Can Proactive Fuel Economy Strategies Help Automakers Mitigate Fuel-Price Risks?

UMTRI-2006-38

WALTER MCMANUS, PHD
DIRECTOR, AUTOMOTIVE ANALYSIS DIVISION
UNIVERSITY OF MICHIGAN TRANSPORTATION RESEARCH INSTITUTE

SEPTEMBER 14, 2006

UMTRI
UNIVERSITY OF MICHIGAN
TRANSPORTATION RESEARCH INSTITUTE

TABLE OF CONTENTS

	PAGE
Abstract	2
Introduction	3
High Fuel Prices Have Diminished Detroit Automakers' Market Share and Profit	5
Technological Options	12
Market Model	17
Scenario Analysis	27
Results: Raising Fuel Economy Performance As a Key Strategy to Maximize Profits	33
Appendix	44
Glossary	51
References	56

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Can Proactive Fuel Economy Strategies Help Automakers Mitigate Fuel-Price Risks?		5. Report Date September, 2006 6. Performing Organization Code
7. Author(s) Walter McManus		8. Performing Organization Report No. UMTRI-2006-38
9. Performing Organization Name and Address Automotive Analysis Division University of Michigan Transportation Research Institute 2901 Baxter Road Ann Arbor, MI 48109-2150		10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address		13. Type of Report and Period Covered 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

Detroit automakers opposed mandatory improvements in fuel economy when legislation was first proposed in the early 1970s, and continue to resist increases in the standards today. Their opposition appears to stem from an assumption that new-vehicle buyers value higher fuel economy only when fuel prices are extremely high. Automakers thus believe that higher fuel economy standards would diminish their profits, especially if fuel prices were much lower. Events of 2005 have made it clear that consumers are reacting to higher fuel prices by migrating to more fuel-efficient options; primarily to the detriment of Detroit automakers market share and profits.

In this paper, we examine the economic viability of improving fuel economy as a strategy to mitigate the risk of high fuel prices and to gain competitive advantage in an automotive market in which customers demand, and are willing to pay for fuel efficiency. We adopt a "scenario analysis" approach where individual automaker fuel economy strategies are tested against various scenarios of fuel prices and other automaker fuel economy strategies. Our goal is to determine which strategies maximize variable profits and U.S. auto industry employment.

17. Key Word	18. Distribution Statement
Proactive Fuel Economy Strategies	Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
None	None	58	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Can Proactive Fuel Economy Strategies Help Automakers Mitigate Fuel-Price Risks?

Walter McManus, PhD
Director, Automotive Analysis Division
University of Michigan Transportation Research Institute

ABSTRACT

Detroit automakers have opposed mandated improvements in fuel economy since legislation was first proposed in the 1970's. Their opposition is based, among other considerations, on the assumption that their customers value fuel economy only when fuel prices are high. This paper presents the findings of our on-going research that strongly refutes this assumption. Using data on sales, prices, and attributes of vehicles in 2005, we find that consumers are willing to pay, on average, $578 per MPG for higher fuel economy. At the price of gasoline prevailing in 2005, $2.30 per gallon, the $578 per MPG that consumers are willing to pay for fuel economy implies that consumers put more weight in choosing vehicles on future fuel savings than most analysts (including ourselves) had thought.

The paper incorporates these new data-driven estimates of the value of fuel economy into an automotive market simulation model that has three components: a consumer demand function that predicts consumers' vehicle choices as functions of vehicle price, fuel price, and vehicle attributes (the new estimates of the value of fuel economy are used to set the parameters of the demand function); an engineering and economic evaluation of feasible fuel economy improvements by 2010; and a game theoretic analysis of manufacturers' competitive interactions.

Using our model, we estimated the market shares and profits of automakers in 128 separate scenarios defined by alternative plausible values for the price of fuel and consumers' discount rates. Under the fuel price risks and the competitive risks that automakers face, our analysis concludes that a proactive strategy of pursuing fuel economy improvements—above and beyond what is required by law—would increase annual profits for Ford ($0.5 billion to $1.4 billion), GM ($0.2 billion to $0.5 billion, and DaimlerChrysler ($0.1 billion). Even if the uncertainty over fuel price were removed, all three automakers would increase profits by pursuing fuel economy improvements, though the gains are smaller with fuel at $2.00/gallon.

Introduction

Detroit automakers opposed mandatory improvements in fuel economy when legislation was first proposed in the early 1970's, and continue to resist increases in the standards today. Their opposition appears to stem from an assumption that new-vehicle buyers value higher fuel economy only when fuel prices are extremely high. Automakers thus believe that higher fuel economy standards would diminish their profits, especially if fuel prices were much lower. Events of 2005 have made it clear that consumers are reacting to higher fuel prices by migrating to more fuel-efficient options; primarily to the detriment of Detroit automakers market share and profits.

In this paper, we examine the economic viability of improving fuel economy as a strategy to mitigate the risk of high fuel prices and to gain competitive advantage in an automotive market in which customers demand, and are willing to pay for fuel efficiency. We adopt a "scenario analysis" approach where individual automaker fuel economy strategies are tested against various scenarios of fuel prices and other automaker fuel economy strategies. Our goal is to determine which strategies maximize variable profits and U.S. auto industry employment.

The paper has five sections:

High Fuel Prices Have Diminished Detroit Automakers' Market Share and Profit. The first section reviews the current state of the auto industry, and in particular, how high fuel prices are a primary contributing factor to the rapid erosion of Detroit automaker's market share, profits, and jobs.

Technological Options. In this section, we summarize what automakers can do to improve fuel economy by 2010. The details are given in an appendix.

Market Model. This section explains the analytical model of the U.S. automotive market we use to describe the behavior of consumers and automakers in response to changes in fuel prices, competitive conditions, and consumer tastes. The model is used in the scenario analysis to predict overall market outcomes (sales, profits, jobs) as well as the sales, prices, variable profits, and attributes of the individual products sold in the market.

Total sales of light vehicles (in units) are estimated in one sub-model as a function of income, demographics, and the average attributes of light vehicles. The market shares of individual vehicles are derived in a second sub-model that predicts the choices by consumers of specific vehicles as functions of the attributes both of these vehicles (including performance, size, and cost of ownership and operation) and of all other vehicles. The preferences and tastes of consumers are measured as estimates of consumers' willingness to pay for attributes of vehicles.

We compute sales in units, revenues, and pretax variable profit for each manufacturer, segment, and vehicle by multiplying total market sales (first sub-model) by vehicle shares (second sub-model) and aggregating the results. We then estimate the impact of changes in the level and mix of sales and production of vehicles on U.S. employment by applying parameters from the REMI (Regional Economic Models, Inc.) model to our predicted sales.

Scenario Analysis. In this section, we characterize the risks and uncertainties facing automakers, and explore the impacts of these risks and uncertainties on their choices of fuel economy strategies. An automaker faces two types of risk when choosing a fuel economy strategy. One type of risk comes from uncertainty about future fuel prices and consumer tastes. The other type of risk comes from uncertainty about the future actions of competitors. We incorporate both types of risk in 128 scenarios defined by different outcomes for fuel prices, consumer trade-offs, and fuel economy strategy choices of the automakers.

In assessing the 128 outcomes from an automaker's point of view, we focus on the automaker's pretax variable profit under each scenario and assume automakers are motivated to maximize that profit.

Results: Raising Fuel Economy Performance as a Key Strategy to Maximize Profits
Findings are summarized and issues for further research are discussed in the final section.

High Fuel Prices Have Diminished Detroit Automakers' Market Share and Profit

The relationship between fuel prices and automakers' product mix and profits has a long history. The events of 2005 reinforce the conclusion that rising fuel prices have a substantial impact on profitability. The key issue here is that automakers that are highly leveraged in truck-based products (SUVs and pickups) are especially vulnerable to higher fuel prices since these products tend to be less fuel-efficient. When fuel prices were low in the 1990's (1990-1999 average gasoline price: $1.50 per gallon in today's money), being dependent on such vehicles for profits was not a liability. It is a serious liability today.

High Fuel Prices Have Reduced Profitability of SUVs and Pickups

In 1975, when Congress passed and President Ford signed the "Energy Policy Conservation Act" into law, light-duty trucks (pickups, vans, and a few SUVs) were only about 20% of all light vehicles sold in America. The Act targeted a doubling of passenger car fuel economy (to 27.5 miles per gallon) by 1984, and instructed the Secretary of Transportation to set light-duty truck CAFE at the "maximum feasible level." The light-duty truck CAFE standard has consistently been 5-8 MPG below that of cars.

Falling fuel prices after 1984 made American automotive consumers less interested in fuel economy and more interested in size and power. However, by this time, automakers had downsized passenger cars (down 10% in wheelbase and 24% in curb weight) to meet CAFE, and were constrained in how much power and size they could add to cars. So they turned to trucks and smudged, if not erased, the personal-use/work-use distinction between cars and trucks by using truck platforms to build SUVs. Light-duty trucks were 55% of all light vehicles sold in the U.S. in 2005. At the same time, the growing demand for SUVs pushed the average truck price from 98.6% of the average car price in 1984 to 108.9% in 1999.

Since January 1999, fuel prices have been rising, and automakers' ability to maintain prices and profits of trucks has steadily declined. However, Detroit automakers are heavily committed to trucks, and switching production from trucks to cars is also costly. Rather than accept lower unit sales of trucks, they accepted lower profits from trucks. Their dependence on trucks contributed to the automakers' failure to react fast enough to the beginning of the end of the shift to light trucks.

Estimated Share of Company's Total Pretax Profits from SUVs, Pickups, and Large Vans, 2004 and 2005

	Ford	GM	DaimlerChrysler	Nissan	Toyota	Honda	Other	Total
2004	62%	61%	44%	36%	28%	0%	16%	44%
2005	58%	57%	44%	39%	25%	0%	13%	41%

Source: Author's calculations based on Ward's Automotive Reports and estimates of pretax variable profits.
Ford includes Mazda; DaimlerChrysler includes Mitsubishi.

As a legacy of Detroit automakers' shift to trucks in the 1980's and 1990's, they continue to earn a large portion of their profits from truck-based products (The table counts as "truck-based" SUVs, pickups, and large vans, but not uni-body crossover vehicles, minivans, or Honda's Ridgeline pickup). GM and Ford earned three-fifths of their total pretax variable profit from truck-based vehicles in 2004. As the market shifted away from trucks, GM and

Ford lost variable profit in truck-based vehicles in 2005 and were not able to offset these losses with gains in car-based vehicles.

DaimlerChrysler earned 44% of its profits from truck-based vehicles in 2004 and again in 2005. The combination of Mercedes-Benz in the luxury market, and Chrysler group's domination of the minivan market, make DaimlerChrysler less exposed to fuel price risks than Ford or GM.

Nissan and Toyota have been behind Detroit in shifting to truck-based vehicles and Honda has stayed exclusively with car-based vehicles. Nissan sold 23% more truck-based vehicles in 2005 than it did in 2004, and boosted its truck-based variable profits from 36 to 39% of total profits as a result. Toyota's sales and profits 2005 over 2004 growth was concentrated in car-based vehicles, so its truck-based variable profits fell from 28 to 25% of total profits.

Financial Health of the Domestic Automakers Have Been Hurt by High Fuel Prices

The poor financial health of GM and Ford can be attributed in large part to the effects of high fuel prices and their dependence on truck-based products. The Chrysler group's minivans (which are more fuel-efficient than SUVs of a similar size) and luxury cars from Mercedes-Benz have somewhat insulated DaimlerChrysler from the effects of higher fuel prices. The Japan 3 are seeing share and profit growth, and are increasing their North American capacity as a result. GM, Ford, and DaimlerChrysler also have significant cost disadvantages compared to the Japan 3, much of which can be attributed to legacy issues (health care and pension costs). However, management decisions, such as focusing on truck-based products, have also contributed to their situation.

Estimated Retail Revenue (Billions)

	DaimlerChrysler	Ford	GM	Honda	Nissan	Toyota
2004	$67.7	$87.4	$114.7	$33.0	$24.5	$52.7
2005	$69.5	$85.7	$113.3	$37.1	$28.1	$58.9
'05 O/U '04	2.6%	-2.0%	-1.3%	12.4%	14.5%	11.7%

Estimated Pretax Variable Profit (Billions)

	DaimlerChrysler	Ford	GM	Honda	Nissan	Toyota
2004	$15.5	$19.6	$25.7	$7.2	$5.5	$12.0
2005	$15.8	$19.2	$25.4	$8.2	$6.3	$13.4
'05 O/U '04	2.0%	-2.3%	-1.4%	13.5%	15.1%	11.4%

Detroit Automakers' Factories and Jobs at Risk

GM and Ford in particular face the toughest challenges of their history. Both are losing money in North America and are closing plants and cutting jobs to bring their domestic production in line with their falling market shares. Ford plans to idle 14 facilities, including seven assembly plants, and eliminate 25,000 to 30,000 jobs by 2012. GM plans to idle or reduce 15 facilities, including eight assembly plants, and eliminate 30,000 jobs by 2008. Ford will announce accelerated cuts to costs and jobs in mid-September 2006.

GM appears to be working through its restructuring more rapidly than Ford. The results of GM's early retirement and buyout program have been stronger than expected. All of GM's 113,000 U.S. hourly workers and 13,000 hourly workers at parts-maker Delphi were offered early retirement or buyout. More than 30,000 GM workers and 12,000 Delphi workers have accepted, allowing GM to eliminate 30,000 jobs two years earlier than planned -- by the end of 2006. GM has named all of the plants that it plans to close or reduce by 2008, but Ford has yet to name all of its targeted facilities.

Last year we released a study (McManus, Baum, Hwang, Luria, and Barua [2005]) that identified a number of plants that were at risk of closure or reduction in the event of higher fuel prices. The study predicted that gasoline prices over $3.00/gallon could lead to combined losses of $7-$11 billion of profits for Detroit automakers. After the report's release, gasoline prices rose 30-60% and spiked over $3.00/gallon. Ford and GM have so far reported over $19.3 billion in combined losses. In addition, they have lost 4.4 points of market share since 2004.

When the report was released, it was criticized by Detroit automakers. They said our fuel price scenarios (We had two: $2.86 and $3.37) were implausible. GM told the *Wall Street Journal* that our estimates of variable profit per vehicle were low (WSJ, 5/13/05). In fact, it was our estimates of the impact of gasoline above $3.00/gallon that were low—the actual impacts on share and profits exceeded our predictions.

Given that the vulnerability of GM and Ford to high fuel prices has been exposed, the question becomes: How are they addressing this vulnerability in their restructuring plans? The answer, in terms of announced closures or reductions in plants and products, is that they are not moving fast enough. Our 2005 study identified as vulnerable the plants that were producing large SUVs and pickup trucks. Events of the past year confirmed that vulnerability, as sales of these vehicles fell.

In our 2005 study, we described signs of weakness and fuel-price vulnerability in large SUVs and pickup trucks in the form of the ever-higher incentives needed to maintain sales in units beginning in 2001. Detroit automakers apparently ignored these early-warning signs or thought they had more time to adjust to the rapid shift away from gas-guzzling large SUVs and pickup trucks. Clearly, their restructuring plans did not adequately prepare them for the precipitous decline in large SUV sales. Instead, they have been forced to begin eliminating or reducing jobs and closing plants, including some that make relatively more fuel-efficient cars. We described signs of weakness and fuel-price vulnerability in large SUVs and pickup trucks in the form of the ever-higher incentives needed to maintain sales in units beginning in 2001. Events of the past year confirmed that vulnerability, as sales and prices of these vehicles fell.

The table below compares our list of vulnerable plants from the 2005 study to the announced plans of GM and Ford. Both announced plans for plant reductions. Both Ford and GM are reducing their capacity in car models that have had high and growing sales into low profit daily rental fleets. They are both also reducing their capacity in midsize SUVs. However, both companies committed more than four years ago to major redesigns of their large SUVs, and they are holding onto capacity to produce these larger, less fuel-efficient vehicles. The next section of this report looks at some actions the automakers could take to address their vulnerability more effectively.

Auto-maker	Plant	Products	2005 UMTRI Study	GM 11/05 Ford 3/06	Other actions
GM	Arlington, TX	Large SUV (Escalade, Suburban, Tahoe, Tukon)	ceased or reduced		potential for reduced demand after initial launch
GM	Janesville, WI	Large SUV (Suburban, Tahoe, Yukon)	ceased or reduced		potential for reduced demand after initial launch
GM	Moraine, OH	Midsize SUV (Bravada, Envoy, Rainier, Trailblazer)	ceased or reduced	reduced 2006	
GM	Oklahoma City, OK	Midsize SUV (TrailBlazer, Envoy)	ceased or reduced	ceased early 2006	
Ford	St. Louis, MO	Midsize SUV (Explorer, Mountaineer)	ceased or reduced	ceased	
Ford	Wayne, MI (Michigan Truck)	Large SUV (Expedition, Navigator)	ceased or reduced		reduced due to lower demand
Ford	St. Thomas, Ontario, Canada	Large Car	ceased or reduced		will benefit from Wixom closure
Ford	Wixom, MI	Large and Specialty Car	ceased or reduced	ceased 2007	
Daimler-Chrysler	Newark, DE	Midsize SUV (Durango)	ceased or reduced		reduced due to lower demand
GM	Toledo, OH	RWD Transmission	reduced		reduced due to lower demand
GM	Ypsilanti, MI (Willow Run)	RWD Transmission	reduced		

Auto-maker	Plant	Products	2005 UMTRI Study	GM 11/05 Ford 3/06	Other actions
GM	Romulus, MI	V8 Engine	reduced		potential for reduced demand after initial launch
Ford	Sharonville, OH	RWD Transmission	reduced		
Ford	Essex, Ontario, Canada	V8 Engine	reduced		reduced due to lower demand
Daimler-Chrysler	Kokomo, IN	RWD Transmission	reduced		reduced due to lower demand
Daimler-Chrysler	Detroit, MI (Mack Avenue)	V8 Engine	reduced		reduced due to lower demand
Ford	Atlanta, GA	Midsize Car (Taurus, Sable)		ceased	
Ford	St. Paul, MN	Small Pickup (Ranger)		ceased	
Ford	Norfolk, VA	Large Pickup (F-150)		ceased	
GM	Lansing, MI Craft Center	Chevrolet SSR		ceased mid 2006	
GM	Spring Hill, TN	Compact Car		reduced late 2006	
GM	Oshawa, Ont. Plant 1	Midsize Car		reduced 2006	
GM	Oshawa, Ont. Plant 2	Midsize Car		ceased 2008	Could be reopened later with new platform
GM	Doraville, GA	Minivan		ceased 2008	

Automaker	Plant	Products	2005 UMTRI Study	GM 11/05 Ford 3/06	Other actions
GM	Flint V6 engine	V8 Engine		ceased 2008	closed due to ripple effect from assembly plant closings
GM	Ste. Catherines Powertrain	Powertrain parts		ceased 2008	closed due to ripple effect from assembly plant closings
GM	Pittsburgh Stamping	Stampings		ceased 2007	closed due to ripple effect from assembly plant closings
GM	Lansing Stamping	Stampings		ceased 2006	closed due to ripple effect from assembly plant closings
Ford	Batavia Transmission	Transmissions		ceased	closed due to ripple effect from assembly plant closings

Technological Options and Strategy Choices

As part of this study, we assessed the ability for manufacturers to incorporate new and existing technologies by 2010 to improve the fuel economy performance of their overall fleet without changing their product portfolios. This section summarizes our assessment, with a more detailed discussion in the appendix. The appendix was written by Feng An, Roland Hwang, Walter McManus, and Alan Baum.

We adopted two means to improve fuel economy. The first, which applies only to new powertrains, is based on a detailed powertrain-by-powertrain engineering assessment and a detailed forecast of product plans for calendar year 2010. Our assessment differs from previous studies (e.g., DeCicco et al. [2001] and NAS [2002]) in that we used a detailed forecast of products and powertrains for each manufacturer for 2010 to estimate near-term fleet-wide potential. The second, which applies to "carry-over" powertrains (introduced before 2005), is based on redirecting extrapolated historical rates of technology improvement.

By combining an engineering assessment of what fuel economy technologies are available with a detailed forecast of each manufacturer's production plans (including the timing when individual models would have an opportunity to integrate new technology), we can develop a realistic assessment of the technical potential to raise fuel economy. We also incorporate a decision-making rule to determine what level of technology to apply based on the incremental costs of alternative fuel-economy-improvement packages and consumers' willingness to pay. In this way, we ensure that the package makes financial sense.

To assess the opportunity for technology improvement, we divide vehicles into two categories. The first category consists of those vehicles that are scheduled for a new engine or new platform in model years 2007 to 2010. These vehicles have modern engines that have the opportunity for substantial improvement. The second category consists of those vehicles that are not scheduled for new engines between now and 2010. While these engines have less opportunity for improvement, there are nonetheless incremental opportunities for improvement -- through refinements of existing technology, recalibration of engines, and by directing the technologies likely to be adopted toward fuel economy improvements (rather than towards increasing power.)

For the first category, we assume that any eligible vehicle model can be improved to the fuel economy level estimated by the National Academy of Science's recent fuel economy study (NAS 2002) for that class segment. We evaluated two packages of fuel-saving technologies. The two packages are the "Cost-efficient, 14-year", and the "Path 2". All of the Path 2 technologies currently exist, but not across the entire fleet. The "Cost-efficient, 14-year" package includes Path 1 (technologies which are likely to be adopted) and a subset of Path 2 technologies -- those that the NS study defines as "Cost-efficient" or pays for itself over 14 years (at $1.50/gallon and 12% discount rate) on the margin. More details on the package and our methodology can be found in the appendix.

For carry-over engines not scheduled for replacement between 2007 and 2010, the "Cost-efficient" and Path 2 packages are not available. Instead, we applied improvements that rely on planned technologies to increase specific power (horsepower per liter) and apply them to enhancing fuel economy. The tradeoff is at the expense of increasing the specific power (horsepower per liter) of the engine. A recent study shows that just using planned technologies, the light truck fleet could be improved by 2.8% per year (EEA 2005). Honda has announced a 5% improvement (although this is probably a combination of new engines and improvements to existing engines.) To illustrate the opportunity for an automaker to rapidly improve fuel economy even without new technologies, Ford recently announced its MY2007 Focus would achieve 3 MPG higher on the highway and 1 MPG higher on the city cycle (a 9% and 4% improvement respectively) simply through powertrain recalibration (Hoffman, "Big Plans for Tiny Focus," Detroit News, 8/2/06).

For the scenario analysis conducted by this study, we defined two choices of fuel economy strategies for automakers. To incorporate the technology options and to explore the impacts of following very different strategies, we assumed that each automaker could choose between:

- Business As Usual (BAU): An automaker following the BAU strategy would make only those fuel economy improvements that are necessary to meet the CAFE requirements in 2010.
- Proactive (PROA): An automaker following the Proactive (PROA) strategy would make all the improvements identified in our technology assessment, provided they make financial sense to consumers.

The table below shows the number of vehicle configurations that would be eligible for fuel economy improvements for each automaker, according to our technology assessment that would make financial sense to consumers. Since the value to consumers of the improvements depends on the price of fuel and the discount rate consumers use to value future fuel savings, the number of vehicle configurations eligible for improvements also depends on these two variables. The table shows if the price of fuel and the consumers' discount rate were known with certainty, then automakers would choose to improve more vehicle configurations if the fuel price were higher or if the consumers' discount rate were lower.

Vehicle Configurations Eligible for Fuel Economy Improvements by 2010

	Automaker	Total	Fuel Price $3.10/gallon Powertrain New	Fuel Price $3.10/gallon Powertrain Carry-Over	Fuel Price $2.00/gallon Powertrain New	Fuel Price $2.00/gallon Powertrain Carry-Over
	DCX	242	28	24	28	1
	Ford	215	31	79	30	63
Consumer	GM	251	44	130	42	73
Discount	Honda	49	1	0	1	0
Rate	Nissan	62	3	32	3	10
0%	Toyota	67	7	4	8	2
	Others	259	8	12	7	0
	All	**1,145**	**122**	**281**	**119**	**149**

	Automaker	Total	Powertrain New	Powertrain Carry-Over	Powertrain New	Powertrain Carry-Over
	DCX	242	28	1	28	0
	Ford	215	30	54	28	27
Consumer	GM	251	40	72	38	5
Discount	Honda	49	1	0	1	0
Rate	Nissan	62	3	9	2	0
7%	Toyota	67	7	0	8	2
	Others	259	8	2	6	0
	All	**1,145**	**117**	**138**	**111**	**34**

However, neither the fuel price in 2010 not the discount rate consumers would use in 2010 to value future fuel savings are known with certainty today, when automakers must decide which vehicle configurations to improve. In order to define one consistent set of vehicle configurations that would be improved under the PROA strategy, we developed probability-weighted forecasts of fuel price and discount rate.

For the discount rate we use the average of 0% and 7%: 3.5%. Given that the average price of fuel in 2006 is likely to be higher than it was in 2005 ($2.60/gallon versus $2.30/gallon), an assumption of equal probabilities for $2.00/gallon and $3.10/gallon is not as acceptable as it is for the discount rates. We thus assigned a somewhat higher probability (.545) for $3.10/gallon than for $2.00/gallon (.455), yielding the probability-weighted predicted price in 2010 of $2.60/gallon.

The table below gives the number of vehicle configurations of each automaker that define the PROA strategy. The percent of base sales represented by these vehicle configurations is also shown.

Vehicle Configurations Eligible for Fuel Economy Improvements by 2010

Automaker	Total	New Powertrain		Carry-Over Powertrain	
		Number	Percent of Automaker's Base Sales	Number	Percent of Automaker's Base Sales
DaimlerChrysler	242	28	23.1%	1	2.0%
Ford	215	30	32.3%	64	34.8%
GM	251	44	17.5%	73	30.7%
Honda	49	1	2.0%	0	0.0%
Nissan	62	3	3.5%	10	13.5%
Toyota	67	7	7.5%	0	0.0%
Others	259	8	8.3%	2	3.2%
All	**1,145**	**121**	16.9%	**150**	15.9%

Fuel price $2.60/gal; discount rate 3.5%
Changes due to sales mix not included

Ford has the most potential to improve fuel economy by either means. By 2010, Ford could improve new powertrains that account for 32.3% of its base sales, and could also improve carry-over powertrains that account for another 34.8% of its base sells. DaimlerChrysler and GM could improve new powertrains representing significant shares of its sales. GM could improve carry-over powertrains representing significant shares of its sales. The larger Japanese automakers, which have significantly more fuel-efficient fleets than do Detroit automakers, have few improvements that would pay for consumers. The implications for measured MPG by manufacturer are shown in the table below.

Increases in MPG by Automaker

Automaker	Base Average MPG	Increase in MPG at Base Sales Mix
DaimlerChrysler	23.60	1.41
Ford	23.71	2.91
GM	23.58	1.47
Honda	27.44	0.18
Nissan	26.23	0.34
Toyota	27.10	1.11
Others	26.88	0.92
All	**24.82**	**1.49**

Fuel price $2.60/gal; discount rate 3.5%

Changes due to sales mix not included

If Ford were to adopt the PROA strategy, then it could increase its baseline fuel economy by 2.91 MPG (a 12% improvement). This potential increase is computed at our baseline sales forecast for Ford's vehicles and does not include the impact of changes in sales mix. By adopting the PROA strategy, GM could increase its baseline fuel economy by 1.47 miles per gallon (6%), and DaimlerChrysler could increase its baseline fuel economy by 1.41 miles per gallon (6 percent). Other automakers have much less potential to increase fuel economy consistent with the willingness of Americans to pay for the fuel-saving technologies. Make no mistake, the opportunity that the Detroit automakers have to profitably increase the fuel economy of their fleets by 7-17%, is largely due to the current lower than average fuel economy level of their fleet. Honda, Toyota, and Nissan have fleets with better fuel economy today and in our baseline; and they would continue to have fleets with better fuel economy than GM, Ford, and DaimlerChrysler even if all automakers made the improvements proposed here. For Detroit, the PROA strategy would narrow, but not eliminate, their disadvantage in fuel economy relative to Honda, Toyota, and Nissan.

At our baseline sales forecast in 2010, we estimate a 6% increase in overall fuel economy from the baseline 2010 fuel economy or 7.4% increase over model year 2005 estimated fuel economy of 24.5 mpg (EPA 2005). The 7.4% increase over today's level is consistent with the 4% to 8.2% range we derived from a review of other studies (see Appendix) and equates to a modest 1.5% annual increase between 2006 and 2010.

Market Model

The market model used in this study was an extension and enhancement of that used in McManus et al. (2005). Our model of the automotive market consists of two sub-models. The first sub-model computes total industry sales of all vehicles, and the second sub-model computes the market share of individual vehicles. The two sub-models simultaneously determine the unit sales and attributes of all vehicles, which can then be aggregated by segment or manufacturer.

1. **Total Industry Sales** (first sub-model) Our base sales for 2010 are from the forecast by The Planning Edge. The Planning Edge forecast incorporates the effects of demographics, economics, and competitive product plans. Starting from base sales, we assess the market impact of different fuel prices and manufacturer fuel economy strategies on vehicle sales.
2. **Market Shares by Vehicle Configuration** (second sub-model) The UMTRI Automotive Consumer Choice model is used to estimate the effects of gasoline prices, consumer tastes, and the competitive behavior of automakers on sales, prices, and variable profit for each of the 1,145 manufacturer, model, engine, transmission, drive, and body style configurations. We aggregate the 1,145 configurations by segment, manufacturer, and other dimensions for analysis. Econometrically, the UMTRI Automotive Consumer Choice model is a nested multinomial logit (NMNL) that describes the mapping of consumers' preferences for attributes of vehicles (power, size, fuel economy) into consumers' preferences for vehicles. In this study, we expanded the NMNL used in McManus et al. 2005.

To estimate the impact of lower sales and production levels on employment for the United States and for three highly auto-intensive states (Michigan, Ohio, and Indiana), we use a well-known regional economic model (REMI).

Change in Total Industry Sales, Example Calculation

The UMTRI Automotive Consumer Choice model predicts changes in shares of sales, so we modeled the impact of scenarios and actions of automakers and consumers on total industry sales in a separate sub-model and fed the result into the UMTRI Automotive Consumer Choice sub-model.

Changes from base total industry sales are determined in the sub-model by the average values of vehicle attributes and estimates of the effects of these attributes on industry-level sales. We measure the effects of attributes on sales through elasticities, which give the percentage change in sales resulting from a 1% change in the attributes. The table below is an example of how the average attributes at our base case, the change in these average attributes weighted by base sales units, and our estimated elasticities used to estimate the impact on total industry sales. The impact of each attribute's change is calculated and these separate changes are summed across attributes to compute the total impact.

Total Industry Sales

Attribute	Base Value of Attribute Average Weighted by Base Sales	New Value of Attribute Average Weighted by Base Sales	Percent Change in Attribute	Impact of Attribute Change on Sales (Elasticity)	Percent Change in Sales
Performance (horsepower per ton)	115	115	0.0%	0.03	0.0%
Curb weight (lb)	3930	3930	0.0%	0.03	0.0%
Footprint (sq ft)	49.4	49.4	0.0%	0.03	0.0%
Fuel Cost (cents per mile)	9.3	12.5	34.8%	(0.10)	(3.5%)
Price	$26,740	$26,740	0.0%	(0.75)	0.0%
Sales					**(3.5%)**

Memo: Implied Fuel-Price Elasticity of Sales

	Base	New	Percent Change	Implied Elasticity
Fuel Price (cents per gallon)	230	310	34.8%	(0.10)

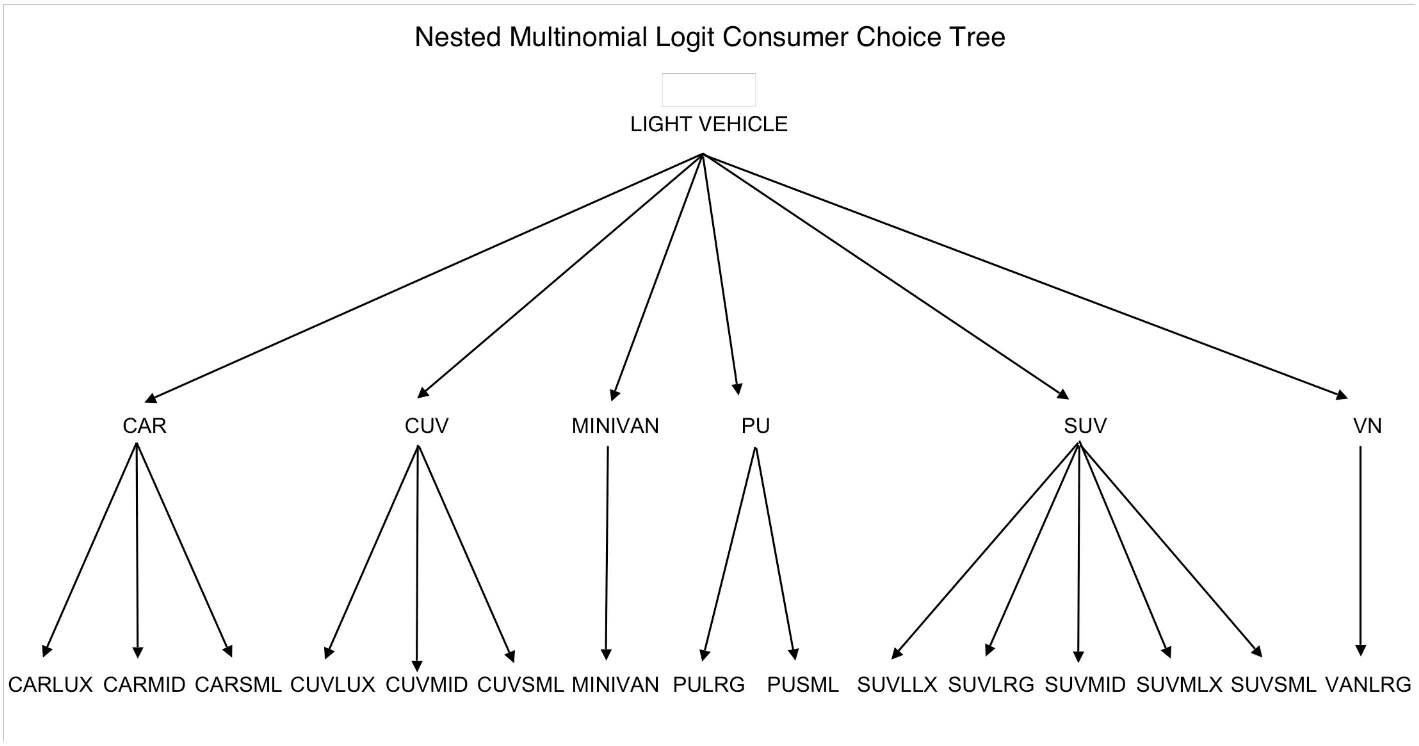
In the UMTRI Automotive Consumer Choice model, the top-level price elasticity is -1.0, but to be conservative we computed the impact on total sales of fuel price and attribute changes with a smaller elasticity, -0.75. The appropriate elasticity for direct price changes (such as a cash rebate) is -1.0, but when the change is indirect (through willingness-to-pay), the impact could be smaller.

The UMTRI Automotive Consumer Choice Model

Discrete choice models are ideally suited to markets with many individual product configurations. These models match the intuitive notion that a vehicle is a bundle of attributes and that its value to a consumer is derived from the value the consumer places on the attributes. The demand for vehicles is seen as a derived demand arising from the demand for vehicle attributes.

This study enhances the model in McManus et al. (2005), which defined vehicles by only two attributes: price and fuel economy. This was an appropriate restriction for that study, since its aim was simply to estimate the sales and profit losses resulting from higher fuel prices. The potential losses we predicted in that study would be massive for Detroit and would likely stimulate investment in fuel-saving technologies.

This study's aim is to assess the potential for Detroit automakers to improve fuel economy by 2010. We expand the list of attributes to include measures of vehicle performance and size. McManus et al. (2005) derived a key parameter, consumers' willingness-to-pay for fuel economy, from assumptions about the useful life of the typical vehicle, the number of miles driven annually, and consumers' rate-of-time preference. While the practice of using such assumptions in this context is common, small variations in assumptions produce an uncomfortably wide range of estimates and conclusions. In this study, we used a procedure (explained below) that narrows this range.


Nested Multinomial Logit Consumer Choice Tree
LIGHT VEHICLE
CAR
CUV
MINIVAN
PU
SUV
VN
CARLUX
CARMID
CARSML
CUVLUX
CUVMID
CUVSML
MINIVAN
PULRG
PUSML
SUVLLX
SUVLRG
SUVMID
SUVMLX
SUVSML
VANLRG

The nested consumer choice tree we used in this study, shown in the figure above, is identical to that used in McManus et al., 2005. Consumers choose among all the 1,145 vehicle configurations available in the U.S. market. The nested tree is a convenient tool for interpreting the model, but should not be taken to imply that consumers choose sequentially. We groups similar vehicles together in the nested structure since they are likely to exhibit similar responses to events and market changes. The highest level captures interactions between six vehicle types: CAR, CUV (crossover utility vehicle), MINIVAN, PU (pickup truck), SUV (sport utility vehicle), and VN (large van). The next level down captures the interactions between vehicle segments within CAR, CUV, PU, and SUV. (MINIVAN and VN are not partitioned into segments, so this step is skipped.) At the third and lowest level we capture the interactions between vehicle configurations within product segments.

Vehicle's Value Comes from Its Attributes

We assume that the value to consumers of a vehicle is derived from the value to consumers of the vehicle's attributes. If I (as a consumer) value fuel economy and would be willing to pay $500 to increase the fuel economy by 1.0 MPG when gasoline costs $2.30/gallon, then, according to our assumption, I would be willing to pay $500 more for a vehicle that offers 1.0 MPG more than another vehicle that is identical in all other respects. I would also be willing to pay more than $500 for the additional MPG if the price of fuel were unexpectedly higher than $2.30.

By treating the value of the vehicle as a bundle of values of attributes, we can predict the impact on demand for vehicles caused by changes in external conditions (e.g., price of fuel) that affect the values of attributes (e.g., MPG). To put this more rigorously in terms of economic theory, our assumption is that the utility that the i^th^ consumer derives from the j^th^ vehicle is given by equation 1.

$$(1) \qquad u_{ij} = a_j + b\left(price_j + w_1 performance_j + w_2 size_j + w_3 \frac{p_g}{mpg_j} \right)$$

The known quantities in equation 1 are the vehicle attributes of price, performance, size, and MPG; and the price of gasoline. The parameters of the utility function that need to be estimated are $\boldsymbol{a_j}$ (an intercept that varies by vehicle); $\boldsymbol{b}$ (the slope of utility with respect to vehicle price); and the three $\boldsymbol{w}$ parameters (consumers' willingness to pay for increments of the associated attributes.) Note that the price of gasoline (in cents per gallon) divided by MPG is the vehicle's fuel cost per mile driven (in cents per mile), so the parameter $\boldsymbol{w_3}$ measures willingness to pay for a one-cent reduction in fuel cost per mile.

Another way to think about of $\boldsymbol{w_3}$ is as the "discounted present value" of lifetime vehicle miles. The value of one-cent per mile ($\boldsymbol{w_3}$) times lifetime vehicle miles would yield the total value—if vehicle miles did not change over time and if consumers valued saving one cent per mile in future years the same as they value saving one-cent per mile this year.

Each of the 1,145 vehicle configurations offered for sale is unique, and most consumers buy only one vehicle at a time. Models of demand that assume a continuously variable product would be inappropriate. Instead, we model the demand for a specific vehicle as the probability that the i^{th} consumer chooses the j^{th} vehicle, as in equation 2.

(2) $$p_{ij} = \frac{e^{u_{ij}}}{\sum_{k \in j} e^{u_{ik}}}$$

Estimates of Parameters

The UMTRI Automotive Consumer Choice model is a nested multinomial logit (NMNL). (McFadden [1973] originated the NMNL. See Train [2003] for a comprehensive description of NMNL and related models.) Researchers have recently begun to apply NMNL models to automotive questions.

One strand of research has concentrated on improving the accuracy of the NMNL model with innovations in statistics and data. Berry, Levinsohn, and Pakes (2004) explored the role of detailed consumer attribute data, together with data on the second choices of consumers (given to them by GM) in estimating a demand system for passenger vehicles. They found GM's second-choice data to be helpful, but concluded that to pin down the absolute level of elasticities, some outside information must be used. (More about GM's data below.)

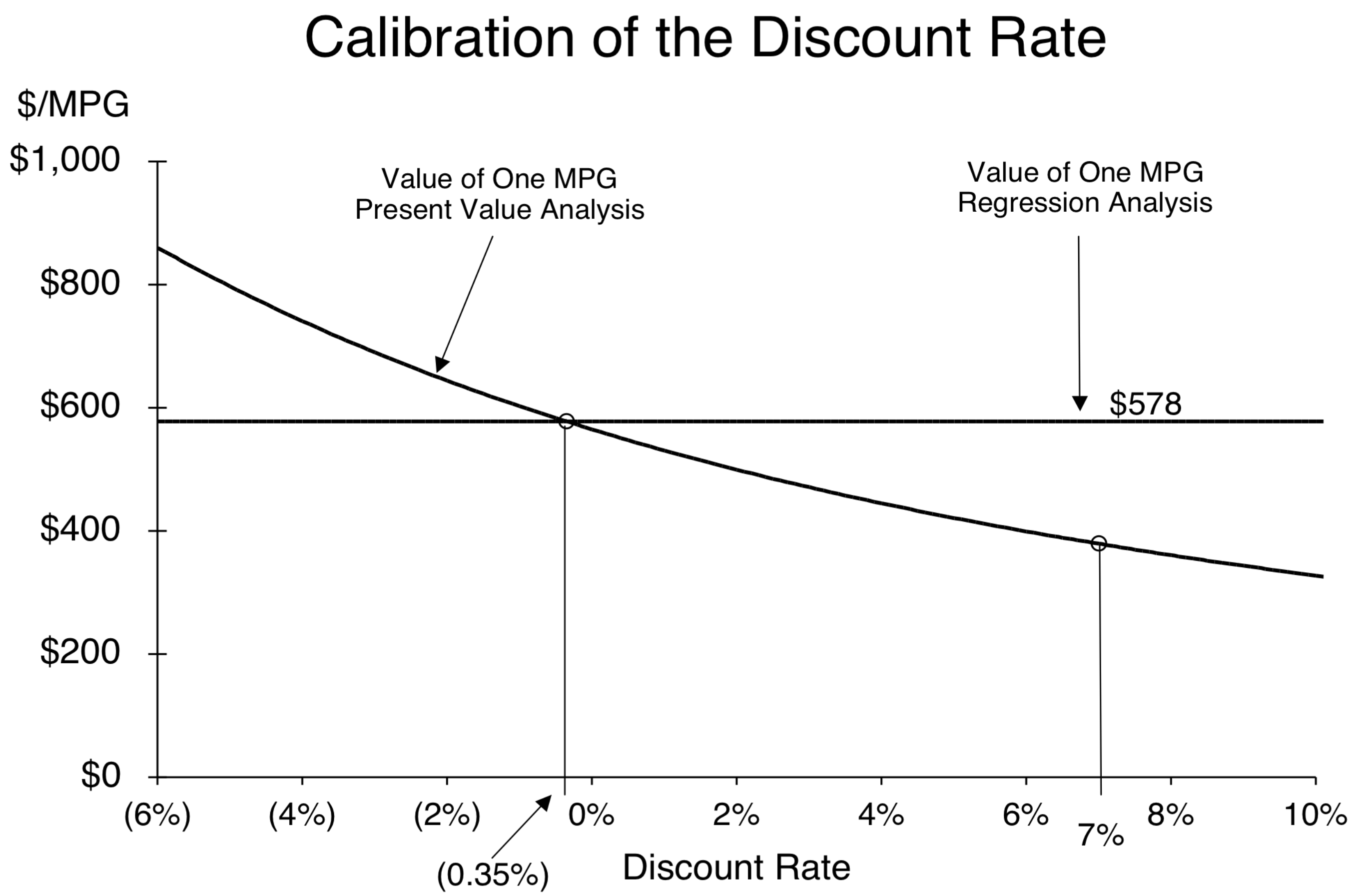
Feng, Fullerton, and Gan, (2004) used ownership rather that purchase as the dependent variable and extended the NMNL by incorporating choices about miles traveled. They found that pollution reduction policies influence both the mix of vehicles a household wants and the number of miles traveled. Bento, Goulder, Henry, Jacobsen, and Von Haefen (2005) also used the NMNL model with ownership rather than purchases as the dependent variable to examine the distributional effects of a gasoline tax. They concluded that whether the tax is regressive or not depends on how tax proceeds are "recycled" to consumers.

Train and Winston (2006) used the NMNL model to examine the causes of the loss in market share for U.S. automakers, and concluded that nearly all of the loss in market share could be explained by changes in the basic attributes of vehicles: price, size, power, operating cost, and body style. These are the variables we use in our model.

A second strand of research has concentrated on applying the NMNL models to inform policy decisions, using the NMNL form and deriving parameter estimates from outside the model. Our model is in this strand of research. Greene, Duleep, and McManus (2004) used the NMNL model with external parameter estimates to examine the future potential of hybrid and clean diesel powertrains. McManus (2005) used a simplified NMNL model with external parameter estimates to predict the impact on sales, profits, and employment of high fuel prices, assuming automakers follow a "Business as Usual" (BAU) strategy on fuel economy. Santini and Vyas (2005) applied the NMNL model with external parameter estimates to simulating advanced vehicles introduction decisions.

One external (external to an NMNL model) source of parameter estimates that has been somewhat overlooked is hedonic regression, a method developed by Griliches (1961) and used today by the U.S. Bureau of Labor Statistics (BLS) to adjust the Consumer Price Index (CPI) for quality changes (See Johnson, Reed, and Stewart [2006] for documentation of the expansion of hedonic regression models at the BLS).

A hedonic regression would estimate the relationship between vehicle price (as the dependent variable) and various attributes of the vehicle (as the independent variables). The regression coefficients measure the implicit "price" of the attributes. Espey and Nair (2005) estimated a hedonic regression with 2002 data on Manufacturer's Suggested Retail Price (MSRP) and vehicle attributes. (Also see Espey's commentary on policy implications in ***Regulation*** (Cato Institute), Winter 2005-2006).



We estimated a hedonic regression using actual transaction prices instead of MSRP as the dependent variable -- with performance, size, and fuel economy as the independent variables. The figure above summarizes our results for the value of fuel economy and shows how we used the hedonic estimate of the value of fuel economy to calibrate the discount rate in our model.

From the hedonic regression, we estimate that the average value of one MPG was $578 in 2005. Espey and Nair (2005) estimated a similar value ($613) in 2002. To calibrate the discount rate, we constructed the present value curve in the figure, which shows the value of improving fuel economy by one MPG as a function of the discount rate, given the fuel price in 2005 ($2.30/gallon). The discount rate at which consumers implicitly discount future fuel savings is that rate that equates the present value calculation and the hedonic value—(0.35%)—the discount rate at which the two lines intersect.

Assuming (along with Espey and Nair [2005] and CBO [2003]) a 14-year useful life for the average vehicle and assuming annual miles decline at 5.2% per year of vehicle age, the discount rate implied by the analysis is negative, (0.35%). The discount rate can be thought of as the real market rate of interest minus the expected rate of inflation in fuel prices (over and above general price inflation). The real market rate of interest is on the order of 7%, so a negative discount rate implies that consumers expect inflation in fuel prices to be faster than 7Espey and Nair (2005) also found very low or negative discount rates, and suggested that consumers value reductions in greenhouse gases and other emissions. This is a plausible interpretation, but we believe expected inflation in fuel prices is a more likely cause of negative discount rates. To be conservative, we used 0% as the lower bound on the discount rate in our scenarios, even though negative discount rates are plausible. This is much lower than rates used in other studies. CBO (2003) and McManus et al. (2005) used 14%. Santini and Vyas (2005) used 10%. Greene, Duleep, and McManus (2004) used 0.0%, but assumed that new vehicle buyers value only about the first three years of cost savings.

Choosing the discount rate to use in our analysis is more than a mere technicality. The discount rate summarizes an assumption about the value consumers place on future benefits and costs and their expectations of future fuel prices. Consumer demand for automobiles is derived from the value consumers put on current and future services (transportation, fashion) offset by current and future costs. The higher the discount rate, the less value put on future services and costs relative to current services and costs.

The table below summarizes this section by giving our estimates of demand elasticities for price, performance, size, and fuel cost per mile. The elasticity of demand for fuel cost per mile is shown at the two alternative discount rates.

UMTRI Automotive Consumer Choice Model: Demand Elasticities

	Price	Performance	Size	Fuel Cost per Mile (Discount Rate 0%)	Fuel Cost per Mile (Discount Rate 7%)
Car-Luxury	(1.90)	0.67	0.50	(0.23)	(0.16)
Car-Midsize	(2.00)	1.29	0.96	(0.46)	(0.31)
Car-Small	(2.30)	1.41	1.31	(0.51)	(0.34)
CUV-Luxury	(1.90)	0.65	0.58	(0.33)	(0.22)
CUV-Midsize	(2.00)	1.00	0.84	(0.47)	(0.31)
CUV-Small	(2.30)	1.37	1.25	(0.59)	(0.40)
Minivan	(2.00)	0.98	0.97	(0.56)	(0.38)
Pickup-Large	(1.40)	0.79	0.75	(0.39)	(0.26)
Pickup-Small	(2.00)	1.36	1.14	(0.62)	(0.42)
SUV-Large Luxury	(1.90)	0.49	0.42	(0.27)	(0.18)
SUV-Large	(2.00)	0.83	0.73	(0.51)	(0.34)
SUV-Midsize	(2.10)	1.12	0.85	(0.58)	(0.39)
SUV-Midsize Luxury	(1.90)	0.43	0.47	(0.28)	(0.18)
SUV-Small	(2.30)	1.86	1.00	(0.49)	(0.33)
Van-Large	(1.50)	0.89	0.98	(0.50)	(0.34)
Car	(2.00)	1.07	0.84	(0.38)	(0.26)
Crossover Utility Vehicle	(1.90)	0.93	0.81	(0.43)	(0.29)
Minivan	(2.00)	0.98	0.97	(0.56)	(0.38)
Pickup	(1.40)	0.82	0.76	(0.39)	(0.26)
Sport Utility Vehicle	(1.90)	0.81	0.66	(0.44)	(0.30)
Van	(1.50)	0.89	0.98	(0.50)	(0.34)
Total Vehicles	(1.00)	0.51	0.44	(0.23)	(0.15)

Elasticity = the percentage change in demand for a 1 percent change in the attribute.

Comparing Price-Elasticities

The price elasticities we use in this study were derived from McManus et al. (2005). GM maintains a set of price elasticities between segments that are based on new-vehicle buyers' second choice—the vehicle they would have bought had the vehicle they actually bought not been available. The studies by Kleit [2004] and Parry et al. [2004] used elasticities provided by GM. (The Kleit [2004] article is a published version of a study done for GM.) Berry, Levinsohn, and Pakes [2004)], as discussed in an earlier section of this report, were given the raw data on the second-choices of consumers. They found GM's second-choice data to be helpful, but concluded that to pin down the absolute level of elasticities, some outside information must be used.

Our elasticities are more conservative than GM's in all but two product segments—luxury car and large SUV. In these two segments, the differences do not appear to influence our results. We do not classify vehicles into the same segments that GM does. We compared our luxury car segment to GM's large car segment, and we had to aggregate a few of our SUV and CUV segments to match GM's large SUV segment. The large car segment is very small so the difference is not important to our results. GM's large SUV segment elasticity is -1.88 while our equivalent segment elasticity is -2.00, a difference too small to affect our results. Overall, our elasticities are more conservative than GM's, and if we were to calibrate exactly to GM's, the impacts described later in this paper would be larger.

Scenario Analysis

In this section, we describe the scenario analysis we conducted for this study. The purposes of the scenario analysis are to understand the risks that automakers face in deciding what fuel economy strategy to follow, to understand how the various risks influence automakers' decisions, and to suggest the decisions that automakers are likely to make and the associated market outcomes. To accomplish these purposes, we need to define automakers' goals and to estimate the impact on these goals of changes in important but uncertain variables (e.g., fuel price). We rely on a model of competitive behavior called "game theory" to predict the likely decisions by automakers. If it turns out that automakers do not appear to be acting as predicted by game theory, then the theory can help identify the sources of the disparity and suggest alternative public policies to achieve desired results.

We defined four market-demand scenarios based on two alternative fuel prices and two alternative consumer discount rates. The diagram below shows the four alternative market demand scenarios. We expect the market demand for fuel economy (and the gains to automakers from improving the fuel economy of their vehicles) to be greatest in the scenario with a fuel price of $3.10/gallon and a consumer discount rate of 0% (Market Demand I) and lowest in the scenario with a fuel price of $2.20/gallon and a consumer discount rate of 7% (Market Demand IV).

		Fuel Price	
		$3.10/gallon	$2.00/gallon
Consumer Discount Rate	0%	Market Demand I	Market Demand II
	7%	Market Demand III	Market Demand IV

On top of these four market-demand scenarios we defined additional scenarios based on strategic choices by five automakers (DaimlerChrysler, Ford, GM, Japan 3, and others) to define a total of 128 scenarios. We aggregated the three largest Japan-based automakers into one "aggregate automaker" and all other automakers into another "aggregate automaker." As described in the section on technological options, we defined two alternative fuel economy strategies "Business as Usual" (BAU) and "Proactive" (PROA) that each automaker is assumed to choose between.

Automakers' Goal: Maximum Feasible Pretax Variable Profit

This study estimates the impact of specific change in gasoline prices and technological choices on automakers' sales and pretax variable profits. It is reasonable to assume that manufacturers base their decisions about technologies to put in their vehicles on their expectations of the impacts of their decisions on their profits. The economic success of an enterprise is measured by its profit—the difference between the revenue it receives from customers for its products and the total costs of producing, selling, and distributing its products. For a specific change in product technologies or market conditions, the change in the enterprise's success is measured by the resulting change in profits.

We focus on the efficiency of various technologies and product decisions in generating incremental profits rather than on total profits, which are the cumulative result of prior actions and decisions. Due to the fact that we are interested in changes in profits resulting from new technologies and products, we ignore fixed costs.

Variable profit-per-unit is defined as a vehicle's wholesale price minus the cost of the materials, labor, and energy inputs used to produce the vehicle. Operationally, we used manufacturer- and segment-specific estimates of gross profit margins to compute variable profits. Variable profit is not affected by the substantial fixed costs associated with building and selling automobiles, such as the amortization of capital equipment (i.e., factories and tools); legacy costs (i.e., pension and medical costs for retirees); marketing costs; and research, development, and engineering costs.

A manufacturer can have substantial variable profits from its automotive operations but still post total pretax losses if its fixed costs are greater than its variable profits. However, the change in total profit resulting from a change in units sold, is always equal to the change in variable profit. This is mathematically true by definition.

Let Q be number of units sold, NP be net profit, VP be variable profit, P be wholesale price, VC be variable cost per unit, and FC be fixed cost. By definition,

$$(1)\, VP = Q(P - VC)$$
$$(2)\, NP = VP - FC\,.$$

Therefore,

$$(3)\;\; NP = Q(P - VC) - FC$$

The first term in equation (3) is a function of the number of units sold (Q). In addition to the direct relationship between net profit (NP) and units sold (Q), there are indirect impacts on profits of units sold because wholesale price (P) and variable cost per unit (VC) are themselves functions of Q. Price (P) is a decreasing function of units sold (Q) because to sell more units the company must lower the price, and variable cost (VC) is an increasing function of units sold because to increase production the company bids up the costs of materials, energy, and other inputs. Fixed costs (FC) by definition do not vary with the number of units sold (Q). The equivalence of changes in total profit and variable profit is demonstrated by the equality of the total differential of net profit (NP) and the total differential of variable profit (VP). These differentials are equal, because the impact of units sold on fixed cost ($\frac{dFC}{dQ}$) is zero by definition.

(4) $dNP = \left[(P - VC) + \left(\frac{dP}{dQ} - \frac{dVC}{dQ}\right)\right]dQ - \frac{dFC}{dQ} = \left[(P - VC) + \left(\frac{dP}{dQ} - \frac{dVC}{dQ}\right)\right]dQ$

(5) $dVP = \left[(P - VC) + \left(\frac{dP}{dQ} - \frac{dVC}{dQ}\right)\right]dQ$

McManus et al. (2005) used variable profit estimates from calendar year 2001-04. We updated our estimates with 2005 data for this study. The table below shows our estimates of average retail transaction prices and variable profit margins by manufacturer and (separately) by segment.

Average Price and Variable Profit Margin, 2010

By Automaker			By Segment		
Automaker	Average Price	Variable Profit Margin	Segment	Average Price	Variable Profit Margin
BMW	$43,245	25%	CARLUX	$41,230	24%
DaimlerChrysler	$27,295	20%	CARMID	$22,200	19%
Ford	$27,670	19%	CARSML	$17,170	18%
GM	$26,570	17%	CUVLUX	$37,180	23%
Honda	$25,890	22%	CUVMID	$27,100	20%
Hyundai	$17,175	19%	CUVSML	$18,490	18%
Nissan	$25,625	22%	MINIVAN	$25,770	20%
Porsche	$74,030	30%	PULRG	$28,910	18%
Subaru	$25,400	18%	PUSML	$20,630	18%
Suzuki	$18,660	18%	SUVLLX	$56,380	25%
Toyota	$26,285	22%	SUVLRG	$35,520	19%
VW	$28,000	23%	SUVMID	$27,190	19%
All	$26,740	20%	SUVMLX	$47,660	24%
			SUVSML	$21,190	17%
			VANLRG	$24,040	17%
			All	$26,740	20%

Fuel Price Uncertainty

A critical risk facing automakers is the future price of fuel. We developed our scenarios with two alternative future fuel prices. The starting point for our fuel price scenarios was the Annual Energy Outlook 2006 (AEO 2006) by the U.S. Energy Information Administration.

Price Scenario	AEO 2006 (2004$)	AEO 2006 (2005$)	This Study
High	$2.46	$2.54	$3.10
Base	$2.11	$2.18	$2.30
Low	$1.99	$2.06	$2.00

The AEO reports historical prices as well as forecast prices in 2004 dollars. We adjusted those figures for inflation in consumer prices from 2004 to 2005 (3.3%), and adjusted the AEO forecast in 2010 to be on a linear trend. The choice of 2010 as the focus is arbitrary, and the general trend is more important than the forecast in any specific year. We define a base case and two alternative scenarios for the price of a gallon of gasoline in 2010.

The AEO high and low price cases are based on different assumptions about how much crude oil exists in proven reserves and on costs of extraction and refining. The AEO high price case assumes 15% lower reserves and higher costs than the base. The AEO low price case assumes 15% higher reserves and lower costs. For this study, the base line was calibrated to the average 2005 price, $2.30, and the range of uncertainty about reserves was doubled to 30% more or less than the base.

Discount Rate Uncertainty

In our scenario analysis, we incorporated uncertainty about the discount rate by computing results with two different discount rates: 0.0% implied by the hedonic analysis and 7.0% as a more conservative alternative. In defining automaker strategies, we used 3.5% (the average of 7% and 0%).

Five Aggregate Automakers: Strategic Players

Our interest is focused on the situation of the Detroit automakers, so we grouped the larger Japanese automakers together in the scenario analysis into a synthetic aggregate referred to as Japan 3 and all other automakers together into an aggregate referred to as "Others". Limiting the number of strategic players also keeps the competitive analysis manageable without a significant loss of realism. The table below lists the market brands included in each of the five aggregates.

Strategic Aggregate Automakers Defined by Marketing Brands

DaimlerChrysler	Ford Motor Co.	GM	Japan 3	Other
Chrysler	Ford	Buick	Acura	Audi
Dodge	Jaguar	Cadillac	Honda	BMW
Jeep	Land Rover	Chevrolet	Infiniti	Hyundai
Mercedes	Lincoln	GMC	Nissan	Kia
	Mazda	Hummer	Lexus	Mini
	Mercury	Pontiac	Scion	Mitsubishi
	Volvo	Saab	Toyota	Porsche
		Saturn		Subaru
				Suzuki
				Volkswagen

Fuel Economy Strategic Alternatives

While there are, of course, many fuel economy strategies that automakers could pursue, we defined two strategies for the scenario analyses that characterize the range of possibilities: BAU and PROA. An automaker with a BAU strategy would make no fuel economy improvements beyond what is necessary to meet the 2010 CAFE standards. An automaker with a PROA strategy would make all fuel economy improvements that would result in a net improvement of the value of the automakers vehicles to consumers (using our consumer choice model to measure value).

Decision-Making Under Uncertainty

Without a clear national policy or a binding agreement among automakers to increase fuel economy performance, individual automakers are free to choose between fuel economy strategies in a highly competitive and risky environment. An automaker's task would be greatly simplified if a number of key uncertainties were removed, such as future fuel prices, how much consumers value fuel economy, competitors' strategies, and what national fuel economy standards will be in place. Since it is not possible to predict the future with certainty, an automaker must somehow take account of the range of possible situations it will find itself facing, and make decisions today that optimize their outcome in light of the uncertain future. To characterize the decision environment the automakers face, we defined the alternative market demand for vehicles and fuel economy that could exist based on the extreme values of the price of fuel and the consumer discount rate, and then estimated the pretax variable profit of each automaker in all possible combinations of choices of BAU and PROA by all the competitors. For example, if the market demand were defined by a fuel price of $3.10/gallon and a 0% consumer discount rate, then one possible outcome would have Ford choosing PROA and all the other automakers choosing BAU. With five strategic players there are $2^5 = 32$ combinations of choices of BAU or PROA by the automakers for each alternative market demand. In total, there are 128 possible market outcomes.

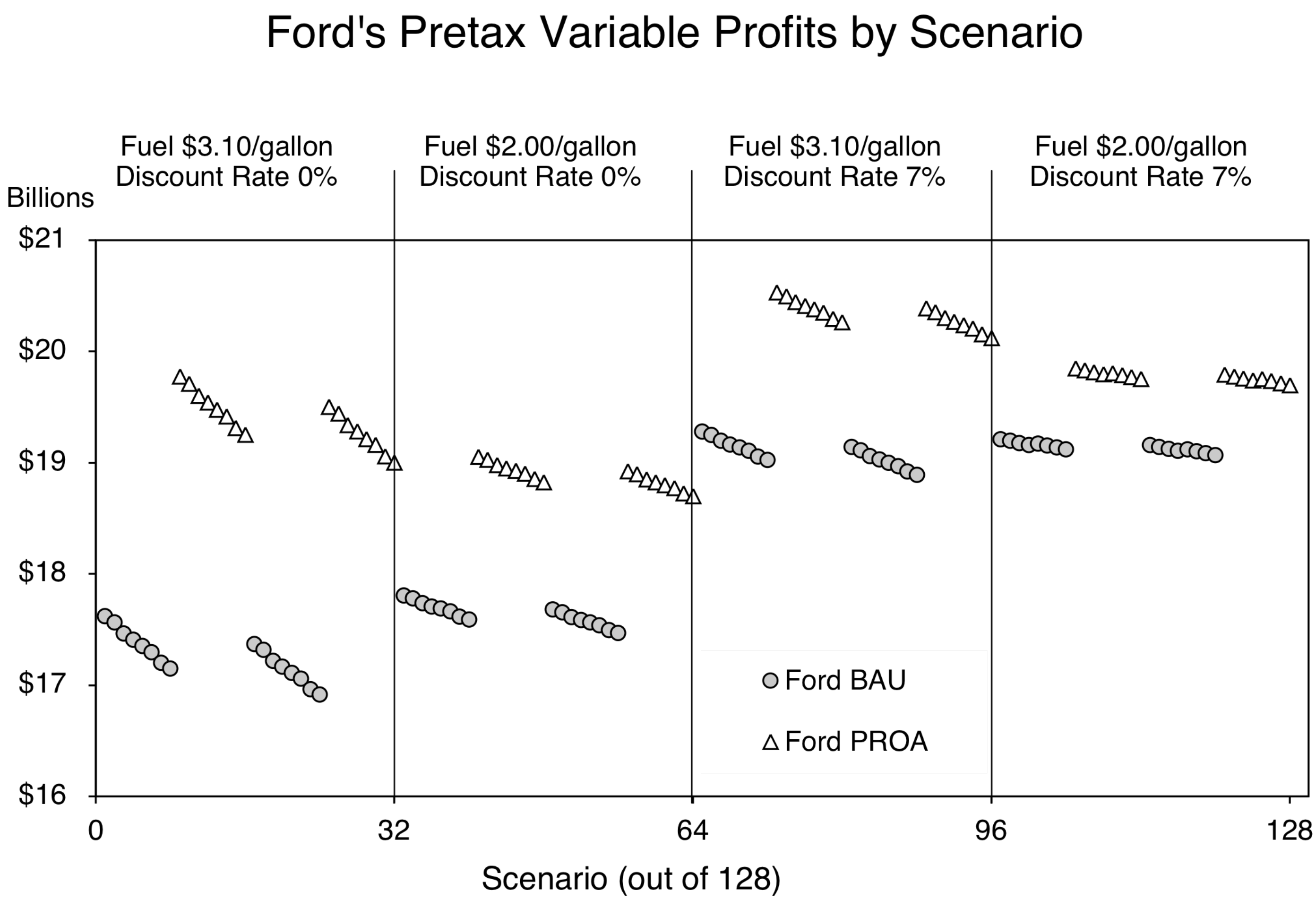
Game theory is ideally suited to analyze the competitive behavior of automakers in this setting and can help researchers and policy-makers predict outcomes in complex market situations. (See Fudenberg and Tirole [1991], the definitive game theory reference textbook.) In this section, we describe a simplified strategic game facing the automakers. Since we are more interested in Detroit automakers than in others (both in the decisions they make and the impacts of competition on them), we define five strategic players: DaimlerChrysler, Ford, GM, Japan 3, and Other. Each strategic player aims to maximize its variable profit and is assumed to have only the two strategic fuel economy options we defined earlier: BAU or PROA.

the "Maximin Rule" (Rawls [1971]) of game theory allows us to "solve" for each competitor's optimal strategy. The maximin principle of game theory suggests a way for an automaker in this situation to decide. For each automaker, the choice of a fuel economy strategy divides the 128 total possible outcomes into two sets: 64 in which it follows BAU and 64 in which it follows PROA.

Within each of these two sets of 64 there are outcomes in which the automaker makes higher profits and other outcomes in which the automaker makes lower profits, and the range of profits in the two sets often overlap. There is a temptation to choose the strategy in which the best outcome is better than the best outcome for the other strategy. However, the automaker can choose only which set of 64 outcomes it receives, not which outcome among the 64 it ultimately gets.

A better approach would be to choose the strategy in which the worst case is better than the worst case for the other strategy. By choosing the strategy with the best worst case, the automaker is certain to attain at least the profit associated with this case, no matter what its competitors choose to do, and no matter what the price of fuel and the consumer discount rate are. The maximin is the best worst case.

As an example, the figure below illustrates the situation for Ford. Ford's pretax variable profit in each of the 128 scenarios is shown. The 64 scenarios in which Ford follows BAU are marked by the filled circles, and the 64 scenarios in which Ford follows PROA are marked by the hollow triangles.



Results

Raising Fuel Economy as a Key Strategy to Maximize Profits

We find that the optimal strategy for all five competitors is the "Proactive" (PROA) fuel economy strategy. Even if fuel price were $2.00/gallon and consumer discount rate were 7%, the strategy that maximizes each automaker's variable profits is to pursue PROA fuel economy improvements. Applying the maximin principle, it turns out that all automakers should choose PROA and increase their fuel economy beyond what is required for CAFE in 2010.

In game theory, Nash equilibrium (Nash [1950]) is a stable market situation in which no automaker can gain by unilaterally changing its strategy if the strategies of the other automakers remain unchanged. The maximin solution in which all five automakers choose PROA is "Nash equilibrium," meaning that no individual automaker would be better if it chose BAU, starting from all five at PROA.

Conclusion: The PROA strategy is a better choice than BAU for each of the five automakers and, if all were to follow PROA, no automaker would have an incentive to differentiate itself by choosing BAU.

This surprising conclusion is true if the price of fuel and the consumer discount rate are not known with certainty, but it is yet more surprisingly also true in each of the four market demand scenarios we evaluated. Regardless of which fuel price or consumer discount rate (among our alternatives) are actually operative, the maximin principle leads to the conclusion that the PROA strategy is the optimal strategy for each and every automaker. What this means is that an automaker that picks PROA today, without knowing what the price of fuel and consumer discount rate are going to be in 2010, would not regret or want to change this decision in 2010.

This conclusion, of course, applies to the Japan 3. However, if all automakers were to choose the PROA strategy (which they should according to the maximin principle), then the Japan 3 automakers would actually have lower variable profits than they would in the base case. Even so, the optimal strategy for the Japanese manufacturers is to pursue fuel economy improvements, since they stand to lose even more profit if they do not improve their fuel economy but the Detroit automakers improve theirs.

Detroit Automakers' Profits are Highly Sensitive to Fuel Prices under Business- As-Usual Fuel Economy Scenarios

To estimate change in variable profits under "Business as Usual" (BAU) fuel economy levels, we compare profits in four cases defined by the two alternative fuel prices ($2.00/gallon and $3.10/gallon) and the two alternative consumer discount rates (0% and 7%) to our base case.

Risk to Variable Profit ($Billions) of Business as Usual on Fuel Economy

Automaker	Base (Fuel $2.30/gal)	Fuel $3.10/gal and Discount Rate 0%		Fuel $3.10/gal and Discount Rate 7%		Fuel $2.00/gal and Discount Rate 0%		Fuel $2.00/gal and Discount Rate 7%	
		Profit	Over/ (Under) Base	Profit	Over/ (Under) Base	Profit	Over/ (Under) Base	Profit	Over/ (Under) Base
DaimlerChrysler	$16.7	$15.6	($1.0)	$15.8	($0.9)	$17.1	$0.4	$17.0	$0.3
Ford	$18.8	$17.6	($1.2)	$17.8	($1.0)	$19.3	$0.5	$19.2	$0.4
GM	$19.6	$18.2	($1.4)	$18.5	($1.2)	$20.2	$0.5	$20.1	$0.4
Japan 3	$29.8	$29.1	($0.8)	$29.0	($0.8)	$30.1	$0.3	$30.1	$0.3
Others	$10.7	$10.3	($0.3)	$10.3	($0.3)	$10.8	$0.1	$10.8	$0.1
Total	**$95.6**	**$90.9**	**($4.7)**	**$91.4**	**($4.3)**	**$97.4**	**$1.8**	**$97.3**	**$1.6**
Detroit 3	$55.1	$51.5	($3.6)	$52.1	($3.1)	$56.5	$1.4	$56.3	$1.2
Percent of Total	58%	57%	77%	57%	72%	58%	78%	58%	73%

As shown in the table above, Detroit automakers' profits are much more sensitive to fuel prices than are the Japanese automakers' profits. These results are consistent with the findings in McManus et al. (2005). Pursuing business as usual, Detroit loses $3.1 to $3.6 billion in variable profits when fuel costs $3.10/gallon compared to $2.30/gallon, accounting for 72-77% of the total industry losses. In contrast, the Japan 3 also see a reduction in variable profits, but at a much lower level, $0.8 billion. Conversely, if fuel prices drop to $2.00/gallon, Detroit automakers do better than the Japanese automakers if both were to continue business as usual. Detroit's variable profits increase by $1.2 to $1.4 billion when fuel costs $2.00/gallon compared to $2.30/gallon. In contrast, the Japan 3 only gain a total of $0.3 billion.

Detroit's profits are much more sensitive to fuel prices than to consumer discount rates. The variable profits of the Japan 3 are much less sensitive to both fuel prices and consumer discount rates than Detroit's are.

The results are driven by the sensitivity of total industry segment mix to fuel prices combined with Detroit's less fuel-efficient segment mix. Higher fuel prices decrease consumer demand for fuel-inefficient products, especially truck-based SUVs, and increase demand for more fuel-efficient vehicles, including crossovers, minivans, and cars. At lower fuel prices, the reverse is true. Detroit automakers sell a much larger fraction of less efficient truck-based vehicle products than other automakers do, so they bear the brunt of changes in fuel prices.

Higher Fuel Economy Performance Benefits Detroit Automakers

Next, we examine how automaker variable profits would change if all automakers aggressively pursue fuel economy improvements, either voluntarily or through a change in national policy. The table below shows the gains in variable profits if all automakers pursued a PROA instead of a BAU fuel economy strategy in the four market demand scenarios.

Results: Automakers' Variable Profits ($Billions)

Discount Rate	Automaker	Base	Fuel $3.10/gal BAU	Fuel $3.10/gal PROA	Fuel $3.10/gal PROA O/(U) BAU	Fuel $2.00/gal BAU	Fuel $2.00/gal PROA	Fuel $2.00/gal PROA O/(U) BAU
Discount Rate 0%	DaimlerChrysler	$16.7	$15.6	$15.8	$0.1	$17.1	$17.1	$0.1
	Ford	$18.8	$17.6	$19.0	$1.4	$19.3	$20.1	$0.9
	GM	$19.6	$18.2	$18.7	$0.5	$20.2	$20.5	$0.3
	Japan 3	$29.8	$29.1	$28.5	($0.6)	$30.1	$29.8	($0.3)
	Others	$10.7	$10.3	$10.4	$0.0	$10.8	$10.8	$0.0
	Total	**$95.6**	**$90.9**	**$92.3**	**$1.4**	**$97.4**	**$98.4**	**$0.9**
Discount Rate 7%	DaimlerChrysler	$16.7	$15.8	$15.9	$0.1	$17.0	$17.1	$0.1
	Ford	$18.8	$17.8	$18.7	$0.9	$19.2	$19.7	$0.5
	GM	$19.6	$18.5	$18.8	$0.3	$20.1	$20.3	$0.2
	Japan 3	$29.8	$29.0	$28.7	($0.2)	$30.1	$30.1	($0.1)
	Others	$10.7	$10.3	$10.4	$0.0	$10.8	$10.8	$0.0
	Total	**$95.6**	**$91.4**	**$92.5**	**$1.2**	**$97.3**	**$98.0**	**$0.8**

As shown in the table above, Detroit automakers benefit from raising the fuel economy of their vehicles in all four cases. That is, regardless of fuel prices or consumer discount rates, our results indicate that a PROA program to raise industry-wide fuel economy performance would increase the variable profits of Detroit automakers. While the gains are greatest in the case with high fuel prices and low consumer discount rates and smallest in the case with low fuel prices and high consumer discount rates, the gains are nevertheless positive in all cases. Ford stands to gain more in variable profit from a proactive program of industry-wide fuel economy improvements. GM's gains are about one-third of Ford's, and DaimlerChrysler's gains are much smaller.

The Japan 3 have very different results from those of Detroit. The Japan 3 actually face a small reduction in their variable profits if all automakers pursue PROA fuel economy strategies. One factor limiting the Japan 3 losses is that they are expected to continue increasing their market share over the next several years at the expense of the Detroit automakers. The Planning Edge forecast predicts the market share of Detroit automakers to fall to 61% by 2010 from 62% in 2005, and predicts the market share of the Japan 3 to increase from 28 to 29%.

The table below shows changes in market share if all automakers pursued PROA instead of BAU fuel economy strategy in the four combinations of fuel prices and consumer discount rates.

Results: Automakers' Market Shares

			Fuel $3.10/gal			Fuel $2.00/gal		
	Automaker	Base	BAU	PROA	PROA O/(U) BAU	BAU	PROA	PROA O/(U) BAU
Discount Rate 0%	DaimlerChrysler	17.2%	16.8%	17.0%	0.1%	17.3%	17.3%	0.0%
	Ford	19.9%	19.5%	20.4%	0.9%	20.1%	20.5%	0.4%
	GM	24.0%	23.5%	23.6%	0.1%	24.2%	24.2%	0.0%
	Japan 3	28.8%	29.8%	28.8%	-1.0%	28.4%	27.9%	-0.5%
	Others	10.2%	10.3%	10.3%	-0.1%	10.1%	10.0%	0.0%
	Total	**100.0%**	**100.0%**	**100.0%**	**0.0%**	**100.0%**	**100.0%**	**0.0%**
	Automaker	Base	BAU	PROA	PROA O/(U) BAU	BAU	PROA	PROA O/(U) BAU
Discount Rate 7%	DaimlerChrysler	17.2%	17.0%	17.0%	0.0%	17.3%	17.2%	0.0%
	Ford	19.9%	19.6%	20.1%	0.5%	20.0%	20.2%	0.1%
	GM	24.0%	23.7%	23.7%	0.0%	24.1%	24.1%	0.0%
	Japan 3	28.8%	29.4%	28.9%	-0.5%	28.5%	28.4%	-0.1%
	Others	10.2%	10.3%	10.3%	0.0%	10.1%	10.1%	0.0%
	Total	**100.0%**	**100.0%**	**100.0%**	**0.0%**	**100.0%**	**100.0%**	**0.0%**

The information in the table above shows that if all automakers followed a BAU fuel economy strategy, then high fuel prices would cause additional losses of 0.8 to 1.2 points of market share by Detroit automakers and equivalent gains by the Japan 3. If all automakers followed a PROA fuel economy strategy, as we have defined it, then Detroit automakers would recover most of these losses at the expense of the Japan 3. Lower fuel prices would have relatively small impact on market shares.

In the section of this report covering technology options, we identified the potential fuel economy improvements that the automakers could obtain by 2010 implementing only the improvements that consumers would value more than the cost. We estimated an overall improvement of 1.5 MPG assuming that the baseline sales of each vehicle would be unchanged. This assumption is appropriate to isolate the impact of technology improvements from the impact of customers moving to more fuel-efficient vehicles. The table below shows the full fuel economy changes that include both the technology and customer impacts. The full improvements are greater than the technology-driven improvements alone (The sole exception is Ford in Market Demand IV in which they are equal). The smallest improvement beyond the technology-driven 1.5 MPG would occur under Market Demand IV (fuel price $2.00; discount rate 7%). Consumer-shifting-driven improvements range from 0.08 to 0.13 MPG beyond the technology-driven improvements.

Results: Automakers' Average Fuel Economy

Discount Rate	Automaker	Base	Fuel $3.10/gal BAU	Fuel $3.10/gal PROA	Fuel $3.10/gal PROA O/(U) BAU	Fuel $2.00/gal BAU	Fuel $2.00/gal PROA	Fuel $2.00/gal PROA O/(U) BAU
Discount Rate 0%	DaimlerChrysler	23.60	23.90	25.84	1.94	23.49	25.20	1.71
	Ford	23.71	24.01	27.33	3.32	23.60	26.67	3.07
	GM	23.58	23.97	25.66	1.69	23.44	24.99	1.55
	Japan 3	27.00	27.58	28.40	0.82	26.79	27.60	0.81
	Others	26.88	27.23	28.32	1.09	26.75	27.81	1.06
	Total	24.82	25.26	27.04	1.78	24.66	26.33	1.67

Discount Rate	Automaker	Base	Fuel $3.10/gal BAU	Fuel $3.10/gal PROA	Fuel $3.10/gal PROA O/(U) BAU	Fuel $2.00/gal BAU	Fuel $2.00/gal PROA	Fuel $2.00/gal PROA O/(U) BAU
Discount Rate 7%	DaimlerChrysler	23.60	23.80	25.53	1.73	23.52	25.10	1.58
	Ford	23.71	23.91	27.00	3.09	23.63	26.56	2.92
	GM	23.58	23.84	25.40	1.56	23.48	24.96	1.47
	Japan 3	27.00	27.39	28.16	0.77	26.86	27.63	0.77
	Others	26.88	27.11	28.12	1.01	26.79	27.79	0.99
	Total	24.82	25.12	26.77	1.65	24.72	26.29	1.58

What explains the advantages to Detroit automakers of an industry-wide adoption of a PROA fuel economy strategy? The key factor is opportunity—the Detroit automakers have lower fuel economy than the Japan 3 and thus have more room for improvement. In the technological options section of this report we identified more improvement opportunities (for both new and carry-over powertrains) for the Detroit automakers than for the Japan 3. We excluded improvements that were not valued by consumers, and potential improvements were more likely to be excluded for the Japan-based than for the Detroit automakers. The Japan 3 could, in principle, maintain their fuel economy advantage at its baseline level by applying more technologies to more vehicles, but they would do so at the cost of variable profits. It is important to note that, while the Detroit automakers could narrow their fuel economy disadvantage relative to the Japan 3 automakers through a PROA fuel economy strategy, the Japan 3 automakers would still have an advantage.

Employment Effects

We estimated the impact of fuel prices on U.S. employment using the well-known model developed and maintained by Regional Economic Models, Inc. (REMI). The REMI model takes the latest national input-output coefficients, which show how much each industry buys from every other industry, and tunes them to particular geographies using trade-flow data generated from the US Census of Transportation. REMI's forecasting and policy analysis system integrates inter-industry transactions, long-run equilibrium features, and economic geography. It includes substitution among factors of production in response to changes in relative factor costs; migration responses to changes in expected income; labor participation rate responses to changes in real wage and employment conditions; wage rate responses to labor market changes; consumer consumption responses to changes in real disposable income and commodity prices; and local, regional and market share responses to changes in regional production costs.[1] We used the REMI model for three classes of finished vehicles: (1) those assembled in the United States by GM, Ford, and DaimlerChrysler, (2) those assembled in Canada or Mexico by the same three automakers, and (3) those assembled in North America by other automakers. Based on reasonable estimates of U.S. parts content by vehicle type, web treat the second and third of the three groups as equivalent to half the U.S. content, and hence jobs, of the first group. For more details on how this model was adopted for this work see McManus et al 2005.

The table below summarizes the effects on U.S. employment *throughout the economy* (automotive, other manufacturing, service sector, and spin offs) in our four market demand scenarios with all automakers following BAU or all automakers following PROA. We show the changes in employment for the Detroit 3 (GM, Ford, and DaimlerChrysler) and the transplants (foreign-owned automakers with plants in North America).

Impact of Fuel Economy Strategy on U.S. Employment

		Consumer Discount Rate 0%			Consumer Discount Rate 7%		
		Business as Usual	Pro-Active	Pro-Active Gain/ (Loss)	Business as Usual	Pro-Active	Pro-Active Gain/ (Loss)
$3.10/gallon	Detroit Three	(42,698)	(7,865)	34,834	(40,486)	(25,914)	14,572
	Transplants	(1,886)	(21,175)	(19,288)	(7,832)	(17,625)	(9,793)
	Total	(44,585)	(29,040)	15,545	(48,318)	(43,539)	4,779
$2.00/gallon	Detroit Three	15,961	27,020	11,059	15,186	13,166	(2,020)
	Transplants	590	(10,302)	(10,891)	2,811	(2,177)	(4,988)
	Total	16,551	16,718	168	17,997	10,989	(7,008)

An industry-wide PROA has favorable impacts on employment linked to the Detroit 3, except under Market Demand IV (fuel price $2.00/gallon; discount rate 7%), and unfavorable impacts on employment linked to the transplants (in all market demand scenarios). The Japan 3 are the bulk of the transplants. The industry-wide proactive strategy shifts market share and profits from the Japan 3 automakers to GM, Ford, and DaimlerChrysler. Employment follows the vehicle market shift, and losses in employment linked to the transplants partially offset gains in employment linked to Detroit. The net

[1] Founded in 1980 by University of Massachusetts economist George Treyz, Regional Economic Models, Inc. is widely used by regional studies scholars and by policymakers evaluating the employment and fiscal impacts of investment and disinvestment events (e.g., base closings). For more information about the REMI model, please see www.remi.com.

impact on employment is favorable, except under Market Demand IV (fuel price $2.00/gallon; discount rate 7%).

Our results imply that investment credits for automakers and suppliers, in support of an industry-wide PROA fuel economy strategy, could strengthen the employment benefits of higher fuel economy.

Summary, Policy Implications, and Directions for Further Research

Detroit Automakers' Profits are Highly Sensitive to Fuel Prices under Business- As-Usual Fuel Economy Scenarios

- Detroit automakers' profits are much more sensitive to fuel prices than the Japanese automakers. These results are consistent with the findings in McManus et al. [2005[. Detroit automakers lose $3.1 to $3.6 billion in variable profits when fuel costs $3.10/gallon compared to $2.30/gallon, accounting for 72 to 77 percent of the total industry losses. In contrast, the three biggest Japanese manufacturers (Toyota, Honda, and Nissan) also see a reduction in variable profits, but at a much lower level, $0.8 billion.

- Conversely, if fuel prices drop to $2.00/gallon, Detroit automakers do better than the Japanese automakers. Detroit's variable profits increase by $1.2 to $1.4 billion when fuel costs $2.00/gallon compared to $2.30/gal. In contrast, the three biggest Japanese manufacturers only gain a total of $0.3 billion.

- The differences in Detroit's profits between high and low consumer discount rates are small compared to the differences generated by fuel prices. The variable profits of the three largest Japan-based automakers (Toyota, Honda, and Nissan) are much less sensitive to both fuel prices and consumer discount rates than Detroit's are.

- These results are driven by two critical factors. First, if fuel prices increase to $3.10/gallon, overall sales decline by 3.5%. At $2.00/gallon, overall sales increase by 1.3%. Second, higher fuel prices decrease consumer demand for fuel inefficient products, especially truck-based SUVs, and increase demand for more fuel efficient options, including crossovers, minivans, and cars. At lower fuel prices, the reverse is true. Consequently, since Detroit automakers sell a much larger fraction of less efficient truck-based vehicle products, they are much more vulnerable to variable fuel prices than the Japan-based automakers are.

Proactively Increasing Fuel Economy would Benefit Detroit Automakers

The results of our simulations were surprising, even to us. In all four market-demand situations we evaluated (defined by fuel price and consumer rate of time discount), proactively increasing fuel economy would be the optimal strategy for all automakers, in that it would result in the highest variable profit that each automaker could be assured of earning, no matter what price of fuel (between $2.00 and $3.10 per gallon), consumer rate of time discount (between 0% and 7%), or actions by its competitors were realized.

What was especially surprising was that the Detroit automakers (General Motors, Ford, and DaimlerChrysler) have more to gain from pursuing the aggressive fuel economy improvement strategy than do the three largest Japan-based automakers (Toyota, Honda, and Nissan). This is because the Detroit automakers face more risk (are more vulnerable) if they pursue business as usual than the Japan automakers do. The Detroit automakers also have more opportunities for improvement, since Detroit automakers currently have lower average fuel economy than the Japan automakers do.

- Detroit automakers would benefit from raising the fuel economy of their vehicles regardless of fuel prices and consumer discount rates. Our results show that a proactive, industry-wide program to increase fuel economy performance would increase the profits of Detroit automakers by $0.8 to $2.0 billion per year (depending on the market-demand situation).

- While the gains are greatest in the case of high fuel prices with low consumer discount rate and smallest in the case with low fuel prices and high consumer discount rate, the gains are nevertheless positive in all four potential market-demand situations we evaluated.

- Ford stands to gain the most in annual profits, more than twice as much as GM or DCX, by proactively pursuing fuel economy performance. Ford's gains are from $0.5 to $1.4 billion, depending on the market-demand situation. GM's gains are from $0.2 to $0.5 billion, depending on the market-demand situation. DCX's gains are $0.1 billion (There are differences in DCX's gains between market-demand situations, but not sufficient to register at this level).

- On the other hand, the three largest Japan-based automakers show very different results from those of Detroit. The Japan-based manufacturers actually see a reduction in their profits of $0.1 to $0.6 billion. In large part this is due to the fact that the Japan-based automakers have more fuel-efficient fleets than the Detroit automakers have, and therefore have less room for improvement. Under a proactive fuel economy strategy, Detroit-based manufacturers narrow the gap in fuel economy performance between their fleets and the fleets of the three largest Japan-based automakers.

These surprising results are driven by the following factors:

- The higher fuel economy level of the fleet helps to insulate total industry sales from declining under the high fuel price scenarios. That is, the entire industry makes more profit under high fuel prices if fuel economy levels are higher, ($1.2 to $1.4 billion). More surprising is our prediction that under low fuel prices, total industry profits are higher by $0.8 to $0.9 billion if all automakers following PROA. This is because at $2.00 per gallon, some of the fuel economy technologies are still cost-effective. This assessment is consistent with recent National Research Council findings on fuel economy [NRC (2002)]

- The key factor that explains the advantages to Detroit-based automakers of adoption of a proactive fuel economy strategy is opportunity—the Detroit-based automakers have lower fuel economy than the three largest Japan-based automakers and thus have more room for improvement. In the technological options section of this report we identified a larger set of improvement opportunities (for both new and carry-over powertrains) for the Detroit-based than for the three largest Japan-based automakers. (We excluded improvements that were not valued by consumers, and such technically possible but not valued improvements were more likely to be excluded for the Japan-based than for the Detroit-based automakers.)

- The three largest Japan-based automakers could, in principle, maintain their fuel economy advantage by applying more technologies to more vehicles, but they would do so at the cost of profits. It is important to note that, while the Detroit automakers could narrow their fuel economy disadvantage relative to the Japan 3 automakers through a proactive fuel economy strategy, the Japan 3 automakers would still have an advantage.

- Our study concludes that the Detroit automakers would benefit from pursuing proactive fuel economy improvements above what CAFE requires. This does not imply that raising CAFE requirements would benefit the Detroit automakers. That question was not directly addressed in the study, and it is important to understand that when we speak of an industry-wide or market-wide proactive fuel economy improvement strategy, we do not mean a higher CAFE standard, we mean the situation in which all automakers have chosen the PROA strategy.

Proactively Increasing Fuel Economy would Protect American Jobs

We estimated the impact of strategic choices by automakers on U.S. employment using the well-known model developed and maintained by Regional Economic Models, Inc. (REMI). The REMI model takes the latest national input-output coefficients, which show how much each industry buys from every other industry, and tunes them to particular geographies using trade-flow data generated from the US Census of Transportation.

- Under high fuel prices, a market-wide proactive fuel economy improvement strategy would create 15,000 to 35,000 new jobs (throughout the whole economy) due to increased production by Detroit automakers. Decreased production by foreign-owned transplants would offset 10,000 to 19,000 jobs, for a net increase of 5,000 to 16,000 new jobs.

- Under low fuel prices, but with low consumer discount rates as well, the net gain in new jobs is smaller (168 net new jobs), as 11,000 new jobs due to increased production by Detroit automakers are nearly fully offset by reduced production by foreign-owned transplants.

- Only in the case with low fuel prices and high consumer discount rate would the market-wide proactive fuel economy increases result in job losses.

Public Policy Implications

In light of our conclusion that the optimal strategy for all automakers is aggressive fuel economy improvement, even with $2.00/gallon fuel, why has it taken a steadily rising fuel price for five years, billions in lost profit, and tens of thousands of job losses to stimulate action by the Detroit automakers? What are the barriers to implementing the optimal strategy?

Deploying new technologies takes time and money to accomplish, and time and money are in short supply in Detroit. The cumulative effects of declining market share, rising fuel prices, and uncompetitive product development are forcing drastic and costly changes at Ford, GM, and DaimlerChrysler. For the first time in more than 20 years, their survival is in doubt. GM and Ford may have just enough cash for one cycle of product development to bring new versions of their full product lines to market. Items seen as important but secondary to new vehicle designs are not getting funded.

Public policy actions that will be accepted by Detroit automakers in the current situation will be actions that enhance their ability to respond to changing market conditions. Our research shows that increased fuel economy has the potential to enhance their flexibility, but pressing concern about what are seen as bigger issues make achieving progress challenging.

To adequately address public policy concerns about fuel economy in the current economic environment requires the active, direct involvement of industry, labor, government, and other organizations in the search for policies that are generally acceptable to all interested parties and, more importantly, that work. New policies are inevitable. If industry leaders do not become engaged with other stakeholders, it is very likely that the new policies will be more onerous.

Improving the fuel economy of America's light vehicle fleet would help reduce our dependence on oil (much of which is in the hands of unstable or hostile regimes) and contribute significantly to reducing emissions of pollutants and greenhouse gases. Our research indicates that improving the fuel economy of Detroit automakers' fleets would also reduce the risks to profits and American jobs of volatility in fuel prices. Reducing fuel consumption has become a national priority for leaders from both political parties. An emerging consensus sees reducing fuel consumption as a means to enhance national security, increase the market flexibility of American workers and communities, and help address climate change.

There are four areas that a formal coalition of stakeholders with a federal mandate to develop policies should address: improving fuel economy, enhancing regulatory rationality and certainty, supporting the development of advanced technologies, and building a domestic supply chain for advanced technology fuel-efficient vehicles. These need to be considered in conjunction with the key policy leverage points at which interventions can have significant effects: the decision by consumers to purchase a vehicle, the decision by automakers of the range of vehicles with different attributes to produce, and the decision by suppliers of which technologies to develop and provide to the automakers.

No one would question the importance of purchase price (capital cost) in consumers' vehicle choices. Tax incentives to encourage consumers to purchase fuel-efficient vehicles are already part of our policy environment, as are tax incentives to purchase inefficient SUVs and trucks. Most observers believe that an increase in the federal excise tax on motor fuels would not find sufficient support in Congress, yet the recent experience with higher fuel prices has demonstrated the power of raising operating costs to influence consumers' vehicle choices and thereby improve aggregate fuel economy.

However it is difficult for consumer-focused instruments alone (incentives and/or fuel taxes) to achieve dramatic improvements in fuel economy. Automakers cannot radically alter their product mix very rapidly, nor do all consumers switch from one type of vehicle to another overnight. We have seen significant evidence of the beginning of a move from SUVs to cars by consumers, and some automakers have acknowledged it, but the present composition of the fleet is not going to change radically in the near term. Encouraging the development of technologies that improve the fuel economy all vehicle segments across the entire market, are needed to produce significant improvements in fuel economy.

Encouraging advanced technologies across the entire fleet of vehicles calls for instruments that increase the portfolio of fuel-saving technologies available, make the technologies now or soon to be in the portfolio more attractive to automakers, and/or enhance the ability of suppliers to develop and commercialize new technologies.

Directions for Further Research

We had a fairly short-run focus in this report (2010), and did not assess the impacts of technologies that are not already available or soon will be. In our on-going work we are examining a broader portfolio of technologies including hybrids, clean diesel, ethanol, bio-fuels, and plug-in hybrids. We also plan to evaluate technologies that increase fuel-economy but do not involve new powertrain technologies (e.g., light-weighting).

While the structure we adopted for the strategic game theory model enabled some important insights, we are developing a more detailed model that treats the fuel economy strategic choice as continuous, rather than as a discrete choice of either BAU or PROA. We plan also to disaggregate the Japan 3 and Other automakers.

We also think that an examination of the process followed by automakers in forming judgments about the market, especially about consumer demand for technologies and attributes, would help explain why the Detroit automakers were slow to recognize the abrupt change in consumer demand we have seen recently, and help speed their reaction in the future.

Appendix: Potential for Near-Term Fuel Economy Improvements for the 2010 U.S. Passenger Vehicle Fleet[2]

Methodology

In this analysis, we assess the ability for manufacturer to incorporate new and existing technologies to improve the fuel economy performance of their overall fleet without changing their product portfolios. We start with a review of historical and forecasted rates of technological improvement in order to get a general sense for what improvement might be possible. We then describe our detailed approach based on engineering assessments and a detailed product plan forecast for calendar year 2010. This assessment differs from those in the past (e.g., DeCicco et al, 2001, NAS 2002) in that it uses a detailed product forecast for each manufacturer by vehicle model-engine-transmission for 2010 to estimate near-term fleetwide potential.

By combining an engineering assessment of what fuel economy technologies are available with a detailed forecast of each manufacturer's production plans including when individual models would have an opportunity to integrate new technology, we can develop a realistic sense for the technical potential to raise fuel economy levels. We also incorporate a decision making rule to determine what level of technology to apply based on the package's incremental cost and a consumer test of willingness to pay. In this way, we ensure that the package makes financial sense for the manufacturer and consumer to apply.

To assess the opportunity for technology improvement, we divide the vehicle fleet into two categories. The first category is those vehicles that are scheduled for a new engine or new platform starting in model years 2005 to 2010. These vehicles have modern engines that have the opportunity for substantial improvement. The second category is those vehicles that are not scheduled for new engines between now and 2010. While these engines have less opportunity for improvement, there are nonetheless incremental opportunities for improvement, through refinements of existing technology and by directing the technologies that are likely to be adopted toward fuel economy improvements (rather than increasing power). An example would be variable valve timing which manufacturers have been steadily incorporating into their existing engines, but primarily using the benefits to improve power rather than fuel economy performance.

---

[2] Written by Dr. Feng An, Energy and Transportation Technologies, LLCD; Roland J. Hwang, Natural Resources Defense Council; Dr. Walter McManus, Automotive Analysis Division, University of Michigan Transportation Research Institute; and Alan Baum, The Planning Edge.

Rate of Improvement Possible based on Historic and Forecasted Rates of Fuel Economy Improvement

Historic Rates of Improvement

Analysis by EPA, DOE and Oak Ridge National Laboratory shows that the historic rate of fuel economy increase since the late 1970s or early 1980s would have been from 1 to 3% if technologies had been used to increase the fuel economy performance of the fleet of to increase vehicle weight, size and performance (EPA 2005, DOE 1995, ORNL 1994).

Table 1. Historic Rate of Efficiency Improvement if Technology Used for Fuel Economy Improvement

Study	Fuel economy potential (mpg)	Increase from baseline (mpg)	Period (years)	Implied Rate of Increase (% per annum)
EPA 2005. *Light-Duty Automotive Technology and Fuel Economy Trends Report: 1975-2005*				
Cars: If 1981 weight & 0-60	36.4	11.3	24	1.6%
Cars: If 1981 size & 0-60	37.1	12.0	24	1.6%
Light Trucks: If 1981 weight & 0-60	28.5	8.4	24	1.5%
Light Trucks: If 1981 size & 0-60	25.0	4.9	24	0.9%
DOE 1995. *Energy Conservation Trends: Understanding the Factors that Affect Conservation Gains in the U.S. Economy*				
Cars and Light Trucks: 1975 to 1993			18	2.2%
Oak Ridge National Laboratory, 1994. *Transportation Energy Efficiency Trends*, 1972-1992				
Cars: 1975-93 if const weight and power	26.4	10.6	18	2.9%

Forecasted Rates of Improvement through Adoption of New Technologies

A number of recent studies have demonstrated that there is substantial technical opportunity to improve the fuel economy of today's fleet. A review of recent study suggests that a roughly 4% annual rate of improvement is consistent with engineering/economic forecasts of what is technically achievable and cost-effective (see Table 1). Based on the technology forecasts from National Research Council, a 2.9 to 4.4% annual increase is possible for the U.S. passenger vehicle fleet without changing weight, size mix, or decreasing performance of today's fleet (NRC 2001). Analysis performed for DOE and DOT, shows that the technical potential for light trucks by 2010 (prior to recent CAFE light truck rulemaking) is 4.1% per year (EEA 2005). Analysis by ACEEE, suggests that a higher rate, 4 to 5.8%, is possible without changing size mix or performance, but using a number of engine and powertrain technologies as well as substituting lightweight, high-strength materials to reduce weight (ACEEE 2001).

Rate of Improvements Using Adoption of Existing and Planned Technologies

A moderate rate of fuel economy increase of 2% annually is seen by limiting the technology to today's "best-in-class" technology (not including hybrids) and assuming a conservative 10-year adoption demonstrates (EPA 2005). The analysis by EEA 2005 also showed that the light truck fleet could be improved by 2.8% per year just using planned technologies (EEA 2005). The very modest NHSTA MY2004 to MY2011 light truck fuel economy standards requires just a 2% annual increase. With no new increase in fuel economy standards, the

Massachusetts Institute of Technology (MIT 2000) estimates that an annual rate of improvement (based on a midsize car) of 2.2% would occur if new technologies that will be entering the fleet are used to improve fuel economy.

Table 2. Forecasted Rates of Fuel Economy Improvement

Study	Fuel economy potential (mpg)	Increase from baseline (mpg)	Period (years)	Implied Rate of Increase (% per annum)
Using Existing and New Technologies				
National Academy of Science 2002. *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards*				
Path 2, <10 years	33.0	9.0	10	3.2%
Path 3, 10-15 years	37.0	13.0	10	4.4%
Path 3, 10-15 years	37.0	13.0	15	2.9%
Energy and Environmental Analysis, 2005. *Fuel Economy Potential for 2010 Light Duty Trucks, report prepared for DOE and DOT*				
Planned and new technologies	26.2	4.7	5	4.1%
Only planned technologies	24.7	3.2	5	2.8%
American Council for an Energy Efficient Economy, 2001. *Technical Options for Improving the Fuel Economy of U.S. Cars and Light Trucks by 2010-2015*				
Moderate package	36.0	12.0	9	4.6%
Advanced package, 10-15 years	42.0	18.0	10	5.8%
Advanced package, 10-15 years	43.0	19.0	15	4.0%
Massachusetts Institute of Technology, 2001. *On the Road in 2020*				
"Evolved" midsize car, no new standards	43.2	15.4	20	2.2%
EPA 2005 "Best In Class" (assuming 10 year phase-in.) *Light-Duty Automotive Technology and Fuel Economy Trends Report: 1975-2005*				
Cars: Best 4 nameplates in size class	36.3	7.4	10	2.3%
Cars: Best 12 vehicles in size class	35.4	6.5	10	2.0%
LTs: Best 4 nameplates in size class	24.9	3.6	10	1.6%
LTs: Best 12 vehicles in size class	25.7	4.4	10	1.9%
Both: Best 4 nameplates in size class	29.5	5.0	10	1.9%
Both: Best 12 vehicles in size class	29.8	5.3	10	2.0%
Existing NHSTA Light Truck Fuel Efficiency Improvements Requirements, MY04-11				
NHSTA CAFE Light Truck Rule Makings	24.1	3.4	8	1.9%

Ongoing adoption of new technologies alone shows that about a 2% rate of improvement is possible if those technologies are used to improve fuel economy rather than increase size, weight and power of the fleet.

Conclusion: 2% to 4% Annual Rate of Improvement is Possible

Based on this review, we reach the conclusion that automakers could achieve an annual increase of roughly 2% fleetwide by using already planned technologies, and achieve another roughly 2% improvement by accelerating adoption of planned and adding new incremental technologies. Examples of incremental planned technologies that are entering the fleet already and automakers will increasingly adopt over next decade include: cylinder deactivation, variable valve lift and timing, improved alternators, 5 and 6-speed transmissions, continuously variable, transmissions, lower viscosity oil, improved aerodynamics, low rolling resistance tires. Example of emerging technologies whose adoption could be accelerated: gasoline direct injection engines, engine downsizing with turbochargers, integrated starter generators (idle off), automated manual transmissions (efficiency of manual, convenience of automatic), camless valve actuation (faster response, reduce friction losses from rollers and cams), mild and full hybrid systems, clean diesel engines.

A 4% annual increase, assuming a 3-year lead time to start the improvements in model year 2009, would imply a 2010 potential for increase of 8.2%. If using just planned technologies and assuming a 1% to 2% annual increase starting in 2007, yields a similar 4% to 8.2% total increase by 2010. These estimates are roughly consistent with Honda's recently announced voluntary goal to improve their fleetwide fuel economy by 5% between 2006 and 2010.

Rate of Improvement based on Engineering Estimates and 2010 Product Forecast

Technology Packages for New Engines and Vehicle Models

We evaluated two packages of fuel-saving technologies based on the National Academy of Science's recent fuel economy study (NAS 2002). The two packages are the "Cost-efficient, 14-year", "Path 2." All of the Path 2 technologies currently exist, but not across the entire fleet. The "Cost-efficient, 14-year" package includes Path 1 (technologies which are likely to be adopted) and a subset of Path 2 technologies, those that the NAS study defines as "cost-efficient' or pays for itself over 14 years (at $1.50/gallon and 12% discount rate) on the margin.

Table 3. NAS Path 2 Technology Package

Engine technologies
Engine Friction Reduction
Low Friction Lubricants
Multivalve, overhead camshaft (SUVs, Minivans, and Pickups only)
Variable valve lift and timing
Cylinder deactivation (Large car, SUVs, Minivan, and Pickups only)
Engine accessory improvements
Intake valve throttling
Transmission technologies
Continuously variable transmission (Small SUV, Compact and Subcompact Car only)
Five or six-speed automatic transmission (Midsize and Large only)
Automatic transmission/manual transmission (AST/ASM) (Midsize and Large Car, Mid SUV, Miniivan, Small Pickup only)
Vehicle technologies
Aero drag reduction
Improved rolling resistance
42-V electrical systems
Integrated starter/generator (idle off-restart) (not on cars)
Electric power steering (Midsize and Large Car only)

Source: NAS 2002.

We assume that for any eligible vehicle model that it can be improved to the fuel economy level estimated by NAS for that class segment. Since the NAS panel did not model crossovers, we compared existing crossovers to the cars that they are based on and found fuel economy at 75% to 90% of the car's fuel economy (e.g, Honda CRV versus Honda Civic.) Therefore to be conservative, we reduce the fuel economy by 20% for the crossovers compared to the car platform segment it is based on. For example for a Honda CRV, we estimate the Path 2 fuel economy potential to be 80% of the 36.6 mpg for the compact car segment.

The retail cost increase for the fuel efficiency packages that we use are also those estimated by NAS. We chose to not adjust the cost to reflect inflation, since the estimates are still within the range of costs that NAS provided. Furthermore, a recent EPA report supports using a much lower 1.26 retail markup factor, rather than the 1.40 used by NAS, a 10 percent difference (Alson 2005).

Table 4. NAS Fuel Economy Potential NAS

Vehicle Class	Fuel Economy (mpg)			Cost	
	base	Cost-efficient	Path 2	Cost-efficient	Path 2
Cars					
Subcompact	31.3	35.1	37.5	$502	$1,018
Compact	30.1	34.3	36.6	$561	$1,088
Midsize	27.1	32.6	36.0	$791	$1,642
Large	24.8	31.4	34.5	$985	$2,167
Light Trucks					
Small SUV	24.1	30.0	31.4	$959	$1,543
Mid SUV	21.0	28.0	30.8	$1,254	$2,227
Large SUV	17.2	24.5	24.7	$1,629	$2,087
Minivans	23.0	29.7	34.0	$1,079	$2,227
Small Pickup	23.2	29.9	34.0	$1,067	$2,227
Large Pickup	18.5	25.5	28.2	$1,450	$2,542

Source: NAS 2002

By 2010, only a portion of the fleet would be eligible for these technology upgrades. Life cycles of cars and trucks last three to five years, and life cycles of engines last eight to twelve years or longer. There is only enough time by 2010 to redesign the models that have relatively new engines with modern technologies. We choose to consider as eligible for the NAS packages vehicles with engines that were introduce in model year 2005 or later. These engines are modern, overhead cam, multivalve engines that have the ability to accommodate variable valve lift and timing technology.

For those vehicles eligible for these technology packages, we apply the package only if the value to consumers exceeds the increase in price. This ensures that the manufacturers will be able to recover their investment cost. We apply the more aggressive of the two packages that meets this test. The test that we apply is whether the technology pays for itself over a 14-year vehicle life (NAS), assuming $2.60 per gallon, and a 3.5% discount rate.

Improvement Possible Through Planned Improvements
For carry-over engines not scheduled for replacement between 2005 and 2010, the "cost-efficient" and Path 2 packages are not available. Instead, we applied improvements that rely on planned technologies to increase specific power (horsepower per liter) and apply them to enhancing fuel economy. The tradeoff is at the expense of increasing the specific power (horsepower per liter) of the engine. As noted above, EEA states that just using planned technologies the light truck fleet could be improve by 2.8% per year (EEA 2005). Honda has announced a 5% improvement (although this is probably a combination of new engines and improvements to existing engines.)

A study by NESCCAF estimated what is equivalent to a 2.8% to 10.4% increase in fuel economy from 2002 to 2009 using planned technologies and holding performance constant (NESCCAF 2004). This equates to a 0.39% to 1.43% annual increase in fuel economy. For this study, we take the same rate of improvement and apply it to four model years (2007 to 2010), which yields annual increases of 1.6% to 5.8%, depending on vehicle class. This is consistent with the above estimate based on a historical review of trends.

Table 5. Carryover Engine Fuel Economy Improvements

Vehicle Class	Fuel Economy improvement, MY02-09	Per annum, MY02-09	Assumption this Study, MY06-09
Small car	2.8%	0.39%	1.6%
Large car	7.4%	1.03%	4.2%
Minivan	7.2%	1.00%	4.1%
Small Truck	10.4%	1.43%	5.8%
Large Truck	6.0%	0.84%	3.4%

Source: NESCCAF 2004.

Product Forecast for 2010
The Planning Edge provided forecasted U.S. sales for 2010 calendar year derived from its ongoing forecast of U.S. sales and North American production for light duty vehicles less than 8,500 lbs GVWR Information is provided at a variety of levels (e.g., unit sales by vehicle-engine-transmission-drive type combinations). The Planning Edge incorporates current and future production plans of automakers into the forecast, combining information from a variety of public and proprietary sources established over 15 years of experience producing forecasts for industry stakeholders. The Planning Edge forecast goes beyond automakers' public announcements to incorporate additional vehicles and powertrains that are expected be in place by 2010 based on the sources mentioned above.

The baseline distribution of sales across engine-transmission-drive types for a particular vehicle is based on the current distribution in production, and incorporates changes in marketing and manufacturing plans between now and 2010 (e.g., additional Escape hybrids to displace V6-powered Escapes as more parts become available and the cost premium for hybrids declines). The baseline assumes a long term fuel price of $2.30 per gallon and that automakers' current fuel economy strategies are unchanged over the forecast period.

To develop the BAU fuel economy forecast, The Planning Edge incorporates EPA data from 2005 and 2006 model years for combined city-highway fuel economy and other attributes for each of the vehicle-engine-transmission-drive types currently in the market that we expect to continue to be sold in 2010. For new vehicle-engine-transmission-drive type configurations expected to be introduced between now and 2010, we estimated fuel economy and other attributes based on relevant attributes of similar vehicle, engine, transmission, and drivetrain combinations.

We then compared the light truck forecast to the recent light truck CAFE rule adopted by NHSTA. For most manufacturers, our forecast matched well. For one/two [Ford others], the forecast was significantly lower then the NHSTA standard. In this/these case(s), we first assumed that the manufacturer would maximize the use of its flex fuel vehicle credits (equivalent to 1.2 mpg). If a gap still remained, we adjusted the fuel economy of the light truck models upwards by the same percentage.

Glossary

Term	Definition
actual transaction prices	Prices consumers pay for vehicles net of incentives
AEO	Annual Energy Outlook published by U.S. Energy Information Administration
attributes	Characteristics of vehicles that consumers value, such as performance, size, and fuel economy
automakers	Corporations that produce new light vehicles (cars and light trucks)
AFE	Average fuel economy (sales-weighted harmonic mean)
BAU	Identifier for the "business as usual" fuel economy strategy: making only those improvements necessary to meet CAFE
Car	A passenger automobile; any 4-wheel vehicle not designed for off-road use that is manufactured primarily for use in transporting 10 people or less. (Legal definition)
CARLUX	Luxury car segment (one of 15 segments)
CARMID	Midsize car segment (one of 15 segments)
CARSML	Small car segment (one of 15 segments)
consumer value of fuel economy	The average market value of one additional mile per gallon; the present value of the fuel costs saved because of differences in fuel economy for otherwise identical vehicles
CAFE	Corporate Average Fuel Economy; the sales-weighted average (harmonic mean) fuel economy, expressed in miles per gallon (mpg), of a manufacturer's fleet of passenger cars or light trucks with a gross vehicle weight rating (GVWR) of 8,500 lbs. or less, manufactured for sale in the United States, for any given model year
CUV	Crossover Utility Vehicle
CUVLUX	Luxury Crossover Utility Vehicle (one of 15 segments)
CUVMID	Crossover Utility Vehicle-Mid sized (one of 15 segments)
CUVSML	Crossover Utility Vehicle-small sized (one of 15 segments)
Detroit automakers	GM, Ford, and DaimlerChrysler
discount rate	The rate at which consumers discount future costs or savings in monetary terms
discounted present value	The value, in today's dollars, of a stream of payments (or savings) in the future

Term	Definition
Elasticity	The percentage change in one variable with respect to a one percent change in another variable; an elasticity of -1.5 for y with respect to x means that a one percent increase in x induces a 1.5 percent reduction in y
fuel economy	The average mileage traveled by a vehicle per gallon of gasoline (or equivalent amount of other fuel) consumed; miles per gallon or MPG
fuel economy improvements	Increases in miles per gallon (MPG)
fuel economy performance	Synonymous with fuel economy; can refer to automaker's fleet
fuel economy standards	The "Energy Policy Conservation Act," enacted into law by Congress in 1975, added Title V, "Improving Automotive Efficiency," to the Motor Vehicle Information and Cost Savings Act and established CAFE standards for passenger cars and light trucks.
fuel economy strategy	Used in this study to refer to the choice by automakers of either BAU or PROA
fuel price	The price in dollars (or cents) per gallon of fuel
fuel price scenarios	Used to examine the impacts that a change in fuel price will have on demand for vehicles; this study used $2.30/gallon as the base, $2.00/gallon and $3.10/gallon as low and high alternatives
game theory	The branch of mathematics concerned with the analysis of strategies for dealing with competitive situations where the outcome of a participant's choice of action depends critically on the actions of other participants.
GVWR	Gross Vehicle Weight Rating; estimated total weight of a road vehicle that is loaded to capacity, including the weight of the vehicle itself plus fuel, passengers, cargo, and other miscellaneous items such as extra aftermarket parts.
hedonic regression	Hedonic regression, or more generally hedonic demand theory, in economics is a method of estimating demand or prices. It decomposes the item being researched into its constituent characteristics, and obtains estimates of the value of each characteristic. In essence it assumes that there is a separate market for each characteristic. It may be estimated using ordinary least squares (OLS) regression analysis.
industry sales	Retail deliveries of all types of light vehicles
Light-duty truck	Truck with GVWR of 10,000 lb or less.
market share	An automaker's (or brand's or model's) percentage share of sales in a market

Term	Definition
maximin	The ***maximin principle*** or ***maximin criterion*** states that the goal of a strategic choice should be to maximize the worst outcome that is, maximize the minimum.
MINIVAN	Minivan segment (one of 15 segments)
MPG	Miles per gallon; fuel economy
MSRP	Manufactures suggested retail price
Nash equilibrium	In game theory, the Nash equilibrium is a kind of optimal collective strategy in a game involving two or more players, where no player has anything to gain by changing only his or her own strategy. If each player has chosen a strategy and no player can benefit by changing his or her strategy while the other players keep theirs unchanged, then the current set of strategy choices and the corresponding payoffs constitute a Nash equilibrium.
NMNL	Nested MultiNomial Logit regression model; an econometric model of consumers' choice among discrete alternatives, such as vehicle models
powertrain	Used to refer to the engine and transmission of a vehicle
pretax variable profit	See variable profits - before taxes are assessed
price elasticity	The percentage change in quantity demanded with respect to a one percent change in price.
PROA	Identifier for the "proactive" fuel economy strategy: making all feasible and profitable improvements above what is necessary to meet CAFE
proactive fuel economy strategy	PROA
probability weighted forecasts	Calculating the future value of a variable using weighted averages of different scenarios.
PU	Pickup truck segment; defined by models included
PULRG	Large pickup truck segment (one of 15 segments)
PUSML	Small pickup truck segment (one of 15 segments)
REMI	Regional Economic Models, Inc.; also refers to the model used to estimate the impact of production changes on U.S. employment
retail transaction prices	Prices consumers pay for vehicles net of incentives

Term	**Definition**
segment	A set of vehicle models that directly compete with each other. In this study we split the light vehicle market into 15 segments
segment elasticity	The percentage change in quantity demanded for a segment with respect to a one percent change in price for the segment.
sub model	Underlying model built within the nested multinomial logit regression model
SUV	Sport Utility Vehicle is a type of passenger vehicle which combines the load-hauling and versatility of a pickup truck with the passenger-carrying space of a van or station wagon. Most SUVs are designed with a roughly square cross-section, an engine compartment, a combined passenger and cargo compartment, and no dedicated trunk.
SUVLLX	Large Luxury SUV (one of 15 segments)
SUVLRG	Large SUV (one of 15 segments)
SUVMID	Midsize SUV (one of 15 segments)
SUVMLX	Midsize Luxury SUV (one of 15 segments)
SUVSML	Small SUV (one of 15 segments)
total industry sales	Includes all vehicles sold in a certain time period
Truck	A 4-wheel vehicle which is designed for off-road operation (has 4-wheel drive or is more than 6,000 lbs. GVWR and has physical features consistent with those of a truck); or which is designed to perform at least one of the following functions: (1) transport more than 10 people; (2) provide temporary living quarters; (3) transport property in an open bed; (4) permit greater cargo-carrying capacity than passenger-carrying volume; or (5) can be converted to an open bed vehicle by removal of rear seats to form a flat continuous floor with the use of simple tools. (Legal definition)
truck-based	Chassis is built on a pickup truck platform
type	An aggregate of one or more segments. This study splits the light vehicle market into six types (CAR, CUV, MINIVAN, PU, SUV, VN).
Uni-body	Unibody vehicles are made of high-strength steel, welded into a single unit frame.
utility	In economics, utility is a measure of the happiness or satisfaction gained from a good or service
Van	It is generally a rather box-shaped vehicle on four wheels, about the same width and length as a large automobile, but taller and usually higher off the ground
VANLRG	Large Van (one of 15 segments)

Term	Definition
variable profits	Variable profit per unit is defined as a vehicle's wholesale price minus the cost of the materials, labor, and energy inputs used to produce the vehicle. Operationally we use gross profits as a proxy for variable profits. Variable profit is not affected by the substantial fixed costs associated with building and selling automobiles, such as the amortization of capital equipment (i.e., factories and tools); legacy costs (i.e., pension and medical costs for retirees); marketing costs; and research, development, and engineering costs.
vehicles	Used to refer to cars and trucks collectively
VN	Identical to VANLRG; Large Van

References

Alson, J., B. Ellies, and D. Ganss, 2005. *Interim Report: New Powertrain Technologies and Their Projected Costs*. EPA420-R-05-1012. U.S. Ann Arbor, MI: U.S. Environmental Protection Agency, Office of Transportation and Air Quality, Transportation and Climate Division. August.

Bento, Antonio M., Lawrence H. Goulder, Emeric Henry, Mark R. Jacobsen, And Roger H. Von Haefen (2005) *"Distributional and Efficiency Impacts of Gasoline Taxes: An Econometrically-Based Multi-Market Study," American Economic Association Papers And Proceedings* May 2005

Berry, Steven, James Levinson, and Ariel Pakes. (1995) *"Automobile Prices in Market Equilibrium."* Econometrica, 1995, 63(4), pp. 841–90.

Berry, S., J. Levinsohn, and A. Pakes. (2004) *"Differentiated Products Demand Systems from a Combination of Micro and Macro Data: The New Vehicle Market*," Journal of Political Economy 112, 68-105.

Congressional Budget Office, (2003) "*The Economic Costs of Fuel Economy Standards Versus a Gasoline Tax".* Congressional Budget Office, Washington, DC.

DeCicco, J., F. An, and M. Ross, ACEEE, 2001. "*Technical Options for Improving the Fuel Economy of U.S. Cars and Light Trucks by 2010-2015,"* American Council for an Energy Efficient Economy.

DOE 1995. "*Energy Conservation Trends: Understanding the Factors Affecting Conservation Gains and Their Implications for Policy Development*." Report DOE/PO-0034. Washington, DC: U.S. Department of Energy, Office of Policy. April.

EEA 2005*.* *"Fuel Economy Potential for 2010 Light Duty Trucks*," prepared for DOE and DOT, Energy and Environmental Analysis.

Espey, M. and Nair, S., *"Automobile Fuel Economy: What is it Worth*?" Contemporary Economic Policy (Western Economic Association). Vol. 23, No. 3, July 2005, 317-323.

Espey, M., *"Do Consumers Value Fuel Economy?"* Regulation (Cato Institute), Winter 2005-2006, 8-10.

Fudenberg, Drew and Jean Tirole (1991) "*Game Theory*," MIT Press.

David L. Greene (2001) *"TAFV: Alternative Fuels And Vehicles Choice Model Documentation"* Center for Transportation Analysis Oak Ridge National Laboratory July 2001

Greene, D.L., and Y. Fan, ORNL 1994. "*Transportation Energy Efficiency Trends, 1972-1992."* Report ORNL-6828. Oak Ridge, TN: Oak Ridge National Laboratory, Center for Transportation Analysis. December.

Greene, D.L., Duleep, K.G., and McManus, W.S., *"Future Potential of Hybrid and Diesel Powertrains in the U.S. Light-Duty Vehicle Market,"* ORNL Report, August 2004.

Griliches, Z. (1961). *"Hedonic Price Indexes for Automobiles: An econometric Analysis of Quality Change"*, in The Price Statistics of the Federal Government, New York, the National Bureau of Economic Research.

Hammett, P. Flynn, M., and Sims, M., *"Fuel-saving Technologies and Facility Conversion: Costs, Benefits, and Incentives,"* Office for the Study of Automotive Transportation, University of Michigan Transportation Research Institute, November 2004.

Heavenrich, R.M, EPA 2005. *Light-Duty Automotive Technology and Fuel Economy Trends, 1975 through 2005*. Ann Arbor, MI: U.S. Environmental Protection Agency, Office of Transportation and Air Quality, Advanced Technology Division. July.

Johnson, David S., Reed, Stephen B., and Stewart, Kenneth J. *"Price measurement in the United States: A decade after the Boskin Report,"* Monthly Labor Review, May 2006.

Kleit, A. *, "Impacts of Long-Range Increases in the Corporate Average Fuel Economy (CAFE) Standard,"* Economic Inquiry 42:2 (April 2004) 279-294. (Published version of "Short- and Long-Range Impacts of Increases in the Corporate Average Fuel Economy (CAFE) Standard," report for the General Motors Corporation, January 2002.)

Kurani, K.S., and T. Turrentine, 2004, *"Automobile Buyer Decisions about Fuel Economy and Fuel Efficiency,"* ITS-RR-04-31, University of California Institute of Transportation Studies Report, Sept. 1.

McFadden, D., *"Conditional Logit Analysis of Qualitative Choice Behavior,"* in P. In Zarembka, Frontiers in Econometrics (New York: Academic Press, 1973).

McManus, Walter S., Alan Baum, Roland Hwang, Daniel D. Luria, and Gautam Barua, *"IN THE TANK How Oil Prices Threaten Automakers' Profits and Jobs,"* Office for the Study of Automotive Transportation, University nof Michigan Transportation Research Institute, July 2005.

McManus, W.S., *"The Effects of Higher Gasoline Prices on U.S.Light Vehicle Sales, Prices, and Variable Profits by Segment and Manufacturer Group, 2001 and 2004,"* Office for the Study of Automotive Transportation, University of Michigan Transportation Research Institute, May 23, 2005.

NAS 2002. *Effectveness and Impact of Corporate Average Fuel Economy (CAFE) Standards,* report by the National Research Council, Washington, DC, National Academy Press.

Nash, John (1950) *"Equilibrium Points in N-person Games"* Proceedings of the National Academy of Sciences.

National Commission on Energy Policy, *"Ending the Energy Stalemate, A Bipartisan Strategy to Meet America's Energy Challenges,"* December 2004.

NESCCAF 2004. *"Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles."* Northeast States Center for a Clean Air Future. September.

NRC, 2002. *"Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards."* National Research Council, Washington, DC, National Academy Press.

Parry, Ian W.H., Carolyn Fischer, and Winston Harrington (2004) *"Should Corporate Average Fuel Economy (CAFE) Standards Be Tightened?"* December 2004 RFF DP 04-53

Rawls, John, (1971) "*A Theory of Justice,"* The Belknap Press of Harvard University Press.

Santini, D. and Vyas, A., (2005) *"Suggestions for a New Vehicle Choice Model Simulating Advanced Vehicles Introduction Decisions (AVID): Structure and Coefficients,"* Argonne National Laboratory, August 2005.

Train, K.E. and Winston, C., (2006) *"Vehicle Choice Behavior and the Declining Market Share of U.S. Automakers"* (2006) Forthcoming, International Economic Review.

Train, Kenneth E. (2003). *"Discrete Choice Methods with Simulation."* Cambridge, UK: Cambridge University Press.

Weiss, M., et al, MIT 2000.., *On the Road in 2020: A Life-cycle analysis of new automobile technologies.* Cambridge, MA: Massachusetts Institute of Technology. October.

Kenneth E. Train Clifford Winston (2004) *"Vehicle Choice Behavior And The Declining Market Share Of U.S. Automakers,"* U.C. Berkeley Brookings Institution July 2004

Williams, H.C.W.L., (1977) *"On the Formulation of Travel Demand Models and Economic Evaluation Measures of User Benefit,"* Environment and Planning, 9A, No.3, pp.285-344, 1977.

Feng, Ye; Fullerton, Don and Gan, Li. (2004) *"Vehicle Choices, Miles Driven and Pollution Policies,"* Working paper, University of Texas at Austin, July 2004.

Ye Feng Don Fullerton Li Gan (2005) *"Vehicle Choices, Miles Driven And Pollution Policies,"* Working Paper 11553 National Bureau Of Economic Research August 2005.