Automobile Fuel Economy Standards[1]

"… the single most important step we've ever taken as a nation to reduce our dependence on foreign oil."

-- President Barack Obama

"… protects American jobs while also increasing fuel economy and reducing greenhouse gas emissions. It levels the playing field ensuring American automakers continue to produce the cars consumers want to buy. It promotes American manufacturing of advanced technology vehicles."

-- U.S. Rep. John Dingell (D-Michigan)

Background

In 1975 Congress established fuel efficiency standards for automobiles. The Energy Policy and Conservation Act (P.L. 94-163) emerged out of the Arab oil embargo of 1973-1974, which tripled petroleum prices. The new fuel economy requirements, called Corporate Average Fuel Economy (CAFE) standards, sought to reduce the amount of gasoline used by American motorists in order to decrease the country's dependence on imported oil.

The legislation gave the National Highway Traffic Safety Administration (NHTSA), a part of the Department of Transportation (DOT), the authority to set and enforce fleet average miles-per-gallon (MPG) targets for new cars and light trucks. It specified an MPG target for cars between 26 and 27.5 miles per gallon. The Agency could propose more stringent standards, but a vote by either the House or the Senate would override the change.[2] The CAFE standards set by NHTSA climbed quickly to the upper limit of 27.5 MPG for cars. They were then lowered slightly for a few model years during the 1980s, thanks to lower oil prices and concerns raised by automobile manufacturers, before returning to the cap. During the 1990s, increasing dependence on foreign oil prompted several efforts to raise the target, but all failed to muster sufficient political support, and the CAFE standard remained at 27.5 MPG for the next two decades.[3] See Figure 1 and Figure 2 for a timeline of the events described in this introduction.

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[1] This case study was written by Grady Killeen and Arik Levinson, with funding from the Georgetown Environmental Initiative (environment.georgetown.edu).
[2] Brent D. Yacobucci and Robert Bamberger, *Automobile and Light Truck Fuel Economy: The CAFE Standards*, CRS Report No. RL33413 (Washington, DC: Congressional Research Service, 2007), 2, http://fpc.state.gov/documents/organization/82504.pdf.
[3] NHTSA, *Summary of Fuel Economy Performance* (Department of Transportation: 2014), 3, http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/Performance-summary-report-12152014-v2.pdf.

The NAS and DOT Study

In May 2000, the Senate authorized the National Academy of Sciences (NAS) and DOT to analyze a potential CAFE increase.[4] The resulting NAS/DOT report on MPG concluded that a more stringent CAFE standard was justified in order to combat foreign oil dependence and climate change associated with greenhouse gases emitted by vehicles. New technologies, such as direct-injection engines, were becoming economically viable and offered potential for even more efficient engines. The study found that companies were "already offering or introducing many of these technologies in other markets (Europe and Japan, for example), where much higher fuel prices ($4 to $5/gal) have justified their development." They therefore concluded that mandating U.S. companies to meet a high MPG target would not place an unreasonable burden on automobile manufacturers.[5]

However, the study also raised several concerns about the existing regulatory structure. First, by encouraging smaller cars that might be less safe for their passengers, the regulation likely caused an additional "1,300 to 2,600 traffic fatalities in 1993." Second, the regulations caused carmakers to cut back on some features consumers like, such as acceleration. As a result, the panel recommended "converting to a system in which fuel economy targets depend on vehicle attributes." Specifically, the report argued that larger and heavier vehicles should be allowed to meet less stringent MPG targets. Although the NAS and DOT were decisive in this determination, some researchers have challenged the conclusion on the basis that smaller cars are less likely to cause fatalities to others and thus impose a lower overall safety risk.[6]

Finally, the report encouraged the development of a system of "tradable fuel economy credits." Any carmaker whose cars exceeded the tighter average fuel economy could sell credits to a carmaker whose cars fell short. That way, higher standards could be established with lower economic costs.[7]

California's Regulations – The Pavley Rule

The federal government did not take immediate action following the NAS/DOT report. However, California State Senator Fran Pavley led an effort to regulate greenhouse gas (GHG) emissions from vehicles, by imposing average limits on carbon dioxide (CO2) per mile. For most gasoline powered cars, the only way to reduce CO2 per mile is to increase fuel economy. So Pavley's proposal looked like stringent versions of NHTSA's limits on MPG. Her proposal was approved in 2004 by the California Air Resource Board (CARB), requiring a 30% reduction in

[4] *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards*, National Academy Press, Washington DC.
[5] Committee on the Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards, *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards* (Washington, DC: National Academy Press, 2001): 112-113, http://www.nhtsa.gov/cars/rules/cafe/docs/162944_web.pdf.
[6] Michael L. Anderson and Maximilian Auffhammer, *Pounds That Kill: The External Costs of Vehicle Weight* (Oxford Journals: Review of Economic Studies, 2013), doi: 10.1093/restud/rdt035.
[7] Committee on the Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards, 111-114.

emissions from light-duty vehicles sold in California by 2016.[8] California thus became the first jurisdiction in the U.S. to regulate greenhouse gas emissions from automobiles.

California's new regulation – sometimes called the Pavley Rule – ran into immediate trouble. Under federal law, only the DOT possesses the authority to establish fuel efficiency standards. Technically, California was regulating GHG emissions not fuel economy, and to justify the Pavley Rule California referenced the Clean Air Act. That legislation would permit California to impose measures more restrictive than those of the Environmental Protection Agency (EPA), but only after obtaining a waiver.[9] In the case of the Pavley Rule, EPA declined California's waiver request, on the grounds that the regulations were not necessary to meet the "compelling and extraordinary standards" described in the Clean Air Act.[10]

CARB submitted another waiver request in 2009, a year after the initial EPA decision. Lisa Jackson, the new EPA Administrator, reversed the initial ruling. She granted the waiver on the basis that California's regulations were "at least as protective of the public health and welfare as applicable Federal standards," a weaker criterion than EPA had used a year earlier in rejecting the Pavley Rule the first time.[11] By the time of Administrator Jackson's decision, twelve other states and the District of Columbia had opted to follow California's stricter standards.[12] Thus California's Pavley Rule set a precedent for regulating vehicles' CO2 emissions that would eventually be adopted by EPA, in its 2012-2016 rule.[13]

NHTSA's 2006 Light-Truck MPG Rule – A transition to an attribute-based regulation

Since their beginning, the CAFE standards treated light trucks (vans and SUVs) differently from cars. Following the NAS/DOT report, in 2006 NHTSA proposed a new attribute-based rule for light trucks. The new rule set MPG targets that differed based on vehicles' sizes, as measured by their footprints -- the area under the vehicles' four tires. Trucks with larger footprints would have lower MPG targets. NHTSA predicted that the footprint-based standard would save more fuel than the prior system, which set a single target for all vehicles.[14] Some economists have since disputed that, arguing that the footprint rule creates a perverse incentive to manufacture larger vehicles with corresponding higher fuel consumption.[15]

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[8] Yacobucci and Bamberger, 13.

[9] State standards, 42 U.S.C. §7543 (2013). Section 7521(a) outlines necessary conditions that regulations must satisfy, namely protecting the public from chemicals.

[10] Air Resource Board, *Clean Car Standards - Pavley, Assembly Bill 1493* (California Environmental Protection Agency, 2013), http://www.arb.ca.gov/cc/ccms/ccms.htm.

[11] EPA, *California State Motor Vehicle Pollution Control Standards; Notice of Decision Granting a Waiver of Clean Air Act Preemption for California's 2009 and Subsequent Model Year Greenhouse Gas Emission Standards for New Motor Vehicles; Notice* (Washington, DC: Federal Register 74, no. 129), 32745, https://www.gpo.gov/fdsys/pkg/FR-2009-07-08/pdf/E9-15943.pdf.

[12] California Clean Cars Campaign, *Other States*, http://www.calcleancars.org/learnMore-state.html.

[13] NHTSA, *Final Regulatory Impact Analysis: Corporate Average Fuel Economy for MY 2012-MY 2016 Passenger Cars and Light Trucks* (Washington, DC: DOT, March 2010), 45-51, http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/CAFE_2012-2016_FRIA_04012010.pdf.

[14] NHTSA, *Average Fuel Economy Standards Passenger Cars and Light Trucks Model Year 2011* (49 CFR Parts 523, 531, 533, 534, 536 and 537) (Washington, DC: Department of Transportation, 2009), 59-60.

[15] Kenneth Gillingham, *The Economics of Fuel Economy Standards versus Feebates* (National Energy Policy Institute: 2013).

NHTSA's proposed rule never took effect. In 2008 a federal court ruled that the Agency failed to adequately consider costs in its benefit-cost analysis, among other concerns.[16] Despite that, the proposed light truck rule established a precedent for the footprint-based standard that forms the basis for the current fuel economy standards for all light-duty vehicles.

Greenhouse Gases, Massachusetts v. EPA, and Resulting Federal Legislation

In 2003, the EPA determined that it lacked authority under the Clean Air Act to regulate greenhouse gas emissions, and declined to set greenhouse gas emissions limits for cars. Massachusetts and 11 other states sued, and in April 2007 the US Supreme court ruled in their favor. The Court determined that NHTSA's regulation of vehicles' fuel efficiency did not free the EPA of its obligation to limit vehicles' greenhouse gas emissions. It ordered the EPA to revisit its determination that it had no authority to regulate greenhouse gases.[17]

President Bush followed in May with Executive Order 13432, mandating "the Department of Transportation, the Department of Energy, and the Environmental Protection Agency to protect the environment with respect to greenhouse gas emissions from motor vehicles."[18] And Congress followed in December of 2007 by passing the Energy Security and Independence Act (EISA). The legislation expanded the scope of NHTSA's program to include medium and heavy-duty trucks; it mandated an attribute-based model, but with an overall minimum MPG; it set a target of 35 MPG for 2020; and it called for a credit trading program among manufacturers in order to lower the economic cost of the program.[19]

NHTSA proposed stricter new standards to comply with EISA. But in 2008 the global financial crisis and its severe consequences for the US auto industry prompted the Bush Administration to postpone finalizing the rule to allow the "next administration to conduct a thorough review of matters affecting the industry, including how to effectively implement the Energy Independence and Security Act of 2007 (EISA)."[20]

The New Administration's Changes

In January 2009, the very first month of the new Administration, President Obama ordered the Department of Transportation to issue separate CAFE rules for model years 2011 and for 2012-2016.[21] The 2011 rule was designed to meet the filing deadline of April 1, 2009, and

[16] 9th Circuit Court of Appeals, *Center for Biological Diversity v. NHTSA* (538 F.3d 1172: 2008), https://cdn.ca9.uscourts.gov/datastore/opinions/2008/08/18/0671891.pdf.
[17] *Massachusetts v. EPA,* 127 S.Ct. 1438 (2007), http://www.supremecourt.gov/opinions/06pdf/05-1120.pdf.
[18] President George W. Bush, *Executive Order 13432* (Washington, DC: FR 72, no. 94), 27712, https://www.gpo.gov/fdsys/pkg/FR-2007-05-16/pdf/07-2462.pdf.
[19] *Energy Independence and Security Act of 2007*, Public Law No. 110-140, 121 Stat. 1499-1503 (2007), https://www.gpo.gov/fdsys/pkg/PLAW-110publ140/pdf/PLAW-110publ140.pdf.
[20] *Average Fuel Economy Standards Passenger Cars and Light Trucks Model Year 2011*, 13.
[21] The White House, *Presidential Memorandum -- Fuel Economy* (Washington, DC: Office of the Press Secretary, 01-26-2009), https://www.whitehouse.gov/the-press-office/2009/01/26/presidential-memorandum-fuel-economy. Deadline from *Average Fuel Economy Standards Passenger Cars and Light Trucks Model Year 2011*, 13.

was largely a hybrid between the existing regulation and the new approach. For instance, a footprint-based rule was implemented, but it was more complicated than the future standards would be. In addition, EPA and greenhouse gas emissions were not included in the 2011 rule.[22]

In May, 2009, the President announced that beginning with MY 2012, automobile manufacturers would be required to meet standards for both fuel economy and greenhouse gases, with the latter being measured as CO2 per mile driven. NHTSA would continue overseeing fuel economy, while EPA would monitor greenhouse gas emissions, requiring collaboration between the agencies. The decision established a unified regulatory system, replacing the patchwork of differing statewide regulations that California and twelve other states had created.[23] As part of this effort, the California Air Resources Board revised its program such that compliance with federal standards would satisfy their own requirement.[24] Moreover, NHTSA set a more aggressive target than EISA required, a sales-weighted MPG of 35.5 by 2016.[25] [26] [27]

The new 2012-16 rule instituted a similar footprint-based standard for GHG emissions (in grams/mile) determined by the Environmental Protection Agency. The annual targets were created to have the same stringency as the Pavley Rule in California.[28] In addition, EPA created a system of credits for innovations such as air conditioning improvements that reduce fuel use, and for alternatively-fueled cars. The A/C credits were unique to EPA's GHG rules and were not included in NHTSA's MPG policy.[29]

Immediately after the final rules for 2012-2016 were finalized in 2012, EPA and DOT proposed fuel economy and GHG rules for the next 9 model years, 2017-25. The Agencies kept the footprint-based standard, sustained a heavy emphasis on technological innovation, and proposed even more stringent standards for both MPG and GHGs.[30] The early release date of the

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[22] NHTSA.

[23] The White House, *President Obama Announces National Fuel Efficiency Policy* (Washington, DC: Office of the Press Secretary, 05-19-2009), https://www.whitehouse.gov/the-press-office/president-obama-announces-national-fuel-efficiency-policy.

[24] NHTSA*, Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule 2012-2016* (40 CFR Parts 85, 86, and 600; 49 CFR Parts 531, 533, 536, et al.) (Washington, DC: DOT & EPA, 2010), 25327-25328, http://www.nhtsa.gov/Laws+&+Regulations/CAFE+-+Fuel+Economy/Model+Years+2012-2016:+Final+Rule.

[25] This 35.5 MPG figure is unweighted, meaning that it is only derived using a 2-cycle test (highway and city driving). As a result, the target overstates the actual fuel economy drivers will experience, which can be more accurately estimated using a 5-cycle test that puts more emphasis on acceleration. Actual MPG averages about 20% lower. In practice, this means that the 2016 requirement is closer to 28.4 MPG than 35.5 MPG.

[26] *President Obama Announces National Fuel Efficiency Policy*. A sales-weighted MPG is a weighted average of a seller's fleet MPG in which the weight an individual model receives is the fraction of overall sales that it accounts for. For example, 2 sales of a 10 MPG car and 1 of a 20 MPG car yields 13.3.

[27] Environmental Protection Agency, *Fuel Economy Testing and Labeling* (Office of Transportation and Air Quality: EPA-420-F-14-015, April 2014), https://www3.epa.gov/fueleconomy/documents/420f14015.pdf.

[28] *Final Regulatory Impact Analysis: Corporate Average Fuel Economy for MY 2012-MY 2016 Passenger Cars and Light Trucks*, 45-51.

[29] *Final Rule 2012-2016*, 25327-25331 & 25401.

[30] NHTSA, *2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Final Rule* (40 CFR Parts 85, 86, and 600 & 49 CFR Parts 523, 531,

proposed 2017-2025 standards meant that the results of the 2012-2016 rules were not available to make adjustments. In addition, NHTSA is only authorized to release rules for five year periods. Thus, as part of that 2017-25 rulemaking, the Agencies promised to conduct a mid-term evaluation of their efficacy before finalizing the standards for MY 2022-25. In July 2016, EPA and NHTSA released a Draft Technical Assessment Report analyzing the effectiveness of the regulations. The document marks the start of the midterm review, which will conclude in 2018 when an updated final rule is announced.[31]

Figure 2 traces CAFE standards for cars from the program's introduction through 2014. In addition, the actual fleet-average MPG is included along with oil prices and recessions. This graph illustrates the correlation between economic conditions and vehicle characteristics.

How the rules work, in practice

Until 2011, regulatory compliance was calculated by taking the sales-weighted average of a manufacturer's car or light truck fleet and subtracting the CAFE standard. If the manufacturer failed to meet the standard, a fee would be imposed of $5 for each tenth of a mile/gallon below the target, multiplied by the number of vehicles sold.[32] The fine was raised to $5.50 in 1998 to adjust for price inflation. Under the new footprint-based standards, manufacturers' each have different targets based on the sales-weighted footprints of their fleets. But the same basic methodology determines any fines.[33]

The footprint-based standard for cars is shown in Figure 3, using data on every car model sold in the U.S. during MY 2014. The graph plots the 2014 standard by footprint, the overall MPG target that NHTSA hoped to achieve on average, and the complete 2014 fleet with the exception of cars getting more than 70 MPG. The majority of excluded cars were electric vehicles, which typically receive mileage far greater than that of gasoline-fueled automobiles. The graph illustrates that the majority of models have a similar footprint, with only a very small number that fall significantly above or below the average. If a vehicle is below the thick black target line, is not attaining the MPG that NHTSA mandated on average given its size.

As of 2014, the cumulative fines paid by all carmakers totaled just under $900 million. Over 99% of penalties to car fleets were charged to imported vehicles over this period. Many European luxury brands such as Daimler (the owner of Mercedes) and BMW had large, relatively inefficient engines. However, since the adoption of a credit trading program, manufacturers have paid far less in fines. Figure 4 plots total fines paid each year. As demonstrated by the graph, fines peaked at the end of the 1980s when gas prices were low, and they have essentially vanished since 2011 when credit trading and footprint-based standards were implemented. Table 1 provides more detail regarding the breakdown of fines, demonstrating that domestic fleets have paid only 0.05% of total fines and that European luxury brands have been

533. et al. and 600) (Washington, DC: DOT & EPA, 2012), http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/2017-25_CAFE_Final_Rule.pdf.

[31] NHTSA, *CAFE Fuel Economy Standards and Midterm Evaluation for Light-Duty Vehicles, MYs 2022-2025*, http://www.nhtsa.gov/Laws+&+Regulations/CAFE+-+Fuel+Economy/ld-cafe-midterm-evaluation-2022-25.

[32] Yacobucci and Bamberger, 3.

[33] *CAFE Fuel Economy Standards and Midterm Evaluation for Light-Duty Vehicles, MYs 2022-2025*, 744.

the most heavily penalized. For instance, BMW has paid over $310 million in fines ($2007) since CAFE standards were implemented.[34]

Due to the higher CAFE fees paid by European manufacturers, in 1994 the European Community (EC) challenged the legality of the standards under the General Agreement on Tariffs and Trade (GATT). The GATT Panel found no issue with CAFE regulations in general, but determined that a provision requiring foreign and domestic fleets to separately comply with MPG targets violated the GATT.[35] The relevant portion requires that products "imported into the territory of any other contracting party shall be accorded treatment no less favourable than that accorded to like products of national origin."[36]

Although the U.S. lost the case, it never altered the regulations because the EC decided not to accept the Panel's finding. The EC felt that the finding legitimized the CAFE rules and did go far enough to repair the disadvantage facing European car manufacturers. It rejected the Panel's finding to preserve future legal flexibility, and the U.S. left the foreign-domestic distinction on the books.[37]

As demonstrated in Figure 5, the disparity between foreign and domestic manufacturers has continued with the transition to an attribute-based standard. Domestically produced cars are consistently larger than imported fleets (this is especially true for GM, Ford, and Fiat-Chrysler), meaning that they face less stringent MPG targets. In addition, domestic fleets regularly exceed their lower emissions targets. Of 7 domestic fleets in 2013 only Fiat-Chrysler was narrowly below its target. However, most domestic fleets are less fuel efficient than overall averages, indicating that they would likely fail to comply with the regulations under the old CAFE format.

NHTSA's rule and the MPG illusion

One important difference between the EPA's greenhouse gas rules and NHTSA's fuel economy rules is their unit of analysis. The EPA regulates grams of CO2 per mile, with the regulatory concern (CO2) in the numerator, and the regulated activity (miles) in the denominator. By contrast NHTSA's rules are stated in terms of miles per gallon (MPG), with the regulatory concern (gallons) in the denominator. In part that's by rhetorical convention – American's are used to thinking about MPG not gallons per mile. But efficiency measures are more typically (and sensibly) stated in terms of input per unit of output, which in this case would be gallons per mile – or gallons per hundred miles (GPhM) to make the units sensible. There's a good reason for that. Fuel savings are a linear function of GPhM. A one GPhM improvement from 4 to 3 saves as much gas as a one GPhM improvement from 3 to 2. But fuel savings are not a linear function of MPG. A 5 MPG improvement from 20 to 25 MPG saves 50 percent more fuel than a 5 MPG improvement from 25 to 30.

[34] CAFE Public Information Center, *Summary of CAFE Civil Penalties Collected* (NHTSA: 2016), http://www.nhtsa.gov/CAFE_PIC/CAFE_PIC_Fines_LIVE.html.

[35] World Trade Organization, *United States — Taxes on automobiles* (Geneva, Switzerland: 1994), https://www.wto.org/english/tratop_e/envir_e/edis06_e.htm.

[36] General Agreement on Tariffs and Trade, Article III: 4 (1947), https://www.wto.org/english/docs_e/legal_e/gatt47_01_e.htm.

[37] Eric Phillips, "World Trade and the Environment: The CAFE Case," *Mich. J. Int'l L.* 17.3 (1995-1996): 851-852.

This effect – called MPG illusion – is illustrated in Figure 6. When MPG increases from 10 to 15, the gallons of fuel needed to travel 1,000 miles drops from 100 (1,000/10) to about 67 (1000/15). This represents a 33% reduction in fuel consumption. In contrast, an increase from 30 MPG to 35 MPG only causes the fuel needed to travel 1,000 miles to fall from 33 gallons to 29 gallons, a 14% decline. Thus, an increase by 5 MPG from 30 to 35 MPG only has about half the fuel efficiency gain of an identical increase for a car that averages 10 MPG. In other words, MPG improvements save less fuel as cars become more efficient.[38]

Because of the nonlinearity of MPG, NHTSA could not use a simple linear relationship between footprint and MPG to determine the standards. If it did, small cars would be rewarded too much for large MPG improvements that do not save much fuel, and large cars rewarded too little for small MPG improvements that save a lot. Instead, NHTSA developed Equation 1 to determine the target MPG associated with each car. The equation is a linear piecewise function with respect to GPM. NHTSA then takes the inverse to convert these figures to MPG.

$$Target\ (MPG) = \frac{1}{Min\left[Max\left(c * footprint + d, \frac{1}{a}\right), \frac{1}{b}\right]} \qquad (1)$$

Where a = the function's upper limit (in MPG), b = the function's lower limit (in MPG), c = the slope (in gpm/square foot), d = an intercept added to the sloped portion for correct scaling, and l and h are the lower and upper bounds beyond which footprint no longer determines the target. NHTSA adjusts d downward each year to tighten the regulation. The Agency uses estimates of vehicle sales in order to estimate the projected overall target based on the fleet's sales-weighted footprint. However, there is not a single official target. The 2016 target is illustrated in Figure 3.[39]

Cost-benefit analysis and NHTSA's rule choice

A summary of the costs and benefits of NHTSA's rule is provided in Table 2. Overall, the Agency predicted that the regulations would have net benefits exceeding $130 billion using 2007 dollars and a 3% discount rate to calculate the present value of future savings. NHTSA also considered a 7% discount rate which still led to predicted net benefits of $94 billion over the course of the program. The majority of benefits were expected to be private, not external. A specific breakdown of the costs and benefits is provided in the following sections.

NHTSA's 2012-2016 rule choice was heavily influenced by three developments. First, President Obama released a new National Fuel Efficiency Policy that set a goal of 35.5 MPG by 2016. This requirement was more stringent than that required by law. Second, the Administration lobbied for a unified national CAFE policy. Thus, Federal Agencies needed to negotiate with California, which had recently received the waiver necessary to implement its Pavley regulations

[38] Fueleconomy.gov, "Electric Vehicles: Learn More About the New Label," https://www.fueleconomy.gov/feg/label/learn-more-electric-label.shtml
[39] EPA & DOT, *Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule* (FR vol. 75 no. 88: May 7, 2010), 25357.

on GHGs from cars.[40] Finally, NHTSA partnered with EPA for the first time as mandated under the *Massachusetts* ruling and Executive Order 13432.[41] [42] These conditions motivated the Agencies to implement standards equally as stringent as those of the Pavley rule which resulted in rules that were sufficiently stringent and nationally uniform.[43]

NHTSA published a regulatory impact analysis (RIA) of its proposed standards prior to their implementation, as mandated by Executive Orders 13563 and 12866. According to EO 13563, agencies must demonstrate that (a) the regulations' benefits justify their costs, (b) regulatory goals are achieved, and (c) the rules maximize net benefits.[44] [45]

In its RIA, NHTSA considered several different possible CAFE standards with varying stringencies and structures. The Agency ultimately implemented the one it called the "Preferred Alternative Approach." This corresponds to an average annual increase in CAFE stringency of 4.3% per year (calculated in GPM then converted to MPG to correct for the MPG illusion). This is the minimum MPG improvement needed to meet the MY 2016 target for CO2 of 250 g/mi adopted by EPA for consistency with California's Pavley Rule. While the average annual increase is 4.3%, the rules were designed to front-load improvements. Thus the increase exceeded 4.3% in 2012 and was less than the average in 2016. [NHTSA 2012, 45-51] [46]

Among the alternatives that NHTSA considered was the "Maximum Net Benefits" approach which equated marginal cost with marginal benefit. While this method would theoretically maximize social welfare, the Preferred Alternative Approach was chosen primarily for consistency with EPA's regulations. [48] This decision coincided with the wishes of the White House and car companies for a national standard.[47] NHTSA needed to calibrate its program to the Pavley rule in order to achieve that goal. Had it implemented the Maximum Net Benefits standard, NHTSA's requirements would have been more stringent than those of EPA. [45-51]

A complete tabulation of costs and benefits of the CAFE standards under the Preferred Alternative is presented in Table 3. NHTSA concluded that private savings tied to decreased fuel usage exceeded total costs. In addition, lower GHG production created savings near $15 billion (at a 3% discount rate), although some of the social benefits of the program were offset by the costs tied to increased driving made possible by higher fuel efficiency. Net benefits fall if a 7% discount rate is used. This is because many of the benefits of the program are accumulated in the

[40] *President Obama Announces National Fuel Efficiency Policy*
[41] *Massachusetts v. EPA.*
[42] *Executive Order 13432.*
[43] EPA, *Final Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards* (EPA-420-R-10-009: April 2010), 3-1 to 3-2, https://www3.epa.gov/otaq/climate/regulations/420r10009.pdf.
[44] EPA, *Summary of Executive Order 12866 - Regulatory Planning and Review*, https://www.epa.gov/laws-regulations/summary-executive-order-12866-regulatory-planning-and-review.
[45] The White House, *Agency Checklist: Regulatory Impact Analysis*, https://www.whitehouse.gov/sites/default/files/omb/inforeg/regpol/RIA_Checklist.pdf.
[46] *Final Regulatory Impact Analysis: Corporate Average Fuel Economy for MY 2012-MY 2016 Passenger Cars and Light Trucks*, 45-51. The 4.3% estimate is calculated excluding FFV credits due to statutory requirements. The RIA will be cited by page numbers in brackets from here forward.
[47] *Presidential Memorandum Regarding Fuel Efficiency Standards*

future as lifetime fuel consumption falls, whereas most costs are immediately accrued when vehicles are built. [14-15]

Costs and benefits under different standards considered

NHTSA calculated the costs and benefits of eight potential standards. The Preferred Alternative Approach – which was ultimately implemented – increased MPG targets between 4% and 5% per year, with an average of 4.3%. The Maximum Net Benefits standard considered an increase such that marginal cost equaled marginal benefit for each year, thus maximizing net benefits. This rule would have been several percent stricter than the preferred alternative approach. Third, NHTSA's Total Cost Equals Total Benefits (TC=TB) approach examined the level of stringency such that the net benefits of the program would equal zero. This would conserve the most fuel without imposing net costs. The remaining five options considered were all fixed annual percentage increases in the MPG target between 3% and 7%. [46]

Table 4 summarizes four of the considered alternatives. The variance between the different standards demonstrates the importance of the specific regulation chosen in determining the aggregate economic effect of a policy. The TC = TB option was calculated as having the largest net benefits. That's because NHTSA only considered technology that already existed in its analysis and there was no point where total costs were greater than or equal to total benefits given already invented improvements.

Likewise, the Maximum Net Benefits method failed to achieve the highest social surplus because NHTSA equated marginal cost and marginal benefit for each individual model year without considering other years. However, once the regulation is set, it may be cheaper for companies to frontload technological improvements in order to comply with standards several years out. For example, installing a hybrid engine in a vehicle may have marginal costs greater than marginal benefits in 2012, but the fuel efficiency gain is great enough that the vehicle would be compliant with regulations through 2016 at no additional cost. Maximizing net benefits for each individual year does not necessarily reflect how auto companies will comply with the rules.[48]

Costs of the NHTSA regulations

NHTSA considered two categories of costs: private and social. The private costs are borne by the vehicle manufacturers and purchasers, and "were estimated based on the specific technologies that were applied to improve each manufacturer's fuel economy up to the level required under each alternative or fines that would be assessed." The social costs increased fatalities and injuries linked to lower vehicle weight, as well as congestion, accident risk, and pollution associated with the increased driving that results from better fuel economy. Some of these social costs are borne by drivers and their passengers; some are borne by other drivers and pedestrians. Fines were not included, as they represent transfer payments without a net burden to the U.S. [1-10]

[48] NHTSA, *Final Regulatory Impact Analysis: Corporate Average Fuel Economy for MY 2017-MY 2025 Passenger Cars and Light Trucks* (DOT: August 2012), 107.

Table 2 and Table 3 summarize the costs. Aggregate costs of the regulations were just over $62 billion (in 2007 dollars). Almost 85% of these costs were private expenditures tied to the adoption of technology necessary to comply with the regulations. [14] A breakdown of the costs and the methodology used to calculate them follows.

Private costs

NHTSA considered the costs as those necessary to maintain current vehicle performance despite increased fuel economy. So there are no costs associated with decreased quality or consumer welfare other than higher vehicle prices. The Agency recognized that in the absence of the regulations, manufacturers might have improved vehicle quality, in which case NHTSA's calculations omit the opportunity cost of those improvements and understate the regulations' costs. However, the Agency opted to continue to calculate costs in this manner for reasons of historical continuity and due to difficulties with predicting innovations that would take place in the absence of the standards. [343-344]

NHTSA divided these vehicle costs into two categories: direct, which refers to the per-vehicle technology costs; and indirect, which refers to the overhead costs associated with developing and marketing those technologies for all cars. The projected direct costs per passenger vehicle of the final rule vary from a low of $29 (Toyota in MY 2013) to $1,884 (Ford in MY 2016), with an average of $695 per vehicle annually. [312] See Table 5. The majority of these costs involve technological improvements such as weight reduction, expanded engine efficiency, and other fuel-saving modifications. The Agency forecast these costs by examining which technologies could be used for compliance, which options were the cheapest, the estimated time for adoption, and the effect of learning curves. Costs differed between manufacturers due to differing fleet compositions and existing MPG. These figures only include direct costs, meaning the physical cost of purchasing and installing the innovations. [147-180, 320-350]

The Agency considered two types of learning curves – cost reductions achieved through production – in its estimation of technology costs: volume-based and time-based. The volume-based curve modeled a situation in which very few units are initially manufactured so the learning was large. For this curve, analysts estimated that for each time the production of a new technology doubled, costs of its implementation would fall by 20%. The learning threshold, the number of vehicles beyond which learning starts to occur, was determined to be 300,000. Moreover, NHTSA assumed that these benefits would be exhausted after 1.2 million units were manufactured. These volume-based savings came from worker familiarity with new technology, the fine tuning of machines, and other such improvements. This curve was applied to relatively complex, new technologies that had not yet been implemented. For example, this learning curve would be applicable to a new engine type developed by a manufacturer.

In contrast, the time-based learning curve modeled a scenario in which production of a technology was already relatively high. Thus, savings were only estimated to be 3% per year. This curve was developed to apply to preexisting technologies that were purchased by numerous manufacturers. For instance, multiple car companies may have purchased low friction tires to increase MPG. These savings originated in annual contract negotiations which resulted in lower prices. In its final calculations, NHTSA applied both learning curves to account for the large early cost reductions linked to learning from production and the smaller long-term savings originating in lower costs of input technology. Only one curve was applied to any given piece of technology. [150]

For indirect costs, NHTSA simply multiplied direct costs by a multiplier, ranging from 1.10 to 1.64 depending on the complexity of the technology. These multipliers were derived from historical data on direct costs, revenues, and profits, along with the fact that profits are just revenues minus total costs (direct and indirect).[49] Equation 2 demonstrates how the multiplier can be estimated from this identity since the multiplier times direct costs must equal revenues less profits.

$$Multiplier \cong \frac{Revenues - Profits}{DirectCosts} \qquad (2)$$

All together, these direct and indirect costs of technology adoption were estimated to be $51.7 billion. [14] More details are available in Table 3 and Table 5. Table 3 provides the aggregate technology costs for each model year, including indirect costs. Overall, these expenditures sum to about $52 billion. The discount rate is irrelevant as they are all paid upfront, not in the future.

Table 5 breaks down the direct costs by manufacturer. Note that these do not sum to the aggregate in Table 3 which includes indirect costs. Although Ford, GM, and Chrysler historically benefited from CAFE regulations – they paid fewer fees than their European competitors – the projected compliance costs for the big three American manufacturers exceeded the average in each year. Japanese manufacturers such as Honda and Toyota had compliance costs well below the fleet average, indicating that the companies were on track to achieve MPGs similar to those mandated by the CAFE standards prior to the release of the final rule.

Social costs

NHTSA considered “social costs” to be all those not related to implementing the fuel-saving technologies. In general, these costs are economic externalities. However, some private costs such as greater accident risk to drivers are also included in the category. One such social cost relates to something called the “rebound effect.” Fuel efficiency makes driving less expensive. If drivers respond by driving more, that will increase congestion, noise, and accidents. To estimate these costs, NHTSA uses “middle estimates” developed by the Federal Highway Commission. For passenger cars these are 5.4 cents/mile for congestion, 2.3 cents/mile for crashes, and 0.1 cents/mile for noise costs. For trucks the external costs are 4.8 cents/mile, 2.6 cents/mile, and 0.1 cents/mile, respectively. NHTSA utilized these values combined with projected VMT increases due to the rebound effect to estimate the total costs created by these externalities. The results are summarized in Table 6. [400]

Safety costs

[49] DOT & EPA, *Joint Technical Support Document: Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards* (April 2010), 3-12 to 3-15.

A second social cost involves potentially reduced safety if manufacturers meet their MPG targets by selling smaller or lighter vehicles and if those vehicles are less safe. The new footprint-based regulations were designed in part to avoid that tradeoff. To estimate remaining safety costs, NHTSA modified the regression analysis from the earlier NAS/DOT report. About half of the safety risks found in the study could be tied to a decrease in automobile weight, while half were tied to a smaller footprint. To confirm this result, researchers compared fatality data across vehicles with different weights but similar footprints. NHTSA calculated the correlation between weight and fatalities within each of ten footprint groups. This method does not control for factors such as driver age or gender as NHTSA's regression analysis did. But the results supported the hypothesis that decreasing vehicle weight reduced safety. [460-469]

Although NHTSA concluded that weight reductions increased fatality risk, there is some uncertainty. A contractor, Dynamic Research, Inc., found that decreasing weight would actually *decrease* fatality risk using similar data to NHTSA. DOT analysts opted to exclude DRI's result due to near perfect multicollinearity between track width, curb weight, and wheelbase. [465] Since then, economists have published a result showing that weight reductions improve safety using different statistical methods. Their conclusion stems from the fact that it is less dangerous to be struck by a lighter vehicle.[50]

Using the results obtained from their regression analysis, NHTSA estimated the effect of vehicle weight on fatality rates—meaning total deaths in an accident. These estimates capture the increased fatality risk to the driver and others involved in the accident. The figures, presented in Table 7, are the net changes in deaths. For all cars and small light trucks, NHTSA predicted that weight reductions would lead to a net rise in fatalities. However, in the case of large light trucks, projected fatalities decreased with weight reductions due to the decreased harm caused to other drivers.

Table 7 presents two estimates of safety changes for each vehicle class. The upper estimates presume manufacturers will comply with CAFE by lowering weight without compensating for the associated safety reduction, a result NHTSA deems improbable. The lower estimates assume that manufacturers will incorporate additional safety technologies to compensate for the lower weight. [460-469]

NHTSA estimated that manufacturers would decrease weight by 1.5% before MY 2014 and by 5-10 percent more between MY 2014 and MY 2016 as a result of CAFE standards. Moreover, the Agency assumed that small vehicles would trend towards a 5% reduction while large vehicles would achieve a number near 10%. NHTSA took estimates of weight reduction and applied projected death changes per pound reduction in mass. Time trends expected to increase vehicle safety were then considered. This led to final predictions as to the number of deaths caused by the rule as recorded in Table 8. Over the five years, NHTSA projected that the number of deaths attributed to decreased vehicle safety would total under 100.

The DOT monetized fatalities at $6.1 million per life consisting of the value of a statistical life (VSL) of $5.8 million plus $0.3 million in external economic costs such as medical

[50] Anderson and Auffhammer.

care, insurance, and legal fees at the time of the RIA. [545] The VSL is calculated from consumers' willingness to pay for reductions in risk. For instance, if workers are willing to accept a job that increases their chance of death by 1 in 10,000, in exchange for an extra $1,000 in pay, the VSL would be calculated at $10 million.[51]

To include costs associated with non-fatal injuries, NHTSA determined that deaths historically account for 44% of the total costs linked to fatal and non-fatal injuries. Analysts thus divided the $6.1 VSL measurement by 0.44 to determine a total cost (including deaths and non-fatal injuries) of about $14 million per death. Multiplying projected increases in deaths by $14 million, NHTSA estimated the total monetary costs of safety reductions. These costs are summarized in Table 8. Overall, these safety decreases are tied to an economic loss of around $1 billion. This value is relatively low because the benefits of lighter trucks virtually offset the negative effects of lighter cars. [545-546]

Benefits of the NHTSA regulations

Decreases in gasoline consumption create private benefits since consumers spend less on fuel and social benefits since less petroleum is imported and burned. Thus, estimating the effect of the CAFE standards on fuel consumption was important to NHTSA's overall calculations. However, the net effect of the regulations on gasoline consumption depends on how many new vehicles are purchased, changes in driving behavior due to the rebound effect, the implication of declining U.S. consumption on global oil prices, and how theoretical mileage improvements translated into actual efficiency. As such, these parameters needed to be estimated prior to calculating the net change in gasoline consumption.

To start, NHTSA used manufacturers' projections of the number of vehicles produced each model year as an estimate for the consumption of new vehicles over the timeframe of the regulations. This determined how many vehicles the CAFE measures would effect.

Second, NHTSA needed to determine the extent that fuel efficiency gains would be offset by individuals driving more. The Agency estimated this rebound effect at 10%. That's lower than historical estimates based in the 1980s and 1990s, because household incomes have risen relative to fuel prices, and demand for driving becomes more inelastic as income grows.[52]

Next, the DOT considered the fact that reduced US oil demand might reduce world oil prices, increasing oil consumption in foreign countries, and thereby increasing foreign GHG emissions. However, the Agency ultimately decided not to include this "take back" effect, citing uncertainty, concerns about double counting, and the fact that any increases in foreign oil consumption would result in higher reported foreign GHG emissions.

[51] Polly Trottenberg and Robert Rivkin, *Memorandum: Guidance on Treatment of the Economic Value of a Statistical Life in U.S. Department of Transportation Analyses* (Washington, DC: DOT, 2015), https://www.transportation.gov/regulations/economic-values-used-in-analysis.
[52] Kenneth A. Small and Kurt Van Dender, "Fuel Efficiency and Motor Vehicle Travel: The Declining Rebound Effect," *The Energy Journal* 28, no. 1 (2007): 25-51, http://www.jstor.org/stable/41323081.

Finally, the Agency needed to account for the fact that CAFE targets are in unadjusted MPG, which is a substantially higher estimate than the adjusted tests that EPA uses to measure real world efficiency. To fix this this, NHTSA used EPA's adjustment factor as described in Equation 3.

$$AdjustedMPG \; = \; 0.8 * (UnadjustedMPG) \qquad (3)$$

These calculations provided NHTSA with the parameters necessary to estimate the net change in gasoline use as described in the next section. [365-371]

Methodology for calculating fuel savings

NHTSA believes that the "main source of economic benefits from raising CAFE standards is the value of the resulting fuel savings over the lifetimes of vehicles that are required to achieve higher fuel economy." The Agency considered gasoline savings for each calendar year a vehicle was projected to stay in use. Lifetime vehicle mileage was estimated by multiplying the VMT in each year by the fraction of cars expected to still be in use. The resulting figure is a survival-weighted VMT.

Total fuel consumption was estimated for cars with the regulations and without. In each case, a vehicle's consumption was predicted by dividing its survival-weighted VMT by adjusted MPG. VMT varied between the two scenarios to account for the rebound effect.

Savings were then calculated as the difference between consumption with and without the change in MPG caused by the CAFE standards. Several adjustments were made to increase the accuracy of these estimates. First, analysts modified VMT to account for decreased driving with vehicle age. Second, NHTSA further changes VMT estimates to account for projected changes in fuel prices. To do so, the Agency used an estimate of own-price elasticity for gasoline of -0.1. Finally, adjustments for expected growth in vehicle use were made.[53]

Once vehicle-specific savings were calculated for each year, NHTSA summed the annual savings of a specific car type over its lifespan to determine the total decrease in gasoline consumption of the vehicle. Projected aggregate savings created by the CAFE standards could then be found by summing the lifetime fuel savings over all vehicles' projected sales. [378-380] Equation 4 summarizes NHTSA's calculations of an individual vehicle's fuel savings for a single model year and for the entire lifespan of a vehicle.

$$Fuel\ savings_i = \sum_{t=1}^{T} P_{it} \frac{VMT_{it}}{AdjustedMPG_{it}} \qquad (4)$$

where *i* denotes the vehicle, *t* denotes the year, and P_{it} denotes the probability that vehicle *i* is still being used in year *t*.

Private benefits

[53] See EIA

Consumer benefits due to improved fuel economy

The economic savings associated with reductions in fuel consumption were determined by multiplying fuel savings in a given year by the expected price of fuel during that time as projected by the EIA in AEO 2010. Taxes were not included, since they are a transfer payment from individuals to the government with no effect on aggregate economic cost. The per gallon costs of externalities associated with fuel consumption were added to include social costs. Aggregate economic savings tied to decreased fuel consumption were the sum of savings over all vehicle types over every year of survival. [380-382] Equation 5 summarizes this method. Adjusted price is the price of gasoline less taxes.

$$\widehat{AggregateSavings} = \sum_{t=1}^{T} \widehat{AdjustedPrice}_t * \widehat{AnnualFuelSavings}_t \quad (5)$$

Table 3 includes a summary of the economic savings tied to decreased fuel use. The sum of lifetime benefits due to the regulations is just under $150 billion in 2007 dollars using a 3% discount rate. [14]

Consumer surplus due to additional driving and range of vehicles

Consumers benefit from the reduced cost of driving, as described above, but they also benefit from the increased driving they do as a consequence of those reduced costs. NHTSA approximated the associated increase in consumer surplus: one half of the change in operating costs per mile times the change in miles traveled. Since the rebound effect changes each year, the gain in consumer surplus is calculated annually and summed to obtain the aggregate welfare gain from additional driving. [384]

Also, because new fuel efficient vehicles can travel farther between fill-ups, drivers will spend less time at gas stations. A CARB study determined that, on average, drivers purchase enough gas to fill 55% of an empty tank.[54] Combined with projected VMT and adjustments for rural versus urban conditions, NHTSA was thus able to estimate how many fewer times drivers needed to stop for fuel due to MPG improvements. Using the fact that the average car has 1.6 passengers and the DOT-recommended hourly value of travel time of $24 ($2006), NHTSA estimated the welfare gain created by longer vehicle range. However, this projection assumes manufacturers will not decrease tank size, driver won't change their refueling practices, refueling stops have the same number of passengers as the average trip, and that average refueling takes 5 minutes. Table 3 summarizes the benefits tied to these savings. [384-387]

Social benefits

Savings from decreased externalities associated with oil imports

[54] California Air Resource Board, *Draft Assessment of the Real-World Impacts of Commingling California Phase 3 Reformulated Gasoline* (California Environmental Protection Agency: May 2002), http://www.arb.ca.gov/regact/mtbepost/appf.PDF.

The DOT considered three externalities unique to petroleum imports. First, reduced U.S. oil consumption reduces the global price of petroleum products due to monopsony power of the United States. A study conducted by Oak Ridge National Laboratories (ORNL) in 1997 and updated in 2008 estimated these benefits to be about $0.298/gallon ($2007).[55] However, NHTSA does not consider this to be a global welfare gain. Rather, it is a transfer among nations and hence excluded from NHTSA's calculation of the benefits of the CAFE rules.

Second, dependence on foreign oil creates the potential for disruptions to the U.S. economy caused by international petroleum shocks. Supply disruptions typically occur rapidly and impose adjustment costs on households and firms that react to the price changes. ORNL estimates these costs at $0.169/gallon.[56] The social welfare gains from reducing these oil shock costs are included in the benefit calculations in Table 3 as "Petroleum market externalities." The sum of these benefits from 2012-2016 was projected to be just under $8 billion.

Finally, oil imports require increased military outlays to secure petroleum supply routes in unstable regions. NHTSA did not believe that the CAFE standards would cause a change in U.S. military policy and thus excluded these calculations from its cost-benefit analysis. However, the Agency did perform a sensitivity analysis in which potential savings were considered. [388-392]

To quantify these benefits from lower petroleum imports, NHTSA needed to determine what fraction of decreased oil consumption would translate into lower imports as opposed to lower domestic production. The Agency estimated that 50% of reductions in fuel consumption caused by the regulations would be reflected in lower imports of refined fuel while the other half would occur through lower domestic refinery production. Of domestic refinery reductions, 90% of crude oil decreases were projected to occur through lower imports while 10% was estimated to originate in decrease domestic production. Hence, each gallon of fuel saved was believed to translate into reduced imports of either refined fuel or crude oil by 0.95 gallons. [393]

Savings from reduced externalities associated with GHG production

NHTSA calculated the CO2 emissions reductions from the CAFE rule. Burning a gallon of motor fuel produces about 20 pounds of CO2.[57] Gasoline savings are calculated as above, including the 10% adjustment for the rebound effect. To put a dollar value on those CO2 emissions reductions, NHTSA multiplied the savings by the social cost of carbon (SCC). These SCC values were calculated by interagency government panel, and are summarized in Table 9.[58]

[55] Paul N. Leiby, *Estimating the Energy Security Benefits of Reduced U.S. Oil Imports* (Oak Ridge National Laboratory: 2008), https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=504469.

[56] Leiby.

[57] Energy Information Administration, "How much carbon dioxide is produced by burning gasoline and diesel fuel?" http://www.eia.gov/tools/faqs/faq.cfm?id=307&t=11.

[58] Interagency Working Group on Social Cost of Carbon, *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866* (U.S. Government: February 2010), https://www3.epa.gov/otaq/climate/regulations/scc-tsd.pdf.

NHTSA also measured changes in local air pollutants such as carbon monoxide, nitrogen oxides, hydrogen compounds, and sulfur dioxide created by increased VMT and decreased fuel consumption. Pollution effects caused by decreased gasoline use included the reduction of GHGs tied to lower refinery utilization. NHTSA calculated the net emissions reduction for each GHG by aggregating vehicle and refinery decreases. The results were monetized based on the damage done by each pollutant. [393-399]

Net effect on vehicle sales

In addition to the cost-benefit analysis, NHTSA estimated the effect that the regulations would have on vehicle sales. This analysis led the Agency to conclude that "the value of fuel savings over the lifetimes of the new vehicles will exceed the increase in their prices, prompting an increase in sales of new vehicles during most model years that the rule affects." Specifically, NHTSA forecasted an increase in sales for every year excluding passenger cars in MY 2012, peaking at an increase of 440,907 vehicles sold in MY 2016. Annual increases in car and truck sales are included in Table 10. These increased sales were not included as a social cost or benefit. [350-354]

Market failures explaining the results

Since NHTSA concluded that private benefits exceeded the private costs of the program, some commenters wondered why car makers needed the rules in order to improve fuel economy. NHTSA had several possible explanations. First, consumers may place less weight on future benefits than NHTSA chose to. If car buyers use a higher discount rate to evaluate the present value of future benefits or consider a shorter time horizon (the period over which future benefits are considered), they will derive a lower value for the benefits of a higher MPG than NHTSA. In addition to issues regarding temporal preferences, NHTSA worried that consumer calculations may be biased due to the MPG illusion.

There are also several possible explanations for this paradox on the supply side of the market. NHTSA argues that a combination of monopolistic competition and information asymmetries between producers and consumers could lead to underinvestment in fuel economy because manufacturers believe they can extract more surplus by keeping MPG lower. Moreover, fuel efficiency may inhibit improvements in vehicle characteristics that are more important to consumers such as vehicle size, safety, or speed. Finally, manufacturers may simply underestimate the value that consumers place on fuel efficiency. [421-428]

The EPA's MY 2012-2016 standards

While the EPA's program aims to reduce CO2 as opposed to increasing MPG, the Agency's targets and analysis are broadly consistent with NHTSA. Both agencies coordinated their regulations with California's Pavley standards in order to establish a consistent national standard. Thus, although NHTSA targeted MPG and the EPA targeted CO2 grams per mile (g/mi), the two agencies ended with similarly stringent standards. [EPA 2012, 3-1 to 3-2] [59] The fleet-average CO2 standards that EPA used are summarized in Table 12. The targets fall from 288 g/mi in 2012 to 250 g/mi in 2016, a reduction by just over 11%.

Despite the similarities to NHTSA's regulations, there are several important differences. For one, the EPA regulates CO2 in grams per mile (input/output). Moreover, EPA provides credits to companies for changes such as air conditioning improvements that lower CO2 output in a way that does not show up in a simple 2-cycle test. By comparison, NHTSA simply modified its targets to adjust for the use of such credits to comply with EPA's rules instead of adopting a similar credit mechanism.[60] Finally, EPA included incentives for electric vehicle production by ignoring the CO2 generated in creating the electricity they run on. Meanwhile, NHTSA used an MPG equivalent to determine the regulatory compliance of such vehicles. [2-1]

As with NHTSA, the EPA has an attribute-based standard such that smaller cars face stricter emissions standards. The EPA uses the piecewise function from Equation 6 in order to factor footprint into its regulations.[61]

$$\begin{gathered} Target(CO_2) = a \; if \; footprint < \; l \\ Target(CO_2) = c \times footprint + d \; if \; l \leq footprint \leq h \\ Target(CO_2) = b \; if \; footprint > h \end{gathered} \tag{6}$$

Where a = the minimum CO2 target value (in g/mi), b= the maximum CO2 target value (in g/mi), c = the slope of the linear function (in g/mi per sq ft), d = is the zero-offset for the line (in g/mi CO2), and l & h are the lower and higher footprint limits, constraints, or the boundary (''kinks'') between the flat regions and the intermediate sloped line.

EPA projected that the regulations would result in aggregate net benefits around $190 billion with a 3% discount rate or $140 billion with a 7% discount rate as demonstrated in Table 12. The values are generally consistent with NHTSA's findings: the regulations are tied to a significant social gain. However, EPA's estimate of net benefits exceeds that of NHTSA by roughly $60 billion. The majority of this difference, about $40 billion, is due to higher EPA projections for fuel savings. [8-26 to 8-29] Such differences are a product of differing estimations as well as real distinctions between the regulations. The following sections explain two of the notable differences: air conditioning credits and electric vehicle incentives.

Air conditioning credits

Air conditioning (AC) systems contribute to climate change in two ways. First, they cause cars to lose fuel efficiency when in operation. This occurs due to the added vehicle weight and the power needed to operate the system. The first effect is accounted for by simple road tests as weight has a constant effect on fuel efficiency and thus CO2 g/mi. The adverse effect of AC's power consumption is not included in the 2-cycle tests (the cycles are conducted with the AC

[59] EPA, *Final Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards* (EPA-420-R-10-009: April 2010), 3-1 to 3-2, https://www3.epa.gov/otaq/climate/regulations/420r10009.pdf. The RIA will be cited using page numbers in brackets for the rest of the case study.
[60] *Final Rule 2012-2016*, 25327-25331 & 25401.
[61] Ibid, 25409.

off) and improvements are thus excluded from NHTSA's compliance calculations. However, EPA opted to directly consider AC energy improvements by granting compliance credits to companies given that such innovations can have a significant effect on CO_2 output.

Second, AC units directly contribute to climate change through coolant leakage, even when not in use. The coolant currently used in car ACs is the hydrofluorocarbon (HFC) R134a (also known as 1,1,1,2-Tetrafluoroethane/HFC-134a). This HFC has a global warming potential of 1430, meaning that it has 1430 times the effect as CO_2 per gram. The coolant must be kept at high pressure. Leaks can result from small failures or bad seals, or during maintenance or following accidents.

Technologies such as more flexible components, better sealants, and alternative coolants can all help to reduce leaks. EPA decided to provide credits for these innovations as well. Overall, AC related GHG contributions accounted for about 9% of total GHG emissions by cars and light trucks at the time EPA's rule was established. More detail is available in Table 11. [2-1 to 2-4]

EPA estimated that credit usage would increase with each model year as technology penetration grew, resulting in fleet average credits of 3.5 in MY 2012 and 10.6 credits in MY 2016. In other words, 3.5 g/mi of manufacturers' MY 2012 CO_2 improvements were projected to come from AC improvements. [2-45]

Electric vehicle incentives

EPA included provisions in the final standards to spur the development of electric vehicles (EV), plug-in hybrid vehicles (PHEV), and fuel cell vehicles (FCV). In the final rule, EVs are treated as if they are responsible for no CO_2 and have a sales weight of up to two, meaning that a manufacturer selling a single EV can receive credits for selling two.[62] EPA proposed eliminating the sales multiplier and capping to the number of vehicles considered to produce 0 g/mi of CO_2 to limit GHG losses given that driving EVs produces CO_2 through power plants. [5-54] In other words, the Agency didn't want EV manufacturers to be able to produce cars responsible for unlimited CO_2 at no cost. However, EPA ultimately abandoned these proposals and included an uncapped sales multiplier in order to incentivize the development of electric vehicles.[63]

EPA estimated the CO_2 losses created by double counting EVs as if they produced no CO_2. The Agency predicted that 500,000 EVs would be responsible for 24.8 million metric tons of CO_2 over their lifetime. NHTSA's rule had no EV incentives, and regulates EV on a kwh per mile basis. [5-54 to 5-57]

Aggregate costs and benefits of the EPA's MY 2012-2016 program

The results of EPA's cost-benefit analysis are summarized in Table 12. Social benefits were understated by a calculation error that reduced the risk associated with foreign oil

[62] *Final Rule 2012-2016*, 25401.
[63] Ibid.

dependence. Despite this mistake, EPA concluded that both social and private benefits exceeded the respective costs of the program. Thus, the regulations were projected to cause a net welfare gain totaling just under $200 billion using 2007 values and a 3% discount rate. [8-26 to 8-28]

The 2017-2025 rules

Under EISA, NHTSA only possesses the statutory authority to establish regulations in five year periods. As a result, NHTSA and EPA released a new round of CAFE regulations beginning in 2017. The new rules are set to last until 2025. However, the agencies are conducting a midterm review of the program in order to comply with NHTSA's legal requirement to set new rules in 2022. The 2017-2025 regulations were not designed to alter the CAFE program in any significant way. Rather, the new rules are slightly modified versions of the 2012-2016 rules.[64]

The 2017-2025 regulations sustain the footprint-based standards, general methodologies for calculating costs and benefits, and a similar pattern for increasing regulatory stringency. As described in Figure 1, the rules were proposed in 2012, the same year that the earlier policy took effect. Thus, NHTSA and EPA committed to conducting a midterm review of the rules, based on the 2012-2016 measures, before making a final decision regarding the 2022-2025 program. The midterm evaluation is designed to analyze the effectiveness of the regulations and identify potential improvements.[65]

NHTSA did make minor changes to its rule. For instance, the 2017-2025 regulation was adjusted to account for AC improvements. However, the Agency continued to use a footprint-based standard with a similar slope. Moreover, NHTSA considered the same set of potential standards: fixed annual increases from 2-7%, a Maximum Net Benefits approach that equates marginal cost with marginal benefit, and a Total Costs Equal Total Benefits (TC=TB) option which would theoretically create no economic gains or losses but would substantially raise MPG.

As with the 2012 rule, NHTSA settled on a Preferred Alternative approach which increases CAFE targets between 3% and 4% annually, with more stringent standards coming later. The Preferred Alternative rule was chosen on the basis that it is the maximum feasible alternative. This conclusion was drawn after considering AC improvements, EPA policy, and currently available technology. Ultimately, NHTSA concluded that it was constrained by fuel-saving technology that currently exists. [NHTSA 2017, 93-107][66]

Projected MPG, fuel savings, costs, and benefits of NHTSA's 2017-2025 rule are provided in Table 13. NHTSA estimated all values using two reference fleets: an extension of the 2008 auto market used for the 2012-2016 rule and an updated 2010-based fleet. Table 13 uses

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[64] EPA and NHTSA, *2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Final Rule* (40 CFR Parts 85, 86, and 600: 10-1502012), 62627-62628.

[65] NHTSA, *CAFE Fuel Economy Standards and Midterm Evaluation for Light-Duty Vehicles, MYs 2022-2025*

[66] NHTSA, *Final Regulatory Impact Analysis: Corporate Average Fuel Economy for MY 2017-MY 2025 Passenger Cars and Light Trucks* (DOT: August 2012), 93-107. The RIA will be cited by page number in brackets for the rest of this case study.

the 2010 fleet for greater accuracy as the 2008 version was heavily influenced by the Great Recession. By 2025, the Agency projected a fleet-average MPG near 50 MPG. This is tied to over $430 billion in net benefits using a 3% discount rate and 2007 figures. As with the earlier rule, NHTSA estimated that private savings tied to lower fuel expenditures, totaling over $430 billion in total, would be responsible for the majority of these benefits. [65]

There are two noticeable variations from NHTSA's earlier analysis. First, an updated study on the relationship between vehicle weight reduction and fatality risk was conducted. The analysis demonstrated that lighter cars are indeed more dangerous, but by a much smaller amount than previously thought. In terms of SUVs, crossovers, and light trucks, reducing weight lowers the overall fatality risk of an accident (including people in other vehicles). As a result, the Agency projected a net drop in fatalities due to weight reductions associated with the rule. [1000-1050; Table IX-6a.] Second, NHTSA calculated the relative value loss of electric vehicles given their shorter life spans compared to traditional cars. [1000] All other costs and benefits were estimated using a similar methodology to the prior rule.

Similarly, EPA's 2017 and later rule utilized a virtually identical methodology to their 2012 regulations in terms of the structure of the standards and the costs and benefits analyzed in the Agency's RIA. Following the trend of the other three CAFE standards, both private and social benefits exceeded costs, with private benefits dwarfing social ones. As demonstrated in Table 14, EPA's projected $428 billion in net benefits again exceed those of NHTSA. Moreover, the $451 billion in estimated fuel savings, a private benefit, is far greater than any other figure, including aggregate costs.[67]

The CAFE standards going forward

In July of 2016, EPA, NHTSA, and CARB released a Draft Technical Assessment Report (TAR), a publication that analyzes the 2012-2016 rule. Overall, EPA and NHTSA concluded that manufacturers were over-complying with the regulations and that the structure of the rules is effective to achieve the Agencies' goals despite possible changes to the vehicle fleet. Specifically, some commentators have expressed concern that the rules may be creating a shift towards SUVs.[68] The Agencies are receiving public comment on the TAR at the time of this case study, a process that lasts for 60 days. After the period for public comment has ended, the Agencies will release an initial then final determination on the regulations for model years 2022-2025 (see Figure 1).

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[67] EPA, *Regulatory Impact Analysis: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards* (August 2012), 7-27 to 7-29.

[68] EPA & NHTSA, *Draft Technical Assessment Report: Midterm Evaluation of Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022-2025* (July 2016), http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/Draft-TAR-Final.pdf.

Table 1: Real Civil Penalties 1978-2014 (1 = $100,000 measured in 2007 dollars)

Manufacturer	Imported Fleet	Domestic Fleet
BMW	3,101.2	0.0
Mercedes Benz	3,025.4	0.0
Daimler-Chrysler[a]	1,165.9	0.0
Volvo	901.2	0.0
Jaguar	684.7	0.0
Porsche	661.0	0.0
Daimler	203.4	0.0
Fiat	187.4	0.0
Sterling	69.7	0.0
Ferrari Maserati	53.5	0.0
Peugeot	46.3	0.0
Maserati	40.2	0.0
Ferrari	27.8	0.0
Small Luxury Manufacturers[b]	2.5	5.2
Chrysler[a]	0.9	0.0
Ford	0.0	0.0
General Motors	0.0	0.0
Fleet share of total fines	99.95%	0.05%

Fines are expressed in real values based on the Consumer Price Index for All Urban Consumers (1982-1984 dollars)

(a) Chrysler merged with Daimler from 1998–2007, forming Daimler-Chrysler during that period. (b) Includes: PAS, Lotus, Saleen, Panoz, Vector, Aston Martin, Spyker, Callaway, Consulier, and Sun International.

Sources: CAFE Public Information Center, US. Bureau of Labor Statistics.

Table 2: NHTSA 2012-2016 aggregate costs and benefits, 3% discount rate ($2007 millions)

	MY 2012	MY 2013	MY 2014	MY 2015	MY 2016	Sum 2012-2016
Total costs	6,575	9,239	12,433	14,983	17,892	61,124
Private costs	5,902	7,890	10,512	12,539	14,903	51,748
Social costs	673	1,349	1,921	2,444	2,989	9,376
Total benefits	12,609	27,190	39,052	50,483	62,499	191,833
Private benefits	10,667	23,065	33,172	42,918	53,161	162,983
Social benefits	1,942	4,125	5,880	7,565	9,338	28,850
Net total benefits	6,034	17,951	26,619	35,500	44,607	130,709
Addendum: Net benefits at 7%	3,587	12,792	19,230	25,998	32,888	94,495

Source: *Final Regulatory Impact Analysis: Corporate Average Fuel Economy for MY 2012-MY 2016 Passenger Cars and Light Trucks*, 14, Table 12.

Table 3: Costs and benefits of 2012-2016 CAFE standards, 3% discount rate ($2007 millions)

	MY 2012	MY 2013	MY 2014	MY 2015	MY 2016	Sum 2012-2016
Private costs and benefits (costs shown as negative benefit)						
Technology	-5,902	-7,890	-10,512	-12,539	-14,903	-51,748
Lifetime fuel expenditures	9,264	20,178	29,082	37,700	46,824	143,048
Consumer surplus from additional driving	696	1,504	2,151	2,754	3,387	10,492
Refueling time value	707	1,383	1,939	2,464	2,950	9,443
Net private benefits	4,765	15,175	22,660	30,379	38,258	111,235
Social costs and benefit (costs shown as negative benefit)						
Congestion	-447	-902	-1,282	-1,634	-2,000	-6,265
Accidents	-217	-430	-614	-778	-950	-2,989
Noise	-9	-17	-25	-32	-39	-122
GHG reductions	921	2,025	2,940	3,840	4,804	14,530
Petroleum market externalities	546	1,153	1,630	2,079	2,543	7,951
Conventional air pollutants	475	947	1,310	1,646	1,991	6,369
Net social benefits	1,269	2,776	3,959	5,121	6,349	19,474
Net total benefits	6,033	17,950	26,619	35,501	44,606	130,709

Source: *Final Regulatory Impact Analysis: Corporate Average Fuel Economy for MY 2012-MY 2016 Passenger Cars and Light Trucks*, 14, Table 12.

Table 4: Results under alternative standards

Standard	2016 average MPG	5-yr fuel savings (mil. gal.)	5-yr cost ($2007 millions)	5-yr benefits		5-yr net benefits	
				3%	7%	3%	7%
3% fixed increase	32.0	21,161	22,944	102,770	82,523	79,826	59,579
Preferred alternative	34.1	35,660	51,748	182,457	146,243	130,709	94,495
5% fixed increase	35.2	39,463	63,350	202,275	162,035	138,925	98,685
Max net benefits	36.9	49,956	102,597	266,830	201,988	164,233	106,936
TC = TB	38.0	53,619	113,577	283,874	227,044	170,297	113,858

Source: *Final Regulatory Impact Analysis: Corporate Average Fuel Economy for MY 2012-MY 2016 Passenger Cars and Light Trucks*.

Table 5: Direct cost per vehicle of CAFE regulations ($2007)

	MY 2012	MY 2013	MY 2014	MY 2015	MY 2016
BMW	157	196	255	443	855
Chrysler	794	1,043	1,129	1,270	1,358
Daimler	160	198	564	944	1,252
Ford	1,641	1,537	1,533	1,713	1,884
GM	552	896	1,127	1,302	1,323
Honda	33	98	205	273	456
Hyundai	559	591	768	744	838
Kia	110	144	177	235	277
Mazda	632	656	799	854	923
Mitsubishi	644	620	1,588	1,875	1,831
Nissan	119	323	707	723	832
Porsche	316	251	307	390	496
Subaru	413	472	988	1,385	1,361
Suzuki	242	625	779	794	1,005
Tata	243	258	370	532	924
Toyota	31	29	41	121	126
Volkswagen	293	505	587	668	964
Average	505	573	690	799	907

Source: *Final Regulatory Impact Analysis: Corporate Average Fuel Economy for MY 2012-MY 2016 Passenger Cars and Light Trucks*, 312, Table VII-2a.

Table 6: Passenger car social costs caused by the rebound effect (millions $2007), 3% discount rate

	MY 2012	MY 2013	MY 2014	MY 2015	MY 2016	Total: 2012-2016
Passengers cars:						
VMT Increase (billion miles)	6.8	13.9	19.5	25.4	30.8	96.4
Congestion Costs	292	603	849	1,106	1,344	4,194
Accident Costs	133	268	379	492	595	1,868
Noise Costs	6	11	16	21	25	79
Combined passenger cars and trucks:						
Congestion Costs	447	902	1,282	1,634	2,000	6,264
Accident Costs	217	430	614	778	950	2,989
Noise Costs	9	17	25	32	39	122

Source: *Final Regulatory Impact Analysis: Corporate Average Fuel Economy for MY 2012-MY 2016 Passenger Cars and Light Trucks*, 14 & 405-410.

Table 7: Estimated fatality change (%) per 100lbs mass reduction with constant footprint

	Lower-estimate	Upper-estimate
Cars below 2,950 pounds	1.02%	2.21%
Cars above 2,950 pounds	0.44%	0.90%
Light trucks below 3,870 pounds	0.41%	0.17%
Light trucks above 3,870 pounds	-0.73%	-1.90%

Source: *Final Regulatory Impact Analysis: Corporate Average Fuel Economy for MY 2012-MY 2016 Passenger Cars and Light Trucks*, 469.

Table 8: Projected change in traffic fatalities and resulting economic costs

	MY 2012	MY 2013	MY 2014	MY 2015	MY 2016
Passenger cars (deaths)	11	17	57	100	134
Light trucks	-2	-3	-31	-77	-112
Combined	9	14	26	24	22
Passenger Cars ($2007 millions)	$126	$193	$658	$1,167	$1,557
Light trucks	-$19	-$29	-$344	-$859	-$1,259
Combined	$107	$164	$314	$307	$298

Source: *Final Regulatory Impact Analysis: Corporate Average Fuel Economy for MY 2012-MY 2016 Passenger Cars and Light Trucks*, 547-551.

Table 9: CO2 costs $/additional metric ton

Discount rate:	5.0%	3.0%	2.5%
2010	4.7	21.4	35.1
2030	9.7	32.8	50.0
2050	15.7	44.9	65.0

Source: *Final Regulatory Impact Analysis: Corporate Average Fuel Economy for MY 2012-MY 2016 Passenger Cars and Light Trucks*, 395, Table VIII-7.

Table 10: Change in vehicle sales due to MY 2012-2016 rule

	MY 2012	MY 2013	MY 2014	MY 2015	MY 2016	Total
Cars	-65,202	46,801	103,422	168,334	227,039	480,394
Light trucks	48,561	106,658	139,893	171,920	213,868	680,900
Combined	16,641	153,459	243,315	340,255	440,907	1,194,577

Source: *Final Regulatory Impact Analysis: Corporate Average Fuel Economy for MY 2012-MY 2016 Passenger Cars and Light Trucks*, 352-357.

Table 11: Cars and light-truck GHG breakdown by cause

Emission source	Percent of total car/truck emissions
Tailpipe CO_2 (no AC)	88.6
Coolant leakage	5.1
CO_2 from AC (excluding leakage)	3.9
N_2O	2.3
CH_4	0.2

Source: *Final Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, 2*-4, Table 2-1.

Table 12: EPA 2012-2016 aggregate costs and benefits, 3% discount rate ($2007 millions)

	MY 2012	MY 2013	MY 2014	MY 2015	MY 2016	Sum 2012-2016
Average emissions: CO_2 g/mi	288	281	275	263	250	n/a
Private costs and benefits (costs shows as negative benefit)						
Technology costs	-4,900	-8,000	-10,300	-12,700	-15,600	-51,500
Pretax fuel savings	16,100	23,900	32,200	46,000	63,500	181,800
Value of additional driving	2,400	3,400	4,400	6,000	7,900	24,000
Reduced refueling time	1,100	1,600	2,100	3,000	4,000	11,900
Net private benefits	14,700	20,900	28,400	42,300	59,800	166,200
Social costs and benefits (costs shown as negative benefit)						
Noise, accidents & congestion	-1,100	-1,600	-2,100	-2,900	-3,900	-11,600
*Oil market externalities	900	1,400	1,800	2,500	3,500	10,100
Conventional air pollutants	700	900	1,300	1,800	2,400	7,000
GHGs	1,700	2,400	3,100	4,400	5,900	17,000
Net social benefits	2,200	3,100	4,100	5,800	7,900	22,500
Net total benefits	16,900	24,000	32,500	48,100	67,700	188,700

Source: *Final Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, 2*-4, *8-26 to 8-28, Table 2-1*, *Table 8-14 & Table 8-16.*

*Due to a calculation error in the rule, these benefits were roughly half of what they should have been.

Table 13: Summary of NHTSA's 2017-2025 rule, using a 3% discount rate and 2010 fleet

	MY 2017	MY 2025	Sum 2017-2025
Fleet-average MPG	35.1	48.7	-
Fuel saved (bil. gal.)	4.8	29.0	161.2
Private costs and benefits ($2007 millions, costs shown as negative benefit)			
Technology implementation	-3,539	-19,030	-108,327
Maintenance	-12	-1,239	-4,947
Pretax fuel savings	12,498	80,175	436,469
Consumer surplus from additional driving	1,193	7,391	40,184
Value of saved refueling time	449	2,329	13,090
Net private benefits	10,589	69,627	376,469
Social costs and benefits ($2007 millions, costs shown as negative benefit)			
Congestion (rebound effect)	-512	-3,126	-17,081
Accidents (rebound effect)	-236	-1,466	-8,010
Noise (rebound effect)	-10	-58	-318
Decreased lifespan of EVs	0	-40	-87
Petroleum market externalities	681	4,081	22,643
Vehicle safety changes	9	54	18
GHGs	1,195	8,433	44,577
Conventional air pollutants	408	2,350	13,616
Net social benefits	1,535	10,229	55,357
Net total benefits	12,121	79,857	431,655

Source: DOT, CPI & Author calculations.

Table 14: EPA 2017-2025 costs and benefits, 3% discount rate ($2007 millions)

	MY 2017	MY 2025	Sum 2017-2025
Private costs and benefits (costs shown as negative benefit)			
Technology	-2,634	-31,946	-142,618
Pre-tax fuel savings	6,694	101,734	451,624
Increase in consumer surplus due to the rebound effect	951	12,931	59,424
Reduced refueling time	260	4,069	17,780
Net private benefits	5,270	86,788	386,210
Social costs and benefits (costs shown as negative benefit)			
Accidents, congestion & noise	-521	-6,694	-30,710
Oil market externalities	347	5,467	23,960
GHG reductions	610	10,269	44,307
Conventional air pollutants	70	1,150	5,191
Net social benefits	507	10,192	42,747
Net total benefits	5,781	96,980	428,805

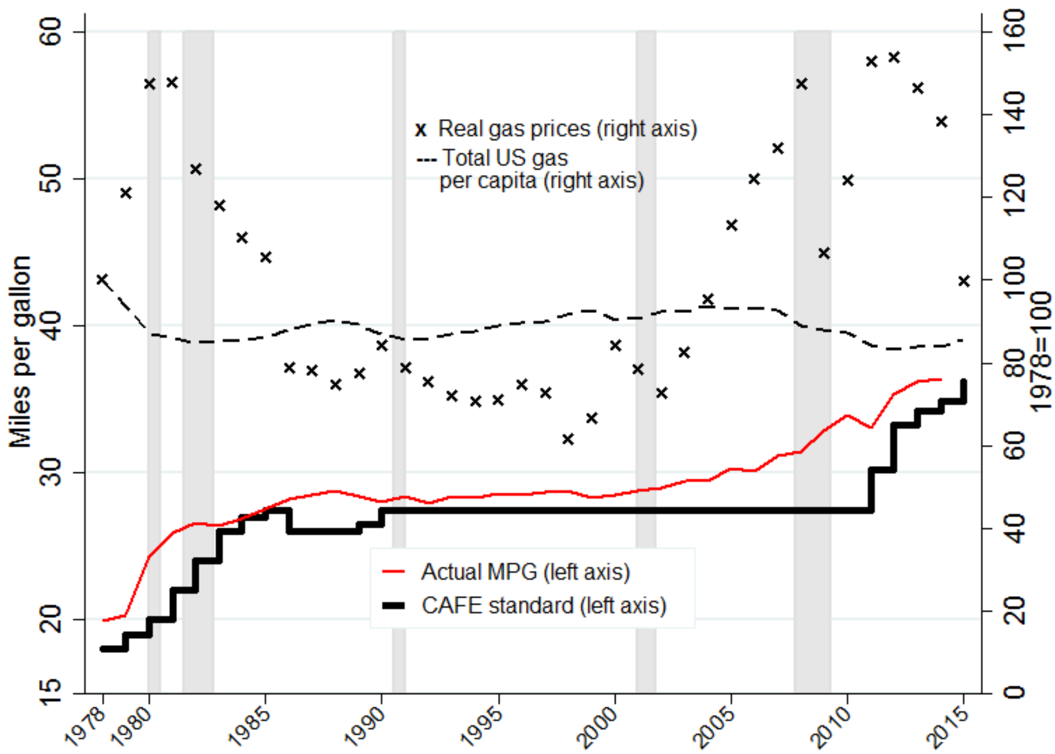
Source: EPA, *Final Rulemaking for 2017-2025,* 7-27 to 7-29.

Figure 1: Timeline of CAFE developments

1975	Energy Policy and Conservation Act
1978	First CAFE standards for cars
1979	First CAFE standards for light trucks
2000	NAS/DOT Study
2004	CARB approves Pavley Rule
May 2007	*Massachusetts v. EPA*
May 2007	Executive Order 13432
December 2007	Energy Security and Independence Act
2009	EPA permits the implementation of the Pavley Rule
2011	First footprint-based CAFE standard
2012	EPA/DOT finalizes rules for 2017-2025
July 2016	Midterm Review: Draft TAR
2017	Midterm Review: Proposed Determination
April 2018	Midterm Review: Final Determination

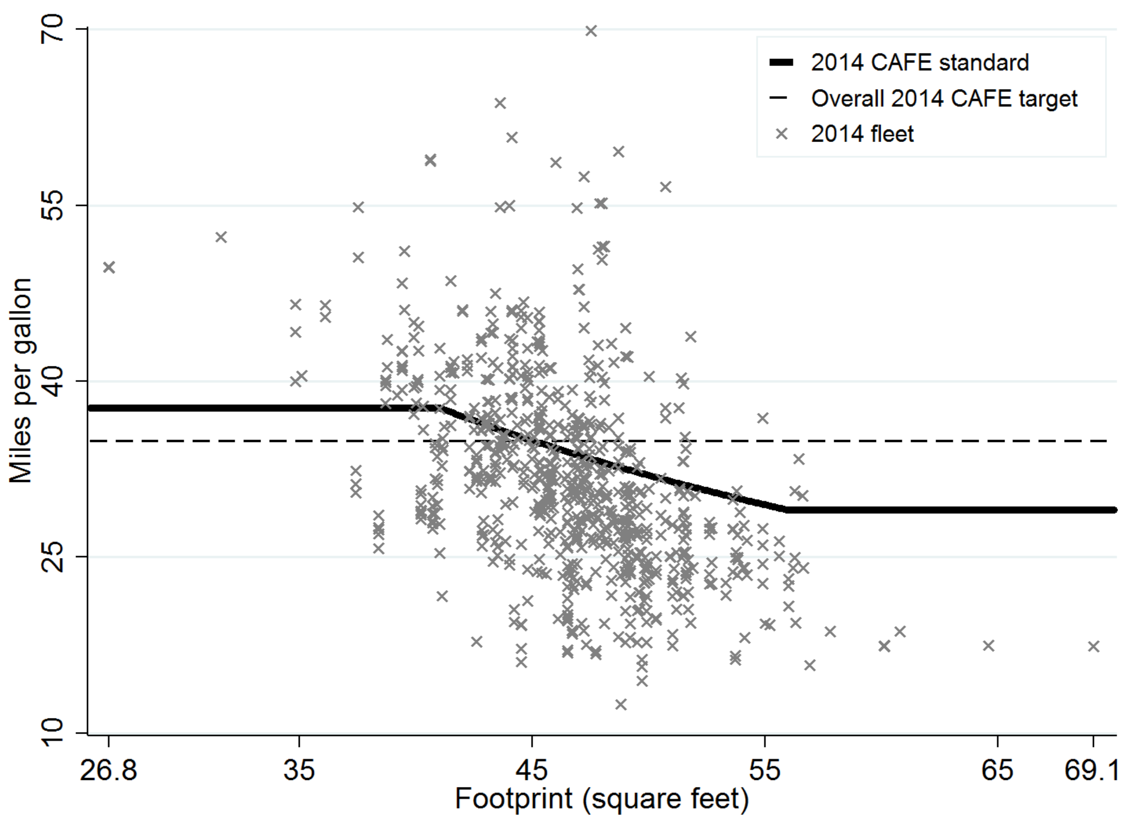
Source: NHTSA, *Summary of Fuel Economy Performance 2014* & Yacobucci and Bamberger

Figure 2: Passenger vehicle CAFE standard and gas consumption/capita



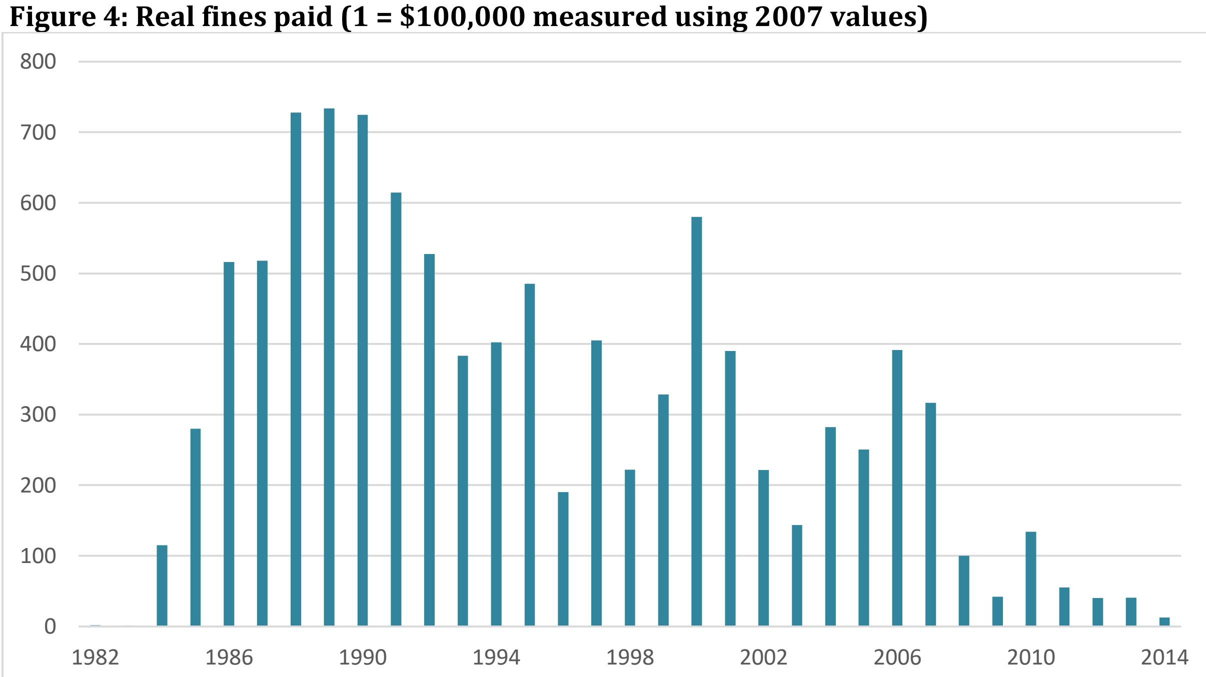
Sources: Authors' calculations based on data from NHTSA, EIA, EPA, DOT, US Census Bureau, US. Bureau of Economic Analysis, and the National Bureau of Economic Research (NBER). Vertical gray bands correspond to US business cycle downturns.

Figure 3: 2016 CAFE target



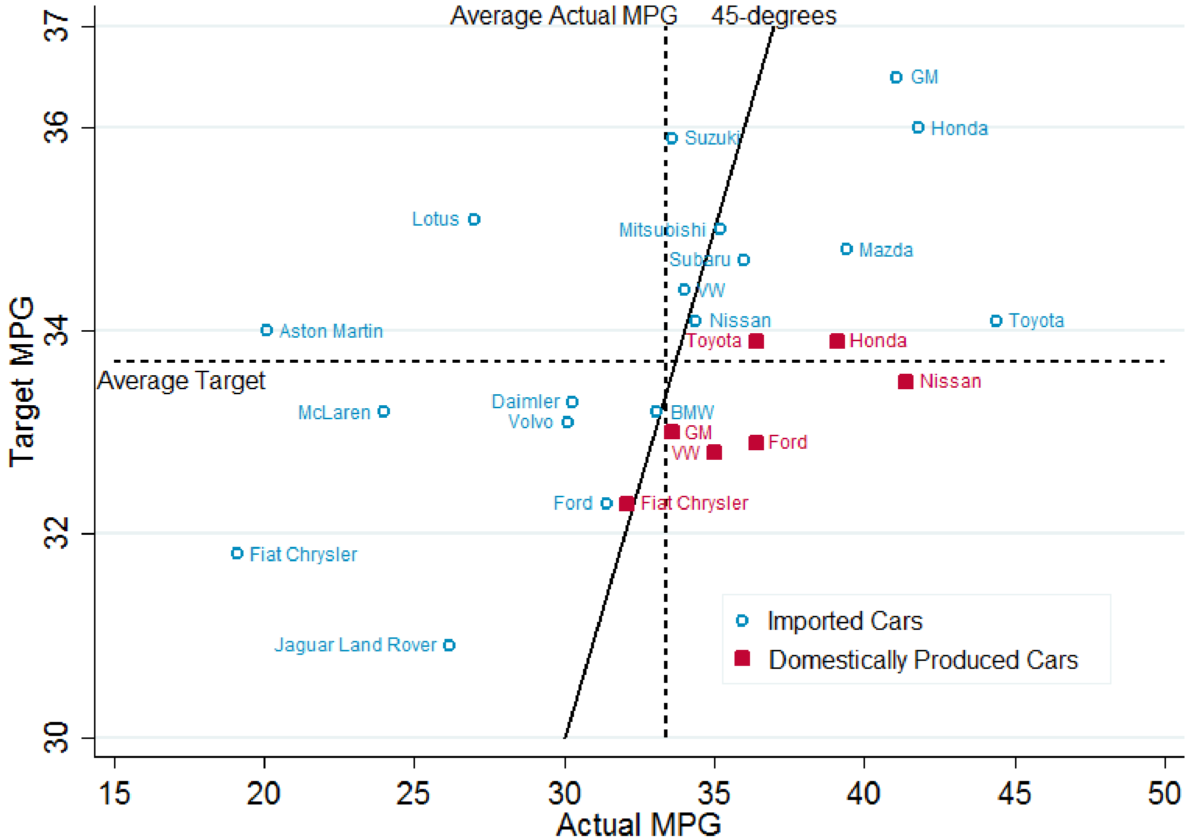
Sources: EPA Trends & NHTSA MY 2012-2016 Final Rule.

Figure 4: Real fines paid (1 = $100,000 measured using 2007 values)



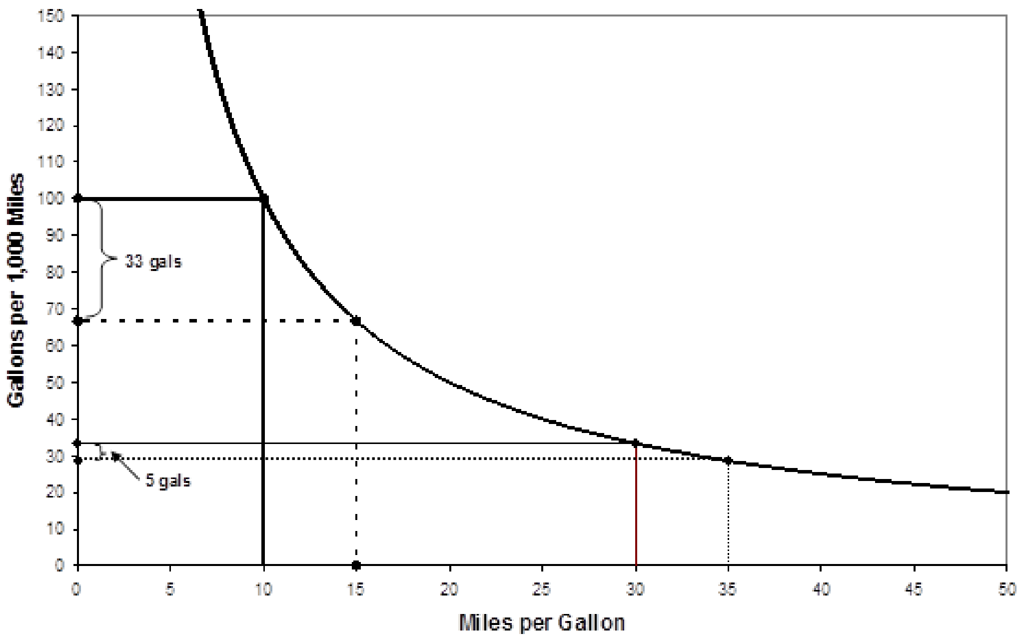
Sources: NHTSA, *Summary of CAFE Civil Penalties Collected* & BLS.

Figure 5: Target v. actual MPG by manufacturer MY 2013



Source: NHTSA, *Summary of Fuel Economy Performance 2014*.

Figure 6: The MPG illusion



Source: Fueleconomy.gov, *Electric Vehicles: Learn More About the New Label.*