ARTICLE CASE

Automobile Fuel Economy and Greenhouse Gas Emissions Standards

GRADY KILLEEN AND ARIK LEVINSON

Georgetown University, Washington DC, USA
Email: Arik.Levinson@georgetown.edu

ABSTRACT In March 2017, EPA Administrator Scott Pruitt reopened an evaluation of the automotive fuel economy and greenhouse gas emissions standards that the EPA had finalized in January. This case provides a history of the rules, along with assessments of their costs and benefits. It addresses numerous debates, including the environmental benefits of the rules, the role of electric vehicles, whether the standards should be less strict for larger cars, and tradeoffs between fuel economy and safety.

KEY MESSAGE

This case describes the history and details of American automobile environmental and fuel economy standards, in sufficient detail for students to be able to have an informed discussion as to their merits. Students should be able to articulate the tradeoffs between the per-mile standards and alternative regulations, describe the rebound effect and how that relates to the estimated costs and benefits of the standards, discuss the pros and cons of weaker standards for larger cars and trucks, and enumerate components of the benefits, including value of a statistical life, the social cost of carbon, accident risk, and congestion.

INTRODUCTION

In January, 2017, the U.S. Environmental Protection Agency (EPA) Administrator Gina McCarthy finalized the greenhouse gas (GHG) emissions rules for cars and light trucks through 2025, saying they will save American drivers billions of dollars at the pump while protecting our health and the environment [1]. Two months later, the new EPA Administrator Scott Pruitt reversed that decision: "These standards are costly for automakers and the American people. We will work with our partners at DOT to take a fresh look to determine if this approach is realistic. This thorough review will help ensure that this national program is good for consumers and good for the environment" [2]. By statute, that EPA review is due by April 1, 2018.

CASE EXAMINATION

Background

In 1975, the U.S. Congress passed the Energy Policy and Conservation Act, which gave the Department of Transportation (DOT), the authority to set and enforce fleet average miles per gallon (mpg) targets for new cars and light trucks sold in the United States. The new regulations, called Corporate Average Fuel Economy (CAFE) standards, climbed quickly to their statutory maximum of 27.5 mpg for cars, where they remained for the next two decades [3]. Since 2011, the CAFE standards have been modified in several ways: they have increased in stringency, are relatively less strict for larger cars, and are tradable among carmakers. Table 1 contains a timeline for important events in the development of the policy and this case study.

The National Academy of Sciences and DOT Study

In May 2000, the Senate asked the National Academy of Sciences (NAS) and DOT to analyze a potential CAFE increase [4]. The resulting report concluded that more stringent CAFE standards were justified in order to combat dependence on imported oil and climate change associated with GHGs emitted by vehicles. The study found that car manufacturers were already introducing new effi-

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TABLE 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
April 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
2010	EPA/DOT finalize rules for model years 2012–2016
2011	First footprint-based CAFE standard
2012	EPA/DOT finalize rules for 2017–2025
January 2017	Midterm Review: Final Determination
March 2017	Midterm Review reopened for reconsideration
April 2018	Midterm Review: Final Determination

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

cient technologies in Europe and Japan, where drivers faced higher fuel prices, and that U.S. manufacturers could meet higher mpg targets [5].

The NAS report also suggested changes to the structure of the CAFE rules. The first involved safety. The report noted that in collisions, occupants of smaller cars suffer more injuries and deaths. It inferred that by encouraging smaller cars that use less fuel, the CAFE regulation likely caused an additional "1,300 to 2,600 traffic fatalities in 1993." To offset this, the NAS recommended allowing heavier vehicles to meet less-stringent mpg targets.

But that NAS report contained a dissenting opinion highlighting possible errors with that inference. While it is true that smaller cars fare worse in collisions between differently sized vehicles, that doesn't mean that proportional reductions in all cars' sizes would increase injuries. Moreover, the NAS analysis failed to account for driver characteristics. If cautious drivers choose larger cars, which makes smaller cars appear more dangerous. The dissenting members argued that the CAFE standards did not increase traffic fatalities.

A third NAS suggestion was tradable fuel economy credits. Any manufacturer whose cars exceed the target average fuel economy should be allowed to sell credits to a carmaker whose vehicles fall short. That way, higher nationwide fuel economy could be achieved with lower total costs [5].

California's Regulations—The Pavley Rule

The federal government did not take immediate action following the NAS report. But in California, State Senator Fran Pavley led an effort to regulate GHG emissions from vehicles by imposing average limits on grams of carbon dioxide (CO_2) emitted per mile. For most gasoline powered cars, the only way to reduce CO_2 per mile is to increase fuel economy. So Pavley's proposal looked like stringent versions of the CAFE standards. In 2004, the California Air Resource Board (CARB) adopted the Pavely Rule, requiring a 30% reduction in emissions from cars sold in California by 2016 [6].

California's new regulation was initially overturned by the EPA on the grounds that only the DOT can set fuel efficiency standards. Technically, California was regulating GHG emissions not fuel economy, and so CARB tried again in 2009 [7]. The new EPA Administrator, Lisa Jackson, reversed the initial ruling. By that time, twelve other states and the District of Columbia had followed California's stricter standards, setting a precedent for regulating vehicles' CO_2 emissions that would eventually be adopted by EPA [8,9].

GHGs, Massachusetts v. EPA, and Resulting Federal Legislation

Again in 2003, the EPA had declined to set GHG limits for cars, on the grounds that it lacked authority under the Clean Air Act to do so. Massachusetts and 11 other states sued, and in April 2007 the U.S. Supreme Court ruled in their favor. The Court ordered the EPA to revisit its determination that it had no authority to regulate GHGs [10]. 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" [11]. And then in December, Congress passed the Energy Independence and Security Act (EISA), which reformed the CAFE standards in accordance with the NAS study. It set a stricter target of 35 mpg for 2020; it mandated that the standards be attribute based; and it called for credit trading among manufacturers [12].

The New Administration's Changes

In May 2009, President Obama announced that beginning in 2012, automobile manufacturers would be required to meet standards for both fuel economy and GHGs. DOT would continue overseeing fuel economy, while EPA would monitor GHGs, requiring cooperation between the agencies. To comply with EISA's requirement that the new standards be attribute based, the new rules set mpg targets that differed based on vehicles' sizes, as measured by their footprints—the area under the vehicles' four tires. Cars and trucks with larger footprints would have lower mpg targets. EPA and DOT finalized that rule in 2010, for model years 2012–2016.

The switch to footprint-based standards was justified mainly by concerns about safety. The NAS report had found that the uniform CAFE standards encouraged sales of smaller cars, and that in collisions, occupants of smaller cars suffer worse injuries. But as dissenters to the NAS report noted, it is not clear whether that was the fault of the larger cars *causing* more damage or the smaller cars *sustaining* more. A proportional reduction in all cars sizes might have no effect on injuries, or even reduce them. As an alternative explanation for the switch, some observers have noted that the original uniform standards disadvantaged American carmakers, and that the switch to footprint-based standards imposes a cost on imports equivalent to a tariff of several hundred dollars per vehicle [13].

The new target, a sales-weighted 35.5 mpg by 2016 for cars, was based on an unadjusted or "2-cycle" fuel economy test. It weights city driving at 55% and highway driving at 45%. The EPA also calculates an adjusted or "5-cycle" mpg estimate that factors in high speed driving, air conditioning, and cold temperatures. New car stickers report this lower, adjusted mpg because it more accurately captures real driving conditions. But the higher unadjusted numbers are used to set CAFE requirements, and that's what we report in all the tables and figures below. On average, the 2-cycle estimates are 25% larger than 5-cycle measurements [14].

Immediately after issuing the rules for 2012–2016, EPA and DOT proposed fuel economy and GHG rules with increasing stringency for the next nine model years, 2017–2025 [15]. That quick turnaround left no time to evaluate the consequences of the earlier rule change. Thus, as a part of their 2017–2025 rulemaking, the Agencies promised to conduct a "mid-term evaluation" of the regulations before finalizing standards for the last three model years, 2022–2025.

Figure 1 traces CAFE standards for cars from the program's introduction through 2014. For context, the graph includes the actual fleet-average mpg along with gas prices and economic conditions.

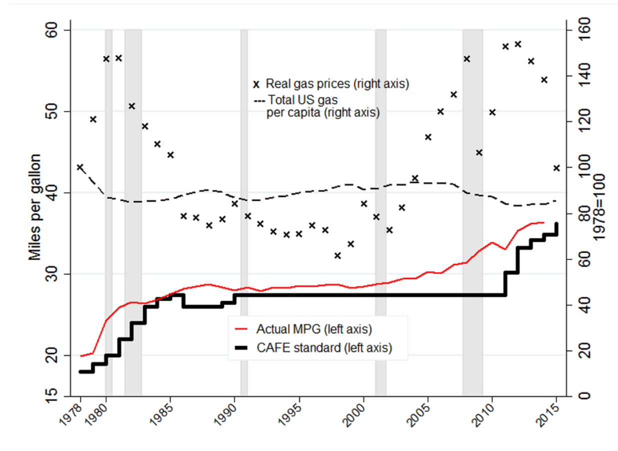

FIGURE 1. Passenger vehicle CAFE standard and gas consumption/capita. Sources: Calculations based on data from EIA, EPA, DOT, U.S. Census Bureau, U.S. Bureau of Economic Analysis, and the National Bureau of Economic Research (NBER). Notes: Vertical gray bands correspond to U.S. business cycle downturns. Real gas prices and total U.S. gas per capita are included as indexes, with 1978 values set to 100.

How the Rules Work in Practice

Before 2011, regulatory compliance had been based on the sales-weighted average fuel economy of each manufacturer's car or light truck fleet sold in the United States. If that average fell short of the target mpg, a fee of US$5.50 would be imposed for each tenth of an mpg below the target, multiplied by the number of vehicles sold [6]. Figure 3 plots total fines paid each year. Table 2 provides more detail [16].

Under the new footprint-based standards, manufacturers' each have different targets based on the sales-weighted footprints of their fleets [17]. The target for any particular car depends on its footprint. While the formula used is complex, it can easily be seen graphically in Figure 2[1]. The thick segmented line plots the footprint-based formula. In 2015, new small cars with footprints less than 41 square feet had to achieve 39 mpg. New large cars with footprints

1. The formula is the following: Target (mpg) = $1/\,Min[\,Max\,(\,c * footprint + d\,, 1/\,a\,), 1/\,b\,]$ where a is the function's upper limit (in mpg), b is the lower limit (in mpg), c is line's slope, and d is an intercept added for correct scaling. The standard gets more stringent each year by raising a and b, and lowering d. For 2016 the parameters were a=41.09; b=30.96; c=0.0005308; d=0.002573.

TABLE 2. Real Civil Penalties 1978–2014 (1 = US$100,000 measured in 2007 dollars).

Manufacturers	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%**

Notes: 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, U.S. Bureau of Labor Statistics.

greater than 56 square feet only had to achieve 30 mpg. Cars in between were on a sliding scale. The dashed line at 36 mpg represents the overall average target. Each year the formula gets more stringent by raising the mpg required for cars of every size.

In Figure 2, each cross represents one make and model. Any model sold that is below the thick segmented footprint line misses its mpg target, and to avoid fines, its sales must be offset by other vehicles that exceed the standard for their footprint.

As of 2014, the cumulative fines paid by all carmakers totaled just under US$900 million. Over 99% of these penalties were charged to imported vehicles. Since the adoption of the credit trading program, manufacturers have paid far less in fines. Total annual fines paid are plotted in Figure 3 and totals by manufacturer are reported in Table 2.

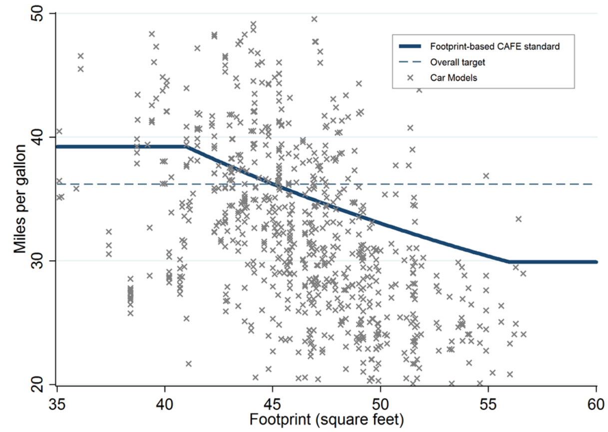

FIGURE 2. 2015 CAFE target. Source: EPA Trends & NHTSA MY 2012-16 Final Rule. Note: Each cross represents a separate make and model.

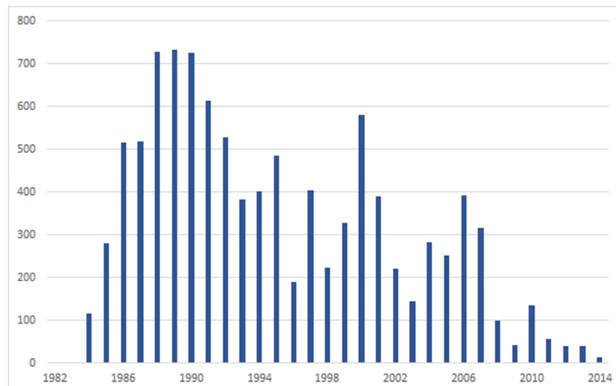

FIGURE 3. Real fines paid (1 = US$100,000 measured using 2007 values). Source: NHTSA, *Summary of CAFE Civil Penalties Collected* & BLS.

COST-BENEFIT ANALYSIS

The costs and benefits of the 2012–2016 CAFE rule are tabulated in Table 3. DOT considered two categories of costs: private and social. Private costs involve the increased expense of manufacturing more fuel efficient cars. Social costs include 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 United States.

TABLE 3. Costs and benefits of 2012-16 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
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.

Private Costs

DOT divided the private 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 these technologies for all cars (Table 4). The projected direct costs per passenger vehicle of the final rule vary from a low of US$29 (Toyota in MY 2013) to US$1,884 (Ford in MY 2016), with an average of $695 per vehicle annually. Most of these involve technological improvements such as weight reduction and engine efficiency.

For indirect costs, DOT simply scaled up the direct costs by a multiplier, ranging from 1.10 to 1.64 depending on the complexity of the technology. The 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) [18]. The private costs of the CAFE standards were estimated to a total of US$51.7 billion (Table 3).

Social Costs

DOT considered social costs to be those unrelated to the fuel-saving technologies. One such cost involves the "rebound effect." Fuel efficiency makes driving less expensive. If drivers respond by driving more, this will increase congestion, accidents, and noise. For passenger cars, DOT estimated these rebound costs at 5.4 cents per mile for congestion, 2.3 cents per mile for accidents, and 0.1 cents per mile for noise. DOT combined these values with the projected rebound effect to calculate their costs. The results are tabulated in Table 5.

A second social cost involves potentially reduced safety. The new footprint-based regulations were designed to reduce incentives to sell smaller cars, but still might result in lighter cars. DOT modified the earlier NAS analysis to estimate the effect of vehicle weight on fatalities. The results are given in Table 6. The upper estimates presume that manufacturers will reduce weight without compensating for associated safety reductions. The lower estimates assume that safety technologies offset lower vehicle weights. In the case of larger trucks, weight reductions reduce projected fatalities suffered by other drivers.

DOT monetized fatalities at $6.1 million per life. That's the agency standard value of a statistical life (VSL) of $5.8 million plus $ 0.3 million in medical care, insurance, and legal fees. The VSL is based on empirically estimated willingness to pay for risk reductions. For instance, if workers demand an extra US$1,000 per year to accept a job that increases their annual risk of death by 1 in 10,000, the VSL would be US$10 million [19]. DOT multiplied the VSL by 2.3 to include injury costs, based on past studies, and then applied discount rates because accidents to current model cars occur in future years. These costs are summarized in Table 7.

TABLE 4. 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 5. Passenger car social costs caused by the rebound effect (millions US$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.

Private Benefits

As with costs, the CAFE standards have both private and social benefits; private benefits are fuel savings and social benefits are pollution reductions. Both depend 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 the DOT's estimated mpg improvements translate into actual efficiency.

DOT begins with manufacturers' own sales projections. They then factor in a rebound effect of 10%, which is lower than historical estimates from the 1980s and 1990s because household incomes have risen and demand for driving becomes more inelastic as income grows [20]. Finally, DOT subtracted 20% from its target mpg to convert the unadjusted 2-cycle values in the CAFE standards to the more realistic 5-cycle mpg values that are closer to actual on-road fuel economy. Together, these calculations

TABLE 6. Estimated fatality change (%) per 100 lbs 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.

yield the net change in gasoline use necessary to calculate private and social benefits.

Savings from reduced fuel consumption were determined by multiplying each year's fuel savings by expected future gasoline prices. Gas tax savings were ignored, as they correspond to reduced gas tax revenues. Externalities associated with fuel consumption were added to include social costs. Table 3 includes a summary of the economic savings tied to decreased fuel use. The sum of lifetime benefits is $143 billion.

Consumers also benefit from the increased driving they do as a consequence of these reduced costs—the rebound effect. DOT approximated the associated increase in consumer surplus: one half of the change in operating costs per mile times the change in miles traveled. And, drivers of fuel efficient cars spend less time at gas stations. A CARB study determined that drivers typically purchase enough gas to fill 55% of a tank [21]. Using an average occupancy of 1.6 passengers and the DOT-recommended hourly value of travel time of US$24, DOT estimated the value of these time savings, reported in Table 3.

According to DOT's calculations, the private benefits of the CAFE standards exceed the private costs of the program by US$111 billion. That led some commenters to wonder why the rules were necessary. DOT provided several responses. First, consumers may place less weight on future benefits than DOT chose to. If car buyers discount future fuel savings more, they'll value fuel efficient cars less. Second, DOT speculated that consumers may be confused by so-called "mpg illusion"—the fact that gas savings are linear in gallons per mile, but fuel economy is described by its inverse, miles per gallon.

There are also several possible explanations from the supplier side of the market. DOT argued that a combination of monopolistic competition and information asymmetries between producers and consumers could lead to underinvestment in fuel economy. Finally, manufacturers may simply have underestimated the value that consumers place on fuel efficiency.

Social Benefits

The DOT considered three possible benefits related to decreased petroleum imports. First, reduced U.S. demand reduces global oil prices. A study conducted by Oak Ridge National Laboratories (ORNL) in 2008 estimated these benefits to be about US$ 0.298/gallon in 2007 [22]. However, DOT considers that to be a transfer among nations, not a net global gain, and hence excluded it from their calculation of the benefits of CAFE. Second, oil imports depend on military outlays to secure supply routes. DOT did not believe that the CAFE standards would cause a

TABLE 7. Projected change in traffic fatalities and resulting economic costs (upper estimates).

	MY 2012	MY 2013	MY 2014	MY 2015	MY 2016
Estimated change in total fatalities over the fleet lifetime					
Passenger cars	11	17	57	100	134
Light trucks	−2	−3	−31	−77	−112
Combined	9	14	26	24	22
Economic costs (US$2007 millions)					
Passenger cars	$126	$193	$658	$1,167	$1,557
Light trucks	−$19	−$29	−$344	−$859	−$1,259
Combined	$107	$164	$314	$307	$298

Note: Costs are monetized at DOT's estimated cost per life of $6.1 million ($5.8 million for the value of a statistical life plus associated external medical, insurance, and legal costs). This is multiplied by 2.3, to include injury costs, and discounted at 3%.

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

change in U.S. military policy and thus also excluded these calculations from its main cost-benefit analysis. Finally, reduced oil imports make the U.S. economy less vulnerable to volatile international petroleum prices. ORNL estimates these benefits at US$ 0.169 per gallon [22]. DOT did include these benefits, and they are listed in Table 3 as "Petroleum market externalities," summing to just under $8 billion.

Burning a gallon of motor fuel produces about 20 pounds of CO_2 [23]. DOT multiplied the gasoline savings from CAFE, times 20, times the social cost of carbon (SCC) as calculated by an interagency government panel [24]. The SCC is reported in Table 8 and the benefits are listed in Table 3. These included changes in refinery emissions.

DOT also measured the net changes in local air pollutants such as carbon monoxide, nitrogen oxides, hydrogen compounds, and sulfur dioxide created by increased travel and decreased fuel consumption per mile. Pollution effects caused by decreased gasoline use also included changes in refinery emissions.

TABLE 8. CO_2 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 9. 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.

THE EPA'S MODEL YEAR 2012–2016 STANDARDS

While the DOT's fuel economy program aims to increase miles per gallon, the EPA's program aims to reduce grams of CO_2 per mile. The two agencies coordinated, resulting in similarly stringent, footprint-based standards [25]. The EPA standards are summarized at the top of Table 10, tightening from 288 grams per mile in 2012 to 250 grams per mile in 2016.

EPA projected that the regulations would result in aggregate net benefits of around US$190 billion with a 3% discount rate or US$140 billion with a 7% discount rate. The values are generally consistent with DOT's findings: the regulations are tied to a significant social gain. However, EPA's estimate of net benefits exceeds that of DOT by almost US$60 billion. The majority of this difference, about US$40 billion, is due to higher EPA projections for fuel savings. Such differences are a product of differing estimations as well as real distinctions between the regulations. Two of the notable differences involve air conditioning credits and electric vehicle (EV) incentives.

EPA's cost-benefit analysis is summarized in Table 10. Social benefits were understated by a now-acknowledged error that reduced the measured risk from imported oil dependence. Despite that mistake, EPA concluded that both social and private benefits exceeded the respective costs of the program. The regulations have a projected net gain of US$189 billion.

EV Incentives

One key difference between the DOT and EPA regulation is that the EPA rule included provisions to spur development of EVs, plug-in hybrids, and fuel cell vehicles. The EPA rule treats EVs as if they are responsible for no CO_2 emissions and have sales weight of up to two, meaning that a manufacturer selling a single EV can receive credits for selling two zero-emission vehicles in their sales-weighted average grams of CO_2 per mile [25]. EPA initially considered eliminating the sales multiplier and capping the number of vehicles considered to produce zero CO_2. In the end, however, EPA included an unlimited sales multiplier. The agency estimated that double counting EVs as if they produced no CO_2 would generate an additional 24.8 million metric tons of CO_2 over these vehicles lifetimes.

THE CAFE STANDARDS GOING FORWARD

The 2017–2025 Rules

Under EISA, DOT has the statutory authority to set regulations only in five-year increments. As a result, for the new round of CAFE regulations governing model years

TABLE 10. EPA 2012-16 aggregate costs and benefits, 3% discount rate ($2007 million).

	MY 2012	MY 2013	MY 2014	MY 2015	MY 2016	Sum 2012-16
Average emissions (CO_2 g/mile)	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, and 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

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

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 and Table 8-16.*

2017 through 2025, the agencies promised to conduct a midterm review of the program, with the option of modifying the rules in light of any new information. The rule required that EPA finalizes that review and the CAFE rules for model years 2022 through 2025, by April 1, 2018.

The 2017–2025 regulations retain the footprint-based standards, general methodologies for calculating costs and benefits, and a similar pattern for increasing regulatory stringency [26].

Table 11 reports the projected mpg, fuel savings, costs, and benefits of DOT's 2017–2025 rule. By 2025, the Agency projects a fleet-average mpg near 50 mpg and over US$430 billion in net benefits. As with the earlier rule, DOT estimates that private savings from lower fuel expenditures—US$436 billion—will be responsible for the majority of the benefits.

Two noticeable differences from DOT's earlier cost benefit analysis stand out. First, DOT used an updated study on the relationship between vehicle weight reduction and fatality risk. The new analysis shows that lighter cars are less dangerous than previously thought. As a result, the Agency projected an overall drop in fatalities due to weight reductions associated with the rule. Second, DOT decreased the benefits from EVs due to their shorter useful life spans.

The EPA's analysis of the 2017–2025 rule for CO_2 emissions uses a virtually identical methodology to their analysis of the 2012–2016 regulations (Table 12). As before, both private and social benefits exceed costs, with private benefits dwarfing social ones. EPA projected net benefits of US$429 billion. The DOT net benefits in Table 11 are slightly higher due to minor differences in assumptions about individual costs and benefits. In both tables, the estimated private fuel savings (US$436 and US$452 billion, respectively) are far greater than any other figures including aggregate costs [27].

The Midterm Review

In July 2016, the EPA, DOT, and CARB began the promised midterm review by issuing an evaluation of the last four years of the 2017–2025 rules. The Draft Technical Assessment Report found that automakers are innovating and adopting new technologies, and that the standards for model years 2022–2025 appear attainable with conventional gas-powered cars at lower costs than anticipated in the original analysis [17]. The agencies circulated the report for public comment. Then on November 30, 2016, EPA Administrator Gina McCarthy issued a "Proposed Determination" that "based on her evaluation of technical information available to her and significant input from the industry and other stakeholders, and in light of the factors listed in the 2012 final rule establishing the MY2017-2025 standards, those standards remain appropriate under section 202 (a) (1) of the Clean Air Act" [28]. As part of that determination, EPA found that that the mpg and CO_2 targets were achievable "without extensive

TABLE 11. Summary of DOT's 2017-25 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 million, 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 million, 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 and author calculations.

TABLE 12. 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
Pretax 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 and 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.

use of strong hybrid or electric vehicles." Public comments were accepted until December 30, 2016.

In January 2017, over a year in advance of the deadline, this determination was finalized, concluding that "the MY2022-2025 standards remain appropriate under section 202 (a) (1) of the Clean Air Act," and leaving the originally proposed standards "entirely as they now exist, unaltered" [29].

On March 3, 2017, the new EPA Administrator Scott Pruitt announced that the EPA and DOT would reconsider the Final Determination as to whether the CAFE standards for model years 2022–2025 are appropriate

[30]. As described by the schedule in the initial rulemaking, they intend to make a new Final Determination no later than the original deadline on April 1, 2018.

CASE STUDY QUESTIONS

1. What are the goals of the standards? Are there better ways to achieve these goals?
2. Discuss Figure 1. What do you think the relationship is between gas prices, economic conditions, CAFE standards, and the actual sales-weighted average fuel economy of new cars sold?
3. Why did the regulations switch from uniform to footprint-based standards? Who were the winners and losers from that switch?
4. Of what significance is the fact that, according to the EPA, the private benefits exceed the costs of the regulations?
5. How should electric cars be treated by GHG emissions standards? How should they be treated by fuel economy standards?
6. If you were advising the EPA, how would you suggest the standards be changed for model years 2022–2025?

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COMPETING INTERESTS
The authors have declared that no competing interests exist.

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