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Potential long-term impacts of changes in US vehicle fuel efficiency standards

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Abstract

Changes in corporate average fuel economy (CAFE) standards have not been made due, in part, to concerns over their negative impact on the economy and jobs. This paper simulates the effects of enhanced CAFE standards through 2030 and finds that such changes could increase GDP and create 300,000 jobs distributed widely across states, industries, and occupations. In addition, enhanced CAFE standards could, each year, reduce US oil consumption by 30 billion gallons, save drivers $40 billion, and reduce US greenhouse gas emissions by 100 million tons. However, there is no free lunch. There would be widespread job displacement within many industries, occupations, and states, and increased CAFE standards require that fuel economy be given priority over other vehicle improvements, increase the purchase price of vehicles, require manufacturers to produce vehicles that they otherwise would not, and require consumers to purchase vehicles that would not exist except for CAFE.

Keywords: CAFE vehicle fuel efficiency standards; Global warming; Jobs

1. Introduction: the ongoing CAFE debate

In the wake of the 1973 oil crisis, Congress established the Corporate Average Fuel Economy (CAFE) program, which required automobile manufacturers to increase the average fuel economy of motor vehicles sold in the US. Congress set the standards, and, at present, they are 27.5 miles per gallon (mpg) for new cars and 20.7 mpg for new light trucks and sport utility vehicles (SUVs).

Federally mandated vehicle fuel efficiency standards are controversial and have been extensively debated over the last three decades. Existing CAFE standards have saved substantial amounts of petroleum and have played an important role in reducing vehicle carbon emissions that are a cause of global warming. But the effectiveness of these standards has long been limited by two problems—they have not been changed in over 17 years and the increasingly popular SUVs and light trucks have lower mpg standards. To date, revision of the CAFE standards has been blocked, in part, by concerns over the economic and job impacts of implementing higher standards.

Credible data are required to assess the energy, economic, and job impacts of tightened CAFE standards, on an industry- and region-specific basis. Thus far, little convincing evidence has been available to question or validate the auto industry's contention that such tightening will hinder profits and cost jobs. In addition, a unique opportunity exists to build on a landmark CAFE study by the National Research Council (NRC) of the National Academy of Sciences (2002). The NRC study analyzed the technical, safety, and related aspects of CAFE and estimated the impacts on vehicle costs of a variety of feasible technical improvements that would increase fuel efficiency. Our analysis relied heavily on the data in the NRC report to derive technical cost and fuel efficiency parameters and to develop realistic scenarios for increasing CAFE standards.

The goal of our research is to provide rigorous analysis of the energy, economic, and job impacts of tighter standards and to address the common perception that enhanced CAFE standards will harm the economy and destroy jobs. Specifically, the analysis is designed to provide needed data and analysis on the energy, environmental, economic, and job impacts of enhanced CAFE standards; disaggregate economic and job impacts by industry, occupation, and state; project the impacts of three CAFE scenarios through 2030; estimate

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the economic and job impacts of tightened CAFE standards; and provide findings that can inform future CAFE policy debates.

2. Previous studies of the economic impacts of CAFE standards

The policy of promoting motor vehicle fuel efficiency by establishing mandated fuel standards has been debated for nearly 30 years, and hundreds of articles and reports have been released on different aspects of the subject. While there have been relatively few studies of the economic and employment impacts of the standards, the limited empirical research indicates that CAFE standards tend to increase employment, output, and income.

In 1980, Dacy et al. (1980) estimated the macro impact of the original CAFE standards and, using the INFORUM input–output model, hypothesized a rate of automobile fuel efficiency improvement (based on DOT/EPA research) in the 1978–1985 period. Using optimistic and pessimistic scenarios for technology improvements, they estimated the amount of weight reduction that would be required to close the gap between the mandated CAFE standards and the mileage improvements reached through technology alone. The values of fuel savings to consumers were estimated, and it was assumed that these savings are spent on other goods and services. The authors projected a net increase in employment of 140,000 jobs by 1985 due to CAFE standards, with the jobs projected in various service industries, plastics, metal stampings, and other sectors outweighing projected losses in steel, petroleum and gas, and wholesale and retail trade.

In 1990, a Motor Vehicles Manufacturers Association (1990) study of the potential impact of increased CAFE standards predicted that tighter CAFE standards would result in the loss of between 159,000 and 315,000 jobs in the motor vehicle industry. The report's conclusions were largely the result of the assumptions made, for MVMA assumed that technical improvements in fuel efficiency under tighter CAFE standards would be very costly and that sales would be lost because of resulting price increases. Further, secondary effects from consumer fuel savings were not estimated and, unlike most other studies of the issue, this report did not consider that fuel savings by consumers would result in additional spending on other products and higher employment in the affected industries.

In 1992, the American Council for an Energy-Efficient Economy (ACEE) used an input–output model to estimate the impact of a "high-efficiency" scenario for the energy-using sectors of the economy (Geller et al., 1992). The study found that by increasing the fuel efficiency of passenger cars from 28 mpg in 1990 to 40 mpg in 2000 and 50 mpg in 2010, 244,000 additional jobs would be created by 2010. An equivalent percentage increase in the fuel economy of light trucks was also assumed, and the study estimated fuel savings of $54 billion (1990 dollars). ACEE assumed that the level of total vehicle sales would remain the same as in the baseline and that the import share of auto sales would also remain unchanged. Two sets of sensitivity analyses were performed, and the results show that if sales are reduced because of higher vehicle costs, or if import penetration increases, then net employment gains would be lower than in the case where these variables were assumed to remain constant.

In studies published in 1996 and 1998, Goldberg (1996) analyzed the effects of CAFE standards on automobile product mix, prices, and fuel consumption. She simulated the impact of existing CAFE standards during the late 1980s, compared her estimates to actual sales during the period, and examined what might have happened had CAFE standards not been in place. She found that, in the short run, vehicle utilization is unresponsive to fuel cost changes; vehicle purchases, however, respond to both car prices and fuel cost. These results imply that, first, contrary to the claims of CAFE opponents, higher fleet fuel efficiency is not neutralized by increased driving (e.g., the "rebound effect" is negligible) and second, policies designed to reduce fuel consumption by shifting the composition of the vehicle fleet towards more fuel efficient vehicles are more promising than policies that target utilization. The results of her study thus indicated that the CAFE standards were effective in reducing fuel consumption.

Goldberg found that, absent CAFE standards, domestic manufactures would move the production of small cars abroad and that producers would set higher prices for smaller, more fuel efficient vehicles and lower prices for larger, fuel inefficient vehicles. She concluded that CAFE has reduced fuel consumption by 19 million gallons per year and that there is almost no substitution effect between new and used cars. She also found that the gasoline tax would have to increase by 780%, or 80 cents per gallon, to achieve the same fuel savings as the CAFE standards.

In 1989, Teotia (1999) and his associates estimated the macroeconomic impacts of the use of clean diesel engine technology in light trucks to comply with CAFE standards. They used the DRI Macro model to estimate GDP, employment, energy use, trade, and other effects of the adoption of new clean diesel engine technology for light trucks. They assumed that the new engines would capture 15% of the light truck market by 2010. Two scenarios were considered: (i) all the new engines are manufactured in the US, and (ii) all of the new engines are imported. In either case, the results are modest. Less than 16% of light trucks switched to the new engines, the cumulative increase in GDP (1992 dollars) was estimated to be $33–$38 billion by 2022, and between 70,000 and 110,000 jobs were created over the period. Most of the income and job gains resulted from increased spending on the new vehicles, increased exports of vehicles and parts, and reduced imports of petroleum. Petroleum imports total $6.5 billion less over the period compared to the base case and, in the domestic production scenario, the US balance of payments improves, while in the imported engines case it deteriorates.

A 2001 Union of Concerned Scientists (UCS) study analyzed the economic effects of increasing CAFE standards to 40 mpg by 2012 and to 55 mpg by 2020 (Friedman et al., 2001). Using the IMPLAN input–output model, UCS estimated that employment, wages, and income would increase over the 10–20-year horizon of the study. The transportation sector and the motor vehicles and equipment industry, as well as some service industries would gain output and employment, while energy-related industries would experience job losses. By 2010, the analysis projected a net increase of over 40,000 jobs and a $5.5 billion increase in GDP ($2000 dollars); by 2020, the study projected an increase of 103,700 jobs and an increase of $5.7 billion in GDP. Most of the income and employment gains are derived from the assumption that fuel savings offset the added costs of automobile production. No losses in auto sales were assumed, and consumers were assumed to use the money from fuel savings to purchase other products.

In a 2002 update of the 2001 study, UCS (2002) highlighted the potential job gains by industry and state resulting from increased CAFE standards. UCS found that 182,700 new jobs would be generated by two effects. First, consumer savings from better gas mileage will generate an average of $2400 in net savings per driver over the life of the vehicle, and this money will be spent and will generate jobs throughout the economy. Second, to implement new fuel economy standards the industry will invest in new automotive technology, and this added investment will also generate jobs. The largest job gains will be in the services sector and in the motor vehicles sector, while job loses will be concentrated in the mineral and resources mining, extraction, and refining sectors, although wholesale trade will also experience some job losses.

A 2002 study by Kleit (2002) estimated supply and demand functions for the motor vehicle industry and used these to estimate the effects of the imposition of new CAFE standards. Kleit found that the imposition of new CAFE standards would result in total costs to society of between $2.2 and $33.9 billions; He estimated that new standards would increase pollution because increased fuel efficiency would lead to more driving (the so-called "rebound effect") and because older, less fuel efficient vehicles would be driven longer since they would be relatively less expensive. His study also estimated that gasoline tax increases of 11–23 cents per gallon would accomplish the same fuel savings as the new CAFE standards analyzed. Kleit did not estimate potential employment changes, although the negative impact on auto sales, a decrease of 57,000 units in his long-run scenario, implies negative employment effects in the automobile manufacturing industry. He conducted no analysis of the wider economic impacts from additional auto industry investment to meet new standards or from additional consumer spending from fuel savings.

3. Technologies available for increasing vehicle fuel efficiency

The technologies available for improving vehicle fuel efficiency are continually evolving, and those currently available can be utilized more widely and efficiently and further refined to achieve enhanced fuel economy. In addition, emerging technologies, now in the late stages of development, will likely be introduced over the next several years and will be increasingly utilized, and advanced technologies currently in the R&D stage could become available over the next 10–15 years. (A more complete discussion of these technical issues can be found in NRC, 2002, 1992; DeCicco and Ross, 1994, 1996; US Office of Technology Assessment, 1995; Greene and DeCicco, 2000; DeCicco et al., 2001.) The technical options for improving vehicle efficiency can be classified into two basic categories: (i) powertrain technologies, which include engines, transmissions, and the integrated starter-generator, and (ii) load reduction technologies, which include mass reduction, streamlining, tire efficiency, and accessory improvements. These technologies and their associate costs and potential fuel efficiency improvements are summarized in Table 1. According to the NRC, the engine, transmission, and vehicle technologies listed here are likely to be available within the next 15 years (NRC, 2002, Chapter 3): some (listed as "production intent") are already available, are well known to manufacturers and their suppliers, and could be incorporated in vehicles once a decision is made to use them; others (designated "emerging") are generally beyond the R&D phase and are under development, and are sufficiently well understood that they should be available within 10–15 years.

With the exception of fuel cells and series hybrids, the technologies summarized in Table 1 are all currently under production, product planning, or continued development, or they are the subject of future product introduction in Europe or Japan. The feasibility of production is therefore well known, as are the estimated production costs. However, within the competitive cost constraints of the US market, only certain technologies are currently considered practical or cost effective for introduction into different vehicle classes.

Table 1
Potential increases in fuel economy and related price increases

Technology	Potential fuel efficiency improvement (%)	Potential average retail price increases ($)
Engine technologies		
Production-intent engine technologies		
Engine friction and other mechanical/hydrodynamic loss reduction	1–5	35–140
Application of advanced, low friction lubricants	1	8–11
Multi-valve, overhead camshaft valve trains	2–5	105–140
Variable valve timing	2–3	35–140
Variable valve lift and timing	1–2	70–210
Cylinder deactivation	3–6	112–252
Engine accessory improvement	1–2	84–112
Engine downsizing and supercharging	5–7	350–560
Emerging engine technologies		
Camless valve actuation	5–10	280–560
Variable compression ratio	2–6	210–490
Intake valve throttling	3–6	210–420
Transmission technologies		
Production-intent transmission technologies		
Continuously variable transmission (CVT)	4–8	140–350
Five speed automatic transmission	2–3	70–154
Emerging transmission technologies		
Automatic shift/manual transmission	3–5	70–280
Advanced continuously variable transmission	0–2	350–840
Automatic transmission with aggressive shift logic	1–3	0–70
Six-speed automatic transmission	1–2	140–280
Vehicle technologies		
Production-intent vehicle technologies		
Aerodynamic drag reduction on vehicle designs	1–2	0–140
Improved rolling resistance	$1–1\frac{1}{2}$	14–56
Emerging vehicle technologies		
42 V electrical system	1–2	70–280
Integrated starter/generator (idle off-restart)	4–7	210–350
Electric power steering	1.5–2.5	105–150
Vehicle weight reduction (5%)	3–4	210–350

Source: National Research Council, 2002.

4. Scenarios for revised cafe standards

A major objective of our study was to estimate the economic and related impacts of changes in CAFE standards, and below we summarize how the alternate CAFE scenarios were derived. While they are hypothetical and are not intended to be recommended or preferred fuel economy standards, we tried to ensure that these scenarios are feasible in terms of technology, economics, and timing. A key source in devising these scenarios was the NRC report (2002), which, in turn, was based on extensive research of current practices and published research within the automotive industry.

As discussed above, there exist numerous engine, transmission, and vehicle technologies for incrementally increasing vehicle fuel efficiency, and these types of technology and cost estimates were the starting point for developing the scenarios utilized here. However, the implied relationships between increased fuel efficiency and incremental costs are not necessarily linear, and there are a large number of possible fuel economy increases and resulting cost increases that are possible.

A key issue that must be addressed in any discussion of increasing CAFE standards is the level of cost increases that may be justified by the resulting increased vehicle fuel efficiency. While there may be legitimate environmental, security, and other reasons for increasing CAFE standards, the tradeoff between improved fuel efficiency and increased vehicle cost is of critical importance. The NRC addressed this issue by estimating the point at which the incremental costs of new technology begin to exceed the marginal savings in fuel costs, and derived an objective measure of how much fuel economy could be increased while still decreasing consumers' transportation costs (NRC, 2002, pp. 64–67). The NRC termed this the cost-efficient level of fuel economy improvement, because it minimizes the sum of vehicle and fuel costs while holding other vehicle attributes constant. We relied on the NRC's analysis of the estimated incremental fuel efficiency benefits and the incremental costs of technologies—illustrated in Table 1—and constructed three CAFE scenarios.

The first scenario is the "business as usual" or base case scenario (Scenario I) that assumes no increase in CAFE standards and no increase in fleet mpg and retains the current distinction between cars and "light trucks." Under this scenario, we assume that average fleet fuel economy remains constant through 2030. We use this as a base case against which to compare the two alternative CAFE scenarios described below.

Scenario II we label the "moderate" scenario, which assumes that (i) CAFE standards increase by 20% as of 2010: for cars from the current 27.5 to 33 mpg and for light trucks from 20.7 to 24.8 mpg; (ii) the increased standards are phased in from 2005 to 2010 and remain at those levels through 2030; (iii) low cost, currently available, cost-efficient, incremental fuel efficiency technologies are implemented; and (iv) average vehicle prices increase by about \$700 (3%).

Scenario III we label the "advanced" scenario. It "pushes the envelope" on the fuel efficiency gains possible from current or impending technologies and assumes that (i) the fuel efficiency gains possible from incremental technologies available or likely to be available by 2015 discussed in the NRC report and other studies are implemented; (ii) CAFE standards are increased 30% in 2010—for cars from 27.5 to 35.75 mpg and for light trucks from 20.7 to 26.9 mpg, and 50% in 2015—for cars from 27.5 to 41.25 mpg and for light trucks from 20.7 to 31 mpg; (iii) the changes are phased in beginning in 2005 and attain full implementation in 2015; (iv) the new CAFE standards remain at those levels through 2030; and (v) average vehicle prices increase about \$2700 (12%) for the 50% increase in mpg by 2015.

The moderate and advanced scenarios are hypothetical ones that may be technologically and economically feasible, and the intent was to determine what the likely costs and impacts of attaining these goals might be. We believe that both of these scenarios are feasible and credible: They are derived from published engineering studies and data, they assume that future vehicle R&D and technology innovation focus on fuel efficiency rather than on other vehicle characteristics, and both rely on technologies that are either currently available or well into R&D phase. Neither require development of "new" vehicles or exotic technologies. The timetable involved, 2005–2015, compares favorably with the original CAFE timetable that mandated a 53% increase (18–27.5 mpg) in the 7 years between 1978 and 1985.

Further, Scenario II is less ambitious than the CAFE standard increases that were being considered by Congress in early 2002, while Scenario III is somewhat more ambitious than those that were considered by Congress. For example: Senate Commerce Committee Chairman Ernest Hollings (D-S.C.) proposed raising the CAFE standard for passenger cars and light trucks to 37 mpg by 2014; Senate Commerce Committee ranking Republican John McCain (R-Ariz.) proposed raising the CAFE standard to 36 mpg by 2016; the bipartisan proposal by Senator McCain and Senator John Kerry (D-Mass.) proposed raising the CAFE standard to 35 mpg by 2015.[1]

However, our hypothesized CAFE increases may also be more challenging than those enacted during the 1970s: The original CAFE enhancements were obtained, in part, by relatively easy weight reductions and by capturing other "low hanging fruit". Future CAFE enhancements will require successful R&D and technological innovation.

In addition, scenarios II and III propose equal percentage fuel economy increases for passenger cars and for light trucks, while the NRC study and related data indicate that it may be desirable and more efficient to require larger fuel economy improvements for light trucks than for passenger cars. Thus, the CAFE scenarios simulated here may not be the "optimal" scenarios that could theoretically be constructed. Nevertheless, the scenarios used here were designed to be generally realistic. Also, as discussed, at present light trucks are exempt from the fuel efficiency standards applicable to passenger vehicles, and requiring both vehicle types to achieve similar fuel efficiency improvements (as simulated here) would be a major accomplishment in and of itself.

It should also be noted that price elasticities for specific vehicles or vehicle types were not estimated in any of the scenarios, and available trend forecasts of future vehicle demand were used. Aside from the practical difficulties of estimating price elasticities through 2030, it must be realized that increasing fuel economy implies trading off other vehicle characteristics, such as horsepower and performance, for increased fuel efficiency. This would change the characteristics of vehicles, compared to what they otherwise would have been in the absence of enhanced CAFE standards. This would impact sales and price elasticities, especially among different classes of vehicles. While it is recognized that these effects would occur, a comprehensive analysis of them was outside the scope of the work conducted here.

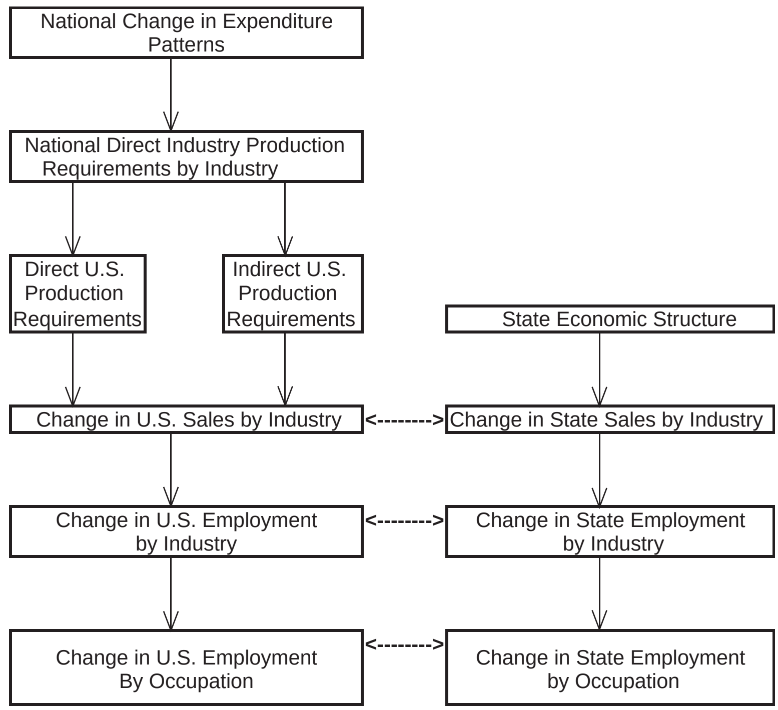
Finally, while the scenarios are technically feasible, there is no free lunch, and increased CAFE standards, no matter what the potential energy, environmental, economic, and employment impacts, will require that fuel economy enhancement be given priority over other types of vehicle improvements, will increase the purchase price of vehicles, will require manufacturers to produce vehicles that they would not in the absence of the enhanced standards, and will require consumers to purchase vehicles that would not exist except for the enhanced standards.

5. Methodology for estimating the economic and employment impacts

The economic and employment effects of revised CAFE standards were estimated using the Management Information Services, Inc. (MISI) model, database, and information system. A simplified version of the MISI model as applied in this study is shown in Fig. 1.

The first step in the MISI model involves translation of increased expenditures for reconfigured motor

[1] In December 2002, NHTSA proposed to increase fuel economy standards for light trucks (including minivans and SUVs) by 1.5 mpg between 2005 and 2007.



Source: Management Information Services, Inc., 2003.

Fig. 1. Use of the MISI model to estimate the economic, employment, and occupational impacts of increased CAFE standards.

vehicles meeting the revised CAFE standards into per unit output requirements from every industry in the economy.[2] Second, the direct output requirements of every industry affected as a result of the revised CAFE standards are estimated, and they reflect the production and technology requirements implied by the enhanced CAFE standards. These direct requirements show, proportionately, how much an industry must purchase from every other industry to produce one unit of output. Direct requirements, however, give rise to subsequent rounds of indirect requirements. The sum of the direct plus the indirect requirements represents the total output requirements from an industry necessary to produce one unit of output. Economic input–output (I–O) techniques allow the computation of the direct as well as the indirect production requirements, and these total requirements are represented by the ''inverse'' equations in the model.

Thus, in the third step in the model the direct industry output requirements are converted into total output requirements from every industry by means of the input–output inverse equations. These equations show not only the direct requirements, but also the second, third, fourth, *n*th round indirect industry and service sector requirements resulting from revised CAFE standards.

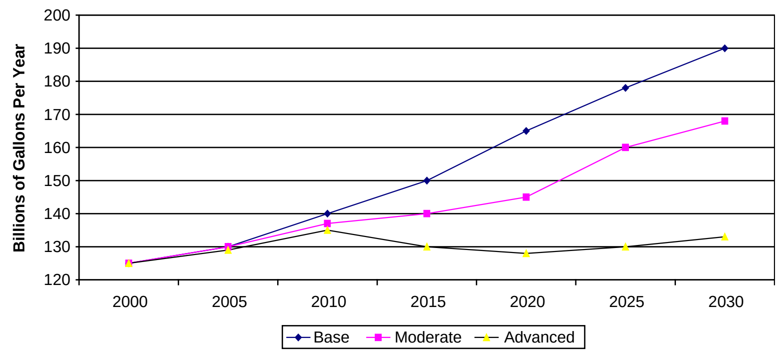
[2]While the MISI model contains 500 industries, in the work conducted here an 80-order industry scheme was used.

Next, the total output requirements from each industry are used to compute sales volumes, profits, and value added for each industry. Then, using data on manhours, labor requirements, and productivity, employment requirements within each industry are estimated. This allows computation of the total number of jobs created within each industry.

The next step requires the conversion of total employment requirements by industry into job requirements for specific occupations and skills. To accomplish this, MISI utilizes data on the occupational composition of the labor force within each industry and estimates job requirements for 700 occupations encompassing the entire US labor force. This permits estimation of the impact of revised CAFE standards on jobs for specific occupations.

Utilizing the modeling approach outlined above, the MISI model allows estimation of the effects on employment, personal income, corporate sales and profits, and government tax revenues in the US. Estimates can then be developed for detailed industries and occupations.

The final step in the analysis entailed assessing the economic impacts on individual states, which were estimated using the MISI regional model. This model recognizes that systematic analysis of economic impacts must also account for the inter-industry relationships between regions, since these relationships largely determine how regional economies will respond to project, program, and regulatory changes. The MISI I–O



Source: Management Information Services, Inc., 2003.

Fig. 2. Gasoline consumption under each scenario.

modeling system includes the databases and tools to project these interrelated impacts at the regional level. The model currently allows the flexibility of specifying multi-state, state, or county levels of regional detail. Regional I–O multipliers were calculated and projections made for the detailed impacts on industry economic output, employment by industry, and employment by occupation at the regional level. Because of the comprehensive nature of the modeling system, these regional impacts are consistent with impacts at the national level, an important fact that adds to the credibility of the results since there is no ''overstatement'' of the impacts at the regional level.

6. Macroeconomic, employment, energy, and environmental impacts of revised cafe standards

We first estimated the likely savings in gasoline consumption under each of the increased CAFE scenarios. As illustrated in Fig. 2, US gasoline consumption is initially reduced modestly under the advanced and the moderate scenarios, but the savings under each scenario increase substantially over time as the new CAFE standards are phased in and as the rolling vehicle fleet is gradually transformed—over time, older vehicles are scrapped and replaced with new, more fuel-efficient vehicles. These savings in gasoline consumption are especially pronounced in the advanced scenario, which is phased in thorough 2015 and has stricter mileage requirements. Thus, starting from actual US gasoline consumption of about 125 billion gallons per year in 2000: In 2015, under the moderate scenario, annual gasoline consumption is 10 billion gallons less than under the base case scenario—about 7%; in 2015, under the advanced scenario, annual gasoline consumption is 20 billion gallons less than under the base case scenario—about 14%; in 2030, under the moderate scenario, annual gasoline consumption is more than 20 billion gallons less than under the base case scenario—about 12%; in 2030, under the advanced scenario, annual gasoline consumption is nearly 60 billion gallons less than under the base case scenario—about 30%.

In fact, under the advanced scenario, total US gasoline consumption actually declines over most of the forecast period, despite continually increasing numbers of vehicles on the road, and by 2030 is little more than in 2005. Thus, this scenario, in effect, ''buys'' the US 25 years of gasoline consumption increases.[3]

The reductions in gasoline consumption under the two increased CAFE scenarios imply significant savings in the cost of gasoline to US drivers. The magnitude of these savings depends on the amount of gasoline saved and the price of gasoline. Since the latter has been volatile over the past three decades, and since this volatility is likely to persist, we used three hypothetical gas prices (2002 dollars) to estimate the likely savings: A ''low'' price of $1.25 per gallon, a ''mid-range'' price of $1.50 per gallon, and a ''high'' price of $1.75 per gallon.

Under the moderate scenario, and depending on the price of gasoline: In 2015, annual savings to consumers range between $15 and $20 billions; in 2020, the annual savings range between $25 and $35 billions; in 2030, between $35 and $50 billions. Under the advanced scenario, and depending on the price of gasoline: in 2015, annual savings to consumers range between $30 and $40 billions; in 2020, between $50 and $75 billions; in 2030, between $75 billion and more than $100 billion.

However, these savings come at a price—the increased costs of the more fuel-efficient vehicles, and the cost increases are much greater under the advanced scenario. Thus, under the moderate scenario, by 2020, drivers will be saving $25–$35 billion annually, whereas increased vehicle costs in this year will total about $13 billion; by 2030, drivers will be saving $35–$50 billion annually, whereas the increased vehicle costs will total about $16 billion. Under the advanced scenario, by 2020, drivers will be saving $45–$75 billion annually, whereas the increased vehicle costs will total about $50 billion; by 2030, drivers will be saving $75 to $100 billion annually,

[3] Nevertheless, in both 2015 and 2030, under both scenarios, annual gasoline consumption is still higher than in 2000.

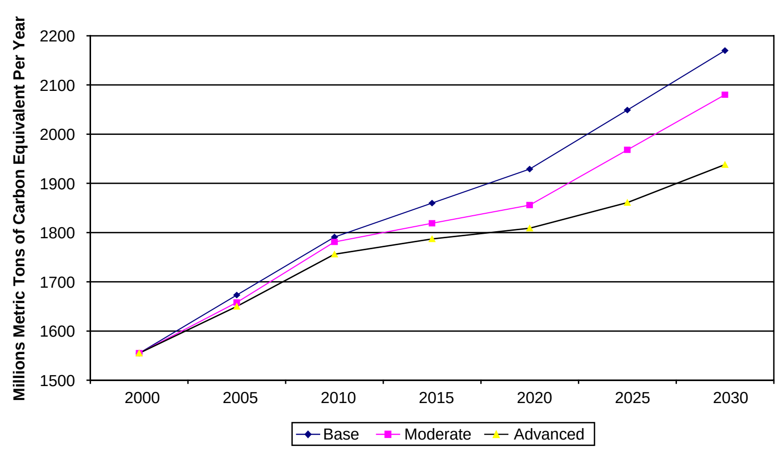
whereas the increased vehicle costs will total about $55 billion.

Motor vehicles account for a substantial portion of the carbon emissions and greenhouse gases produced in the US. Transportation accounts for about one-third of all US carbon emission and more than 75% of carbon emissions from petroleum, and carbon emissions from transportation are about equal to those from the industrial sector. Since greenhouse gas (GHG) emissions are closely related to gasoline consumption, reduction in the rate of growth in gasoline consumption will reduce the rate of growth of GHG emissions. While increased CAFE standards will not reduce total US GHG emissions over the forecast period, they will reduce their rate of growth—as shown in Fig. 3. Specifically, under the moderate scenario, annual US GHG emissions are reduced by 70 million tons by 2020 below the base case (nearly 4%) and by 90 million tons by 2030 (more than 4%); under the advanced scenario, annual US GHG emissions are reduced by 120 million tons below the base case by 2020 (about 6%) and by 230 million tons by 2030 (nearly 11%).

In comparison, the Kyoto Protocol would have required the US to reduce GHG emissions by 400–500 million tons per year (about 20%). Thus, the advanced scenario could eventually achieve about half of the US GHG reduction implied by the Kyoto Protocol. Nevertheless, while increased CAFE standards can make an important contribution to reducing GHG emissions, other measures would also be required.

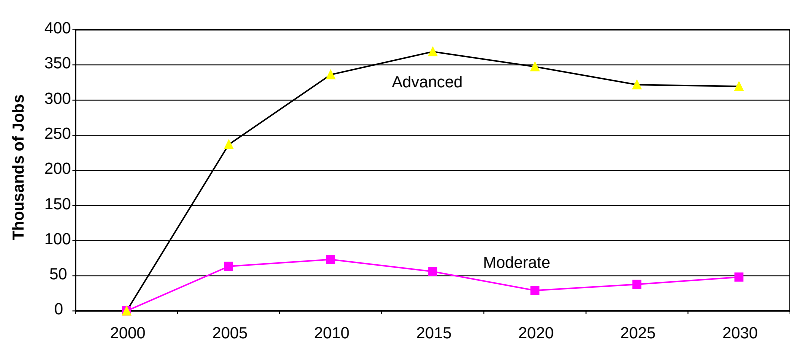
One of the major findings of our research is that enhanced CAFE standards will likely increase employment substantially, and we estimate that the two CAFE increase scenarios analyzed will increase employment by between 70,000 (under the moderate scenario) and 380,000 jobs (under the advanced scenario)—as shown in Fig. 4. While significant, these job gains must be put into perspective: In 2010, US employment will total 142 million; in 2020 it will total 154 million; in 2030 it will total 166 million.

However, while the net employment effects are strongly positive under the enhanced CAFE scenarios, in both cases substantial job displacement is also occurring. As shown in Table 2, under both the moderate and the advanced scenarios there are substantial job shifts and displacements. For example, in 2020, under the moderate scenario, 101,000 jobs are created, 72,000 jobs are displaced, and net employment



Source: Management Information Services, Inc., 2003.

Fig. 3. US greenhouse gas emissions under each scenario.



Source: Management Information Services, Inc., 2003.

Fig. 4. Net benefits to US employment.

Table 2
Summary of CAFE scenario job impacts, 2010–2030

	2010		2020		2030	
	Moderate scenario	Advanced scenario	Moderate scenario	Advanced scenario	Moderate scenario	Advanced scenario
Jobs created	78,749	344,135	101,071	432,966	126,688	505,987
Jobs displaced	5771	7870	72,157	86,018	78,676	186,902
Net job gain	72,978	336,265	28,914	346,948	48,012	319,085

Source: Management Information Services, Inc., 2003.

increases by 29,000; under the advanced scenario, 433,000 jobs are created, 86,000 jobs are displaced, and net employment increases by 347,000. Thus, while there are job gains and job displacements under each enhanced CAFE scenario, the net job change is positive, and a major finding here is that, overall, increasing CAFE standards will create jobs, not eliminate them.

7. Detailed sector, industry, occupational, and state impacts of increased CAFE standards

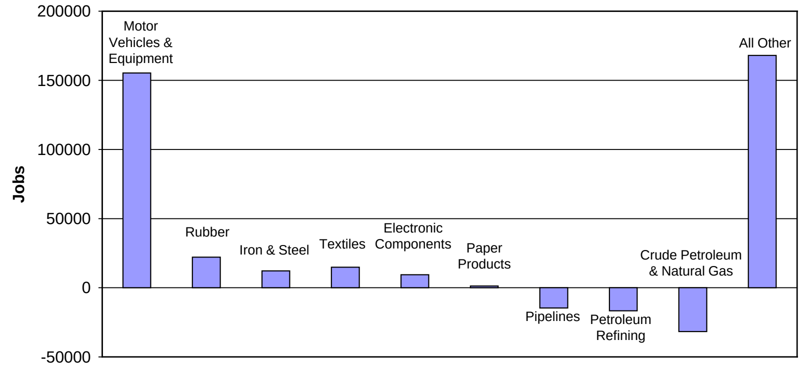
We estimated the impacts of increased CAFE standards on economic output and employment within specific industries and, as illustrated in Fig. 5, these impacts would vary substantially. The Motor Vehicle and related industries would be major winners, whereas employment in petroleum products and related industries would decrease. For example, in 2020, compared to the business as usual case, under the advanced scenario jobs in the Motor Vehicle and Equipment industry would increase by 155,000, jobs in the Rubber industry would increase by 22,000, and jobs in the electronic components industry would increase by 9500. However, in this case, jobs in the Crude Petroleum and Natural Gas industry would decrease by 32,000 and jobs in the Petroleum Refining industry would decrease by 17,000.

Putting these job losses and job gains into perspective, they can be compared to the natural ebb and flow of employment as shown by overall US job creation and destruction. Job flows among industries can be affected by the business cycle, the length of the measurement period (quarterly or annually), the geographic size of the study (state-level or national-level), and other exogenous factors. Most comparative analyses have focused on establishment-level data (Davis and Haltiwanger, 1990, 1999; Privetz and Searson, 2001). However, there are clear trends in the measurements. Overall, US job flows in the 1990s averaged an 11% annual creation rate and a 10% destruction rate. Industries with rates that consistently exceeded 15% include construction, mining, and agriculture. Industries with the consistently lowest rates for both job creation and job destruction included manufacturing (5–8%) and the finance industry (6–9%). Thus, the industry job losses and gains likely to result from enhanced CAFE standards would generally be relatively modest compared to those occurring otherwise.

Jobs in all occupations would also be affected, but to a very different degree and, while most occupations would gain jobs, in some occupations jobs would decrease. For example, as illustrated in Fig. 6, in 2020 under the advanced scenario jobs would be created for 700 computer programmers, 900 mechanical engineers, 1100 industrial engineers, 1000 electronic equipment assemblers, 1500 computer controlled-machine tool operators, and 2700 machinists. On the other hand, petroleum engineering jobs would decrease by 700 and jobs for petroleum pump operators would decrease by 6,100. Even within the occupations experiencing net job gains there will be substantial job shifts. For example, in the case of computer programmers, 1100 jobs will be created, 400 jobs will be lost, and the net gain is thus 700 jobs.

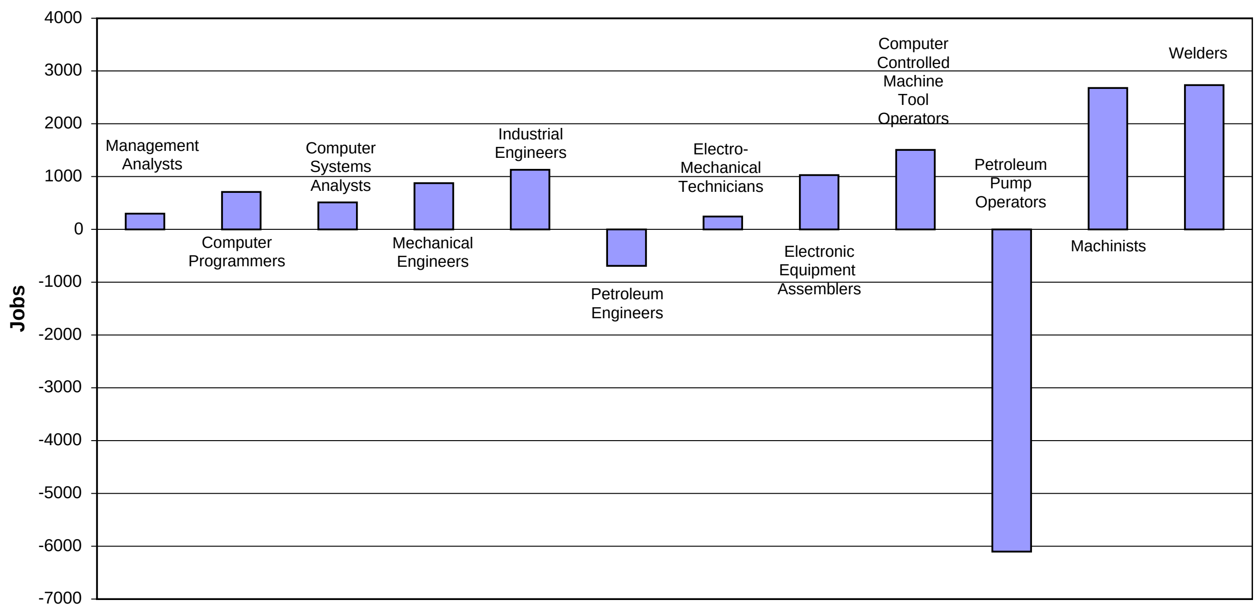
Thus, as was the case with employment in different industries, under the two CAFE scenarios considerable job shifting and displacement occurs within occupations. For example, focusing on the occupations in Fig. 6, under the advanced scenario in 2020 jobs for 1100 computer programmers are created and jobs for 400 computer programmers are displaced, resulting in a total net increase of 700 jobs in this occupation; jobs for 1000 computer systems analysts are created and jobs for 500 computer systems analysts are displaced, resulting in a total net increase of 500 jobs in this occupation; jobs for 3560 welders are created and jobs for 820 welders are displaced, resulting in a total net increase of 2740 jobs in this occupation.

There are thus substantial job gains, displacement, and shifting occurring among industries, sectors, occupations, and skills under the CAFE scenarios. Table 3 provides further insight into the occupational job shifting and displacement that would occur under the advanced scenario in 2020. It illustrates that among the 500 computer systems analyst jobs displaced, more than 300 of these job losses occur in the Petroleum Refining industry; the 1150 jobs created for mechanical engineers are spread widely throughout many industries, and



Source: Management Information Services, Inc., 2003.

Fig. 5. Industry job impacts in 2020 under the advanced scenario.



Source: Management Information Services, Inc., 2003.

Fig. 6. Job impacts in selected occupations under the 2020 advanced scenario.

the largest number created in one industry sector—Rubber and Plastics—is 100; of the total of 280 new jobs created for electro-mechanical technicians, about one-fourth of these (80) are created in the Motor Vehicles industry.

Finally, most states will gain substantial numbers of jobs, but the gains will be distributed unevenly among the states. For example, as detailed in Table 4, in 2020 under the advanced scenario Michigan gains 54,500 jobs, Ohio gains 29,300 jobs, California gains 28,400 jobs, Indiana gains 22,300 jobs, Illinois gains 16,300 jobs, New York gains 15,400 jobs, Pennsylvania gains 13,300 jobs, Wisconsin gains 10,700 jobs, Georgia gains 10,200 jobs, Maryland gains 3300 jobs, Texas gains 2500 jobs, and Rhode Island gains 1000 jobs.

Once again, the job gains in the states will be accompanied by substantial job shifts among industries, sectors, and occupations within each state. For example, in 2020 under the advanced scenario in California, the net job gain of 28,400 reflects 5900 job losses in industries such as Crude Petroleum and Natural Gas, Petroleum and Coal Products, Transportation, and other industries that are more than offset by job gains in Motor Vehicles and Equipment, Fabricated Metal Products, Services, Manufacturing, and other industries. In Texas, the net job gain of 2500 reflects 17,400 job losses in industries such as Crude Petroleum and Natural Gas, Construction, Petroleum and Coal products, Transportation, and other industries that are more than offset by job gains in Motor Vehicles and

Table 3
Selected occupational impact highlights at the industry level under the 2020 advanced scenario

Occupational title	*Selected industry highlights*
Automotive service technicians & mechanics	4939 gain in the automotive repair & services industry (largest)
Customer service representatives	1255 gain in the finance industry (2nd)
Welders	396 gain in screw machine products & stampings industry (2nd)
Machinists	1118 gain in the motor vehicles industry (largest)
Sewing machine operators	1101 gain in the miscellaneous fabricated textile industry (largest)
Truck drivers, tractor trailers	1330 gain in the motor freight transportation industry (2nd)
Computer-controlled machine tool operators	567 gain in motor vehicles industry (largest)
Janitors and cleaners	368 loss in the real estate & royalties industry (largest)
Industrial engineers	786 gain in the motor vehicle industry (largest)
Electronic equipment assemblers	240 gain in the electronic components & accessories industry (2nd)
Mechanical engineers	100 gain in the rubber & plastics industry (2nd)
Accountants and auditors	447 gain in the finance industry (2nd)
Computer programmers	483 gain in the wholesale trade industry (largest)
Telemarketers	345 gain in the wholesale trade industry (largest)
Computer systems analysts	322 loss in the petroleum refining industry (largest)
Security guards	264 gain in the other business & professional services industry (largest)
Management analysts	401 loss in the petroleum refining industry (largest)
Electro-mechanical technicians	80 gain in the motor vehicles industry (2nd)
Lawyers	205 loss in the legal, engineering & accounting services industry (largest)
Petroleum engineers	565 loss in the crude petroleum industry (largest)
Petroleum pump operators	3227 loss in the pipelines industry (largest)

Source: Management Information Services, Inc., 2003.

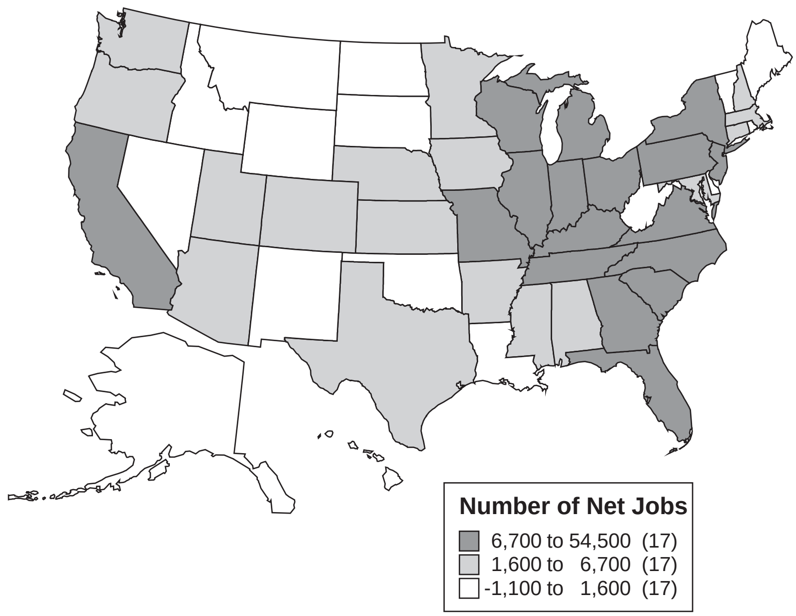
Equipment, Fabricated Metal Products, Services, Trade, Manufacturing, and other industries.

The overall regional job impact in 2020 under the advanced scenario is illustrated in Fig. 7, which categorizes the states on the basis of the number of net jobs created within each state. While there are diverse impacts among the states and regions, this figure indicates that, in general, California and states in the Midwest and the southeast would gain the most jobs, states in the Pacific Northwest, the south central region, and New England are impacted to a lesser degree, while many of the mountain states and Louisiana, Oklahoma, West Virginia, Vermont, and Maine are affected the least or actually experience net job displacement. Clearly, though, with the exception of California, in

Table 4
Net employment change by state in 2020 under the advanced scenario

State	Net job change
Michigan	54,500
Ohio	29,300
California	28,400
Indiana	22,200
Illinois	16,300
New York	15,400
Pennsylvania	13,300
North Carolina	13,100
Tennessee	12,500
Wisconsin	10,700
Georgia	10,200
Missouri	9500
Kentucky	9200
Florida	9100
Virginia	7100
New Jersey	6900
South Carolina	6700
Minnesota	6400
Massachusetts	6100
Alabama	6100
Iowa	5200
Washington	5100
Oregon	4700
Arkansas	4200
Connecticut	4100
Arizona	3800
Maryland	3300
Mississippi	2700
Utah	2600
Texas	2500
Colorado	2500
Kansas	2400
Nebraska	2200
New Hampshire	1700
Maine	1100
Idaho	1100
Rhode Island	1000
South Dakota	900
Nevada	900
Delaware	800
West Virginia	700
Vermont	700
North Dakota	500
Hawaii	400
DC	400
Oklahoma	300
Montana	200
New Mexico	−50
Alaska	−300
Wyoming	−500
Louisiana	−1100
US, total	346,900

Source: Management Information Services, Inc., 2003.



Source: Management Information Services, Inc., 2003.

Fig. 7. Job impacts by state of the advanced CAFE scenario in 2020.

terms of net job gains, most of the benefits of increased CAFE standards would be distributed to states east of the Mississippi river, while the region located between the Mississippi river and the west coast would benefit the least. In particular, every state in the Midwest would benefit substantially, as would the border states of Kentucky and Tennessee, the North Central states, the Atlantic coast southeastern states, and the Pacific coast states.

8. Conclusions

Several major conclusions emerge from this research. First, enhanced CAFE standards would increase employment, although some industries and occupations will lose jobs. Under the moderate scenario, 70,000 net new jobs would be created by 2010 and 30,000 would be created by 2020; under the advanced scenario 335,000 net new jobs would be created by 2010 and 350,000 would be created by 2020. The largest number of jobs are in the Motor Vehicles industry, but most industries gain jobs. Jobs in most occupations increase, but some occupations would lose jobs, and even in those occupations that gain jobs, some workers will be displaced.

Second, there are regional implications. Most states will gain substantial numbers of jobs—for example, under the 2020 advanced scenario Michigan gains 54,500 jobs, Ohio gains 29,300 jobs, California 28,400 jobs, and Indiana 22,300 jobs. However, job increases and decreases will be spread unevenly among different sectors and industries within each state, and there will thus be job shifts within states as well as among states.

Finally, enhanced CAFE standards would: (i) reduce US annual oil consumption by 20–40 billion gallons by 2020 and 25–60 billion gallons by 2030; (ii) save drivers $30–$70 billion annually by 2020 and $40–$100 billion annually by 2030, at increases of between $16 and $55 billion in annual vehicle costs; (iii) reduce annual US GHG emissions by 60–130 million tons by 2020 and 90–180 million tons by 2030.

In sum, the research summarized here indicates that enhanced CAFE standards would have positive energy, environmental, economic, and job benefits. Our findings indicate that increased CAFE standards will not harm the US economy or destroy jobs, and they thus question arguments made that enhanced CAFE standards will harm the economy and cost workers their jobs. Hopefully, the information provided here can inform future policy debates over CAFE standards.

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