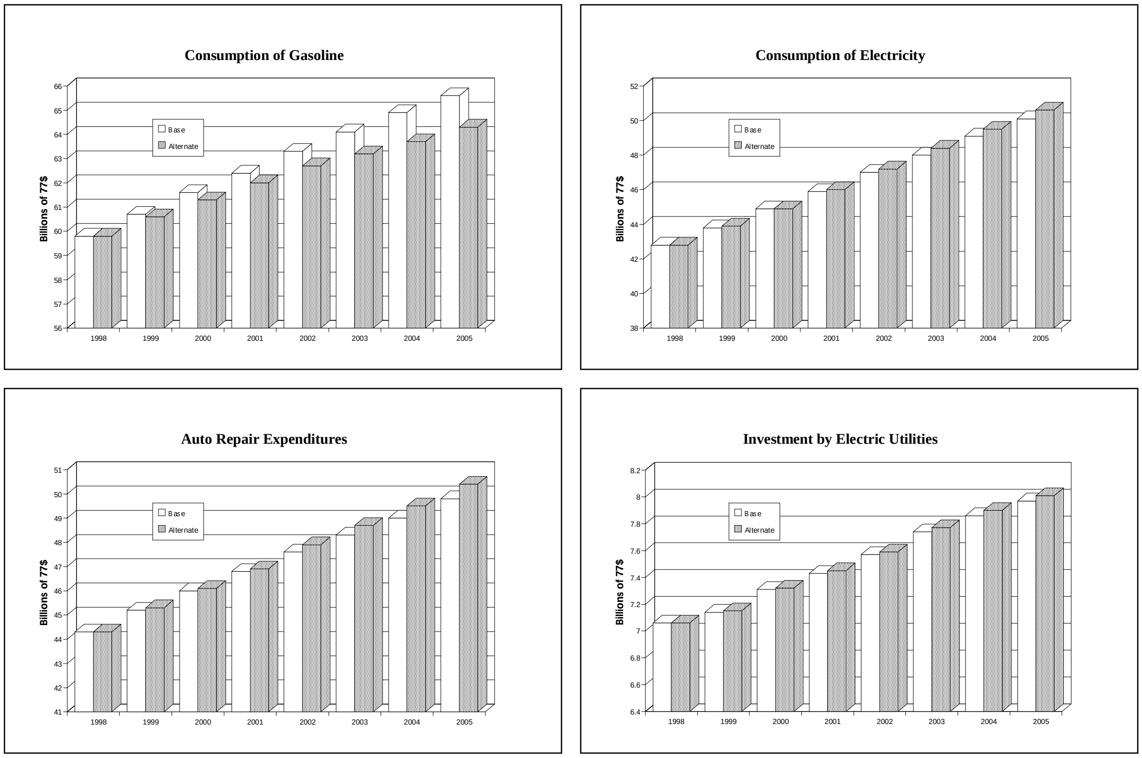
	(1) *LIFT PCE Auto Repair* **(mil 1977$)**	(2) *Unit Cost of Repair for Gasoline Cars* **(77$/unit)**	(3) *Gasoline Car Auto Repair Alternate* **(mil 1977$)**	(4) *Assumed Unit Cost of Elec. Car Repair* **(77$/unit)**	(5) *Elec. Car Auto Repair* **(mil 1977$)**	(6) *Total Cost of Auto Repair: Alt.* **(mil 1977$)**	(7) *Difference* **(mil 1977$)**
1998	44556.9	359.4	44505.1	539.1	62.2	44567.3	10.4
1999	45469.0	357.3	45342.9	536.0	169.1	45512.0	43.0
2000	46258.6	354.4	46039.3	531.6	308.8	46348.1	89.5
2001	47046.7	351.4	46717.5	527.2	480.1	47197.6	150.9
2002	47941.1	348.9	47443.7	523.4	741.8	48185.5	244.4
2003	48676.6	345.4	47961.3	518.2	1086.3	49047.6	371.0
2004	49396.5	342.1	48490.1	513.2	1412.3	49902.4	505.9
2005	50123.4	339.0	49051.5	508.5	1719.2	50770.6	647.3

Figure 4. - Differences in Input Coefficients in the Auto Repair Industry



Source: Coefficients calculated similarly as in Figure 3, based on information supplied by the Chrysler/Westinghouse consortium, as well as special assumptions relating to battery life.

Figure 5 - Model Assumptions



Note: These numbers represent exogenous assumptions supplied to the LIFT model.

Table 10 - Model Results: Macroeconomic Variables

Expenditures in Billions of Constant 1977 Dollars, Unless Otherwise Indicated

	1998	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*
Gross National Product	3155.90	3217.50	3276.50	3334.80	3401.70	3465.90	3527.70	3590.40
	0.00	-0.20	-0.30	-0.40	-0.50	-0.80	-0.90	-1.00
Personal consumption expend.	2123.00	2164.90	2206.70	2248.70	2294.30	2336.50	2376.40	2415.10
	0.00	-0.10	-0.20	-0.10	-0.10	-0.10	-0.30	-0.20
Exports of goods & services	514.50	528.50	539.90	550.00	563.30	577.20	592.50	610.00
	0.00	0.00	-0.10	-0.10	-0.20	-0.20	-0.30	-0.40
Imports of goods & services	539.60	554.40	568.40	580.60	594.70	607.70	620.10	633.10
	0.00	0.10	0.10	0.10	0.20	0.30	0.40	0.40
Unemployment Rate	6.40	6.40	6.30	6.40	6.30	6.20	6.00	5.90
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GNP Deflator	266.60	276.50	286.90	297.10	307.40	318.20	329.60	341.50
	0.10	0.00	0.00	0.10	0.10	0.20	0.20	0.30
Federal deficit, NIPA	-260.10	-266.00	-272.00	-274.20	-267.00	-257.20	-245.70	-232.40
	0.00	0.00	-0.10	-0.20	-0.30	-0.40	-0.70	-0.80
Balance of trade	37.20	39.70	39.40	34.70	37.60	43.80	55.00	73.20
	0.00	0.00	-0.10	-0.30	-0.50	-0.60	-0.60	-0.90
Exports, cu$	1149.30	1218.20	1285.20	1349.90	1423.30	1502.50	1589.00	1685.00
	0.10	0.10	0.20	0.20	0.30	0.50	0.60	0.60
Imports, cu$	1112.10	1178.50	1245.80	1315.20	1385.70	1458.70	1534.00	1611.80
	0.10	0.10	0.30	0.50	0.80	1.10	1.20	1.50

Note: For each variable, the first line represents the figures for the base run, and the second line indicates the absolute change of the figures in the alternate run with respect to the base. This is also true of Tables 11 to 14.

Table 11 - Model Results: Industry Outputs

Expressed in Billions of Constant 1977 Dollars

	1998	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*
6 Crude petroleum	26.29	26.46	26.57	26.73	26.98	27.17	27.34	27.52
	-0.01	-0.03	-0.06	-0.08	-0.12	-0.18	-0.22	-0.26
17 Petroleum refining	120.74	122.43	124.00	125.58	127.42	129.11	130.72	132.38
	-0.04	-0.09	-0.16	-0.24	-0.36	-0.51	-0.65	-0.76
25 Ferrous metals	48.69	48.76	48.50	48.53	48.77	48.85	48.94	48.98
	-0.04	-0.06	-0.09	-0.11	-0.16	-0.22	-0.23	-0.23
26 Copper	8.26	8.34	8.39	8.45	8.55	8.63	8.72	8.81
	0.02	0.03	0.04	0.05	0.07	0.10	0.10	0.10
27 Other nonferrous metals	36.66	37.88	38.96	40.14	41.52	42.84	44.17	45.59
	0.02	0.03	0.04	0.05	0.08	0.12	0.12	0.11
29 Engines and turbines	10.37	10.64	10.80	10.90	11.11	11.40	11.69	12.06
	-0.01	-0.02	-0.03	-0.04	-0.06	-0.08	-0.09	-0.09
34 Misc non-electrical mach	40.47	42.05	43.26	44.40	45.76	47.14	48.71	50.23
	-0.02	-0.02	-0.03	-0.04	-0.07	-0.09	-0.10	-0.10
38 Communic eq, electronic comp	133.81	139.32	144.61	149.17	154.20	159.13	164.31	169.84
	0.11	0.17	0.21	0.25	0.40	0.55	0.52	0.48
39 Elec indl app & distrib eq	23.81	24.72	25.51	26.09	26.89	27.72	28.63	29.54
	0.03	0.04	0.05	0.07	0.11	0.14	0.14	0.14
41 Elec lighting & wiring eq	29.54	30.36	31.17	31.88	32.72	33.55	34.40	35.26
	0.28	0.44	0.59	0.75	1.16	1.58	1.61	1.65
43 Motor vehicles	141.94	145.24	147.58	150.72	154.61	157.95	161.60	165.39
	-0.15	-0.27	-0.41	-0.54	-0.82	-1.14	-1.28	-1.37
56 Electric utilities	100.95	103.30	105.56	107.82	110.31	112.69	115.01	117.35
	0.02	0.05	0.09	0.14	0.22	0.33	0.42	0.52
67 Automobile repairs	65.90	67.88	69.70	71.44	73.40	75.16	76.89	78.64
	0.01	0.04	0.08	0.14	0.23	0.35	0.47	0.62

Table 12 - Model Results: Industry Employment

Expressed in Thousands of Persons

	1998	1999	2000	2001	2002	2003	2004	2005
5 Crude Petroleum, Natural Gas	485.6	491.1	496.2	503.8	512.5	520.6	527.7	534.3
	-0.1	-0.3	-0.6	-0.9	-1.4	-2.0	-2.6	-3.1
25 Ferrous metals	447.4	441.4	435.4	429.3	425.6	422.0	417.8	413.4
	-0.2	-0.5	-0.7	-0.9	-1.2	-1.7	-1.9	-1.9
34 Misc non-electrical mach.	728.6	744.1	758.3	768.9	781.0	794.3	809.3	824.3
	-0.2	-0.4	-0.5	-0.7	-1.0	-1.4	-1.6	-1.6
38 Communic eq, electronic comp	974.2	966.9	958.3	944.2	931.4	917.6	904.4	892.1
	0.7	1.1	1.4	1.6	2.3	3.1	2.9	2.6
39 Elec indl app & distrib eq	354.3	360.7	368.8	374.3	379.4	386.3	393.7	401.6
	0.2	0.5	0.7	0.9	1.2	1.8	2.0	1.9
41 Elec lighting & wiring eq	382.4	385.8	389.0	391.1	393.7	396.4	399.1	401.7
	2.4	4.9	6.8	8.6	12.4	17.1	18.7	18.8
43 Motor vehicles	820.1	818.5	815.8	813.6	815.2	816.0	816.4	817.3
	-0.6	-1.3	-2.0	-2.7	-3.8	-5.3	-6.3	-6.7
56 Electric utililities	776.4	785.1	793.5	801.5	810.4	818.9	826.6	833.9
	0.1	0.4	0.6	1.0	1.5	2.2	2.9	3.5
59 Wholesale trade	7307.7	7410.5	7513.7	7600.1	7695.9	7794.7	7884.5	7973.4
	0.2	0.1	-0.4	-0.9	-1.2	-1.8	-3.0	-4.0
67 Automobile repairs	1232.3	1237.7	1248.7	1277.6	1314.3	1349.3	1383.2	1417.4
	0.0	0.1	1.1	2.3	3.8	5.8	8.0	10.5
Total, All Industries	113813.1	115356.8	116971.0	118431.1	120058.2	121707.3	123241.8	124737.6
	4.6	6.8	7.3	9.0	14.9	21.0	17.5	15.4

Table 13 - Model Results: Industry Prices

Index: 1977 = 100

	1998	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*
41 Elec lighting & wiring eq	237.3	245.7	254.5	263.2	271.8	280.8	290.2	299.9
	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5
43 Motor vehicles	235.6	243.9	252.3	261.3	270.0	278.7	287.8	297.2
	0.2	0.4	0.7	0.8	1.3	1.8	2.0	2.3
67 Automobile repairs	272.4	279.2	287.2	295.7	304.6	314.2	324.1	334.4
	0.1	0.2	0.2	0.4	0.5	0.7	0.8	0.9

Table 14 - Model Results: Imports by Industry

Expressed in Billions of Constant 1977 Dollars

	1998	1999	2000	2001	2002	2003	2004	2005
6 Crude petroleum	34.91	35.63	36.33	37.01	37.72	38.41	39.09	39.77
	-0.01	-0.02	-0.03	-0.05	-0.07	-0.10	-0.12	-0.14
17 Petroleum refining	7.28	7.49	7.68	7.88	8.11	8.32	8.54	8.76
	0.00	-0.01	-0.01	-0.02	-0.03	-0.05	-0.06	-0.07
27 Other nonferrous metals	8.52	8.90	9.20	9.43	9.69	9.93	10.16	10.37
	0.01	0.02	0.02	0.03	0.04	0.05	0.05	0.05
38 Communic eq, electronic comp	37.19	38.67	40.15	41.50	42.93	44.30	45.66	47.12
	0.03	0.05	0.07	0.10	0.15	0.21	0.22	0.23
39 Elec indl app & distrib eq	7.63	7.99	8.32	8.59	8.94	9.27	9.59	9.95
	0.01	0.02	0.03	0.04	0.06	0.08	0.08	0.08
41 Elec lighting & wiring eq	5.30	5.42	5.57	5.76	5.96	6.14	6.29	6.46
	0.07	0.10	0.14	0.18	0.28	0.39	0.40	0.41
43 Motor vehicles	57.17	59.40	61.18	62.86	65.07	66.80	68.44	70.13
	-0.06	-0.07	-0.08	-0.08	-0.12	-0.16	-0.11	-0.06