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The Potential Effects of the 2017-2025 EPA/NHTSA GHG/Fuel Economy Mandates on the U.S. Economy

CAR

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EXECUTIVE SUMMARY

This study conducted by the Center for Automotive Research (CAR) constitutes an economic cost benefit analysis of the national standards for light duty vehicle fuel economy and greenhouse gas emissions (GHG) set by the U.S. National Highway Traffic Safety Administration (NHTSA) and the Environmental Protection Agency (EPA) for the years 2017-2025. Past CAFE standards mandated an increase in fuel economy from 18.0 MPG in 1978 to 27.5 MPG by 1990 for passenger cars. Passenger car standards were 36.5 MPG in 2015 and are mandated to reach a projected 54.5 MPG by 2025. The analysis estimates the net value of the fuel economy improvements to the consumer that are mandated by the federal government during 2016-2025. The study also estimates the likely net benefits or costs to the new vehicle buyer of the technologies needed to meet the higher fuel economy mandates in 2025 and the effects of net fuel economy benefits on consumer purchases of total vehicles. For evaluation purposes, a baseline forecast for the U.S. motor vehicle market and industry in terms of sales, production, and employment through the year 2025 is presented that assumes the standards are not in place for 2017-2025. The study analysis, then, measures the effect of higher fuel economy mandates and the adoption of related expensive technologies on U.S. motor vehicle market, production, and automotive manufacturing and automotive dealership employment in the year 2025. Finally, this study discusses other effects of the mandates on the U.S. economy and contains CAR's policy recommendations pertaining to the mid-term review of the national standards for 2022-2025.

The major estimation results in this study include the following:

- As mandated, average real world fuel economy for new vehicles will increase by a projected 12.7 MPG between MY 2016 and MY 2025. Real world fuel economy is derived by adjusting the mandate standards for real world driving conditions. Thus, the MY 2016 real world driving standard is 27.3 MPG and 40.0 MPG in 2025.
- This study employs the most recent range of gasoline price forecast levels from the U.S. Energy Information Agency (EIA). In 2025 US dollars the forecast levels are $2.44/gallon, $3.00/gallon, and $4.64/gallon.
- A review of 14 published studies on new vehicle consumer valuation of fuel economy produces an average desired payback of 3.4 years for the cost of fuel economy technologies.
- Evaluated at the EIA range of fuel prices, fuel savings over three years are worth $1,287 ($2.44/gal.), $1,583 ($3.00/gallon), and $2,448 ($4.64/gallon) when adjusted for a rebound effect in miles traveled applied to a survey estimated average mileage traveled by new vehicles in the first three years of ownership.
- When evaluated at three fuel economy mandate cost levels of $2,000, $4,000, and $6,000, and a forecast price trend through 2025 for new vehicles, the study estimates nine scenarios for an increase or decrease in the net cost of buying a 2025 vehicle. The scenarios range from a net price decrease of -1.3 percent at a fuel price of $4.64/gallon and a fuel economy mandate cost of $2,000 to the highest of eight net cost increase scenarios of 14.1 percent at a fuel price of $2.44/gallon and a fuel economy mandate cost of $6,000. The study assumes that the full value of the change in net cost to the consumer is passed along to vehicle prices.
- The study estimates a long-run, own-price elasticity for new vehicle sales revenue of .61. Therefore, the effect on motor vehicle demand in terms of sales revenue in 2025 ranges from

+.82 percent at a fuel price of $4.64/gallon and a fuel economy mandate cost of $2,000 to the largest decrease of eight scenarios of -8.6 percent at a fuel price of $2.44/gallon and a fuel economy mandate cost of $6,000. The first scenario is associated with vehicle sales increase of 410,000 units and the second scenario with a loss of 3.71 million vehicle sales in the United States compared to the base sales forecast model. Three of the scenarios estimates a sales loss of 3 million or more vehicle sales.

- The estimated changes in vehicle sales are converted to changes in U.S. vehicle production through the use of a forecast of vehicle sourcing ratios. As a result, the 2025 fuel economy mandates produce changes in U.S. vehicle production that range from an increase of 240,000 units at a fuel price of $4.64/gallon and a fuel economy mandate cost of $2,000 to a decrease of 2.07 million units at a fuel price of $2.44/gallon and a fuel economy mandate cost of $6,000. Eight of the nine scenarios estimate a production decrease compared to the baseline estimate with five scenarios resulting a loss of over 1 million units in vehicle production.
- The estimated changes in U.S. vehicle production can be used to also estimate losses in automotive manufacturing employment in the vehicle and parts manufacturing sectors through the use of estimate of labor productivity in those industries in 2025. The changes in auto industry employment range from an increase of 15,700 at a fuel price of $4.64/gallon and a fuel economy mandate cost of $2,000 to a loss of 137,900 at a fuel price of $2.44/gallon and a fuel economy mandate cost of $6,000. Eight of the nine scenarios project a loss in industry employment.
- The overall change in vehicle sales, larger than the change in U.S. vehicle production, as a result of the 2025 fuel economy mandates, will also impact employment at new vehicle dealerships. Based on a trend in dealership labor productivity through 2025, the study estimates that in one scenario, dealership employment would rise by 18,000, in the case of $4.64/gallon gasoline price and $2,000 in fuel economy mandate cost, and eight scenarios in which dealership employment would fall – the largest being a decline of 99,000 in the case of $2.44 price of gasoline and $6,000 in fuel economy mandate cost.
- The projected gain and losses in automotive manufacturing and dealership employment as a result of the 2025 fuel economy mandates will affect the U.S. economy through a multiplier effect. Recent studies of the economic contribution of automotive manufacturing and new vehicle dealership employment have estimated that 5.6 jobs additional are created for every job in automotive manufacturing, and 1.3 jobs for every job in new vehicle dealerships. Using the multipliers of 6.6 for change in automotive manufacturing employment and 2.3 for changes in new vehicle dealership employment produces an increase in overall employment on the U.S. economy in 2025 of an increase of 144,020 jobs in the case of $4.64/gallon gasoline price and $2,000 in fuel economy mandate cost and eight scenarios with negative employment change including the loss of 1.13 million jobs in the case of $2.44/gallon gasoline price and $6,000 in fuel economy mandate costs.

An important conclusion of this study is the overwhelming and direct importance of fuel prices in forecasting the economic effects of the 2025 fuel economy mandates. If the value of fuel savings to the new vehicle buyer falls short of the cost of mandated fuel economy technologies then U.S. automotive sales, production, and manufacturing will fall with serious consequences for the U.S. economy. This study utilizes a special econometric analysis to estimate the influence of fuel prices on the demand for fuel efficient vehicles. The influence is powerful even in the short-run and particularly in periods of reasonable growth in personal disposable income and employment when greater wealth and access to consumer credit offers consumers the opportunity to move up-market in vehicle purchases.

Should fuel prices remain moderate or historically low as the result of increased oil supply and/or reduced global demand it will be challenging to sell advanced technology fuel efficient vehicles at costs above the value of fuel savings captured by the new vehicle buyer. Two of the three long-term 2015 EIA gasoline price scenarios portray this moderate or low gasoline future ($3.00 and $2.44 per gallon, respectively in 2025). It is difficult to recommend the best public policies for accommodating the current fuel economy mandates for 2022-2025 in a moderate or low gasoline price future when some polices are considered politically infeasible.

The recommendation section outlines several policies to encourage consumer demand for the commercialization of advanced fuel efficiency technologies and a larger share of fuel efficient vehicle sales by increasing the value of fuel efficient technologies to the consumer. These recommendations include utilizing a gasoline/fuel tax or a carbon tax mechanism; providing additional strong-hybrid and plug-in hybrid vehicle purchase incentives; recognizing and incentivizing the benefits of both on- and off-cycle technologies; and extending the mandate timeline to allow the market additional time to achieve projected learning curves and technology efficiencies. More recognition of on- and off-cycle technologies alone in no way ensures the industry a realizable path to meet the 2025 EPA/NHTSA mandates that are misaligned with the market demand for fuel economy. Applying these recommendations in some combination will better create and identify the benefits of saving fuel in the judgement of the American new vehicle consumer and, in the process, better align market demand for vehicle fuel efficiency.

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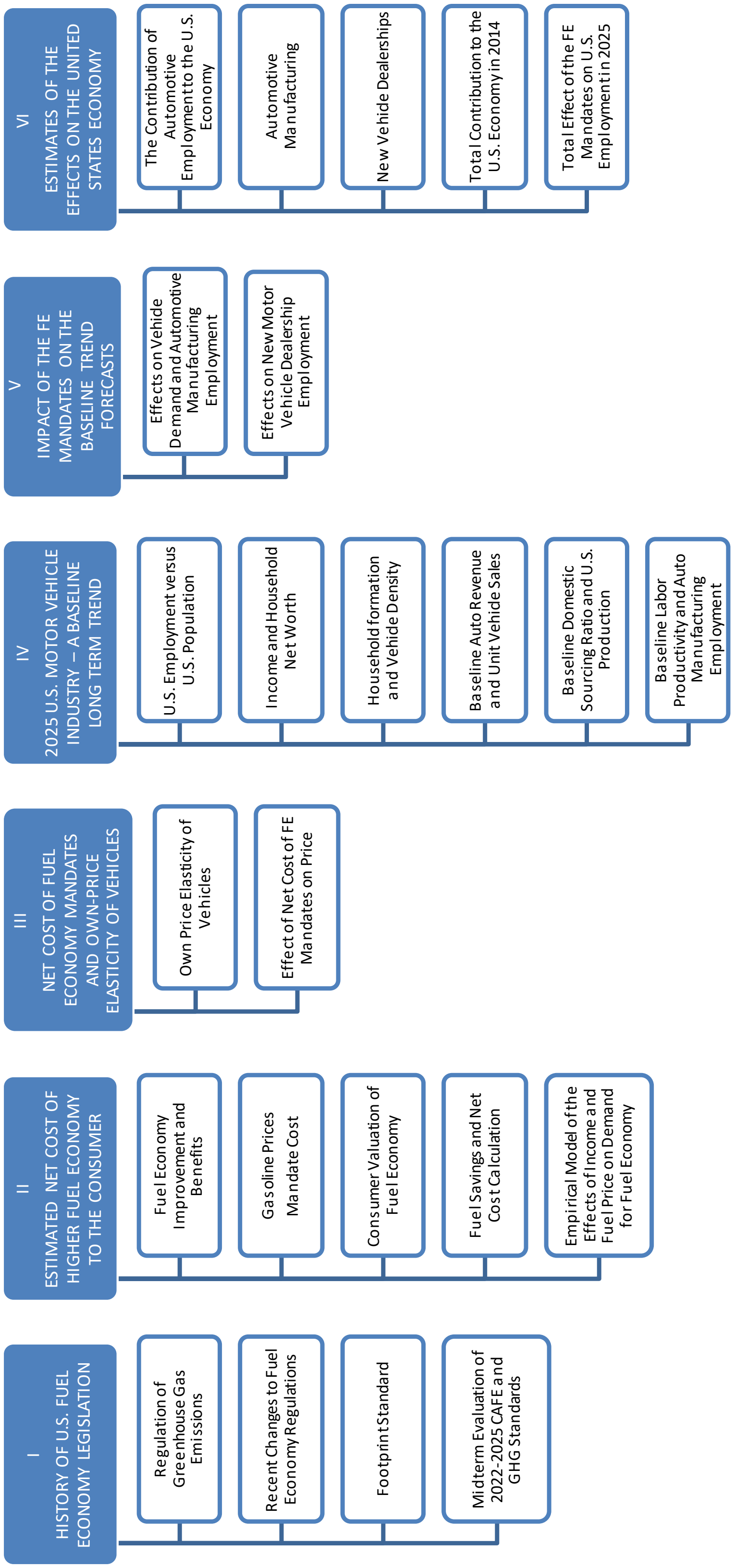
INTRODUCTION

This study conducted by the Center for Automotive Research (CAR) constitutes an economic cost benefit analysis of the national standards for light duty vehicle fuel economy and greenhouse gas emissions (GHG) standards set by the U.S. National Highway Traffic Safety Administration (NHTSA) and the Environmental Protection Agency (EPA) through the years 2017-2025. Past CAFE standards mandated an increase in fuel economy from 18.0 MPG in 1978 to 27.5 MPG by 1990 for passenger cars. Passenger cars standards were 36.5 MPG in 2015 and are mandated to reach a projected 54.5 MPG by 2025.The first section provides background on vehicle fuel economy and greenhouse gas regulations and standards mandated by the U.S. government (EPA/NHTSA). The second section estimates the net value of the fuel economy improvements to the consumer that are mandated by the federal government. The second section of this study also estimates the likely net benefits or costs to the new vehicle buyer of the technologies needed to meet the higher fuel economy mandates to the American consumer of new light vehicles in 2025. The third section estimates the effects of net fuel economy benefits on consumer purchases of total vehicles and types of vehicles. The fourth section presents a baseline forecast for the U.S. motor vehicle market and industry in terms of sales, production, and employment through the year 2025 based on long-term social and economic factors and assuming the standards for 2017-2025 are not in place. The fifth section of this study also analyzes how the impact of higher fuel economy mandates and the adoption of related expensive technologies will affect the U.S. motor vehicle market, production, and automotive manufacturing and automotive dealership employment in the year 2025. The final or sixth section of this study will discuss other effects on the U.S. economy and contain CAR's policy recommendations pertaining to the mid-term review of the national standards for 2022-2025.

The major estimation tasks performed in this study are reviewed in Figure 1 which shows six major steps or components in the estimation as well as details, discussed later in the study, of estimation sub-components of analysis.

For example, in step one, once the effect of higher net costs due to mandated fuel economy standards are passed through to prices, CAR can estimate the impact on total light vehicle sales in 2025. The effect on the U.S. industry is estimated in step five which must use an estimated domestic sourcing ratio to determine the effect on U.S. vehicle production, and also employ a labor productivity trend estimate through 2025 to derive the effect on U.S. automotive manufacturing employment. Change in dealership employment is more straight forwardly estimated without a sourcing trend. In step six, this study's estimates of the change in automotive manufacturing and dealership employment are expanded to estimate an effect on total U.S. employment. CAR uses employment multipliers from a recent major study of the contribution of the industry to the U.S. economy in 2014 to determine this total effect.

Figure 1: Research Inputs and Outputs



I. History of U.S. Fuel Economy Legislation

Before proceeding to CAR's estimation of the effect of the national standards on the U.S. economy, it should prove useful to describe the history of vehicle fuel economy regulation in the United States through the Corporate Average Fuel Economy (CAFE) standards set by National Highway Transportation Safety Administration (NHTSA), a division of the U.S. Department of Transportation (USDOT). This description also covers the regulation of greenhouse gas emissions by EPA and the California Air Resources Board (CARB). These three agencies, CARB, EPA, and NHTSA have collaborated to harmonize their standards through model year 2025.

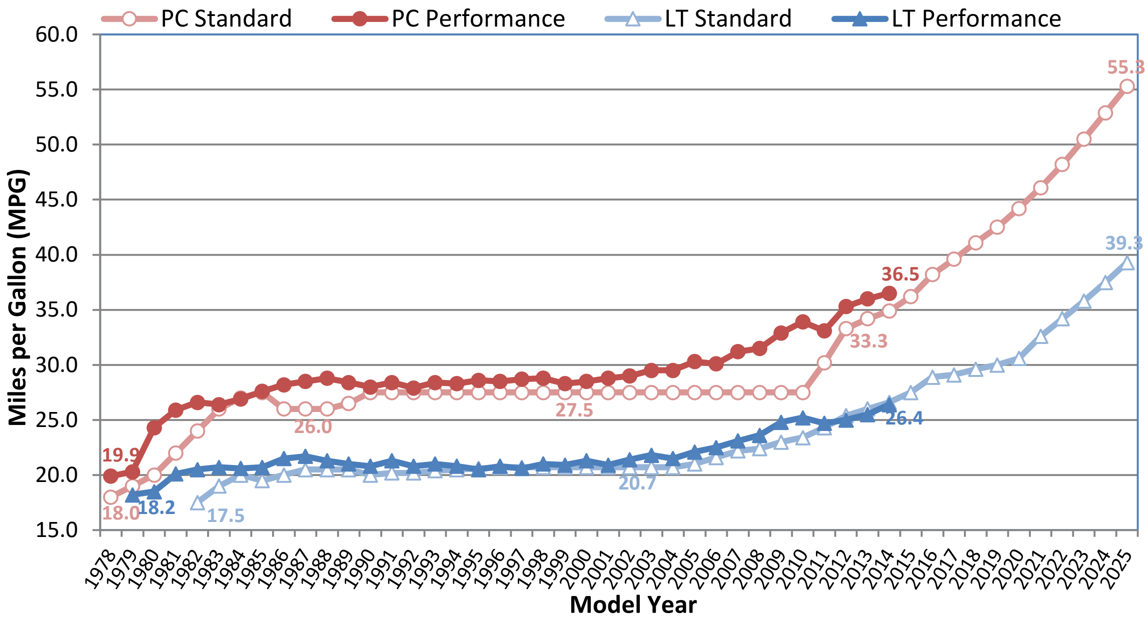
In response to the 1973 oil crisis, the U.S. Congress passed the Energy Policy and Conservation Act (EPCA) in 1975, which established the Corporate Average Fuel Economy (CAFE) program, in an attempt to decrease U.S. dependence on foreign oil. CAFE refers to the average fuel efficiency—measured in miles per gallon (MPG)—of all the vehicles a company produces of a given model year that are sold in the United States. The CAFE program was designed to decrease fuel consumption of the vehicles sold in the United States by requiring automakers to meet increasing fuel efficiency targets. CAFE regulations came into effect for passenger cars beginning in 1978 and for light-duty trucks—which include pickups, vans, and sports utility vehicles (SUVs)—beginning in 1979.

From 1978 to 1985, the combined CAFE requirement for passenger cars increased more than 50 percent from 18.0 MPG to 27.5 MPG, and the actual fuel economy of vehicles sold also increased (see Figure 2). In response to petitions from automakers struggling to meet CAFE requirements, NHTSA relaxed the standard for model years 1986-1989. For model year 1990 the CAFE standard was restored to its 1985 level of 27.5 MPG and would remain unchanged until model year 2011.

Figure 2 shows from the mid-1980s through 2010, CAFE requirements remained virtually unchanged, and improvements in vehicle efficiency were used to satisfy strong consumer preferences for performance (e.g., improved horsepower, torque, and acceleration) and other features (e.g., improved ride and handling, safety, air conditioning, sound systems, power seats and mirrors, sun roofs, and emissions equipment) rather than increasing fuel economy.[1] In addition, a shift in market share from passenger cars to SUVs and pickup trucks during that period led to lower overall fuel efficiency than would have been expected had the vehicle segmentation mix remained constant.[2]

[1] Knittel, Christopher R. (2011). "Automobiles on Steroids: Product Attribute Trade-Offs and Technological Progress in the Automobile Sector." American Economic Review, 101(7): 3368-3399. December 2011. <http://pubs.aeaweb.org/doi/pdfplus/10.1257/aer.101.7.3368>.
[2] Ibid. Knittel. (2011).

Figure 2: CAFE Summary by Year (Actual Performance & Regulatory Standard) for Passenger Cars (PC) and Light Trucks (LT), Model Years 1978-2025



Source: NHTSA 2009, NHTSA 2011, and NHTSA 2014

Regulation of Greenhouse Gas Emissions

The Clean Air Act of 1963 was the first federal law regulating air quality in the United States. It was expanded by amendments passed in 1970, 1977, and 1990.[3] Among other responsibilities, the Clean Air Act requires EPA to set standards for stationary and mobile sources (i.e., vehicles) of air pollution. Under the Clean Air Act, the EPA has set standards for "criteria pollutants:" carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide. At the request of the U.S. Congress, EPA has also addressed other issues, including hazardous and toxic air pollutants, acid rain, depletion of the ozone layer, regional haze, and other emerging problems, such as greenhouse gases (GHGs).

In 2003, the EPA denied a 1999 petition to regulate GHG emissions from vehicles under the Clean Air Act because: 1) Congress had not granted EPA authority to regulate GHGs under the Clean Air Act, and 2) setting vehicle GHG emission standards was not appropriate at the time.[4] A coalition of states, cities, and environmental organizations challenged the EPA decision, and in 2006, the matter was taken before the U.S. Supreme Court in the Massachusetts v. EPA case.[5] In April 2007, the Court in a 5-4 ruling determined that GHGs are pollutants and may be regulated under the Clean Air Act. A month after the Supreme Court decision, President George W. Bush ordered the EPA to regulate GHG emissions from vehicles in

[3] EPA. (2015). "Clean Air Act Requirements and History." U.S. Environmental Protection Agency. Accessed April 28, 2015. <http://www.epa.gov/air/caa/requirements.html>.
[4] EPA. (2003). "EPA Denies Petition to Regulate Greenhouse Gas Emissions from Motor Vehicles." U.S. Environmental Protection Agency. August 28, 2003. <http://yosemite.epa.gov/opa/admpress.nsf/fb36d84bf0a1390c8525701c005e4918/694c8f3b7c16ff6085256d900065fdad!OpenDocument>.
[5] Supreme Court. (2007). "Supreme Court of the United States: Massachusetts et al. V. Environmental Protection Agency et al." Legal Information Institute, Cornell University Law School. April 2, 2007. <https://www.law.cornell.edu/supct/html/05-1120.ZS.html>.

cooperation with the USDOT and the U.S. Department of Energy (USDOE).[6] In 2009, the EPA released its endangerment finding, in which it declared that GHGs, including those from motor vehicles, endanger the health and welfare of Americans and merit regulation.[7]

Regulation of GHG emissions from vehicles has also taken place at the state level in California. In 2002, the California State Assembly passed a law requiring CARB to regulate GHG emissions from vehicles. In September 2004, CARB approved regulatory standards which would limit GHG emissions from new passenger vehicles and light duty trucks beginning with model year 2009.[8] In order to proceed with the new standards, CARB required a waiver from EPA, which it requested in December 2005.[9] Over the following two years, California Governor Arnold Schwarzenegger wrote to and met with EPA Administrator Stephen Johnson in pursuit of the waiver. After the April 2007 Supreme Court ruling, the EPA announced two public hearings to consider the California waiver request.[10] In May 2009, CARB agreed to harmonize its GHG emissions standards with those proposed by EPA and NHTSA in return for a waiver from EPA,[11] and in June 2009, EPA granted the waiver.[12]

Recent Changes to Fuel Economy Regulations

In December 2007, the Energy Independence and Security Act (EISA) was signed into law by President George W. Bush. Among other things,[13] EISA required NHTSA to increase CAFE requirements beginning in 2011.[14] EISA required a CAFE requirement of at least 35 MPG by 2020. By model year 2007, total fleet fuel economy was already increasing and continued to do so year after year.[15]

On May 19, 2009, President Barack Obama announced a new national fuel economy program requiring a more aggressive timeline than had been prescribed by EISA. With a fuel economy standard of 35.5 MPG for new light vehicles sales by 2016, the plan moved up the EISA timeline by four years.[16] The new program also required EPA and NHTSA to harmonize the EPA GHG regulations and NHTSA CAFE regulations for model years 2012-2016.[17] In September 2009, the two agencies proposed a harmonized program covering

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[6] Bush, George W. (2007). "Executive Order 13432." Federal Register, National Archives and Records Administration, 72(94): 27717-27719. May 16, 2007. <http://www.gpo.gov/fdsys/pkg/FR-2007-05-16/pdf/07-2462.pdf>.
[7] Federal Register. (2009). "Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act." Federal Register, National Archives and Records Administration, 77(239): 66496-66546. December 15, 2009. <http://www.epa.gov/climatechange/Downloads/endangerment/Federal_Register-EPA-HQ-OAR-2009-0171-Dec.15-09.pdf>.
[8] CARB. (2007). "Fact Sheet: Climate Change Emissions Standards for Vehicles." California Air Resources Board, California Environmental Protection Agency. May 30, 2007. <http://www.arb.ca.gov/cc/ccms/factsheets/ccfaq.pdf>.
[9] Under the Clean Air Act, California is allowed to set standards that are stricter than federal standards, but required a waiver from the EPA to do so. Once California receives a waiver, other states can elect to adopt California's standards.
[10] Ibid. CARB. (2007).
[11] Nichols, Mary D. (2009). Letter to The Honorable Lisa P. Jackson, Administrator of the United States Environmental Protection Agency and The Honorable Ray LaHood, Secretary of the United States Department of Transportation. California Air Resources Board, California Environmental Protection Agency. May 18, 2009. <http://www.epa.gov/otaq/climate/regulations/air-resources-board.pdf>.
[12] EPA. (2009). "EPA Grants California GHG Waiver." U.S. Environmental Protection Agency. June 30, 2009. <http://yosemite.epa.gov/opa/admpress.nsf/6427a6b7538955c585257359003f0230/5e448236de5fb369852575e500568e1b!OpenDocument>.
[13] In addition to CAFE, EISA addressed other fuel economy programs (advanced vehicle technology programs and federal vehicle fleets), biofuels (the national renewable fuel standard, research and development, and refueling infrastructure), and standards for buildings and appliances.
[14] Energy Independence and Security Act of 2007, Public Law 110-140 [H.R. 6] (42 USC 17001).
[15] Ibid. NHTSA. (2014).
[16] White House. (2009). "President Obama Announces National Fuel Efficiency Policy." Office of the Press Secretary, the White House. May 19, 2009. <https://www.whitehouse.gov/the_press_office/President-Obama-Announces-National-Fuel-Efficiency-Policy/>.
[17] NHTSA is tasked with regulating fuel economy and EPA is tasked with regulating GHG emissions—though these metrics are closely related, meeting one regulation does not guarantee meeting the other regulation. The two agencies were tasked with harmonizing the disparate standards to enable automakers to satisfy both sets of regulations.

model years 2012-2016.[18] In May 2010, Obama directed EPA and NHTSA to start planning new fuel economy and GHG emissions standards for 2017-2025.[19]

In October 2010, EPA and NHTSA took the first step by announcing their initial assessment, or Notice of Intent (NOI), for stringent standards for model year 2017-2025 vehicles.[20] In a joint document, the Interim Joint Technical Assessment Report (TAR), CARB, EPA, and NHTSA, proposed four potential GHG emissions reduction scenarios through 2025: 3.0, 4.0, 5.0, and 6.0 percent annual reductions from the mandated 2016 level.[21]

In July 2011, the Obama administration proposed a fuel economy target of 54.5 MPG—163 grams of carbon dioxide (CO_2) per mile—by 2025.[22] The target is within the range of the four TAR scenarios, with the stringency of the standards increasing at approximately 5.0 percent annually. In the announcement, the Administration claimed that by 2025 a total of $1.7 trillion would be saved in fuel costs, or an average of $8,000 per vehicle. The targets were established with input from federal and state agencies, 13 automakers,[23] environmental groups, and other stakeholders. In August 2012, EPA finalized the standards for model years MY 2017-2025 and NHTSA for MY 2017 - 2021.[24]

Footprint Standard

The new fuel economy regulations include a vehicle footprint standard. The standard assigns different fuel economy targets to vehicles based on individual footprint, which is equivalent to the vehicle width multiplied by the wheelbase.[25] Vehicles with a smaller footprint are assigned a more stringent fuel economy standard than vehicles with larger footprints. Researchers have suggested that a footprint-based CAFE standard incentivizes automakers to increase the size of the vehicles they produce.[26]

[18] Ibid. Federal Register. (2009).
[19] White House. (2010). “Presidential Memorandum Regarding Fuel Efficiency Standards.” Office of the Press Secretary, the White House. May 21, 2010. <https://www.whitehouse.gov/the-press-office/presidential-memorandum-regarding-fuel-efficiency-standards>.
[20] NHTSA. (2010). “DOT and EPA Announce Next Steps Toward Tighter Tailpipe and Fuel Economy Standards for Passenger Cars and Trucks.” National Highway Traffic Safety Administration, U.S. Department of Transportation. October 1, 2010. <http://www.nhtsa.gov/About+NHTSA/Press+Releases/2010/DOT+and+EPA+Announce+Next+Steps+toward+Tighter+Tailpipe+and+Fuel+Economy+Standards+for+Passenger+Cars+and+Trucks>.
[21] EPA, NHTSA, and CARB. (2010). “Interim Joint Technical Assessment Report: Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2017-2025.” U.S. Environmental Protection Agency, National Highway Traffic Safety Administration, and California Air Resources Board. September 2010. <http://www.epa.gov/oms/climate/regulations/ldv-ghg-tar.pdf>.
[22] White House. (2011). “President Obama Announces Historic 54.5 mpg Fuel Efficiency Standard.” Office of the Press Secretary, the White House. July 29, 2011. <https://www.whitehouse.gov/the-press-office/2011/07/29/president-obama-announces-historic-545-mpg-fuel-efficiency-standard>.
[23] The automakers included BMW, Chrysler (now FCA), Ford, General Motors, Honda, Hyundai, Jaguar/Land Rover, Kia, Mazda, Mitsubishi, Nissan, Toyota and Volvo.
[24] White House. (2012). “Obama Administration Finalizes Historic 54.5 mpg Fuel Efficiency Standards.” Office of the Press Secretary, the White House. August 28, 2012. <https://www.whitehouse.gov/the-press-office/2012/08/28/obama-administration-finalizes-historic-545-mpg-fuel-efficiency-standard>.
[25] Federal Register. (2012). “2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards.” Federal Register, National Archives and Records Administration, 77(199): 62624-63200. October 15, 2012. <http://www.gpo.gov/fdsys/pkg/FR-2012-10-15/pdf/2012-21972.pdf>.
[26] Whitefoot, Katie and Steven Skerlos. 2012. “Design Incentives to Increase Vehicle Size Created from the U.S. Footprint-based Fuel Economy Standards.” Energy Policy 41: 402-411. February 2012. <http://www.sciencedirect.com/science/article/pii/S0301421511008779>. and Gillingham, Kenneth. (2013). “The Economics of Fuel Economy Standards versus Feebates.” Working Paper. National Energy Policy Institute. April 4, 2013. <http://www.ourenergypolicy.org/wp-content/uploads/2013/07/Gillingham-CAFE-Standards-vs-Feebates-Apr-20131.pdf>.

The footprint standard was required in order to maintain the fleet composition and reduce potential safety consequences of downsizing the fleet (i.e., without a footprint standard, automakers could sell fewer large vehicles and more small vehicles to improve CAFE performance). Though it may aid in maintaining the current fleet composition, a footprint standard will likely increase the cost of meeting CAFE targets, as automakers will become more reliant on expensive technologies to improve efficiency rather than producing smaller, lighter vehicles.[27]

Midterm Evaluation of 2022-2025 CAFE and GHG Standards

Both EPA and NHTSA committed to conducting a mid-term evaluation of the 2022-2025 standards. The two agencies submitted a draft Technical Assessment Report (TAR) in July, 2016 and will make final decisions based on the evaluation by April 1, 2018. According to the Federal Register notice,[28] the mid-term evaluation will be "a totally fresh consideration of all relevant information and fresh balancing of statutory and other relevant factors in order to determine the maximum feasible CAFE standards for MYs 2022–2025." The agencies will work with CARB and other stakeholders to "develop and compile up-to-date information for the mid-term evaluation, through a collaborative, robust and transparent process, including public notice and comment." The Federal Register lists several factors that will be considered, including available technology, effect on employment, alternative fuel infrastructure, vehicle and fuel costs, payback periods, vehicle sales and fleet mix, market penetration, and other factors relevant to the review. Draft final rulings for the agencies may be submitted in January, 2017 and would set standards for NHTSA for MY 2022-2025 and a possible change in EPA standards (increase or decrease) or no change for 2022-2025.

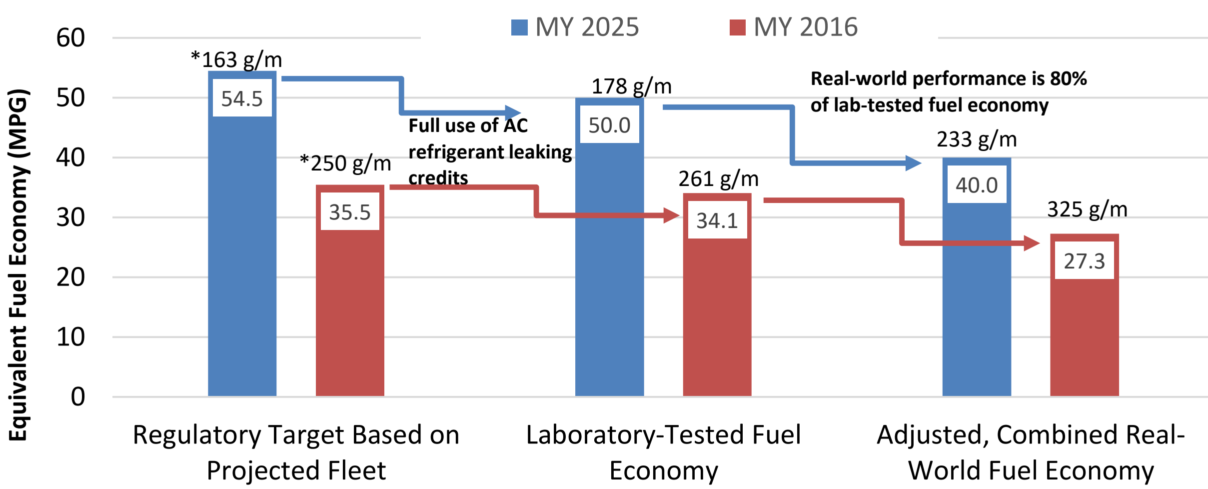
[27] Jacobsen, Mark R. (2012). "Fuel Economy and Safety: The Influences of Vehicle Class and Driver Behavior." Working Paper 18012. National Bureau of Economic Research. April 2012. <http://www.nber.org/papers/w18012.pdf>.
[28] Ibid. Federal Register. (2012).

II. ESTIMATED NET COST OF BENEFITS OF HIGHER FUEL ECONOMY TECHNOLOGIES TO THE CONSUMER

Fuel Economy Improvement and Benefits

This study considers the mandated improvement in fuel economy from 2016 to 2025 – the only personal benefit or gain to the 2025 fuel economy mandates that are realized or recognized by the vast majority of buyers of new motor vehicles. The estimated greenhouse gas levels required to meet U.S. greenhouse gas regulations are 250 g/mile (equivalent to 35.5 MPG) for MY 2016 vehicles and 163 g/mile (equivalent to 54.5 MPG) for MY 2025 vehicles; however, these levels may be reached through a combination of tail pipe emissions reductions and credits granted for reduction of air conditioning system refrigerant leakage.[29] If the air conditioning (AC) refrigerant credits are utilized to the extent the regulators estimate, which is the expectation of CAR researchers, the unadjusted, lab-tested fuel economy would be approximately 261 g/mile (equivalent to 34.1 MPG) for MY 2016 vehicles and 178 g/mile (equivalent to 50 MPG) for MY 2025 vehicles. Real-world fuel economy is estimated to be 80 percent of lab-tested fuel economy,[30] after adjusting the lab-tested fuel economy, the real-world fuel economy of the average vehicle would be 27.3 MPG for MY 2016 and 40.0 MPG for MY 2025 (see Figure 3).[31,32] Thus, between MY 2016 and MY 2025, the real-world fuel economy of the average vehicle will increase by a projected 12.7 MPG (this assumes AC refrigerant credits are used).

Figure 3: Calculation of Fuel Economy Target for MY 2016 and MY 2025 Vehicles



Source: EPA and NHTSA Final Rule, 2012

**Based on CO_2 emission requirement (grams per mile).*

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[29] EPA. (2014). "Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2014." U.S. Environmental Protection Agency. October 2014. <http://www.epa.gov/fueleconomy/fetrends/1975-2014/420r14023a.pdf>.

[30] EPA and NHTSA. (2012). "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards" Final Rule. Environmental Protection Agency and National Highway Traffic Safety Administration, U.S. Department of Transportation. October 15, 2012. <http://www.nhtsa.gov/fuel-economy>. P. 62988 - 62990

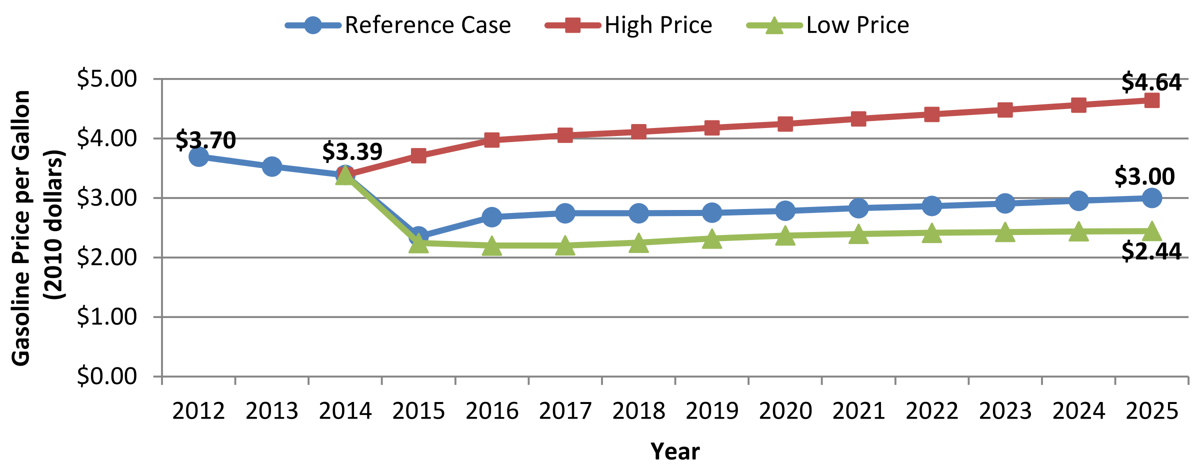
[31] Ibid. Table III-4

[32] EPA estimated fuel economy for MY 2016 would be 27.8 mpg. The 27.3 mpg estimate of MY 2016 fuel economy is based on restrictions within the NHTSA CAFE program for MY 2016. The reduction in MY 2016 fuel economy in this report will lead to additional fuel savings.

Gasoline Prices

In the United States, energy prices are tracked and forecasted by the U.S. Energy Information Agency (EIA). In the EIA reference (most likely) forecast, the price for a gallon of gasoline will be $3.00 in constant 2015 dollars in 2025. The EIA also provides forecast estimates for high petroleum prices ($4.64 per gallon of gasoline) and low petroleum prices ($2.44 per gallon of gasoline) for that year. The EIA gasoline price forecast through 2025 is displayed in Figure 4.

Figure 4: Motor Gasoline Prices and Forecast, 2012-2025



Source: EIA 2015 "Annual Energy Outlook 2015." U.S. Energy Information Administration. April 14, 2015. <http://www.eia.gov/forecasts/aeo/tables_ref.cfm>.
Note: Prices reflect sales weighted-average price for all grades, including federal, state, and local taxes.

Crude oil is priced by the barrel, and there are multiple benchmark spot prices that are used when referring to the global price of oil. The most common benchmark blends are "Brent" from the North Sea of Europe, West Texas Intermediate (WTI) in the southwestern United States, and Dubai/Oman in the Middle East. Because these benchmark blends vary in refining properties as well as delivery locations, they have different prices, which are constantly changing as traders buy and sell crude oil contracts.

In addition to the EIA, several other organizations produce long-term oil price forecasts, including the International Energy Agency (IEA), the Organization of the Petroleum Exporting Countries (OPEC), and the World Bank, as well as several economic consulting groups. The EIA reference 2025 forecast assumes per barrel oil prices of $91 (Brent Crude), $85 (WTI), and $82 (average import price). The average (mean) of selected publicly available oil price forecast estimates[33] is $97 per barrel in 2025,[34] which is equivalent to the 2025 forecast value from a November 2014 OPEC report. The EIA reference case forecast estimate values (Brent, WTI, and average import price) are all below the average 2025 forecast price. The EIA price

[33] Including forecast estimates from Arrowhead Economics; EIA; Energy Security Analysis, Inc. (ESAI); Energy Ventures Analysis (EVA); IEA; Interindustry Forecasting Project at the University of Maryland (INFORUM); OPEC; Securing America's Future Energy (SAFE); Strategic Energy & Economic Research Inc. (SEER); and the World Bank.

[34] EIA "Annual Energy Outlook" 2014, EIA "Annual Energy Outlook" 2015, IEA "World Energy Outlook" 2014, OPEC "World Oil Outlook" 2014, SAFE "Oil Security 2025" 2014, World Bank "World Bank Commodities Price Forecast" 2015. Oil price forecasts are in constant 2013 dollar, unless otherwise noted.

forecast is below those offered from the IEA and several of the consulting groups. The EIA forecast estimate is also in line with forecast values from OPEC and the World Bank. Given that the EIA oil price forecast estimates, which serve as the basis for gasoline price forecasts, are either below or in-line with other benchmark forecasts, the EIA forecast gasoline prices can defensibly be used in CAR's analysis.

Mandate Cost to the Consumer

A 1991 study performed by Greene concluded that, for every one mile-per-gallon increase in vehicle fuel economy, the average, per-vehicle cost would be within the range of $100-200 dollars, in constant 1985 dollar terms, and corresponding to a range of $200-400 in 2010 dollars.[35] A review of CAFE by Klier and Linn (2011) found that numerous other studies have confirmed these figures.[36] Using the range found in the literature, the projected 12.7 MPG improvement in fuel economy would cost on average somewhere between $2,500 and $5,000 per vehicle. Taking this range into account, CAR considers three different compliance costs for the 2025 fuel economy mandate: $2,000, $4,000, and $6,000. These costs represent the average per-vehicle cost (in 2015 dollars) to comply with the 2025 fuel economy regulations. It is useful, however, to review the elements of mandate cost (**MC**), sometimes called "retail price equivalent (RPE)," that can be passed along to the consumer in purchasing the vehicle in 2025:

Direct Manufacturing Cost of Producing the FE Technology (DMC), or the price an automaker would pay a supplier for a fully manufactured part ready for assembly in a vehicle, or the automaker's total cost of internally manufacturing the same part.

Indirect Cost (IC), often referred to as "overhead" or expenditures not directly required for manufacturing a component but necessary for the operations of the automaker. These costs include such elements as warranty expenses, purchasing and parts testing expenses, research and development, depreciation and appreciation, maintenance repair operations, general and administrative services, retirement costs, transportation costs, marketing costs, and normal profit.[37]

Dealership Gross Margin (DGM) would include dealership net profit margin, business taxes, operating costs including new vehicle sales labor, vehicle preparation costs, marketing costs, and floorplan expenses. In fact, many of these expenses do vary with vehicle price including some retail store expenses and servicing equipment needed for warranty work.

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[35] Greene, David L. (1991). "Short-Run Pricing Strategies to Increase Corporate Average Fuel Economy." *Economic Inquiry* 29(1): 101–114.

[36] Klier, Thomas and Joshua Linn. (2011). "Corporate Average Fuel Economy Standards and the Market for New Vehicles." *Annual Review of Resource Economics* 3(1): 445-462.

[37] Much has been made by analysts at the regulatory agencies and a handful of outside academics of the level of new technology in determining indirect cost as well as the effect of so-called "learning curves" on both indirect costs and direct manufacturing costs. These assumptions have been used in the agencies' assessments despite the fact in the 2016 Draft Technical Assessment Report it states "there is no actual cost data from industry to support them." It should be needless to point out that the fuel economy mandates have resulted in an unprecedented acceleration in the pace of product development and technology deployment, especially in powertrain and the use of new materials. New technologies are being deployed in the market for shorter and shorter lifespans before replacement. This obvious fact alone should overwhelm any outdated discussion of learnings curves or technology levels. Overhead rates have increased dramatically as production volumes fall for each model introduction. Even so, CAR uses the 1.50 indirect cost or RPE multiplier researched by Vyas, Anant, et. al., Comparison of Indirect Cost Multipliers for Vehicle Manufacturing, Technical Memorandum in support of Electric and Hybrid Vehicle Cost Estimation Studies, Center for Transportation Research, energy systems division, Argonne National Laboratory, Argonne IL., 2000, and Rogozhin, Alex, et. al., RTI International. Automobile Retail Price Equivalent and Indirect Cost Multipliers. February 2009. CAR disagrees with the RTI analysis on many grounds including the exclusion of automaker net profits and the underestimation of dealer gross margin in retail price.

Sales Taxes (ST) paid by the consumer to state and local governments on the final price of the vehicle.

Insurance Cost and Financing Cost (INC, FC) paid by the consumer on the addition to final "roll-away" price that is determined by the elements described above for five years (average ownership period). Since American consumers finance about 90 percent of their vehicle purchases and about 84.9 percent of buyer's finance or lease their purchases – finance costs are adjusted for these percentages.

Therefore, if **IC, DGM, INC**, and **FC** are converted to ratios of **DMC**, for example, **ICR = (DMC+FC)/DMC**

MC = ((DMC * ICR)*DGMR)*STR)*(INCR+FCR-1)

Where,

ICR = Indirect cost rate, roughly 1.50 (Source: NHTSA, NAS 2012). CAR believes however, that the ICR is used to set the manufacturer's invoice price to the dealer, not the manufacturer's suggested retail price to the consumer (MSRP). The MSRP does reflect what automakers think the dealer should receive as a gross margin over MSRP. However, the final price of the vehicle is in control of the dealer, not the automaker. MSRP is almost never the price paid by the consumer.[38]

DGMR = Dealership gross margin rate or roughly 1.0375, or the margin the dealer receives above the manufacturers invoice price.[39]

STR = Sales tax rate or roughly 1.055. This is applied to the final "roll away" price paid by the consumer. (Source, NHSTA 2012)[40]

INCR; FCR = Insurance cost rate, 1.080; Financing rate =1.0415 (using NHTSA gross finance cost of 5.43% for 5 years adjusted for 10% down payment and 85.9% of buyers financing.[41]

Thus the gross cost to the consumer is **$MC = $DMC * 1.84**. It is this cost that is netted for future fuel savings to gauge the impact of the FE mandates on the new vehicle consumer in terms of higher upfront vehicle cost.

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[38] Department of Transportation. (2012) *Corporate average fuel economy standards for MY 2017-MY 2025 passenger cars and light trucks*. Final Regulatory impact analysis. Retrieved from www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/FRIA_2017-2025.pdf, pp.763-793.
National Research Council, Cost, (2015*) Cost, effectiveness, and deployment of fuel economy technologies for light duty vehicles.* Committee on the Assessment of Technologies for Improving Fuel Economy of Light-duty Vehicles*,* Phase 2. Board on Energy and Environmental Systems. Division on Engineering and Physical Sciences. Washington D.C. National Academies Press. Pp. 245-261. However, it must be assumed that both the NHTSA and NRC analysts include dealership gross margin in the RPE rate of 50 percent. This would be disturbing to dealerships who control their own margins.

[39] National Association of Automobile Dealers, *NADA Data 2015*. Retrieved from https://www.nada.org/nadadata/ Alexandria, VA, 2016.

[40] Department of Transportation. (2012) *Corporate average fuel economy standards for MY 2017-MY 2025 passenger cars and light trucks*. Final Regulatory impact analysis. Retrieved from www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/FRIA_2017-2025.pdf, p.830.

[41] Ibid, pp.830-832. CAR is willing to accept the very low discount rate of 3 percent in this case since the finance rate is fixed with no risk and insurance cost is semi-fixed compared to highly variable fuel prices. The method of discounting at the beginning of the year is acceptable for finance payments but not insurance payments which are typically paid at the beginning of the year. Szakaly, Steven, Chief Economist, NADA, *A Future of Dreamers or Drivers*, a presentation given at the 2016 CAR Management Briefing Seminars, Traverse City, Michigan, August 2, 2016. Slide, 10.

Consumer Valuation of Fuel Economy

Discount rates are an important part of determining the present value of future savings. Discount rates are comprised of three components: time preferences when evaluating present and future consumption, expected inflation, and the risk premium. When valuing an uncertain future payoff, the risk premium represents the probability a lower-than-expected payoff will occur. Given the high volatility of gasoline prices and potential uncertainty surrounding new fuel economy technologies, it is expected that consumers will have an extremely high risk premium when judging likely future fuel savings. The great majority of consumers can be assumed to be risk or loss averse in terms of economic behavior. In line with this expectation, the literature on consumer valuation of fuel economy typically identifies relatively high discount rates. These high implicit discount rates could be due to credit constraints, risk aversion, the long-term nature of the investment, or uncertainty about future prices or new technologies. High implicit discount rates may also be the result of valuation mistakes due to imperfect information or bounded rationality.[42]

Evidence suggests that consumers do not take the full vehicle lifetime fuel cost into account when purchasing a new vehicle.[43] Rather, new-vehicle buyers require that investments in fuel efficiency produce net benefits during a relatively short period, either before the loan is paid off, or within the anticipated ownership period. Numerous sources, including the market research departments of automakers and their advertising and marketing consultants, suggest that consumers investing in fuel economy demand an undiscounted three-year payback (see Table 1 for an averaging of implicit discount rates and desired payback periods for fuel economy in a number of relevant studies) to win consumer acceptance. Thus, the cost of fuel economy improvement should be no more than three times the annual savings.[44] If consumers discount the benefits and costs of fuel savings over a typical five-year ownership, the assumed three-year undiscounted payback would be equivalent to a discount rate of 19.85 percent over five years if benefits are evaluated at the end of the year. Such high consumer discount rates are commonly seen in the literature; in fact, some studies have found much higher implicit discount rates for investing in vehicle fuel economy.[45] For this analysis, CAR assumes that consumers value the fuel economy of a new vehicle at the total amount of the undiscounted fuel savings for the first three years of vehicle ownership.

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[42] Helfand, Gloria and Ann Wolverton. (2010) "Evaluating the Consumer Response to Fuel Economy: A Review of the Literature." Fourth World Congress of Environmental and Resource Economists, Montreal, Canada. June 28-July 2, 2010. <http://www.webmeets.com/files/papers/WCERE/2010/415/Helfand_Wolverton_062110.pdf>.

[43] TRB. (2002). "Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards." Committee on the `Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards; Board on Energy and Environmental Systems; Division on Engineering and Physical Sciences; Transportation Research Board; National Research Council. 2002. <http://www.nap.edu/catalog/10172/effectiveness-and-impact-of-corporate-average-fuel-economy-cafe-standards>.

[44] TRB 2002; Kubik, Michelle. (2006). "Consumer Views on Transportation and Energy (Third Edition)." National Renewable Energy Laboratory, Office of Energy Efficiency & Renewable Energy, U.S. Department of Energy. Technical Report NREL/TP-620-39047. January 2006. <http://www.nrel.gov/docs/fy06osti/39047.pdf>; Greene, David L., John German, and Mark A. Delucchi. (2009). "Fuel Economy: The Case for Market Failure." In Reducing Climate Impacts in the Transportation Sector. Springer. Pages 181-205; and Greene, David L. (2011). "Uncertainty, Loss Aversion, and Markets for Energy Efficiency." *Energy Economics* 33(4): 608-616. July 2011.

[45] Greene, David L. (2010). "How Consumers Value Fuel Economy: A Literature Review." Office of Transportation and Air Quality, U.S. Environmental Protection Agency. Report EPA-420-R-10-008. March 2010. <http://www.epa.gov/otaq/climate/regulations/420r10008.pdf>.

Table 1: Review of Fuel Economy Valuation Studies

Authors	Year	Title	Implicit Discount Rate	Desired Payback Period
Allcott and Wozny	2010	Gasoline Prices, Fuel Economy, and the Energy Paradox (Working Paper)	18 to 27%	
Delucchi	2007	Cost-Benefit Analysis of Fuel-Economy Improvement	19%	
Dreyfus and Viscusi	1995	Rates of Time Preference and Consumer Valuations of Automobile Safety and Fuel Efficiency	11 to 17%	
Espey and Nair	2005	Automobile Fuel Economy: What is it Worth?	3 to 6.5%	
McManus	2006	Can Proactive Fuel Economy Strategies Help Automakers Mitigate Fuel-Price Risks?	7%	
Sallee, West, and Fan	2011	The Effects of Gasoline Prices on the Demand for Fuel Economy in Used Vehicles	10%	
Fan	2009	Hedonic Price Model for Light-Duty Vehicles: Consumer's Valuations of Automotive Fuel Economy	7%	3 years for cars; 1 year for trucks
Fischer, Harrington, and Parry	2007	Should Automobile Fuel Economy Standards be Tightened?		3 years
Greene, Patterson, Singh, and Li	2005	Feebates, Rebates, and Gasguzzler Taxes: A Study of Incentives for Increased Fuel Economy		3 years
Greene	2011	Uncertainty, Loss Aversion, and Markets for Energy Efficiency		3 years
Greene, German and Delucchi	2009	Fuel Economy: The Case for Market Failure		3 years
Hirdrue, Parsons, Kempton, and Gardner	2011	Willingness to Pay for Electric Vehicles and their Attributes		5 years
Kubik	2006	Consumer Views on Transportation and Energy (Third Edition)		2.9 years
Turrentine and Kurani	2007	Car Buyers and Fuel Economy?		Within ownership or loan payment period
		Average*	**12%**	**3.4 years**

Source: Center for Automotive Research 2015

Averages use a loan payment period of 4 years for the payback period of the Turrentine and Kurani study.

Vehicle Miles Traveled

Data on annual vehicle miles traveled (VMT) by age of vehicle can be obtained from the National Household Travel Survey (NHTS).[46] Two considerations must be made before using the NHTS data to evaluate driving habits, however. First, consumers will tend to drive more when fuel cost per mile decreases (whether from reduced fuel prices or improved fuel consumption). This tendency, which has been documented in numerous studies,[47] is generally referred to as the rebound effect. Based on review of several models estimating the rebound rate,[48] CAR's study assumes a 20 percent rebound effect on VMT due to improved fuel economy.[49] Second, due to the nature of the data in the NHTS, some adjustments must be made to the VMT figures for these data to provide an accurate image of changes in VMT resulting from the rebound effect, going from 2016 to 2025 fuel economy levels. The data for the 2009 NHTS were collected during the period March 2008 through April 2009.[50] This time period corresponds to sales of two model years of new vehicles. By the standard model year schedule of October to September, the data collection period is split evenly, with seven months of MY 2008, and seven months of MY 2009 vehicles. Thus, vehicles in their first year of life during the data collection period were approximately 50 percent MY 2008, and 50 percent MY 2009. Consequently, the average, real world fuel economy for vehicles indicated as in their first year of life, in the 2009 NHTS, would be the average fuel economy rating of these two model years: 21.7 MPG. The same logic applies to vehicles of other ages. Vehicles in their second year of life were a mix of model years 2007 and 2008, with an average fuel economy of 20.8 MPG, and vehicles in their third year of life were a mixture of model years 2006 and 2007, with an average fuel economy of 20.35 MPG. Thus, to use the 2009 NHTS data to evaluate the rebound effect on VMT, going from 2016 to 2025, the reported VMT data must first be adjusted to correspond to a single fuel economy level. CAR uses the 2016 model year real world fuel economy requirement for this purpose.

[46] NHTS. (2015). National Household Travel Survey, Federal Highway Administration, U.S. Department of Transportation. Accessed August 18, 2015. <http://nhts.ornl.gov/>.

[47] Greene, David L., James R. Kahn, and Robert C. Gibson. (1999). "Fuel Economy Rebound Effect for U.S. Household Vehicles. *Energy Journal* 20(3): 1-31. <http://www.jstor.org/stable/41322836?seq=1#page_scan_tab_contents>.

Small, Kenneth A. and Kurt Van Dender. (2007). "Fuel Efficiency and Motor Vehicle Travel: The Declining Rebound Effect." *Energy Journal* 28(1): 25-51. <http://www.jstor.org/stable/41323081?seq=1#page_scan_tab_contents>.

Hymel, Kent, Kenneth A. Small, and Kurt Van Dender. (2010). "Induced Demand and Rebound Effects in Road Transport*," Transportation Research Part B – Methodological* 44(10): 1220-1241. <http://econpapers.repec.org/article/eeetransb/v_3a44_3ay_3a2010_3ai_3a10_3ap_3a1220-1241.htm>.

Linn, Joshua. (2013). "The Rebound Effect for Passenger Vehicles." Resources for the Future. Discussion Paper 13-19. July 2013. <http://www.rff.org/files/sharepoint/WorkImages/Download/RFF-DP-13-19.pdf>.

[48] Greene, David L. (2012). "Rebound 2007: Analysis of U.S. Light-duty Vehicle Travel Statistics." *Energy Policy* 41: 14-28. February 2012.

[49] A 20 percent rebound effect implies that a 1.0 percent increase in fuel economy leads to a 0.2 percent increase in travel. The rebound effect is meant to account for additional benefits derived from more fuel efficient driving. The causality of mpg and VMT is two-way: people can drive more because the cost per mile is cheaper, and people who drive more tend to own more fuel efficient vehicles. The total cost to commute remains basically constant. The cost is similar to time spent on commuting: studies show people tend to spent the same amount of time commuting, regardless of how they commute. In actual fact, only about 27-29 percent of VMT are commuting miles. In general people live farther away from work if they have access to more efficient transportation systems, lower price fuel, or better fuel economy.

[50] NHTS. (2015). National Household Travel Survey Frequently Asked Questions. U.S. Department of Transportation. <http://nhts.ornl.gov/faq.shtml>.

Table 2: MY 2009, 2016 NHTS VMT and Real World Miles per Gallon by Age of Vehicle

	First Year	Second Year	Third Year	Three-Year Total
2009 NHTSA VMT by Vehicle Age	13,629	12,887	12,611	**39,127**
Model Years Reflected	2008 and 2009	2007 and 2008	2006 and 2007	
Average Real World MPG[51]	21.70	20.80	20.35	
Model Year 2016 Real World MPG	27.3			
%Δ from NHTS to Model Year 2016	25.8%	31.3%	34.2%	
Rebound Effect	20%			
VMT %Δ versus the 2009 NHTS	5.2%	6.3%	6.8%	
Model Year 2016 Miles Traveled	14,332	13,692	13,472	**41,497**

Source: Center for Automotive Research 2015

While simply summing together the 2009 NHTS data for vehicles of ages one through three years yields a total of 39,127 miles traveled, adjusting these figures to a single fuel economy level, the total three-year travel is markedly higher. Based on the 2009 NHTS, a vehicle with real world fuel economy equal to the 2016 requirement of 27.3 MPG would be driven 41,497 miles during its first three years of life. With the baseline travel for a MY 2016 vehicle established, CAR was able to move on to evaluating the change in mileage which is likely to result from the change in fuel economy from the 2016 model year, to the 2025 model year, can now be evaluated.

Table 3: MY 2016 VMT and Real World Miles per Gallon by Age of Vehicle

	First Year	Second Year	Third Year	Three-Year Total
Model Year 2016 VMT	14,332	13,692	13,472	**41,497**
MY 2016 Real World MPG	27.3			
MY 2025 Real World MPG	40.0			
Fuel Economy Percent Change	46.5%			
Rebound Effect	20%			
Resulting %Δ in VMT	9.3%			
Model Year 2025 VMT	15,666	14,966	14,726	**45,358**

Source: Center for Automotive Research 2015

From the 2016 to the 2025 model years, the real world fuel economy required for CAFE compliance increases by 46.5 percent. With a rebound effect of 20 percent, total travel for each year of a vehicle's life would increase by 9.3 percent, due to the improvement in fuel economy. From the baseline travel figure established for vehicles matching the real world fuel economy requirement of the 2016 model year, total travel for over the first three years of the vehicle's life would thus increase from 41,497 to 45,358 miles.

[51] As discussed, the time collection period for the 2009 NHTS reflected overlapping model years for new vehicles, with an even split between the older and newer model year, with seven months of sales for each. These figures are an average of the model years covered by the collection period, for vehicles at each age, e.g., the First Year mpg figure is the average fuel economy of the 2008 and 2009 model years. For the individual model years, real world fuel economies for each model year reflected in the 2009 NHTS were: MY 2006=20.1; MY 2007=20.6; MY 2008=21.0; MY 2009=22.4

Fuel Savings and Net Cost Calculation

Taking the real world fuel economy figures using the 2016 baseline and 2025 VMT the change in fuel consumption can be estimated. However, though the rebound VMT should in theory only apply to the 2025 vehicle, for this analysis, it is being applied to both vehicles. Using the same VMT for 2016 and 2025 vehicles inflates the fuel savings for higher fuel economy vehicles, but is appropriate in this case, because there is no attempt to estimate the value consumers place on the additional miles traveled due to the rebound effect.

Using the 45,358 VMT figure and dividing by 27.3 MPG average for MY 2016 vehicles yields a baseline gasoline usage of 1,661.5 gallons during the first three years of driving. Performing the same operation for the 40.0 MPG average for MY 2025 vehicles yields a gasoline usage of 1,134.0 gallons during the first three years of driving. The fuel savings from fuel economy improvements between MY 2016 and MY 2025 is the difference of those two calculations: 527.5 gallons.

Multiplying 527.5 gallons by the forecast 2025 gasoline prices yields a savings of $1,287 for gasoline at $2.44, $1,583 for gasoline at $3.00, and $2,448 for gasoline at $4.64. These are also the “break-even” fuel economy mandate costs at each price of gasoline forecast by the EIA above. The difference between these savings estimates and the estimated cost results in an estimate of the net cost of the higher fuel economy mandated in the 2025 standards. These estimates can be seen in Table 4.

Table 4: Net Cost by Fuel Economy Cost and Gasoline Price Scenarios

Gas Price	Fuel Economy Cost	Savings	Net Cost
$2.44	$2,000	$1,287	$713
	$4,000	$1,287	$2,713
	$6,000	$1,287	$4,713
$3.00	$2,000	$1,583	$417
	$4,000	$1,583	$2,417
	$6,000	$1,583	$4,417
$4.64	$2,000	$2,448	-$448
	$4,000	$2,448	$1,552
	$6,000	$2,448	$3,552

Source: Center for Automotive Research 2016

As can be seen in Table 4, at either the low gasoline price of $2.44 or the reference case price of $3.00, the net cost is positive for all fuel economy mandate cost scenarios considered ($2,000, $4,000, and $6,000). A positive net cost implies that the value the consumer places on improved fuel economy is less than the cost of the fuel economy improvement. For the high gasoline price of $4.64, only the $2,000 fuel economy cost scenario results in a negative net cost (i.e., savings) to the consumer, while the other fuel economy mandate cost scenarios ($4,000 and $6,000) result in a positive net cost. It is interesting to note that the “break-even” fuel price for each level of cost is that cost level divided by 527.5 (gallons) or $3.79 per gallon for $2,000, $7.58 per gallon for $4,000, and $11.37 per gallon for $6,000.

The Empirical Relationship Between Income, Employment, Fuel Prices and the Demand for Fuel Efficient Vehicles

The previous section of the report establishes the dynamic of consumer choice driven by the payback for the additional vehicle purchase cost (investment) in advanced fuel efficiency in return for reduced fuel cost in operation. As was shown, there has been many academic and consumer research studies related to consumers' valuation of fuel economy in their purchase decision regarding vehicle preference, powertrain options, and other content.

This section of the study relies on a review of 14 past studies of the valuation of fuel economy by automotive consumers. The studies' authors examined the payback of investments in vehicles with higher fuel economy in terms of lower fuel consumption. Investment cost can either be the cost of technologies that produce higher fuel efficiency or the loss of vehicle attributes also valued by the consumer. The most recent study was completed in 2010 and the oldest in 1995. Much has changed in terms of vehicle offerings and fuel prices since the studies were completed. CAR has performed a recent empirical analysis that not only examines the critical and obvious role of fuel prices in consumer choice of fuel economy performance in vehicles, but also the important role of household or consumer income and employment. This analysis using macroeconomic data broadens the discussion of the complexity of aligning fuel efficiency public policy objectives by correlating savings in fuel consumption (investment payback), personal disposable income (ability to afford more vehicle choices) and employment (need for transportation as well as access to loans and more choice) and the demand for smaller, fuel efficient, and electrified vehicles.

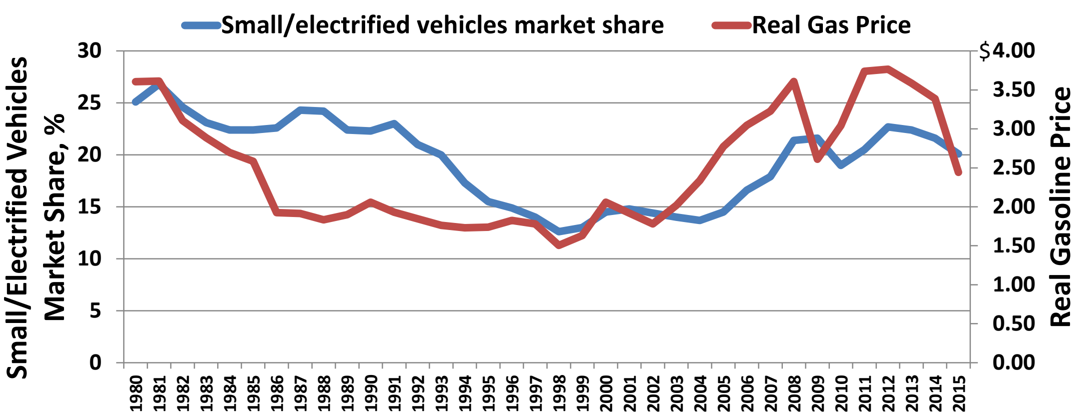
New vehicle demand is a complex function of consumer perceptions, styling, and functionality, subject to price. Of course, each of these attributes are influenced in turn by a number of trends including, but not limited to, personal income growth, the availability of consumer credit to purchase the vehicle, new product introductions, household and employment requirements and commuting patterns that influence demand for basic transportation, and, of course, operating costs related to price of fuel, depreciation, and other related costs such as insurance and maintenance of the vehicle. Fuel economy, therefore, is just one of many attributes consumers weigh in their decision in buying a particular vehicle.

CAR has performed an analysis of the influence of fuel prices on the demand for small cars and electric vehicles while controlling for the effects of consumer income and employment. The small car segment along with electric vehicles is a proxy for consumer demand for vehicles that deliver lower operating costs – specifically regarding fuel consumption and the price of fuel. In addition to simply measuring the powerful effect of fuel prices on small/electrified car demand, CAR's research also shows small car and electric vehicle (EV) demand is also sensitive to income and employment trends. The correlation between fuel prices and small car demand is obvious. For many years, the only choice consumers were offered to mitigate the costs of higher fuel prices was smaller vehicles with smaller powertrains than the market average. However, at the end of the 1990s, several new innovations with respect to fuel consumption, hybrid and electric vehicles, appeared in the U.S. market. The major difference between small cars with standard powertrains and the new electrified vehicles has been price. Consumers would now have to pay more to gain even higher fuel economy performance. That is why industry and policy makers need also to consider how concurrent trends of incomes and employment also influence vehicle demand overall and segmentation changes in particular.

Historical Trends

Figure 5 below illustrates the general relationship in the United States between real gasoline price and the market share of small car and electrified vehicles. For the purpose of this paper, "small cars" refers to the generally accepted compact and sub-compact passenger car segments and "EVs" (from 1999 and on) includes gasoline-electric hybrids, plug-in hybrids and full battery electric vehicles.

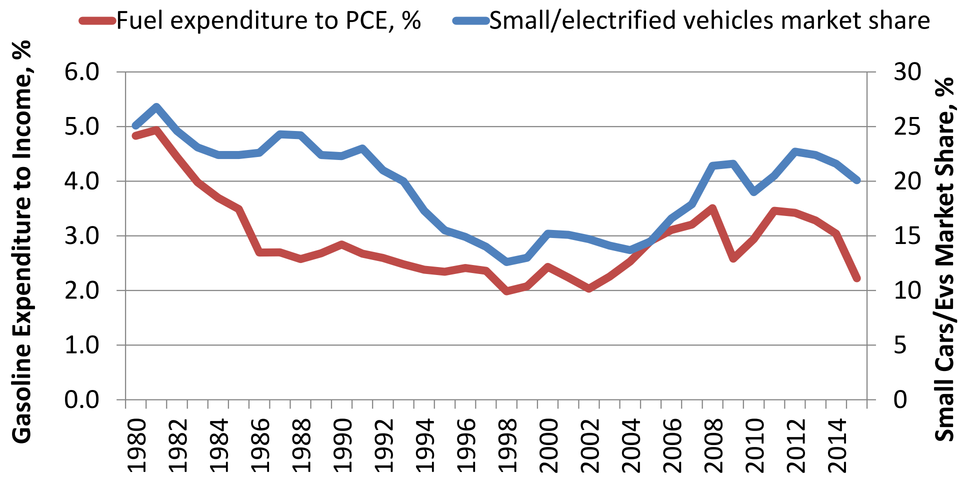
Figure 5: Small Cars and Electrified Vehicles Market Share and Real Gasoline Price 1980 –2015



Source: Wards Auto; U.S. Energy Information Administration

During the second oil crisis in 1980 to 1981, real gasoline prices spiked to $3.57 per gallon. In turn, market share for small cars soared to 26.8 percent. Personal consumption on motor vehicle fuel jumped to 5.0 percent from 3.5 percent of total personal expenditure in 1978, as shown in Figure 6. Today with real gasoline prices trending below $2.00 per gallon, the market share of small cars and EVs has fallen to 20.1 percent.

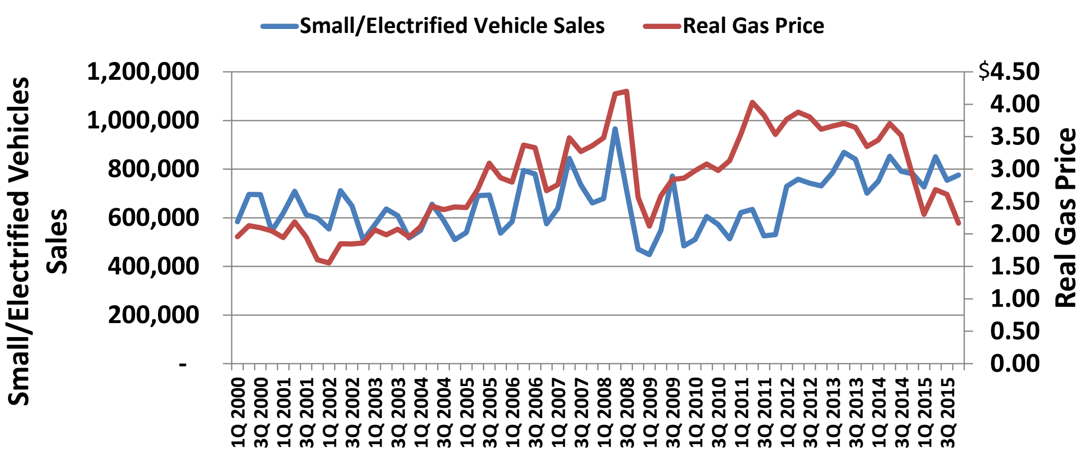
Figure 6: Personal Consumption on Motor Fuel As Percentage of Total Personal Expenditure, and Small Cars/EVs Market Share, 1980 - 2015



Source: Wards Auto; Bureau of Economic Analysis

Figure 7 depicts the sales pattern between fuel efficient vehicles, as defined above of small car and electrified vehicles, and gasoline prices on a quarterly basis. This detailed time series shows the close correlation that plays out within a calendar year. For vehicle manufacturers the management of assembly plant and supply chain sourcing is difficult given the tight relationship between gasoline prices and fuel efficient vehicle demand as market share can fluctuate dramatically within a 12-month period.

Figure 7: Small Car/Electrified Vehicle Sales and Real Gasoline Price, 1Q 2000 - 4Q 2015

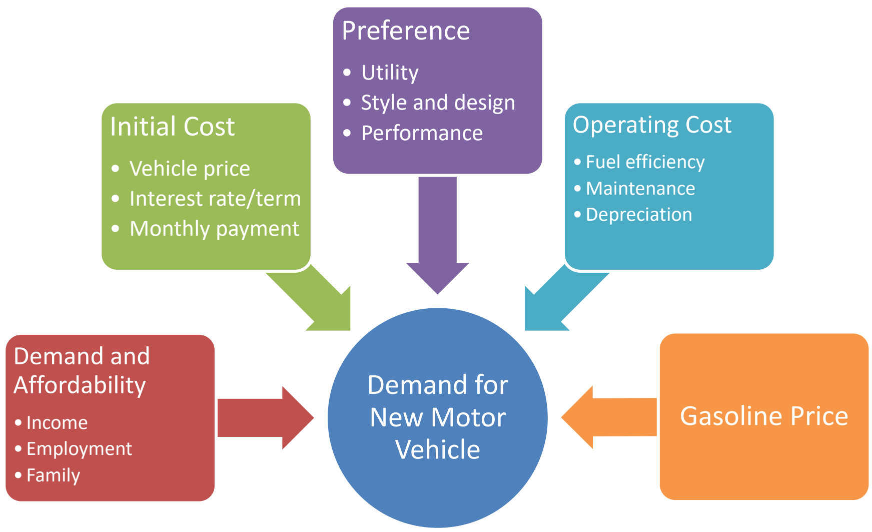


Source: Wards Auto; U.S. Energy Information Administration

CAR's Income, Employment and Fuel Price Model for Small Car and EV Demand

Since fuel price is a major component of vehicle operating costs, fuel prices do drive the demand for specific vehicle segments as well as powertrain options. However, vehicle demand is not a single, simple dimension. Given the aspirational aspects and functional preferences of new vehicle ownership, it is natural to envision that an increase in income will drive consumers to look at purchasing passenger cars and light trucks at higher price points through a variety of means: larger physical size, more content, or larger and complex powertrain and drivetrain combinations. Employment trends certainly drive personal income but also considerations for the type of vehicle for dependable transportation for commuting and even additional functionality due to the increased opportunity for leisure and latitude for family formation. Figure 8 illustrates a concept of demand for new motor vehicle from which the regression model is derived.

Figure 8: Concept of Demand for New Motor Vehicle



CAR regressed fuel prices (real, conventional gasoline price per gallon), income (real per capita disposable personal income in 2009 chain-linked dollars) and unemployment (using the simple, headline U.S. unemployment rate) against small car and EV market share developing the model and associated coefficients (Table 5). The model focuses on demand for fuel efficient vehicles such as small and electrified cars. Therefore, consumer preference block (vehicle utility, style, design, and vehicle performance) is omitted for purpose. A quarterly data series from 1980 through 2015 was used and represents a robust test as it includes five recession periods, the introduction of a record number of new vehicle models and powertrains, and at least nine peak-to-trough real gasoline price cycles.

The model results estimates that an increase or decrease in gasoline prices by $1.00 per gallon results in an increase or decrease in the small car/EV market share by 110 basis points or 1.1 percent. The quarterly time series (Figure 7) above shows how this relationship has historically played out leaving vehicle dealers with large inventories of small cars and EVs, and offering incentives, as gasoline prices (and the expectation of future prices) fall in one part of the year only to be followed by vehicle shortages and selling near manufacturer suggested retail price as gasoline prices rise in later quarters of a calendar year. This pattern also plays out in geographic regions that may have temporary spikes or declines in gasoline prices and the resulting dealer sales and inventories may fluctuate dramatically.

The CAR model illustrates that there are other macro-economic factors, such as per capita personal disposable income (PDI), that influence the sale of small car and EV models. For example, it is somewhat intuitive that as PDI increases consumers have greater opportunities to purchase vehicles that may have greater functional utility, status and/or features. While not always mutually exclusive, greater utility may mean the demand for larger, heavier vehicles could steer customers to rugged, off-road styling and features that include larger engine displacement, four-wheel drive combinations, greater interior space and other styles or platforms that are less fuel efficient. CAR's model estimates that for every $1,000 increase or decrease in PDI, small car/electric vehicle share will decrease or increase by 50 basis points or .50 percent.

Higher levels of PDI improve the consumer's access to financing needed for vehicle loans and contracts for vehicle leasing. Increases in PDI typically opens the door to affording larger monthly payments and that naturally leads to the ability to purchase larger vehicles or vehicles with different content that impede transportation fuel efficiency for that individual customer. Of course, a decline in PDI results in pressure to be more conservative in purchase decisions and the level of personal financial leverage. Here CAR's model shows that PDI must rise by $2,039 to overcome the negative effects of a $1.00 per gallon reduction in gasoline price on market share for small cars/EVs. The reason for the discrepancy between gasoline price and PDI is Marginal Propensity to Consume (MPC). MPC implies for one-dollar increase in PDI, consumption increase will be less than one dollar. Vice versa, consumption increase by one dollar will lead to more than one-dollar increase in PDI.

CAR's model also ties in the unemployment rates as an independent variable as it is certainly a driver for PDI as well as providing underlying support for the need for transportation to secure continued employment as well as consumer confidence to purchase a major durable good. The model shows a decrease in the unemployment rate will drive a decline in the small car/EV market share.

Table 5: CAR's Estimation of the Demand for Small Cars/EVs

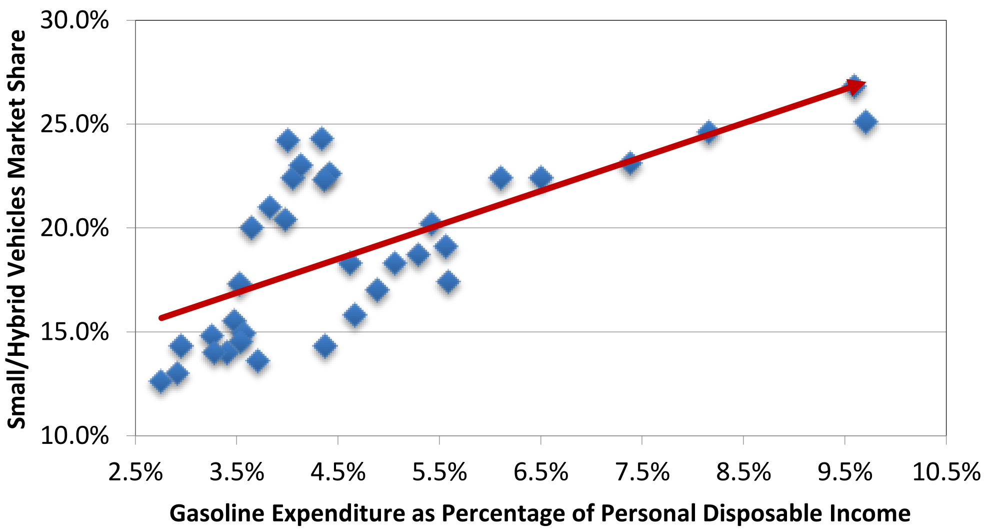
Dependent Variable: MKT				
Method: Least Squares				
Sample: 1980 2014				
Included observations: 35				
Convergence achieved after 15 iterations				
MA Backcast: 1978 1979				
	Coefficient	Std. Error	t-Statistic	Prob.
C	32.09891	3.150881	10.18728	0.0000
INCOME	-0.000517	0.000107	-4.852762	0.0000
GAS	1.054403	0.334341	3.153676	0.0037
UNEMP	0.597753	0.286341	2.087559	0.0454
MA(1)	1.367177	0.175346	7.797038	0.0000
MA(2)	0.971969	0.013968	69.58372	0.0000
R-squared	0.899910	Mean dependent var		19.47778
Adjusted R-squared	0.883228	S.D. dependent var		4.119370
S.E. of regression	1.407666	Akaike info criterion		3.672755
Sum squared resid	59.44570	Schwarz criterion		3.936675
Log likelihood	-60.10959	Hannan-Quinn criter.		3.764870
F-statistic	53.94602	Durbin-Watson stat		1.591252
Prob(F-statistic)	0.000000			
Inverted MA Roots	-.74+.65i	-.74-.65i		

Results:

One-dollar increase in gasoline price per gallon will increase small/hybrid vehicle market share by 1.1%. However, a $1,000 increase in per capita personal disposable income will offset the small cars market share by 0.5%. Therefore, if gasoline price increase by one-dollar per gallon, it takes a $2,039 increase in per capita personal disposable income to cancel out the effect on small cars market share of the gasoline price increase.

Finally, Figure 9 below shows the scatter plot of small car and hybrid market share versus gasoline expenditures as a percent of PDI between 1980 and 2014. The scatter plot is constructed by per capita disposable personal income (nominal) versus annual gasoline price (nominal) multiplying by an estimate of 550 gallons of gasoline usage. The CAR regression model shows the relationship between the independent variables of gasoline prices and PDI as described above and their effect on small/EV market share. Because it is shown as a percentage, gasoline expenditures or PDI can be moving independently – which typically occurs, PDI can be growing faster or slower – and the scatter plot shows the relationship that the appeal of small car/EV vehicles increases as the consumer pays a relatively greater share of their available dollars for gasoline versus other purchases. CAR's model shows that small car/EV demand is under the greatest pressure in periods of time of falling or relatively low- and stable-gasoline prices. It also shows that, holding gasoline prices constant, demand for small cars/EVs or fuel economy falls as PDI and employment increases. Many economists have categorized goods whose demand is negatively correlated with income as "inferior goods." CAR's current cost-benefit study of the effect of the 2025 mandates on the U.S. economy has focused on the net price of higher fuel economy. It should also be said that demand for higher fuel economy vehicles and technologies will also fall with an improving economy.

Figure 9: Small Car/Hybrids Market Share and Gasoline Expenditure as Percent of Income 1980 – 2014



Source: Wards Auto; Bureau of Economic Analysis; U.S. Energy Information Administration

III. NET COST OF FUEL ECONOMY TECHNOLOGIES AND THE OWN-PRICE ELASTICITY OF NEW VEHICLES

In order to evaluate the impact of a change in vehicle prices on the purchase of new vehicles, it is important to first quantify this relationship. For this purpose, CAR has created an econometric estimate of the responsiveness – the elasticity – of spending on new vehicles to changes in vehicle prices. The purpose is not to directly estimate the effect of a price change on unit sales, but rather evaluate the effect on consumer new vehicle expenditure. CAR's estimate of the unit impact is contingent upon expectations for the average new vehicle price, as described in the baseline scenario in the section below.

Using annual data for the period 1953-2013, the model evaluates the change in consumer spending on new vehicles, in response to changes in several factors: income, new vehicle prices, used vehicle prices, consumer credit, interest rates, and household formation. Further details of CAR's model are included in Appendix I.

CAR finds a short-run own-price elasticity of -0.79, indicating that if new vehicle prices increase by one percent, consumer spending on new vehicles falls by 0.79 percent in the year following. The corresponding long-run elasticity resulting from the model is -0.61, indicating that the final impact of this one percent price increase is a decrease of 0.61 percent in spending on new vehicles. For most goods, the long-run elasticity is higher, as the ability to substitute other products increases over time. However, the only substitutes for a new vehicle is the purchase of a used vehicle or retaining a current vehicle (delaying purchasing), and the only source of used vehicles in the long run, is new vehicles. That both the short- and long-run elasticities are less than unitary defines motor vehicles as necessities (inelastic), reflective of the extreme importance of private vehicle ownership in the United States. In other words, an automotive consumer can choose to delay his/her purchase of a vehicle for only so long.

The estimated short-run cross-price elasticity between new vehicle expenditures and used vehicle prices is 0.53, indicating that a one percent increase in used vehicle prices results a 0.53 percent increase in new vehicle expenditure, as consumers switch away from used vehicles, to new vehicle purchases. The long-run value is of 0.41. As with the own-price elasticity, the lack of substitutes leads to a lower long-run response.

CAR's short-run elasticity of -0.79 estimate is substantially lower than results typically found in the literature; across all models, CAR finds an average short-run elasticity of -1.09. Focusing upon only those models which also employ time series methods, the average short-run own-price elasticity is higher yet, at -1.25. However, this is explained by differences in the variables considered. Most existing studies do not account for consumer credit or interest rates, and many likewise exclude used vehicle prices. Re-estimating this report's model without consumer credit and the interest rate variable finds a significantly higher short-run elasticity value of -1.31, similar to the estimates of other time series models.

CAR's long-run price elasticity figure is also below the average of the literature, -0.72, though when one study, which produced an extreme outlier, is excluded from consideration, the average long-run elasticity in the survey of prior work falls to -0.61, exactly in-line with the findings. Appendix I provides a simple averaging, summarizing the previous literature on the new vehicle own-price elasticity.

The short-run income elasticity indicated by the model is near unity, at 0.90. Applying the Koyck Transformation to generate a long-run figure, this model indicates that the income elasticity will eventually fall to 0.70. This suggests that, following an increase in incomes, consumers will first elect to purchase additional or more expensive vehicles, and thereafter gradually shift their additional income towards other purchases.

Rather than a high short-run own-price elasticity, as previous literature has found, CAR's model indicates that expenditure on new vehicles is elastic with regard to consumer credit. Specifically, the short-run elasticity of consumer spending on motor vehicles is found to be 1.32, and the corresponding long-run elasticity is 1.01. This may reflect an increased reliance upon credit in the purchase of new vehicles. Indeed, the loan-to-value ratio on motor vehicle loans has increased each decade, averaging 87.3 percent in the 1970s and 91.9 percent in the 2000s.[52]

CAR estimates the effect of the change in net prices resulting from the fuel economy mandates by applying the long-run elasticity value of -0.61 to the baseline long term trend for motor vehicle sales described below. CAR considered three scenarios for the price of gasoline, and three scenarios for the cost of the additional fuel economy technologies needed to meet the mandates, and assume that the full consumer cost of the technologies is passed along to new owner/buyers, yielding generally higher vehicle prices.[53]

In the nine scenarios which result, the effect on demand or consumer expenditures on vehicle purchases of the price increase, net of fuel savings, ranges from an increase of 0.8 percent, in the case of low fuel economy costs ($2,000) and high gasoline prices ($4.64 per gallon, in constant, 2015 dollars), to a decrease of 8.6 percent, in the high fuel economy cost ($6,000) and low gasoline price ($2.44 per gallon) scenario. These results are shown in Table 6 in the final column. The low cost, high price scenario is the only case where the net impact on expenditures is positive: in all eight other scenarios, expenditures on new motor vehicles falls by at least one percent.

[52] Board of Governors of the Federal Reserve System. Release G19: Consumer Credit. Loan-To-Value Ratio of New Car Loans at Auto Finance Companies. Data series spans June 1971 to January 2011.

[53] There is certainly the possibility that larger and/or more efficient automakers may not pass along the whole cost of the FE technology mandates to consumer prices for some period of time. In this case there is the risk of industry consolidation as smaller, weaker firms that must recoup costs are driven out of the market by their large competitors. In the long run, the prospect of oligopolization due to expensive regulations exists with even higher prices passed to the consumer as a result. This certainly may be the case in the pharmaceutical industry where expensive regulations on drug testing may have provided the largest competitors with effective barriers to competition from smaller firms however innovative. In fact, large competitors may even seek such regulatory barriers to preserve and increase their monopoly power.

Table 6: Short and Long Run Effect on Demand of Net Cost of Fuel Economy Technologies

Net Costs and Short-Run and Long-Run Demand Impacts						
All at Rebound VMT				Percent Vehicle Cost Increase	Short-Run Demand Impact	Long-Run Demand Impact
Net Cost by Cost and Gas Scenario						
Gas Price per Gallon	Cost of fuel economy	Savings	Net Cost			
	$2,000	$1,287	$713	2.1%	-1.7%	-1.3%
$2.44	$4,000	$1,287	$2,713	8.1%	-6.4%	-5.0%
	$6,000	$1,287	$4,713	14.1%	-11.1%	-8.6%
	$2,000	$1,583	$417	1.2%	-1.0%	-0.8%
$3.00	$4,000	$1,583	$2,417	7.2%	-5.7%	-4.4%
	$6,000	$1,583	$4,417	13.2%	-10.4%	-8.1%
	$2,000	$2,448	$-448	-1.3%	1.1%	0.8%
$4.64	$4,000	$2,448	$1,552	4.6%	-3.7%	-2.8%
	$6,000	$2,448	$3,552	10.6%	-8.4%	-6.5%

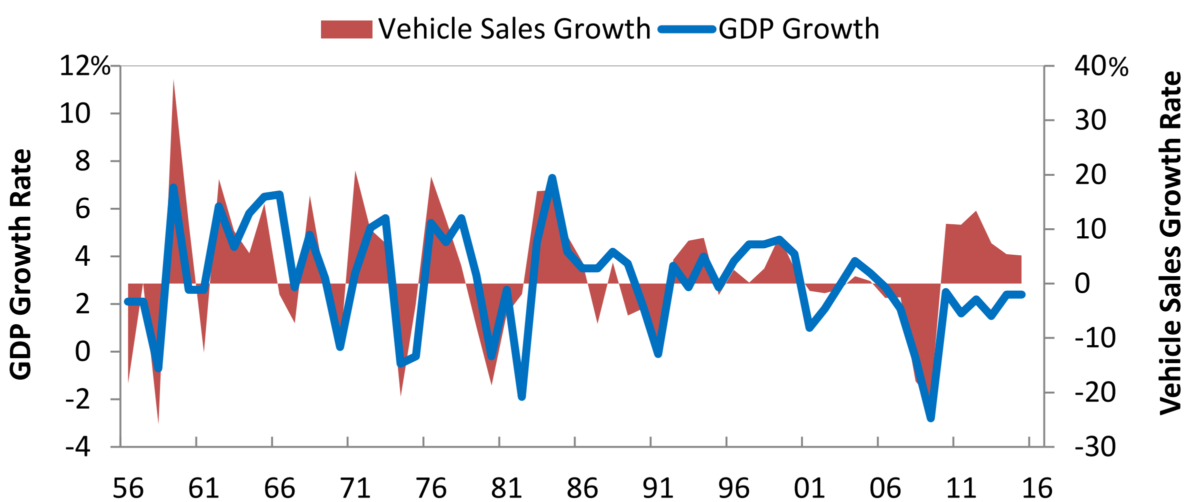
Source: Center for Automotive Research 2015

IV. 2025 U.S. MOTOR VEHICLE INDUSTRY—A BASELINE LONG-TERM TREND

Introduction

The year 2015 saw the sixth consecutive annual increase in U.S. motor vehicle sales. During this period, the average annual growth rate for U.S. motor vehicle sales was 9.1 percent.[54] It is the strongest vehicle sales recovery since 1983-84.[55] This growth occurred despite the fact the overall U.S. economy experienced its slowest recovery after a major recession. Real GDP growth averaged 2.2 percent per year from 2010 to 2015, compared to a 3.6 percent growth rate during 1992-1997 and 4.6 percent during 1983-1988.[56] Traditionally, growth in the U.S. GDP and growth in vehicle sales were highly correlated (as shown in Figure 10). However, since 2010, growth rates for the U.S. economy and vehicle sales seem to have decoupled. The two variables appear to be on different recovery tracks going forward. Previously defined motor vehicle market determinants such as population and income growth that drive economic growth may have fundamentally changed in terms of their influence on vehicle sales. To estimate the outlook of the U.S. motor vehicle market in 2025, CAR revisited its previous modeling of vehicle sales used in CAR's 2011 study[57] and developed a new model for vehicle sales with new determinants that will drive the future of the U.S. motor vehicle demand.

Figure 10: U.S. GDP Growth Rate and Vehicle Sales Growth Rate 1956 – First Half of 2015



Source: Bureau of Economic Analysis; Automotive News

U.S. Employment versus U.S. Population

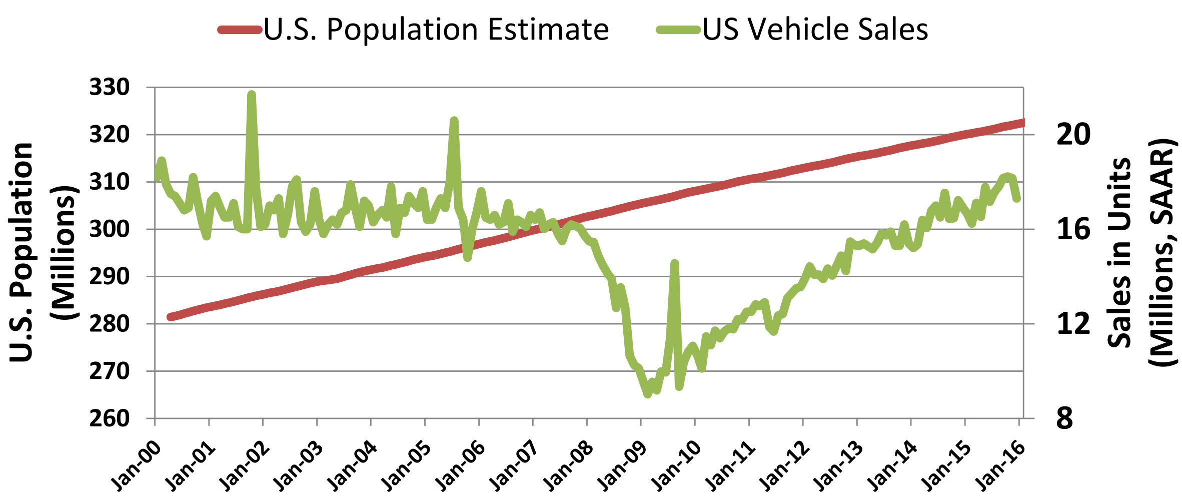
Since the late 1990s, U.S. vehicle registrations per household have averaged just above two vehicles per household.[58] This ratio indicates there are more vehicles in a typical U.S. household than adults who live

[54] National Economic Accounts: Supplemental Estimates: Motor Vehicles, Bureau of Economic Analysis, Department of Commerce
[55] *Ibid.*
[56] National Economic Accounts: Gross Domestic Product, Bureau of Economic Analysis, Department of Commerce
[57] Center for Automotive Research, "The U.S. Automotive Market and Industry in 2025," June 2011.

[58] U.S. Census Bureau, Current Population Reports, "Families and Living Arrangements" ; U.S. Federal Highway Administration, Highway Statistics

in it. Presently, there are more operating vehicles than adults in the U.S. population. To many observers, it seemed likely that the future of U.S. motor vehicle demand will be mainly driven not by vehicle density, but by growth in the natural population or number of households. The trend in vehicle sales, however, has not been as smooth as growth in U.S. demographics. During 2000 – 2015, the U.S. sales market cycled from 17.4 million vehicle sales in 2000 to 10.4 million sales in 2009 and then recovered to 17.5 million in 2015. During the same period, the U.S. population steadily grew at 0.93 percent per year from 2000 to 2010 and then slowed to 0.8 percent per year 2010 - 2015[59]. Unlike the motor vehicle sales, U.S. population growth has been steady even during the recent economic downturn, as shown in Figure 11.

Figure 11: U.S. Population and U.S. Vehicle Sales, Jan' 2000 – Dec' 2015

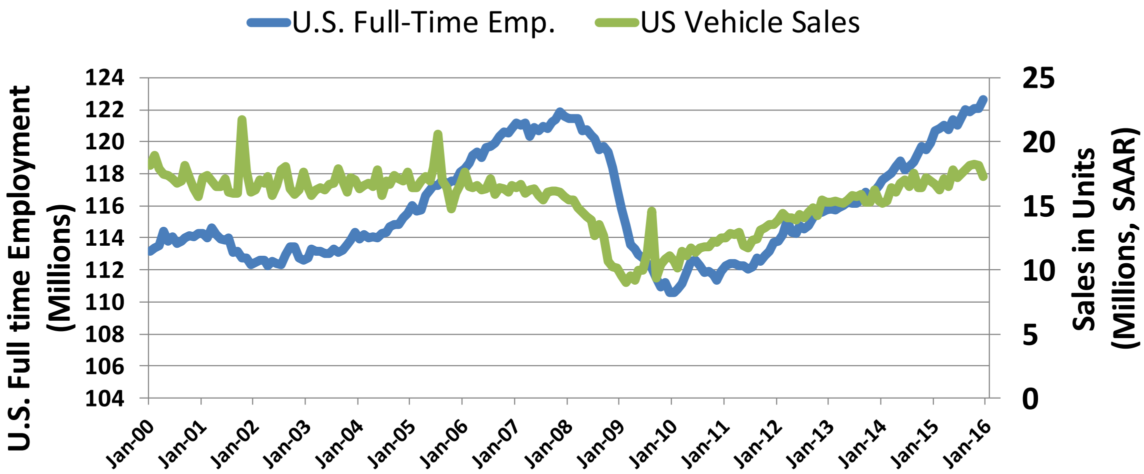


Source: Bureau of Labor Statistics; Census Bureau

In contrast to recent growth in population, full-time employment is highly sensitive to the U.S. economy. Since 2010, while motor vehicle sales rebounded at double-digit rates, full-time U.S. employment also recovered at an average of 2.0 percent annual growth rate, which was much stronger than the U.S. population growth at 0.8 percent.[60] This relationship is shown in Figure 12. The relationship between full-time employment and vehicle sales could be explained by the fact that full-time employment is related to steady income growth and financial security.

[59] U.S. Census Bureau, Current Population Reports, "Population Estimates and Projections"
[60] Bureau of Labor Statistics, Current Employment Statistics

Figure 12: U.S. Full-Time Employment and U.S. Population Estimate – January 2000 – June 2015

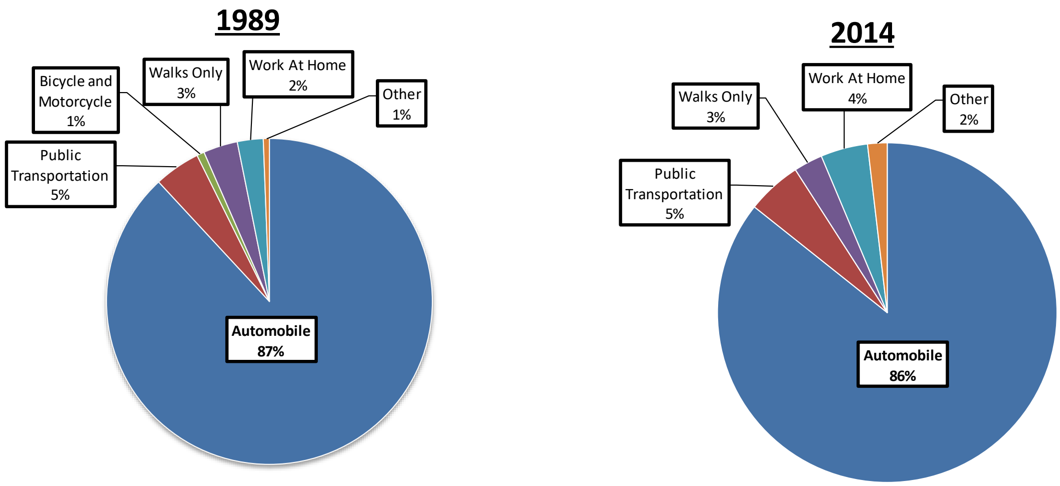


Source: Bureau of Labor Statistics; Census Bureau

Working full-time usually means the workers are required to be at workplaces on time every work day. Reliable commuting between the workplace and home becomes a critical requirement of employment. The U.S. Census reported that in 2014, 86 percent of the employment still relied on personal automobiles as the principal means of transportation to work compared to 87 percent in 1989,[61] as Figure 13 demonstrates. The demand for motor vehicles is clearly related to stable earnings, financial security, and a need for reliable personal transportation equipment to maintain employment. Finally, it has been stated in a number of consulting and media forums that Americans or U.S. households are less interested in owning motor vehicles than in the past. Presumably this is based on buying and travel behavior, as well as expectations in the 2008-2009 recession. The year 2015 certainly saw a reversal in any such trends towards de-motorization.

[61] U.S. Department of Housing and Urban Development, American Housing Survey, U.S. Census Bureau

Figure 13: U.S. Principal Means of Transportation to Work 1989 and 2014

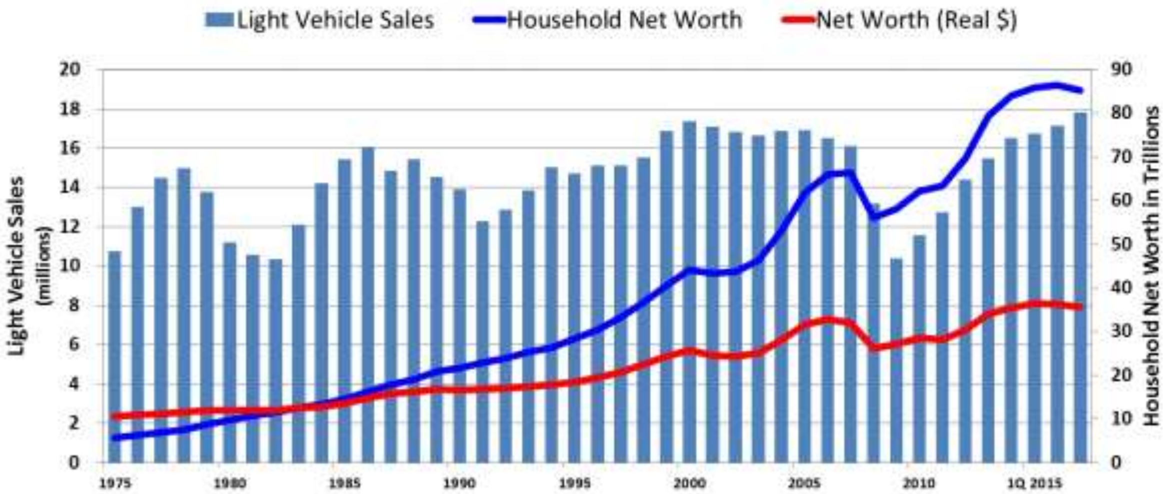


Source: U.S. Department of Housing and Urban Development, American Housing Survey, 1989, U.S. Census Bureau U.S. Department of Commerce, American Community Survey, 2014, U.S. Census Bureau

Income and Household Net Worth

Household net worth and personal income growth also play important roles in long-term motor vehicle demand. Figure 14 shows the long-term trends of motor vehicle sales and household net worth. While the trend in nominal household net worth shows a high rate of growth before the 2009 recession, real household net worth shows steady growth and moves up and down with auto sales. Real personal disposable income matches the trend in household net worth. Motor vehicles are expensive durable goods and can be the single most expensive consumer goods purchased by most people after their home. With proper maintenance, a new vehicle can last more than a decade and provide long-term utility to consumers. Therefore, purchasing a motor vehicle can also be seen as an investment which yields dividends over time in terms of transportation services. Therefore, income and household net worth, indicators of consumers' ability to purchase motor vehicles, are two long-term economic indicators that determine U.S. auto sales through 2025.

Figure 14: Household Net Worth and Vehicle Sales 1975-3Q 2015



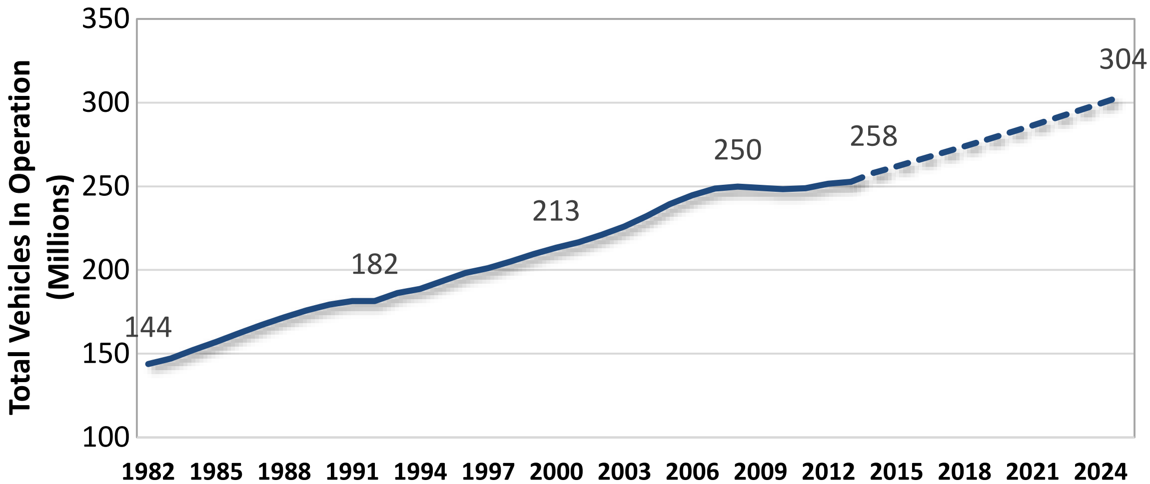
Source: Federal Reserve Statistical Release, Z.1, Flow of Funds Accounts of the United States

Household Formation and Vehicle Density

Important determinants of the long-term trend in the demand for motor vehicles include the relative growth of U.S. motor vehicles in operation and U.S. households. These trends are shown in Figure 15 and Figure 16 below. The number of U.S. motor vehicles in operation are measured by total motor vehicle registrations. From 1982 to 2008, vehicle registrations steadily grew at about 2.0 percent per year.[62] The number of household also increased steadily at around 1.3 percent per year.[63] The constant growth of both registered vehicles and households from 1980 to 2010 resulted in vehicles per household ratio, or "vehicle density," to grow from 1.7 to over 2.1. During the recession, vehicle registrations stopped growing while the household formation fell to a slower rate of 0.4 percent per year. Vehicle density dropped a little, but stayed above 2.0 vehicles per household. After the recession, vehicle density slowly climbed to near 2.1 again. The levels of households and motor vehicles in use are "stock" variable, and motor vehicle sales is a "flow" variable. As long as the outlook for stock variables are steady and positive, which is the case of U.S. household formation and motor vehicles in use, the long-term flow variable, which is auto sales in this study, can be expected and measured.

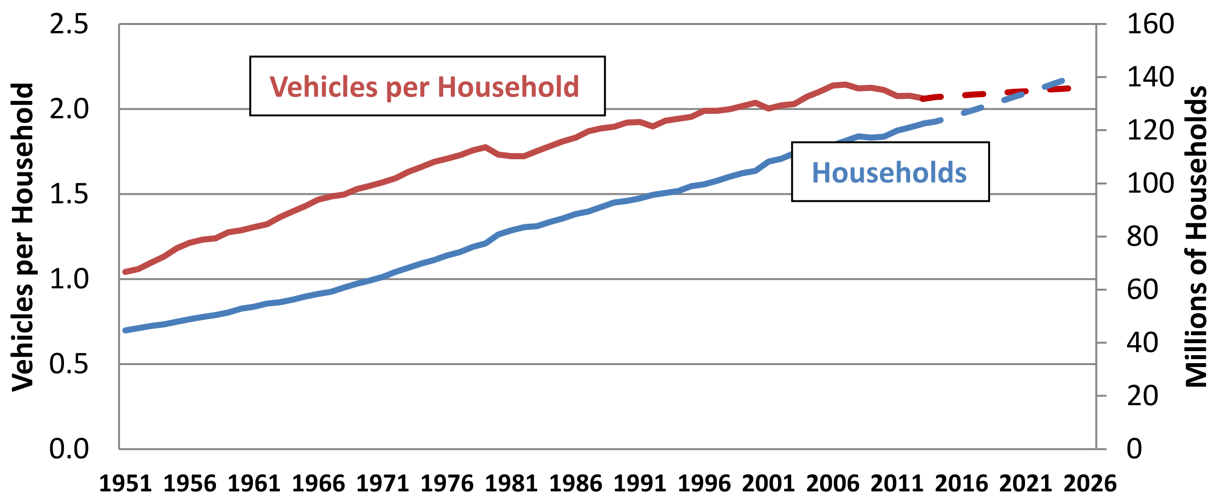
[62] IHS Automotive via Ward's 2015 Motor Vehicle Facts & Figures
[63] U.S. Census Bureau, Current Population Reports, "Families and Living Arrangements"

Figure 15: Total Vehicles in Use in the U.S. 1982 – 2014; 2015 – 2025



Source: IHS Global Insight. Total vehicle registration includes heavy duty trucks.

Figure 16: Estimated Number of Households and Vehicles Per Household: 1951-2025



Source: U.S. Census Bureau, Current Population Reports, "Families and Living Arrangements," U.S. Federal Highway Administration, Highway Statistics

Motor Vehicle Demand in 2025

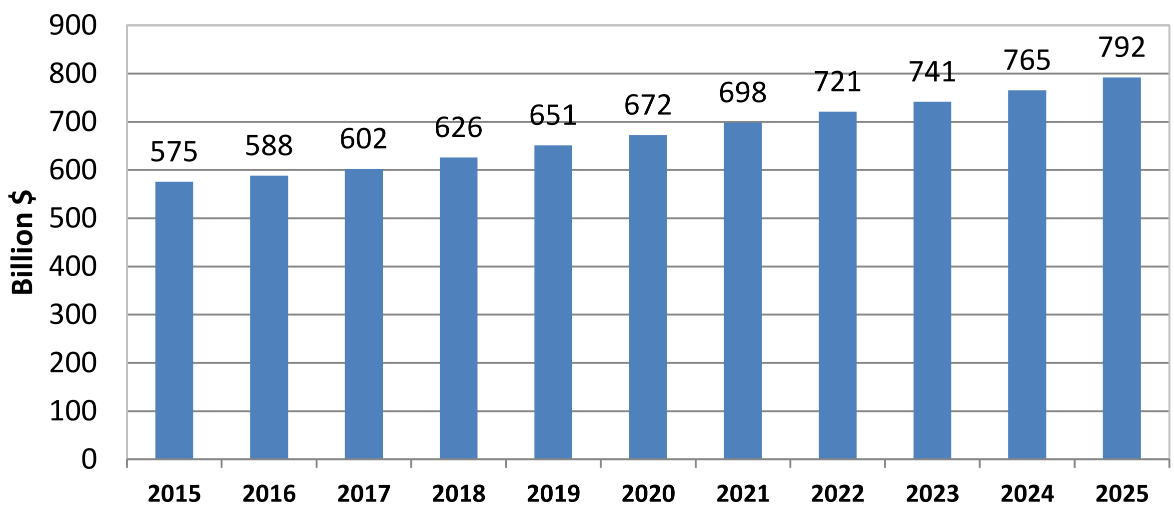
Using an estimation model largely based on the motor vehicle sales determinants reviewed above, CAR estimated the U.S. motor vehicle market's long-term trend through 2025, <u>assuming no additional government fuel economy mandates for the 2017-2025 period.</u> The following assumptions for explanatory variables were used to activate the model:

- U.S. full-time employment would reach 135 million in 2025;
- real personal income, excluding current transfer receipts, would reach $13.7 trillion;
- U.S. unemployment rate would trend at around 6.0 percent;

- household formation would grow at 1.2 percent per annum;
- the stock of registered motor vehicles will regain momentum and grow at the same rate as household formation growth;
- and that vehicle density would peak at around 2.1 vehicles per household.

An auto-regressive econometric model was constructed to estimate the total U.S. nominal expenditures by consumers, governments, and firms on new vehicles in 2025. The specification and results for this model are shown in Appendix III. The results indicate that nominal U.S. expenditures on new motor vehicles will grow at an average annual rate of 3.2 percent through 2025 and reach $792 billion in current dollars as shown in Figure 17.

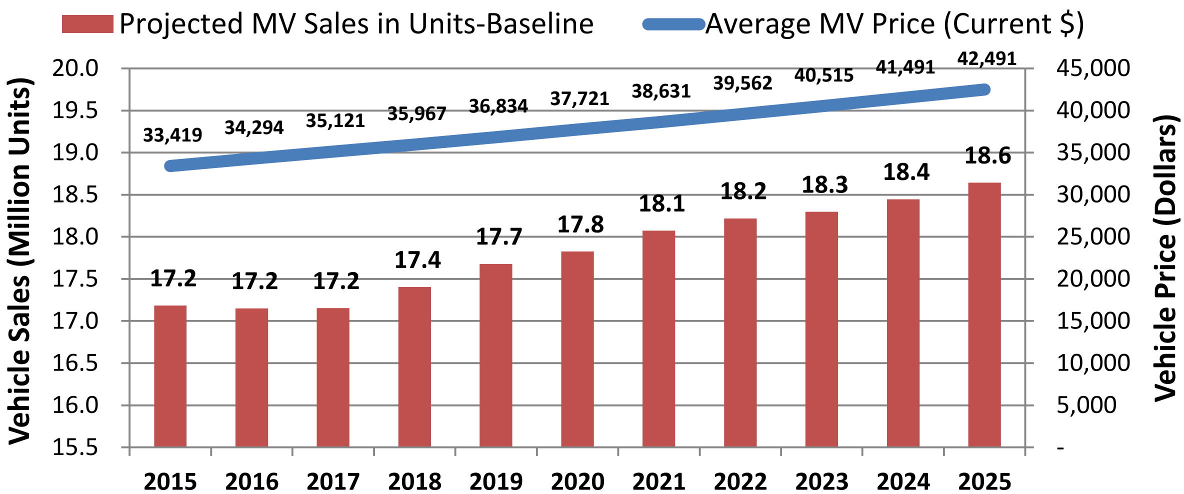
Figure 17: Long-Term Trend of U.S. Motor Vehicle Demand, 2015 – 2025 ($ Current Billions)



Source: Center for Automotive Research 2015

In a similar fashion, the average retail transaction price for motor vehicles, obtained from the National Automobile Dealership Association (NADA), is forecast to inflate by an average rate of 2.4 percent per annum, which results in an average transaction price of $42,491 per vehicle in 2025. This motor vehicle transaction price and the result of motor vehicle demand model for 2025 ($792 billion) yield a long-term U.S. sales level of 18.64 million vehicles in 2025. Results for the baseline forecast are shown in Figure 18 below.

Figure 18: Long-Term Trend of New Motor Vehicle Transaction Price and U.S. Motor Vehicle Sales, 2015 – 2025



Source: Center for Automotive Research 2015

U.S. Motor Vehicle Production Estimate in 2025

Motor vehicle sales is one of the key elements to U.S. economic growth, because it reflects personal income and expenditure increases, household formation, and job growth in the private sector. On the other hand, U.S. motor vehicle production is closely tied to U.S. manufacturing employment, which for decades has been considered a foundation of the American middle class and the backbone of the U.S. economy. Due to the globalization in the manufacturing industry, the U.S. automotive industry has become one of the most competitive industries, and the traditional Detroit Three automakers (GM, Ford, and FCA) now account for less than 50 percent of U.S. market share. Many major foreign automakers have had production operation in the United States since the 1980s. In 2015, these foreign automakers produced 47 percent of total U.S. motor vehicles output.

The U.S. sourcing ratio is defined as the share of U.S.-produced vehicles in the total U.S. motor vehicle market. The total U.S. motor vehicle production number is not a subset of sales, because motor vehicle sales include imported vehicles and motor vehicle production includes vehicles for exports. To estimate the long-term trend of U.S. motor vehicle production, CAR collects and analyzes U.S. motor vehicle sales, production, imports, and exports data by makes and models. The U.S. sourcing ratio analysis includes sales of imported vehicles and vehicle production for international markets. (See Table 7 for the 2014 U.S. sourcing ratio.)

Table 7: U.S. Motor Vehicle Sourcing Ratio - U.S. Light Vehicle Sales by Country of Origin, 2014

Imports					North American Sourcing				
Germany	Japan	S. Korea	Others	**Total Imports**	USA	Canada	Mexico	**Total N.A**	**Total Sales**
888,695	1,681,347	591,804	195,757	**3,357,603**	9,209,329	1,787,399	2,176,739	**13,173,467**	**16,531,070**
5%	10%	4%	1%	**20%**	56%	11%	13%	**80%**	**100%**

Source: Center for Automotive Research 2015

U.S. motor vehicle sourcing analysis indicates the ratio for 2014 is at a level of 56 percent, indicating that for every 100 vehicles sold, there are a corresponding 56 vehicles produced in the United States. Indicators have shown that Mexico is increasing motor vehicle production and exports to the U.S. and Canada[64]; and the result by 2025 is that the U.S. motor vehicle production might be lower than it was in 2014 despite possibility sales might be higher. This trend can be altered by trade policies, currency exchange rate, regional environmental and safety issues, and many other factors that are not covered in this study; therefore, CAR assumes the sourcing ratio remains unchanged through the studied period. The 56 percent sales-to-production ratio is applied to the 2025 motor vehicle sales estimate of 18.6 million units and results in 10.4 million units of motor vehicles produced in the United States. Further, CAR also assumes an additional 2.5 million units of vehicles would be produced for export purpose. The exports number would not be affected by the fluctuation of the U.S. motor vehicle market. It would nonetheless affect the total U.S. motor vehicle manufacturing industry employment, and is included in the figure of total U.S. motor vehicle production that allows CAR to estimate the total U.S. motor vehicle manufacturing employment by 2025.

U.S. Automotive Manufacturing Employment Estimate in 2025

To transform U.S. motor vehicle production to U.S. automotive manufacturing employment, CAR constructs a long-term trend through the use of a U.S. vehicle production to automotive manufacturing labor index or motor vehicle production per automotive manufacturing worker per year. Automotive manufacturing workers are those employed in two U.S. automotive industries: Motor Vehicle Manufacturing and Motor Vehicle Parts Manufacturing, as defined by the Bureau of Labor Statistics (NAICs 3361 and 3363). This ratio can be highly volatile and correlated with economic conditions, but it also shows a long-term progressive growth in vehicles assembled per worker. Figure 19 indexes this ratio for 1960-2014. The shaded areas highlight U.S. economic recessions in the past 50 years. Each recession was accompanied by a steep drop in the ratio and was followed by a rapid recovery before the next economic cycle.

From 2009 to 2014, U.S. motor vehicle output doubled, but U.S. motor vehicle manufacturing employment grew just 30 percent. As a result, the index jumped from 91 to a historical peak of over 140. Comparing U.S. motor vehicle production and employment levels from before and after the recession, 2014 vehicle production was 10 percent higher than the level achieved in 2007, but automotive employment was 12 percent less than the employment level in 2007. The U.S. automotive industry is producing more vehicles with a much smaller manufacturing labor force.

This unusually high production-labor force ratio could be attributed to several factors. First, after the recession, the U.S. automotive industry consolidated and concentrated their operations, slashed or outsourced less productive operations, and significantly reduced their hourly labor force. When the economy recovered and demand increased, workers often took on more work and worked overtime, increasing observed labor productivity.

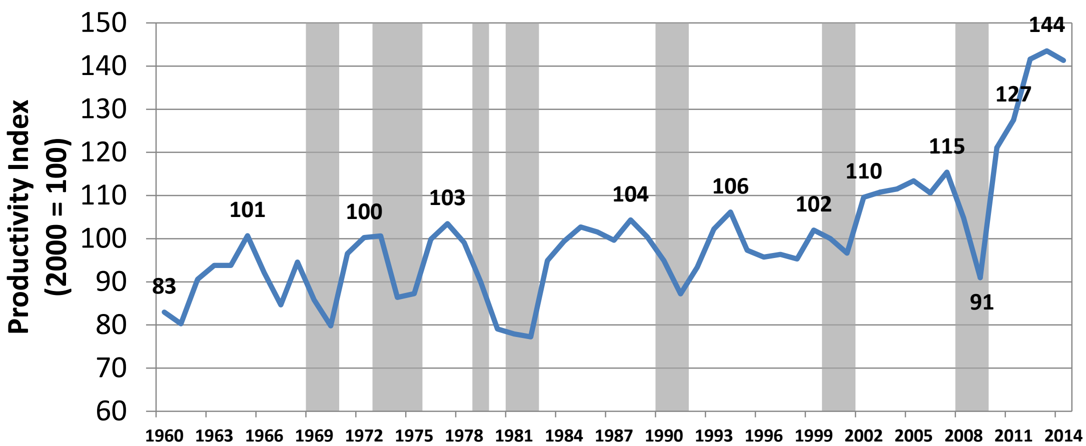
[64] Bernard Swiecki, Debra Maranger Menk. *The Growing Role of Mexico in the North American Automotive Industry,* Center for Automotive Research, Ann Arbor, MI, July 2016.

Second, U.S. motor vehicle parts manufacturing jobs have severely declined and moved to Mexico or to other low cost countries. Imported parts have replaced many supplier jobs in the United States. In 2014, motor vehicle parts manufacturing employment was still 12 percent below its employment level in 2007, despite the fact that vehicle production was 10 percent higher. Recently the supplier jobs have slowly increased from its trough, but it is still near its lowest level in the past 20 years.

Third, some "non-core" jobs—including sequencing and kitting, material handling, and other jobs not directly tied to the production line—have been taken by other workers in other industries, such as trucking and logistic industry employees. These workers work outside (and in some cases, inside) the assembly plants doing sub-assembling work. These positions were previously held either by auto maker or by auto supplier employees.

CAR constructs an index of the U.S. vehicle production to employment ratio. Which CAR expects this index will gradually converge to its long-term trend by 2025. Historically the ratio increased at a rate of 0.4 percent per year. By 2025, it is expected the ratio would be at the level of 127, similar to the levels observed in 2011, which can be translated to 15 vehicles per automotive manufacturing worker.

Figure 19: U.S. Vehicle Production/Employment Index (2000 = 100)



Source: Center for Automotive Research

It is apparent that previous peaks in labor productivity reverted to a long-term trend level which is the rationale behind the forecast of 127 in the index in 2025. For example, an eventual fall in the value of the dollar versus many currencies of countries that export auto parts to the U.S. automotive industry could return parts production and related employment to the United States. This index is meant to compare changes in motor vehicle output in units and changes in automotive manufacturing industry employment.[65]

Since this index is not true labor productivity, it can explain why the ratio can be expected to decrease to 127 by 2025 from 144 in 2014. It is not a fall in labor productivity but instead a decrease that

[65] The employment number does not distinguish production and non-production workers, and the output does not account for any increase in vehicle content. So the index is not really "labor productivity". It is an indexed ratio of U.S. vehicle production to motor vehicle and parts manufacturing employment.

anticipates output per employment will return to the long-term trend, with reductions in the use of overtime, temporary and third-party workers, or other non-production means that artificially raise the index usually during post-recession periods such as 2008-2015.

V. EFFECTS OF THE FUEL ECONOMY MANDATES ON THE BASELINE TREND FORECASTS

Vehicle Demand and Automotive Manufacturing Employment

To account for the effects of the standards on the 2025 price level, the percent net cost change calculated for the 2016 model year is applied to the baseline price. Thus, rather than a single 2025 vehicle price, CAR has nine – one for each of the net cost scenarios.

The average of the nine scenarios indicates that the average vehicle price in 2025, net of fuel economy costs and gasoline savings, will be $44,719. Across all scenarios the average impact on the baseline estimate of new light vehicle expenditures is a decline of 4.1 percent. This indicates a new market size $32 billion below the baseline, with an aggregate 2025 expenditure level of $760 billion, and a sales volume of 16.83 million – lower than the baseline estimate by 1.8 million. The average loss of $32 billion in the sales revenue model is a net loss to the industry. In other words, any so-called creation of employment because of higher mandated FE technology content is exceeded by even greater revenue loss due to lower sales. The output effect is far larger than any so-called substitution effect except in one scenario. The higher price already accounts for higher content, but it generates an even larger loss in vehicle content in terms of sales revenue and thus units.

Table 8 fully details each of the nine scenarios. In Table 8a, the low gasoline price scenario is evaluated at each fuel economy mandate cost level. At $2.44 per gallon (constant, base-year 2015 dollars), the total value of fuel savings is $1,287, yielding a vehicle net price increase of $713, if the cost of the additional fuel economy technology is $2,000, and fully passed through to the consumer. This net price increase translates to a decline of 1.3 percent from baseline expenditure levels in 2025, entailing 630,000 lost sales versus the baseline forecast. With this fall in sales volumes, so too does production, and thus employment, decline. Overall this scenario entails a level of American automotive employment below the baseline by a total of 22,900. If the cost of fuel economy improvement is higher, the impacts are more severe. At a cost of $4,000, the market size is nearly 5.0 percent below the baseline, with lost sales of approximately 2.3 million units, production reduced by 1.3 million units, and automotive employment lowered by 83,600. Should the fuel economy mandate cost be $6,000 and gasoline $2.44 per gallon, the worst impact occurs, sales would be off by 3.7 million units, with dramatic production and employment effects: almost 2.1 million fewer vehicles would be produced and there would be 137,900 fewer automotive parts and assembly jobs in the United States.

Table 8:Long Run Demand Effect with Gasoline Price of $2.44 per gallon (2015 constant dollars)

Table 8a: Long Run Demand Effect: Gasoline $2.44 per gallon				
Cost of Fuel Economy Technology	**Baseline**	$2,000	$4,000	$6,000
Total MV Expenditure ($Billion)	**792**	782	753	724
Effect of 2025 CAFE ($Billion)	-	-10.0	-39.0	-68.0
Effect of 2025 CAFE Percent	-	-1.30%	-4.95%	-8.60%
Vehicle Price (2025$)	**$42,491**	$43,397	$45,940	$48,483
Light Vehicle Sales (Million Units)	**18.64**	18.01	16.39	14.93
Light Vehicle Production (Million Units)*	**12.93**	12.59	11.68	10.86
Automotive Manufacturing Employment	**862,000**	839,100	778,400	724,100
Automotive Manufacturing Employment Impact	-	-22,900	-83,600	-137,900
Automotive Manufacturing Employment Impact, Percent	-	-2.66%	-9.70%	-16.00%

Table 8b: Long Run Demand Effect: Gasoline $3.00 per gallon				
Cost of Fuel Economy Technology	**Baseline**	$2,000	$4,000	$6,000
Total MV Expenditure ($Billion)	**792**	786	757	728
Effect of 2025 CAFE ($Billion)	-	-6.0	-34.9	-63.9
Effect of 2025 CAFE Percent	-	-0.76%	-4.41%	-8.06%
Vehicle Price (2025$)	**$42,491**	$43,022	$45,565	$48,108
Light Vehicle Sales (Million Units)	**18.64**	18.27	16.61	15.14
Light Vehicle Production (Million Units)*	**12.93**	12.73	11.80	10.98
Automotive Manufacturing Employment	**862,000**	848,700	787,000	731,700
Automotive Manufacturing Employment Impact	-	-13,300	-75,000	-130,300
Automotive Manufacturing Employment Impact, Percent	-	-1.54%	-8.70%	-15.12%

Table 8c: Long Run Demand Effect: Gasoline $4.64 per gallon				
Cost of Fuel Economy Technology	**Baseline**	$2,000	$4,000	$6,000
Total MV Expenditure ($Billion)	**792**	798	770	741
Effect of 2025 CAFE ($Billion)	-	6.5	-22.4	-51.4
Effect of 2025 CAFE Percent	-	0.82%	-2.83%	-6.48%
Vehicle Price (2025$)	**$42,491**	$41,922	$44,465	$47,008
Light Vehicle Sales (Million Units)	**18.64**	19.05	17.31	15.76
Light Vehicle Production (Million Units)*	**12.93**	13.17	12.19	11.32
Automotive Manufacturing Employment	**862,000**	877,700	812,800	754,900
Automotive Manufacturing Employment Impact	-	15,700	-49,200	-107,100
Automotive Manufacturing Employment Impact, Percent	-	1.82%	-5.71%	-12.42%

Source: Center for Automotive Research 2015

Table 8b presents the results corresponding to the Energy Information Administration's reference case for gasoline prices, $3.00 per gallon in 2025. At this gasoline price level, all of the fuel economy mandate cost scenarios continue to overwhelm the value of the consumer's fuel savings. Here, lost sales are 370,000, 2.03 million, or 3.50 million, for the low ($2,000), mid ($4,000), and high ($6,000) fuel economy cost scenarios, respectively. Corresponding production levels are below baseline by 200,000, 1.1 million, or almost 2.0 million. Employment levels fall from the baseline of 862,000 by 13,300 in the low-cost scenario, 75,000 for the mid-level cost, or 130,300 in the high-cost case.

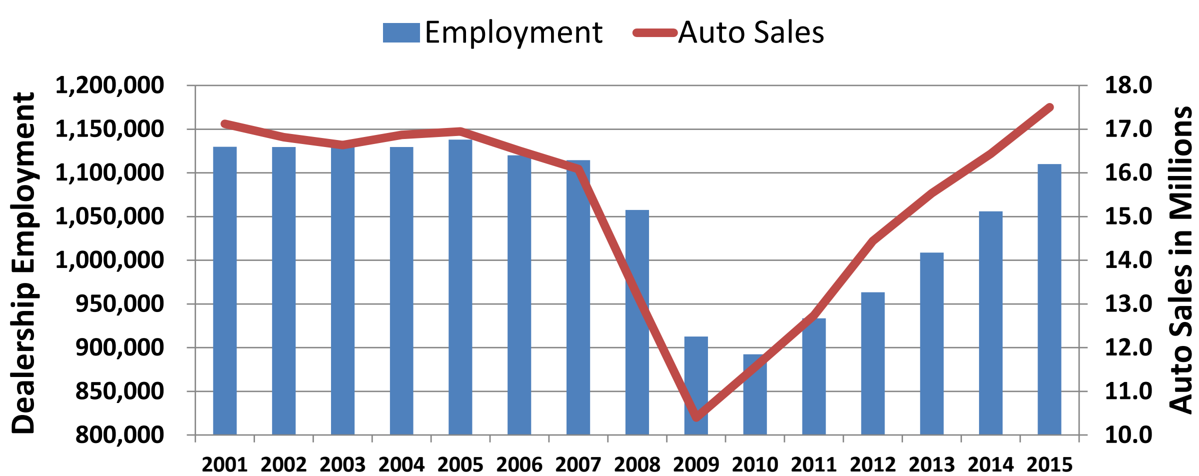
Table 8c provides the effect of each fuel economy cost level for the EIA's high gasoline price forecast, where one gallon of gasoline is $4.64. At this price, the low cost scenario provides a net benefit to consumers, and the market expands by 0.8 percent, resulting in 410,000 additional vehicle sales versus the baseline. Here, production would expand by 240,000 units, and employment in automotive parts and assembly would be higher by 15,700. The mid- and high-cost scenarios, however, remain negative. If the additional fuel economy cost is $4,000 or $6,000, the new vehicle expenditure level would be below the baseline level by 2.8 percent or 6.5 percent, respectively. In the $4,000 cost scenario, sales would be off by 1.3 million units, production down by 740,000 units, and U.S. automotive manufacturing employment diminished by 49,200. At the $6,000 cost level, sales in 2025 are below the baseline figure by nearly 2.8 million, production is off by 1.6 million units from the baseline, and employment 107,100 persons lower.

Effect on new motor vehicle dealership employment

The loss of motor vehicle sales will also negatively impact employment in the motor vehicle retailing industry. In the United States, new motor vehicle dealerships are the only source of sales for new motor vehicles, with the exception of one low-volume automaker in a small number of states. In 2015, the U.S. motor vehicle retailing industry operated 16,545 motor vehicle dealerships and 30,397 franchises; invested $211 billion in facilities, inventory, and working capital; and provided more than 1.1 million local jobs and $63 billion of payroll.

The motor vehicle dealership business is directly affected by the volume of motor vehicle sold each year, as shown in Figure 20. From 2007 to 2009, motor vehicle sales plunged 35 percent from 16.1 million units to 10.4 million units, and total motor vehicle dealership employment dropped by 18 percent. Since 2010, both vehicle sales and dealership employment steadily recovered. By end of 2015, the employment had recovered to 1.1 million.

Figure 20: U.S. New Vehicle Dealership Employment and Auto Sales 2001 – 2015



Source: NADA, Automotive News

Because motor vehicle dealership employment is directly tied to vehicle sales volume, the sales drops due to vehicle price increases would significantly reduce dealership employment. On the other hand, an increase in motor vehicle sales due to price drops would also increase dealership employment. The sales mentioned here are *unit* sales, not dealership revenue.

In Table 9, the first column is the 2025 baseline estimates—18.6 million units of motor vehicles sold and 810,000 employees in U.S. dealership new car departments and warranty service. The employment level is roughly 70 percent of total dealership employment, because for the purpose of this study only employment impacts from change in new vehicle sales and warranty service are considered. Focusing on the sales and service of new vehicles only (and not used) more accurately reflects the footprint of new motor vehicle sales.[66]

To the right of baseline estimates are nine scenarios, each has a gasoline price assumption and a fuel economy cost estimate. The impacts of these scenarios on dealership employment range from *adding* 18,000 jobs to reducing 99,000 jobs. The lowest fuel economy cost ($2,000), highest gasoline price ($4.64) scenario would increase dealership employment by 10,000. The highest fuel economy cost ($6,000), lowest gasoline price ($2.44) scenario would reduce dealership employment by 99,000 persons. The median fuel economy cost ($4,000) and reference gasoline price ($3.00) would decrease dealership employment by 55,000 persons.

The effects of falling sales on dealership employment are not linear. Prices of motor vehicles do not directly influence dealership employment, but instead, can indirectly affect the efficiency of dealership salespersons' productivity. The underlining assumption is that higher vehicle prices would slightly reduce the number of vehicles sold per salesperson. Increasing vehicle technology content would also require more complex service training and thus increase service time, which would also bring down service employment productivity.

Table 9: Effects on U.S. Dealership Employment in New Vehicle Department

	Long Run Demand Effect									
Gas Price/Cost of Fuel Economy	-	$2.44/ $2,000	$2.44/ $4,000	$2.44/ $6,000	$3.00/ $2,000	$3.00/ $4,000	$3.00/ $6,000	$4.64/ $2,000	$4.64/ $4,000	$4.64/ $6,000
Light Vehicle Sales (Million Units)	**18.64**	18.01	16.39	14.93	18.27	16.61	15.14	19.05	17.31	15.76
U.S. Dealership Employment (New Vehicle Dept.) (2025)	**810,000**	783,000	745,000	711,000	794,000	755,000	721,000	828,000	787,000	750,000
Impact on U.S. Dealership Employment	-	-27,000	-65,000	-99,000	-16,000	-55,000	-89,000	18,000	-23,000	-60,000

Source: Center for Automotive Research 2015

[66] Previous studies of the economic contribution of the automotive industry to the U.S. economy determined that about 70 percent of total dealer employment was connected to new car sales. Off-warranty service work and used vehicle sales are not directly related to new vehicle sales, the focus of this study. See "Contribution of the Automotive Industry to the U.S. Economy in 1998: The Nation and Its Fifty States." Institute of Labor and Industrial Relations and the Office for the Study of Automotive Transportation, University of Michigan and the Center for Automotive Research. Sean P. McAlinden, et al. Winter 2001.

VI. ESTIMATES OF THE EFFECTS OF THE MANDATES ON THE UNITED STATES ECONOMY

If employment in automotive manufacturing falls by up to 137,900, the effects on the overall U.S. economy in terms of lower employment, lower income, and lower tax revenues will be severe. In numerous studies, CAR has shown that the jobs multiplier for U.S. automotive manufacturing is one of the highest of any industry. In CAR's most recent study of the economic contribution of the motor vehicle manufacturing industry to the U.S. economy,[67] the jobs multiplier for direct employment at automakers and auto parts manufacturers was estimated to be 6.6. In other words, 5.6 jobs are created elsewhere in the U.S. economy for every job located at an automotive vehicle or parts manufacturing firm. In 2014, about 843,000 direct U.S. jobs were located at auto and auto parts manufacturers; the 2015 CAR study also estimated that these direct jobs generated an additional 2.1 million supplier jobs, largely in non-manufacturing sectors of the economy. The combined total of nearly 3.0 million jobs generated a further spin-off of 2.7 million jobs in the U.S. economy that depend on the consumer spending of direct auto manufacturing and other supplier employees, for a total jobs contribution from U.S. auto manufacturing of 5.6 million jobs in 2014.

The employment of new vehicle dealerships is also affected by the mandates. It should be pointed out that while U.S. vehicle production is projected to fall by 2.1 million units in the worst case ($2.44/gallon and $6,000 of engineering cost), dealership new vehicle sales will fall by 3.7 million units or the full loss of sales. CAR's most recent industry contribution study has estimated that about 1.3 additional jobs are contributed for each job connected to new vehicle sales located at a new vehicle dealership. There were about 710,000 such jobs at dealerships in 2014 that contributed a total of almost 1.7 million jobs in the U.S. economy, as shown in Table 10. This grand total of 7.3 million U.S. jobs supported by the auto industry represents 3.8 percent of all the private sector jobs in the U.S. economy and about 3.3 percent of total private sector compensation in 2014. A description of how these employment contributions are arrived at in two recent CAR studies follows.

The Contribution of Automotive Employment to the U.S. Economy

This section details the estimated employment contributions of automotive manufacturing employment to the U.S. economy in 2014. Employment estimates are broken out by direct employment (people employed directly by automotive companies), intermediate employment (people employed by suppliers to the motor vehicle industry), and spin-off employment (expenditure-induced employment resulting from spending by direct and intermediate employees).

Automotive Manufacturing

Employment and income estimates are derived from analyses using a regional economic model, supplied by Regional Economic Models, Inc. (REMI), of Amherst, Massachusetts. The 2014 employment and compensation data used to perform the research were provided by motor vehicle companies or gathered through publicly available data; the intermediate and spin-off effects were generated by the model. The remaining data on the U.S. economy and the automotive industry were collected by CAR from a wide variety of publicly available sources and are listed in the references. Direct employment

[67] Kim Hill, Debra Maranger Menk, et. al., *Contribution of the Automotive Industry to the Economies of All Fifty States and The United States,* Center for Automotive Research, Ann Arbor, MI, January 2015.

data include headquarters, office, research, design and development, manufacturing, assembly and logistics job classifications. All employment numbers cited below are rounded; income and tax receipt numbers are also rounded.

Automaker employment was classified according to the North American Industry Classification System (NAICS) into multiple job-type categories for input into the model — motor vehicle and motor vehicle parts manufacturing (category numbers: NAICS 3361-3363); management of companies (NAICS 551); professional, scientific and technical services (NAICS 541); securities, commodity contracts and investments (NAICS 523); warehousing and storage (NAICS 493); administrative services, facilities and support services (NAICS 521) and wholesale trade (NAICS 42).

As can be seen in Table 10 there were 2,069,300 intermediate jobs that support the direct employment of 843,000 at auto manufacturers and parts makers. The spin-off jobs supported by the incomes and spending of the people who work in the direct and intermediate jobs add another 2,687,700 jobs, bringing the total jobs associated with motor vehicle manufacturing activities in the United States to 5,600,000 jobs. The ratio of total jobs created to direct employment produces an employment multiplier of 6.6 (5,600,000 ÷ 843,000). The multiplier for motor vehicle manufacturing and assembly (automaker) jobs alone is 7.6 (2,443,000 ÷ 322,000). More than six additional jobs in the U.S. economy are contributed for every job in automobile manufacturing operations.

The direct employees of automakers include researchers, engineers, managers and administrative support, as well as workers on the assembly lines. Because the actual manufacturing of parts and assembly of vehicles draws on a deep supply chain for components and materials, manufacturing jobs have a high downstream (intermediate and spin-off) employment multiplier. When considering only assembly line employment, the jobs multiplier for automaker vehicle manufacturing activities is approximately 11.0.[68] That is, for every job on a vehicle assembly line, 10 additional jobs are created or supported in the economy.

Compensation in the private sector associated with the total jobs (direct plus intermediate plus spin-off) amounts to $375.3 billion. Estimated personal taxes to be paid, resulting from employment in automotive manufacturing operations, are nearly $45 billion.

To put the compensation and employment numbers in context, the direct, intermediate, and spin-off jobs associated with vehicle and parts manufacturing account for nearly three percent of employment in the entire U.S. economy and almost three percent of total U.S. compensation.

[68] Not shown in Table 10. Vehicle assembly operations and employment are a subset (and comprise approximately 70 percent) of the 322,000 total jobs at automakers.

Table 10: Total Contribution of all Motor Vehicle Manufacturing and Dealership New Vehicle Operations to the U.S. Economy in 2014[69]

Economic Impact	Automakers	All Motor Vehicle-related Manufacturing (incl. Automakers)	Auto Dealerships	Total
Employment				
Direct employment	322,000	843,000	710,000	1,553,000
Intermediate	805,000	2,069,300	246,700	2,316,000
Total (Direct + Intermediate)	1,127,000	2,912,300	956,700	3,869,000
Spin-off	1,316,000	2,687,700	693,300	3,381,000
Total (Direct + Intermediate + Spin-off)	**2,443,000**	**5,600,000**	**1,650,000**	**7,250,000**
Multiplier	7.6	6.6	2.3	4.7
Compensation ($billions nominal)	167.7	375.3	116.0	491.3
Less: transfer payments & social insurance contributions	-21.6	-41.5	-15.9	-57.4
Less: personal income taxes	-23.0	-44.7	-19.4	-64.1
Equals private disposable personal income ($billions nominal)	123.2	289.1	80.7	369.8
Contribution as % of total private economy				
Employment	1.6	2.9	0.9	3.8
Compensation	1.7	2.7	0.6	3.3

Source: Center for Automotive Research, 2015

New Vehicle Dealerships

Employment and income estimates from new vehicle dealerships were derived from analyses using the REMI model mentioned earlier. The employment and compensation data used to perform the research was provided by the National Automobile Dealers Association (NADA); the intermediate and spin-off effects were generated by the model. The remaining data on the U.S. economy and the automotive industry was collected by CAR from a wide variety of publicly available sources, which are listed in the references.

While total employment at U.S. auto dealerships in 2014 was slightly over one million people, the direct employment and resulting downstream jobs estimates are for new vehicle sales and warranty service only. Focusing on the sales and service of new vehicles only (and not used) more accurately reflects the footprint of new motor vehicle sales. Complete U.S. automotive dealership employment for new vehicle sales and service totaled 710,000. As can be seen in Table 10, there were 246,700 intermediate jobs that supported direct employment in the industry. The spin-off jobs associated with spending from the people who worked in the direct and intermediate jobs add another 693,300 jobs, bringing the total jobs associated with new motor vehicle retail operations in the United States to 1,650,000 jobs. The ratio of total jobs created to direct employment produced an employment multiplier for motor vehicle retail

[69] Kim Hill, Debra Maranger Menk, et. al., *Contribution of the Automotive Industry to the Economies of All Fifty States and The United States,* Center for Automotive Research, Ann Arbor, MI, January 2015.

operations; this number is 2.3. This multiplier of 2.3 means there is slightly more than one additional job in the U.S. economy for every job in automobile dealership operations.

Compensation in the private sector associated with total jobs (direct plus intermediate plus spin-off) amounts to $116 billion. Estimated personal taxes to be paid resulting from employment in automotive manufacturing operations are nearly $20 billion.

Total Contribution to the U.S. Economy in 2014

Table 10 also sums the combined effects from all new motor vehicle and parts manufacturing operations. Summing the direct employment from all operations (1,553,000), intermediate employment (2,316,000) and spin-off employment (3,381,000), more than 7 million jobs are supported or directly provided by the industry to the U.S. economy. Comparing total employment to direct employment produces an overall employment multiplier of 4.7.[70] This means that there are 3.7 additional jobs in the U.S. economy for every job in the industry. The industry contributes, at least in the short run, 3.8 percent of all private sector employment in the United States.

Total compensation for all 7.3 million private sector jobs is nearly $500 billion, which represents 3.3 percent of the private sector compensation in the U.S. economy. From this amount, more than $64 billion is paid for personal income taxes and $57 billion in other public contributions, such as Federal Insurance Contribution Act (FICA). Net disposable income for these workers totals $370 billion.

Even though the overall industry jobs multiplier is 4.7, the effect of the mandates on total U.S. employment will be estimated in two separate calculations: the effect of reductions (or increases) in U.S. vehicle production and thus automotive manufacturing employment will be translated to U.S. employment through the use of the 2014 study multiplier for automotive manufacturing. The effect of reductions (or increases) in new vehicle sales on new vehicle dealership employment will be estimated by first translating lost vehicle sales into lost new vehicle dealership employment, and then the loss to overall U.S. employment is estimated through the use of the CAR 2014 study employment multiplier for dealerships.

Total Effect of the Fuel Economy Mandates on U.S. Employment in 2025

Estimates of employment change contained in Table 10 are used in Table 11 along with the jobs multipliers shown in Table 10 to produce nine scenarios of total U.S. employment change due to the fuel economy mandates in 2025. For example, the scenario for $2.44 gasoline and $2,000 in fuel economy mandate cost reduces automotive manufacturing employment by 22,900 in 2025. This number is multiplied by 6.6 to yield a total effect on the economy of 151,140 due to manufacturing job losses. The same scenario results in a loss of new vehicle dealership employment of 27,000. This number is multiplied by 2.3 to yield a total loss of 62,100 jobs in the economy due to dealership job losses. The two job loss totals, manufacturing and dealership, are combined to yield a total loss estimate of 212,240.

[70] The multiplier is determined by dividing the total employment contribution by the number of direct employees: (7,250,000 / 1,553,000) = 4.7.

Table 11: Total Effects of the Fuel Economy Mandates on Motor Vehicle Manufacturing, New Vehicle Dealership, and Total Private Sector Employment in the U.S. Economy in 2025

	Long Run Demand Effect								
GAS Price/Cost of Fuel Economy Assumptions	$2.44/$ $2,000	$2.44/ $4,000	$2.44/ $6,000	$3.00/ $2,000	$3.00/ $4,000	$3.00/ $6,000	$4.64/ $2,000	$4.64/ $4,000	$4.64/ $6,000
Impact Due to Automotive Manufacturing Job Losses	-151,140	-551,760	-910,140	-87,780	-495,000	-859,980	103,620	-324,720	-706,860
Impact Due to Automobile Dealership Job Losses	-62,100	-149,500	-227,700	-36,800	-126,500	-204,700	41,400	-52,900	-138,000
Double Counting Adjustment*	1,000	3,000	4,000	0	2,000	4,000	-1,000	2,000	3,000
Total Impact on US Private Employment	**-212,240**	**-698,260**	**-1,133,840**	**-124,580**	**-619,500**	**-1,060,680**	**144,020**	**-375,620**	**-841,860**

Source: Center for Automotive Research 2015
**Impact of automotive manufacturing job losses on U.S. economy includes some dealership job losses related to lower purchases by auto manufacturing employees.*

CAR's study estimates the job loss/gain range of higher real world fuel economy mandates increasing from 27.3 to 40.0 MPG by 2025 will range from 0.1 million (33,700 direct jobs) to -1.1 million jobs (-236,900 direct jobs) in the U.S. economy. Clearly the influence of gasoline price and the costs of fuel economy technology are seen in Table 11.

The scenario combination of high fuel economy mandate costs and low gasoline prices can produce truly catastrophic jobs numbers for the future of an economy still locked in a painfully long recovery from the 2008-2009 Great Recession.

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Conclusions

This study has investigated the likely effects of higher fuel economy or GHG emission mandates on the U.S. auto industry and economy of 2025. This was a complex task that required a series of estimations using real data in original economic models.

The major estimation results in this study include the following:

- As mandated, average real world fuel economy for new vehicles will increase by a projected 12.7 MPG between MY 2016 and MY 2025. Real world fuel economy is derived by adjusting the mandate standards for real world driving conditions. Thus, MY 2016 real world driving standard is 27.3 MPG and 40.0 MPG in 2025.
- This study employs the most recent range of gasoline price forecast levels from the U.S. Energy Information Agency (EIA). In 2025 US dollars the levels are $2.44/gallon, $3.00/gallon, and $4.64/gallon.
- A review of 14 published studies on new vehicle consumer valuation of fuel economy produces an average desired payback of 3.4 years for the cost of fuel economy technologies.
- Evaluated at the EIA range of fuel prices, fuel savings over three years are worth $1,287 ($2.44/gal.), $1,583 ($3.00/gallon), and $2,448 ($4.64/gallon) when adjusted for a rebound effect in miles traveled applied to a survey-estimated average mileage traveled by new vehicles in the first three years of ownership.
- When evaluated at three fuel economy mandate cost levels of $2,000, $4,000, and $6,000, and a forecast price trend through 2025 for new vehicles, the study estimates nine scenarios for an increase or decrease in the net cost of buying a 2025 vehicle. The scenarios range from a net price decrease of -1.3 percent at a fuel price of $4.64/gallon and a fuel economy mandate cost of $2,000 to the highest of eight net cost increase scenarios of 14.1 percent at a fuel price of $2.44/gallon and a fuel economy mandate cost of $6,000. The study assumes that the full value of the change in net cost to the consumer is passed along to vehicle prices.
- The study estimates a long-run, own-price elasticity for new vehicle sales revenue of .61. Therefore, the effect on motor vehicle demand in terms of sales revenue in 2025 ranges from +.82 percent at a fuel price of $4.64/gallon and a fuel economy mandate cost of $2,000 to the largest decrease of eight scenarios of -8.6 percent at a fuel price of $2.44/gallon and a fuel economy mandate cost of $6,000. The first scenario is associated with vehicle sales increase of 410,000 units and the second scenario with a loss of 3.71 million vehicle sales in the United States compared to the base sales forecast model. Three of the scenarios estimate a sales loss of 3 million or more vehicle sales.
- The estimated changes in vehicle sales are converted to changes in U.S. vehicle production through the use of a forecast of vehicle-sourcing ratios. As a result, the 2025 fuel economy mandates produce changes in U.S. vehicle production that range from an increase of 240,000 units at a fuel price of $4.64/gallon and a fuel economy mandate cost of $2,000 to a decrease of 2.07 million units at a fuel price of $2.44/gallon and a fuel economy mandate cost of $6,000. Eight of the nine scenarios estimate a production decrease compared to the baseline estimate with five scenarios resulting in a loss over 1 million units in vehicle production.
- The estimated changes in U.S. vehicle production can be used to also estimate losses in automotive manufacturing employment in the vehicle and parts manufacturing sectors through

the use of estimates of labor productivity in those industries in 2025. The changes in auto industry employment range from an increase of 15,700 at a fuel price of $4.64/gallon and a fuel economy mandate cost of $2,000 to a loss of 137,900 at a fuel price of $2.44/gallon and a fuel economy mandate cost of $6,000. Eight of the nine scenarios project a loss in industry employment.

- The overall change in vehicle sales, larger than the change in U.S. vehicle production, as a result of the 2025 fuel economy mandates, will also impact employment at new vehicle dealerships. Based on a trend in dealership labor productivity through 2025, the study estimates that in one scenario, dealership employment would rise by 18,000 jobs, in the case of $4.64/gallon gasoline price and $2,000 in fuel economy mandate cost, and eight scenarios in which dealership employment would fall – the largest being a decline of 99,000 jobs in the case of $2.44 price of gasoline and $6,000 in fuel economy mandate cost.
- The projected gain and losses in automotive manufacturing and dealership employment as a result of the 2025 fuel economy mandates will affect the U.S. economy through a multiplier effect. Recent studies of the economic contribution of automotive manufacturing and new vehicle dealership employment have estimated that 5.6 jobs additional are created for every job in automotive manufacturing, and 1.3 jobs for every job in new vehicle dealerships. Using the multipliers of 6.6 for change in automotive manufacturing employment and 2.3 for changes in new vehicle dealership employment produces an increase in overall employment on the U.S. economy in 2025 of 144,020 jobs in the case of $4.64/gallon gasoline price and $2,000 in fuel economy mandate cost and eight scenarios with negative employment change including the loss of 1.13 million jobs in the case of $2.44/gallon gasoline price and $6,000 in fuel economy mandate cost.

An important result in this study and in the conclusions for this study is the overwhelming and direct importance of fuel prices in determining the economic effects of the fuel economy mandates for 2025. If the value of fuel savings to the new vehicle buyer falls short of the cost of mandated fuel economy technologies, then U.S. automotive sales, production, and manufacturing employment will fall with serious consequences for the U.S. economy. The influence of fuel prices on the demand for fuel efficient vehicles is directly estimated in this study in a special econometric analysis. The effect is powerful even in the short run and especially in periods of reasonable growth in the level of personal disposable income and employment.

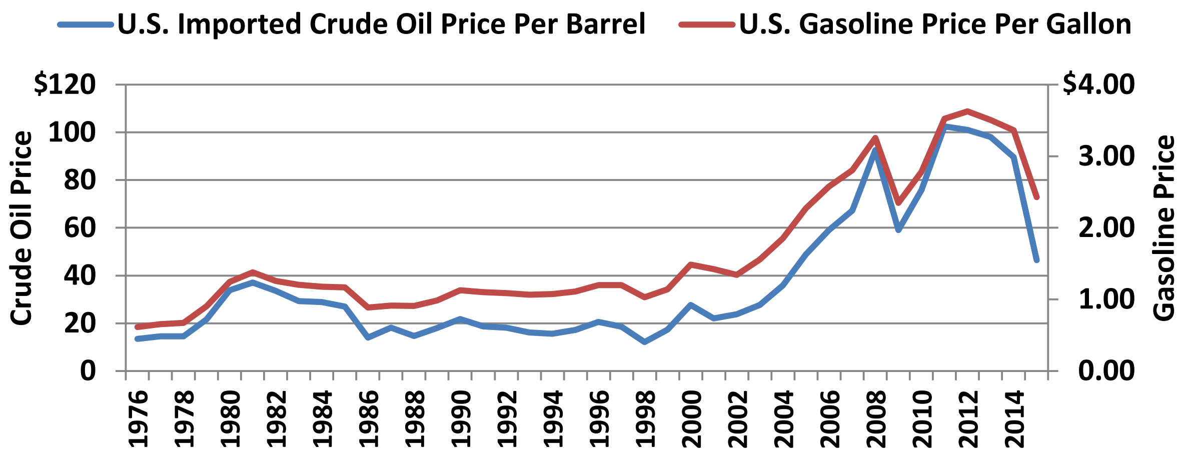
FINAL OBSERVATIONS

The authors reviewed a wide range of studies in the areas of consumer valuation of fuel savings and the own-price elasticity of demand for motor vehicles before producing their own models. This review of studies showed that automotive consumers only value fuel savings for a relatively short future period which is the product of the extreme volatility of actual fuel prices over the last 30 years. In short, there is no fuel economy "energy paradox" on the part of automotive consumers. A reasonable question to ask is if large corporations and the government have repeatedly failed to accurately forecast the price of fuel into the distant future, how can consumers? Of course they cannot – and do not. And a mistake on the part of consumers on this issue can result in a major loss in the resale value of the specific purchased vehicle as recent prices for used hybrids and electric vehicles can testify.[71] Current automotive buyers are some of the most experienced in U.S. market history. Their median age is almost 52,[72] their average household annual income is just under $100,000 and education levels are high as well.[73] Since the 2006 model year, more than 50 percent of new vehicle buyers have been age 50 or older, and the largest age group has been consumers age 65 or older since at least model year 2000, for cars, and model year 2003, for light trucks.[74] Current buyers are certainly not first-time buyers and they are acting quite rationally in regards to their valuation of fuel economy benefits.

Figure 21 below amply illustrates the close relationship between the price for crude oil and that for gasoline in the U.S. market. As a rule of thumb, a $0.25 increase in the price of gasoline is usually associated with a $10.00 per barrel increase in the price of oil.[75] Gasoline prices in the U.S. are now averaging between $2.00 to $3.00 per gallon and imported oil at about $40.00 per barrel. In order for the price of gasoline price to once again reach the region of $4.00 per gallon, the price of oil must increase by 200 percent or to $120.00 per barrel. This is highly unlikely for any significant period of time through 2025, given both the fracking revolution (yet to be applied globally) in production of petroleum and the slowdown in the growth of Chinese and other developing economies.

[71] See for example, National Automobile Dealers Association, (2016, April). NADA Used Car Guide, Perspective: Alternative Powertrains, analysis of Recent Market Trends & Value Retention, a division of J.D. Power, McClean, VA, page 6.
[72] Szakaly, Steven, August 2016, slide 26.
[73] Szakaly, Steven, National Automobile Dealers Association, August 4, 2015
[74] Ward's Automotive. Ward's U.S. New Vehicle Buyer Demographics. Various years.
[75] Hamilton, James. "Gasoline prices coming down." *Econbrowser.* June 24, 2012. http://econbrowser.com/archives/2012/06/gasoline_prices_7

Figure 21: Crude Oil and Gasoline Nominal Price, 1976 – 2015



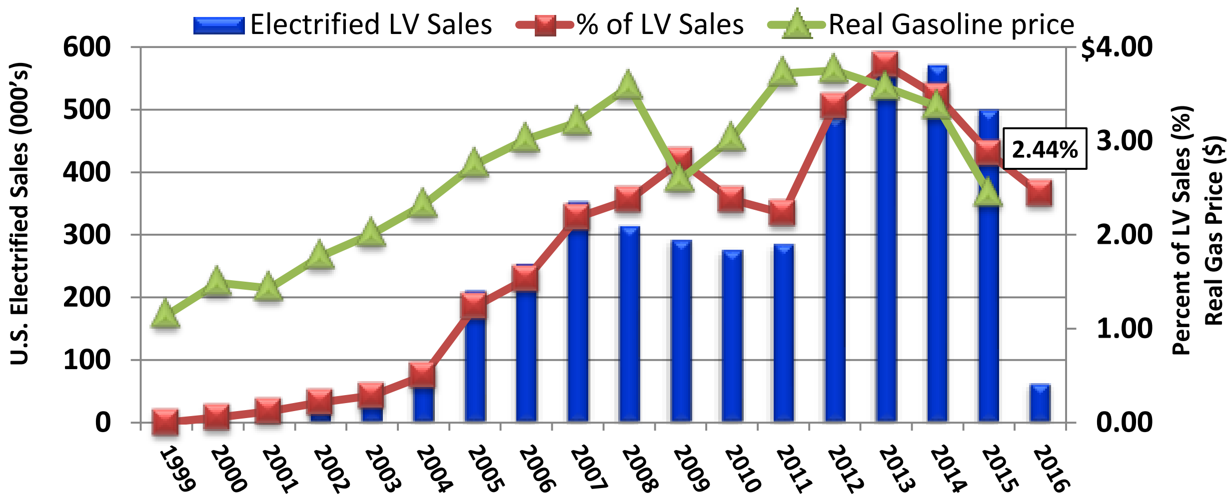
Source: EIA/USDOE

The reasonable expectation that fuel prices will remain low (perhaps well below $3.00 per gallon) through 2025 is important in the context of CAR's cost-benefit calculation for fuel economy technologies. Section II of this study estimated that consumers break-even at a cost of $4,000 in fuel economy technology if gasoline price is at a level of $7.58 a gallon, and only break-even at a fuel economy mandate cost of $6,000 if gasoline reaches $11.37 per gallon. Only at a low cost of $2,000 for a fuel economy mandate cost can a break-even be calculated of $3.86 per gallon – the highest price ever seen on an annual basis in U.S. history.

Many current observers of the pace of fuel economy improvements and the introduction of fuel economy technologies now believe automakers will have to sell electrified vehicles (HEVs, PHEVs, BEVs) at a much larger share of total sales in 2025 to meet the mandates than is assumed by EPA or NHTSA authorities. If so, this is an argument and warning about the eventual cost of meeting the mandates and the effects on the U.S. auto industry and economy. Electrified vehicles are the most expensive technologies that also require the greatest change in the current fueling infrastructure and reduce the greatest degree current vehicle attributes. As Figure 22 shows below, the share of electrified vehicle sales in overall vehicle sales is not increasing, but is decreasing–rapidly. Market share for electrified vehicles actually peaked in 2013 at 3.8 percent. In the first two months of 2016, electrified vehicle share averaged 2.4 percent, a drop of 36 percent from its historic peak in share. Clearly, this falloff was partially due to the fall in fuel prices. Given the poor resale values for current electrified vehicles, it is unlikely that many owners of this technology will be repeat buyers.[76] New motor vehicles with a poor return are too expensive to be given a second chance by most households.

[76] http://www.prnewswire.com/news-releases/ev-and-hybrid-loyalty-falls-to-all-time-low-even-as-overall-fuel-economy-thrives-says-edmundscom-300254960.html; http://www.edmunds.com/about/press/hybrid-and-electric-vehicles-struggle-to-maintain-owner-loyalty-reports-edmundscom.html

Figure 22: U.S. Electrified Light Vehicle Sales and Take Rate 1999 – 2016 YTD



Source: Ward's Automotive Reports, HybridCars.com and CAR Research; EIA
Note: Electrified vehicles consist of BEV, HEV and PHEV

The combination of likely low fuel prices and high fuel economy mandate cost will make it very difficult for the U.S. auto industry to meet the 2025 mandates without a serious loss of sales, production, and employment. The prospect of a 900,000 to 1,200,000 loss of employment in the U.S. economy of 2025 cannot be fairly dismissed. This outcome is even more likely if the consumer does not value the costs of NHTSA safety actions and mandated equipment that will be additional to the costs of fuel economy technology. Recently, automakers have agreed to incorporate automatic braking by 2022 in the vehicle. Consumers may or may not value the addition of this feature at its expected cost along with a number of other likely assisted driving technologies. It is also expected that NHTSA will mandate a connectivity "box" by 2018 which will produce few benefits to buyers until over half the U.S. operating fleet is so equipped. What is true is that value by the consumer or not, the addition by mandate of so many emissions and safety technologies will increasingly put the average new vehicle out the economic reach of the average American household.

However, higher prices and lower sales will, without question, result in an older operating fleet of private vehicles (the Cubanization Effect) and the result will be a loss of performance in both fuel consumption efficiency and safety, and many vehicle attributes for all Americans. It will also result in the loss of personal mobility, currently the highest in the world, across the American population which will not only lower the standard of living for American households but also reduce their productivity in the economy and especially the labor market. This study has not estimated these negative aggregate effects on national well-being. These effects should not be left out of any future study or discussion of the impact of mandates on the motor vehicle industry.

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RECOMMENDATIONS

1. Raise the gasoline/fuels tax to ensure fuel economy technologies are a net benefit to consumers and to prevent a rebound in VMT. Consider replacing the CAFE program entirely with a sufficient carbon tax on motor fuels. If there is a convincing environmental benefit argument (given the national security argument has significantly depreciated with the creation of massive new U.S. petroleum capacity) for doubling the fuel consumption performance of the operating light vehicle fleet, then surely the case can be made with the public and Congress for such taxation to bring this result about.
2. Provide additional subsidies to consumers and compliance credits for the purchase of standard hybrid vehicles to lower their acquisition costs and their perceived risk to promote their long-term sales trend in the market. In contrast to battery electric vehicles (BEVs), strong hybrids (HEVs) and plug-in hybrids (PHEVs) sacrifice far less in terms of standard vehicle attributes in the eyes of consumers and so subsidies could produce a greater effect on sales and thus fuel consumption for HEVs versus BEVs (which may even travel far fewer miles per year). In fact, plug-in HEVs or extended range BEVs may result in a larger number of miles traveled on electricity than BEVs because of their potentially higher sales volumes and travel miles per year.
3. Provide additional off-cycle credits for other advanced fuel economy technologies such as light-weighting or stop-start in order to encourage automaker commercialization by overcoming price inflation and to support the development of new supply chains for lightweighting materials and advanced internal combustion engine (ICE) and electric vehicle (EV) components. In effect, these supply chains are the required infrastructure for a new fuel efficient motor vehicle industry and should be treated no differently than public investment needed for charging stations to re-charge BEVs.
4. Provide the industry an additional five years to reach the mandates, assuming the customer market needs further long-term development to accept such vehicles (especially in an environment of low fuel prices) and permit the industry to produce these technologies at a more affordable cost and to allow the development of adequate infrastructure. In the opinion of CAR, learning curves for new technologies have been overestimated by regulators and barriers to new fuel economy innovations underestimated, requiring consumers additional time to adjust their standard operating models of transportation for new technologies.

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APPENDIX I: A MODEL OF NEW LIGHT VEHICLE SALES OWN PRICE ELASTICITY

CAR models personal consumption expenditures on new motor vehicles as a function of income, new and used vehicle prices, consumer credit, interest rates, and the number of households. Income is incorporated as personal income excluding both supplements to wages and salaries, and transfer receipts. Supplements such as health insurance benefits cannot be spent on motor vehicle purchases, and those receiving transfer payments such as unemployment are unlikely to participate in the new vehicle market. This income construct, less taxes, was also analyzed. However, the statistical performance of the model was notably lessened when also excluding taxes, thus pre-tax income is used. New and used motor vehicle prices are represented by the consumer price indices for new vehicles, and used cars and trucks, respectively. Total consumer credit outstanding and the Moody's Seasoned BAA Corporate Bond Yield are included to capture credit conditions. The BAA yield was selected as, among interest rates reviewed, it best mirrors the significantly shorter series available for auto loan rates. The nominal interest rate is employed, rather than the real interest rate, to better account for liquidity effects: the real interest rate would likely present a clouded picture as credit is extended based upon nominal data, and repayments set in nominal terms.

The model is estimated over an annual dataset covering the period 1953 through 2013. Data is sourced from the U.S. Bureau of Economic Analysis, the Bureau of Labor Statistics, the U.S. Federal Reserve, and the U.S. Census Bureau. Variable definitions and data sources are indicated in Table 12.

Table 12: Variable Definitions and Sources

Variable	Definition	Source
cNMV_PCE	Personal Consumption Expenditures on New Motor Vehicles	BEA Table 2.5.5 Personal Consumption Expenditures by Function. Line 55 deflated by CPI_NMV
cPIXSTR	Personal income excluding supplements to wages and salaries and transfer receipts	BEA Table 2.1 Personal Income. Line 1 less line 6, less line 16, deflated by CPI_All
CPI_NMV	Consumer Price Index for New Motor Vehicles Annual average of non-seasonally adjusted data	BLS, Series ID: CUUR0000SETA01
CPI_UMV	Consumer Price Index for Used Cars and Trucks Annual average of non-seasonally adjusted, monthly data	BLS, Series ID: CUUR0000SETA02
CPI_All	Consumer Price Index for All Items Annual average of non-seasonally adjusted, monthly data	BLS, Series ID: CUUR0000SA0
cTCC	Total Consumer Credit Owned and Securitized, Outstanding. Annual, seasonally adjusted data, end of period values	St. Louis Federal Reserve, Federal Reserve Economic Data, Code: TOTALSL. Deflated by CPI_All
BAA	Moody's Seasoned Baa Corporate Bond Yield Annual average of non-seasonally adjusted, monthly data	St. Louis Federal Reserve, Federal Reserve Economic Data, Code: BAA
HH	Total households	Census, Families and Living Arrangements. Table HH-1 Households by Type: 1940 to Present
Time Period	The estimated dataset includes annual observations of all variables for the period 1953-2013.	

The regression is estimated with all variables in log-difference form, save for the interest rate and the number of households, which are first-differenced as shown in Table 13.

Table 13: Log Difference Models

Dependent Variable: LD_CNMV_PCE Method: Least Squares Sample (adjusted): 1955 2013 Included observations: 59 after adjustments HAC standard errors & covariance					
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**	
C	-0.08948	0.02923	-3.06098	0.00350	***
LD_CNMV_PCE_1	-0.30076	0.06746	-4.45802	0.00000	***
LD_CPIXSTR	0.90411	0.47107	1.91927	0.06060	*
LD_CPI_NMV	-0.78902	0.42781	-1.84434	0.07090	*
LD_CPI_UMV	0.52902	0.22285	2.37389	0.02140	**
LD_CTCC	1.31507	0.32018	4.10727	0.00010	***
D_BAA	-0.03563	0.00846	-4.21189	0.00010	***
D_HH	0.00005	0.00002	2.50089	0.01560	**
R-squared	0.68092	Mean dependent var		0.03342	
Adjusted R-squared	0.63713	S.D. dependent var		0.13072	
S.E. of regression	0.07875	Akaike info criterion		-2.11971	
Sum squared resid	0.31625	Schwarz criterion		-1.83801	
Log likelihood	70.53153	Hannan-Quinn criter.		-2.00975	
F-statistic	15.54794	Durbin-Watson stat		1.96056	
Prob(F-statistic)	0.00000	Durbin's h		0.0959	
Prob(Wald F-statistic)	0.00000	Wald F-statistic		47.32962	

In log-difference models, such as this, the coefficient estimates are direct representations of the short-run elasticities. Thus, the short-run own-price elasticity for consumer spending on new motor vehicles is found to be approximately -0.79. This is sharply lower than the average result from the aggregate market, time series models, which held an average short-run elasticity of -1.25. The result is likewise markedly lower than the values from disaggregate, cross-sectional models, where the average short-run elasticity was -0.99. Nonetheless, these discrepancies are easily explained: the majority of past models exclude both consumer credit, and interest rates. Re-estimating the model without cTCC and BAA finds a short-run elasticity value of -1.31, similar to the estimates of other time series models.

To arrive at an estimate of the long-run own-price elasticity, the Koyck Transformation is applied: the coefficient on the price variable is divided by one less the coefficient on the lag of the dependent variable: $\beta_2 / (1 - \beta_0)$. The resulting elasticity value is -0.61, near the midpoint of the range identified by the literature, but lower than the average found. Note that β_0, the coefficient on the lag of the dependent variable, is negative; all long-run elasticities resulting from this model will be lower than their short-run counterparts. Specifically, given a β_0 value of -0.30, the long-run figures estimated via the Koyck Transformation will always be approximately 77 percent of the short-run value.

The short-run income elasticity indicated by the model is near unity, at 0.90. Again applying the Koyck Transformation to generate a long-run figure, this model indicates that the income elasticity will eventually fall to 0.70. This suggests that, following an increase in incomes, consumers will first elect to purchase additional or more expensive vehicles, and gradually shift the additional income to other purchases thereafter. Likewise, the short-run cross-price elasticity of new vehicle expenditure with used vehicle prices falls from 0.53 to a long-run value of 0.41. Expenditure on new vehicles is found to be highly elastic with regards to the outstanding volume of consumer credit, with a short-run elasticity of 1.32, and a corresponding long-run elasticity of 1.01.

Both stationary and non-stationary, cointegrated series possess stable, long-run relationships which they revert to following a shock. Stochastically trending, non-cointegrated series do not have stable long-run relationships. Rather than reverting after a shock, the variables continue trending from this new point to which the shock has propelled them. Trend-stationary series revert to their previous trend line following a shock, and as with stochastically trending series, do not have stable long-run relationships. The variables in the dataset follow stochastic trends, but the dataset is not cointegrated. Ergo, the long-run relationship calculated from the Koyck Transformation may not be a useful guide to changes in motor vehicle sales, following a change in price. The results presented here are intended to address an on-going need for long-run estimates, while work on robust model results continues. However, the results of Fischer, et al. (2007) suggest that the findings of this initiative understate the actual impact of a change in prices on the market for new motor vehicles.

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APPENDIX II: A BRIEF REVIEW OF OWN-PRICE ELASTICITY STUDIES

Research on automotive demand largely follows two strains: aggregate models which analyze the development of the overall market over a long time period, and disaggregate models of vehicle choice, typically examining make-model sales during a single model year. Table 14 below summarizes the own-price elasticity results of studies covered within CAR's review of existing academic literature.

The earliest models followed the aggregate, time series approach. Here, the behavior of the overall market is statistically estimated over a dataset typically spanning multiple decades. Time series models employ the quantity of vehicles sold, or total expenditure on vehicles as the measure of demand. Vehicle prices are most often incorporated into these models as the ratio of a vehicle price index and an overall price index, for example, the ratio of the new vehicle consumer price index to the all items consumer price index.

Among the time series studies covered within CAR's literature review, short-run own-price elasticities for vehicle demand range between Nerlove's (1957) finding of -0.9 and Hess's (1977), result of -1.63, with an average value of -1.25. Long-run price elasticities also range widely, with a low estimate of -0.3 found among the various specifications examined by Hymans, Ackley, and Juster (1970), and a high figure of -1.2 resulting from Nerlove's analysis. The average long-run elasticity across CAR's review of the literature is -0.72. Nerlove's figure is a dramatic outlier, nearly 50 percent larger than the next-highest. If it is excluded from consideration, the average long-run elasticity estimate is, instead, -0.61.

By studying aggregate figures, the time-series approach suffers from an implicit assumption of homogenous products, with estimation results describing an "average" vehicle. Due to this trait, aggregate, time series models are unable to illuminate consumer valuation of vehicle attributes. By the mid-1970s, the time series approach largely fell out of use, as attention turned to the valuation of vehicle-specific attributes, such as safety ratings and perceptions of quality.

This second strain of research examines the influence of vehicle attributes on the probability that a purchaser of a new vehicle will select a specific make-model, from among the whole menu of make-model combinations, rather than examining the evolution of the new vehicle market over time. For example, this approach might illuminate such questions as, "What determines a consumer's decision between purchasing a Chevrolet Sonic versus another subcompact?"

This approach has an advantage of providing a direct estimate of consumer valuation of vehicle attributes, but suffers from several limitations in the application of these results. These models are typically estimated over a dataset which examines new vehicle purchases within a single model year, suggesting that their results cannot be generalized far outside of the period for which data employed by the estimation covered. The structure of these models further limits their applicability to analysis of the overall new vehicle market. These models represent only the choice between vehicle make-models among actors who did purchase a new vehicle in the observed time period. Two important stages of the new vehicle purchase decision are excluded from the disaggregate models. Occurring outside of these models are: 1) the decision to buy a vehicle and 2) the choice between new and used vehicles. As these choices are relevant to determining the economic impact of a market-wide change in new vehicle prices, the present utility of disaggregate studies is imperiled. The exclusive focus upon new vehicles also precludes the availability of a cross-price elasticity between new and used vehicles available. As the primary, and in the long-run the only, substitute for a new vehicle purchase is a used vehicle purchase, total market elasticities arrived at from these studies are likely to be significantly biased.

Table 14: Previous Own-Price Elasticity Estimates

Authors	Year	Aggregation	Time Period	Short-Run	Long-Run
Atkinson	1952	Aggregate; Overall Market	1925-1940	-1.33	
Nerlove	1957	Aggregate; Overall Market	1922-1941; 1948-1953	-0.90	-1.20
Suits	1958	Aggregate; Overall Market	1929-1941; 1949-1956		-0.55 to -0.59
Chow	1960	Aggregate; Overall Market	1921-1953		-0.70
Suits	1961	Aggregate; Overall Market	1929-1941; 1949-1956		-0.53 to -0.82
Hymans, Ackley, and Juster	1970	Aggregate; Overall Market	1954-1968	-1.14	-0.46
Hess	1977	Aggregate; Overall Market	1952-1972	-1.63	
Trandel	1991	Disaggregate; Make-Model Sales	1983-1985	-1.43	
Levinsohn	1988	Disaggregate; Make-Model Sales	1983-1985	-0.81 to -0.83	
McCarthy	1996	Disaggregate; Make-Model Sales	1989	-0.87	
Bordley	1993	Disaggregate; Make-Model Sales	Not indicated	-1.00	
Fischer, Harrington, and Parry	2007	Disaggregate; Make-Model Sales	Not indicated	-1.00	−0.79 for cars -0.85 for trucks
		Average Price Elasticities:	**Aggregate Models**	**-1.25**	**-0.69**
			Disaggregate Models	**-0.99**	**-0.82**
			All Models	**-1.09**	**-0.72**

Source: Center for Automotive Research 2015

APPENDIX III: MOTOR VEHICLE DEMAND MODELING: LONG-TERM TREND THROUGH 2025

This model (shown in Table 15) is used to estimate the long-term trend of motor vehicle demand in current dollars. Nominal motor vehicle prices instead of real prices are used because real motor vehicle price discounts nominal price by factoring in improvements in motor vehicle attributes such as reliability, durability, safety, fuel efficiency, horsepower, utility, etc. Many of these improvements are driven by consumer preferences, but some expensive "improvements" are mandated by government. Consumers must purchase mandated equipment for their motor vehicles regardless of their preferences. Including them all into the consideration of real price does not truly reflect the product consumers wish to pay for, and it significantly underestimates the cost consumers bear. For example, the U.S. Bureau of Labor Statistics estimated that the consumer price index on new motor vehicles merely increased by 3.5 percent from 2000 to 2015. However, the per new motor vehicle average transaction price (NADA) actually increased by 34.1 percent, from $24,900 to $33,400.

An econometric model is needed to forecast motor vehicle demand in 2025. The dependent variable is a first- difference form of motor vehicle expenditures. Several non-stationary explanatory variables are used to minimize the impact of autocorrelation. The U.S. unemployment rate and a vehicle density proxy, i.e. vehicles per household, are stationary variables so no difference form is needed. Log-difference form was not chosen due to a mix of indexed variables and level form variables. Because forecasting the demand trend is the purpose of the estimation, coefficient analysis is not part of this study.

U.S. full-time employment is used as a proxy for economic condition. Full-time employment is more sensitive to economic fluctuation than total employment because part-time employment movement moves negatively to full-time employment during recession and recovery periods. Excluding part-time employment improves model effectiveness. A year-end value in first-difference form is used to capture whole year employment growth. The unemployment rate is used to capture variance that is not explained by full-time employment.

Nominal, real-world motor vehicle transaction price is used in the model to capture the actual fluctuation in motor vehicle price, regardless of changes in motor vehicle model, segment mix, performance, and features. Relative price in term of competitive good (used car price) would have been used if used vehicle nominal price were available. Personal income net of transfer payments is used because it has better explanatory power in the model than one including transfer payments.

Vehicles per household, denoted VH, is a vehicle density concept variable. Vehicle density is an important concept in forecasting international motor vehicle market trends. Not every country has well documented economic indicators to analyze and portray the motor vehicle market. An estimate of the household number is one of the indicators that most countries have. Vehicles per household explains expansion and contraction of motor vehicle market in a country. It also serves a foundation for motor vehicle demand trend. Depending on rate of household formation and a desired vehicle density, long-term motor vehicle demand can be fairly portrayed and estimated.

The U.S. average population per household has changed, but the changes are rather small from 1980 to 2010, comparing to that from 1950 to 1980. The U.S. average population per household decreased from 3.37 in 1950 to 2.76 in 1980, an 18 percent drop in the 30-year period. In 1990, the number was 2.63, about a 5 percent drop during the 10-year interval. After 1990, the decreasing rate slowed down further. The average population per household in 2010 was 2.58, a slight drop of 2 percent in a 20-year span. The size of U.S. household is not a significant factor to contemporary motor vehicle demand per household, because the vehicle density per household continued to increase while the size of household continued to shrink or remained flat.

Table 15: Base Line Motor Vehicle Sales Revenue Model: 2017 - 2025

Variable	Definition	Source
DMVE	Motor vehicle expenditure in current dollars	BEA Table 7.2.5B. Motor Vehicle Output. Line 6 + Line 13 + Line 21
DEMP	U.S. full-time employment, year-end data, seasonally adjusted	BLS, Series ID: LNS12500000
DPRICE	New vehicle retail price in current dollars	National Automobile Dealers Association
DINCOME	Personal income excluding transfer receipts, in billion dollars (2009$)	BEA Table 2.1. Personal Income and Its Disposition Line 36
UN	U.S. Unemployment rate, annual data, not seasonally adjusted	BLS, Series ID: LNU04000000
VH	Vehicles per household	Center for Automotive Research

All variables are in first degree differentiation, except for unemployment rate (UN) and vehicle per household (VH). All variables are stationary, except VH. Data range: 1979 – 2014, annual.

Dependent Variable: DMVE				
Method: Least Squares				
Sample (adjusted): 1979 2014				
	Coefficient	Std. Error	t-Statistic	Prob.
C	-304.8082	116.6498	-2.61302	0.0139
DEMP	8.305339	2.110144	3.935912	0.0005
DPRICE	0.017408	0.007186	2.422603	0.0217
DINCOME	0.05097	0.022845	2.231165	0.0333
UN	9.594916	2.244726	4.274425	0.0002
VH	112.1198	53.77519	2.084973	0.0457
R-squared	0.770522	Mean dependent var		12.525
Adjusted R-squared	0.732276	S.D. dependent var		31.24343
S.E. of regression	16.16599	Akaike info criterion		8.554708
Sum squared resid	7840.177	Schwarz criterion		8.818628
Log likelihood	-147.9847	Hannan-Quinn criter.		8.646823
F-statistic	20.14633	Durbin-Watson stat		2.182023
Prob(F-statistic)	0			

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