The rise of SUVs in the US and its impact on greenhouse gas emissions from 2000-2017

April 2021

Abstract: Since the 1970s, the United States has strengthened fuel economy standards in order to reduce oil consumption and emissions from light-duty vehicles. However, there has been a dramatic market shift away from cars and towards light trucks, particularly sport utility vehicles, during this same period. This study quantifies the total impact of the rise of light trucks from model years 2000-2017. These additional light trucks will produce 867-3,519 million short tons of greenhouse gases across their lifetimes, compared to three alternative scenarios. These emissions are enough to offset 19-75% of the projected savings from the model year 2011-2025 CAFE standards. The combined cost of these emissions and the increased risk of traffic fatalities light trucks pose may reach $94.3-350.7 billion. These costs indicate the need for the federal and state governments to update transportation policies, including amending fuel economy standards, raising fuel taxes, and regulating vehicles based on weight.

Introduction

The Intergovernmental Panel on Climate Change (IPCC) estimates that global emissions of greenhouse gases (GHGs) must reach net zero levels by 2050 to limit global warming to 1.5°C (2018). However, global GHG emissions have continued to increase in recent years, and the transportation sector is responsible for much of this trend. The International Energy Agency (IEA) reported that transportation produced 25% of GHGs globally during 2017, and these emissions have increased by 2% per year from 2000-2017 (2019a). Transportation's contribution is particularly acute in the United States (US), where it has been the single largest source of GHGs since 2016. Light-duty vehicles (LDVs), including passenger cars and light trucks, generated 59% of total transportation sector emissions in the US during 2017 (US EPA 2019a).

GHG emissions from LDVs are a function of three factors: fuel choice (e.g. gasoline, diesel, and electricity), fuel economy, and vehicle miles traveled (VMT). The US government has focused primarily on just one of these three factors - fuel economy. Congress first established corporate average fuel economy (CAFE) standards in 1975, and they have been updated multiple times since. Yet, while LDVs have gotten more efficient over the past four decades, the marketplace has shifted considerably during this time, with light trucks - particularly sport utility vehicles (SUVs) - eating away at the share of passenger cars. From model years (MY) 1975-2017, the share of passenger cars in the US was halved from 80.6% to 41%, while the share of light trucks tripled from 19.4% to 59%. SUVs have driven this trend, growing from just 1.8% of LDVs to 43.3% during this period, a staggering 2,306% growth rate. Because they are taller, heavier, more powerful, and less aerodynamic than passenger cars, light trucks are approximately 25% less fuel efficient. Accordingly, any increase in demand for light trucks should reduce the overall fuel economy of the LDV fleet and increase GHG emissions.

Nevertheless, while previous studies have looked at the impact of the shift towards light trucks on fuel economy and gasoline consumption, none has quantified the emissions impact of this trend towards light vehicles in the US. This study is the first to estimate the additional GHGs from MY2000-2017 LDVs by comparing real-world emissions to those from three alternative scenarios: market shares from the MY1980 fleet, the MY1996 fleet, and the fleet in the European Union (EU). It also estimates the total lifetime emissions of MY2000-2017 LDVs. Based upon this analysis, the market shift towards light trucks over the past two decades will lead to at least 867 million short tons of carbon dioxide equivalent (MTCO2e) and as much as 3,519 MTCO2e through 2047. These emissions are enough to offset 18.5-74.8% of the projected GHG savings from the MY2011-2025 CAFE standards. This latter estimate is also equal to more than 57% of all GHG emissions in the US during 2017. The combined cost of these additional emissions and the increased risk of traffic fatalities from SUVs is $94.3-350.7 billion, enough to counteract 19.3-72.6% of the total net benefits of the MY2011-2025 CAFE standards.

The rest of this paper is structured as follows. Section 2 briefly traces the history of fuel economy regulations in the US from the 1970s, analyzes the debate around their efficacy, and discusses the factors that contributed to the rise of SUVs and other light trucks. Section 3 outlines the data and methodology utilized, and Section 4 details the results. Section 5 includes a discussion of the results and their policy implications. Section 6 concludes the paper.

Literature Review

History of fuel economy regulations in the US

Prior to the 1970s, the federal government devoted little attention to reducing oil consumption or improving fuel efficiency. Focus turned, instead, to the effort to curb emissions of conventional tailpipe pollutants in order to tackle the country's air pollution crisis. That all changed in October 1973, with the onset of the Yom Kippur War. The Arab members of the Organization of Petroleum Exporting Countries (OPEC) launched an embargo on oil exports to countries supporting Israel. This caused the price of a barrel of oil to quadruple by January 1974 (Hamilton 2011). Though the US was a major oil exporter during the first half of the 20th century, oil production peaked in 1972, leaving it highly vulnerable to the price shock. Lawmakers responded in 1975 by passing the Energy Policy and Conservation Act (EPCA). Title V of EPCA established the first fuel economy standards for passenger cars, beginning at 18 miles per gallon (mpg) for MY1978 and increasing to 27.5 mpg by MY1985. EPCA empowered the Secretary of Transportation to determine the appropriate CAFE standard from MY1981 on, a task delegated to the National Highway Traffic Safety Administration (NHTSA).

While the fuel economy of the LDV fleet increased rapidly after the passage of EPCA, the Reagan administration weakened the MY1985 standard to 26 mpg, where it remained through MY1989 (Byrne 2003). Despite this freeze, the CAFE program did improve fleet fuel economy by 2% per year, from 11.9 mpg in 1973 to 16.9 mpg in 1991 (Sivak and Tsimhoni 2009). Legislators worked to reform CAFE in 1991, but President George H.W. Bush strongly opposed their efforts, ensuring the standards remained frozen. During the Clinton administration, Congressional Republicans attached a rider to each of the 1995-2001 transportation appropriations bills that prohibited any strengthening of fuel economy standards (Hathaway 2018).

[Figure 1 near here]

This prolonged stasis stymied the early progress that the standards had facilitated. From 1980-2000, the average fuel economy of new LDVs increased by less than 6.5%, or just 0.26% per year (Knittel 2011). Once again, a spike in oil prices provided the impetus for reform, this time in the form of the 2007 Energy Independence and Security Act (EISA). Title I of the Act required NHTSA to begin setting new annual standards in MY2011 that would eventually increase to 35 mpg by 2020. It also directed the Agency to set the "maximum feasible average fuel economy standard" for each MY after that point. The Obama administration capitalized on this legislative writ in 2010, when NHTSA and US EPA set fuel economy and GHG emissions standards for MY2012-2016 LDVs. These regulations required average fuel economy to improve to 29.7 mpg in MY2012 and 34.1 mpg by MY2016. The GHG standards mandated a 15.3% reduction in average CO2 emissions from 295 grams per mile (gpm) to 250 gpm.

The agencies subsequently set standards for MY2017-2025 two years later, requiring new LDVs to average 48.7 mpg and 163 gpm in 2025. In 2020, the Trump administration weakened these standards for MY2021-2026, and US EPA rescinded California's waiver to implement its own emissions standards under Section 209 of the Clean Air Act. The Biden administration has committed to reviewing and strengthening these revised standards on an expedited timeline.

CAFE standards and their effectiveness

There is an ongoing debate in the literature over the efficacy of the CAFE standards. Supporters (Greene and Fan 1994; Greene 1998) argue that they have been effective at reducing oil consumption and fostering technological advances. According to Greene, Sims, and Muratori (2020), the standards are responsible for saving approximately two trillion gallons of gasoline since 1975. Others have argued that CAFE standards have allowed automakers to make other improvements in vehicle performance that consumers value. Had vehicle performance stayed at 1980 levels, average fuel economy would have increased by 18.5% by 2006; however, CAFE enabled automakers effectively to trade two-thirds of this increase in order to add 14% more weight, double horsepower, increase torque by more than 45%, and improve acceleration by nearly 40% (Knittel 2011). Importantly, the standards appear to be more politically palatable than alternatives like higher gasoline taxes (Anderson et al. 2011). Supporters also argue that the standards create thousands of jobs and reduce GHG emissions (BlueGreen Alliance & ACEEE 2012). NHTSA (2012) estimates that the combined MY2011-2025 CAFE standards will save 4.7 billion tons of CO2e over the lifetimes of these vehicles, making them the single most important GHG reduction tool in US government history to date.

Economists generally take the opposite side of this debate, arguing that fuel economy standards are an inefficient tool for cutting oil consumption and emissions. Linn and McConnell (2019) identify three major drawbacks with the standards: they only regulate emissions rates, not actual emissions; they only apply to new vehicles, doing nothing to cut emissions from existing LDVs; and they reduce the marginal cost of driving, causing an increase in VMT known as the rebound effect. A number of CAFE critics have claimed the standards drive automakers to reduce vehicle weight, which can have negative effects on road safety and increase traffic fatalities (Crandall and Graham 1989; Jacobsen 2013). Others have claimed that the standards are regressive, because they raise the market price of used LDVs. The relative cost of the CAFE standards is twice as high for households in the bottom income decile than for those in the top decile (Davis and Knittel 2019). Several researchers have also argued that the standards create perverse incentives for automakers to sell larger and larger LDVs (Thorpe 2018; Anderson et al. 2011), in part because there is a distinction between passenger cars and light trucks written into the program.

Reasons for the shift towards light trucks and SUVs

The ongoing debate over the CAFE program can obscure the question over why American consumers have moved away from passenger cars and towards light trucks. This shift to SUVs was not the inevitable result of market trends and consumer preferences. Instead, it was the product of decades of intentional actions by automakers. While Americans may favor larger vehicles and see SUVs as a status symbol, marketing has heavily influenced this perception. As one American car company representative put it, ‘sometimes you have to introduce something the market is not necessarily asking for, and it begins to take hold’ (Hathaway 2018, 19).

[Figure 2 near here]

Automakers have clearly prioritized their advertising dollars towards light trucks. According to an analysis from the Northeast States for Coordinated Air Use Management (NESCAUM), Chevrolet spent more than $100 million advertising its Silverado truck in 2017, compared to less than $15 million on its all-electric Bolt. Toyota spent more than $80 million on its RAV4 SUV but less than $5 million on its popular Prius hybrid (2018). And, of the 20 most advertised vehicles during the fourth quarter of 2017, 13 were SUVs and 3 were pickups. (Center for Biological Diversity 2018). Prior to the rise of SUVs, drivers looking for vehicles with more seating and cargo space likely would have opted for station wagons. But SUVs have crowded them out of the market. In MY1985, there were 185 models of station wagons available in the US; by MY2000, this number had fallen to just 57.

Although several studies have examined the effects of this shift towards light trucks, none has fully quantified the impact on GHG emissions in the US. Greene and Fan (1994) estimated that the rise of light trucks cut fleet fuel economy by 4% from 1972-1992. Sivak and Tsimhoni (2009) calculated that replacing all light trucks with cars would cut vehicle fuel consumption by 6.9%, but this was a rough estimate based upon differences in fuel economy. Ajanovic et al. (2012) considered the issue for the EU, concluding that larger vehicles ate away 900 picojoules (PJ) of energy savings that member states had gained from improved fuel economy and fuel taxes. Whitefoot and Skerlos (2012) assessed the impact of adopting footprint-based standards, finding that its incentive to produce larger vehicles increased GHG emissions by 24-76 MTCO2e per year.

The problem with SUVs is not just their fuel economy, however. They stay in the vehicle fleet longer, with 32.4% of them still on the road after 20 years, compared to just 15.7% for cars (US EPA, NHTSA, and California Air Resources Board, 2016).

Drivers also use them more; average lifetime VMT is 18.3% higher for SUVs (US Department of Transportation, 2006). And these estimated emissions may be too low. People drive SUVs faster than cars due to their higher seat position, and fuel economy is closely tied to speed (Rudin-Brown 2006). SUVs also appear to 'masculinize' the behavior of female drivers, leading them to drive more recklessly and to violate traffic laws more frequently (Wallner, Wanka, and Hutter 2017). This behavioral impact likely produces elevated GHG emissions, as aggressive driving cuts fuel economy by up to 31% (Sivak and Schoettle 2012). Recently, the IEA (2019b) considered the impact of the rise of SUVs on global emissions from 2010-2018, estimating that it led to an additional 544 million metric tons of CO2e, which offset all the fuel economy improvements that occurred for cars during that period more than seven times over. But even the IEA report fails to quantify the lifetime GHG impact of the shift towards light trucks in the US, as this paper does.

Materials and Methods

This study focuses on GHG emissions from the LDV fleet in the US from MY2000-2017. It does this for a handful of reasons. First, previous studies in the US have primarily focused on the impact of CAFE from the mid-1970s through the early 2000s. Second, this span includes all of the major changes that have occurred to the CAFE program recently, including the adoption of footprint-based standards and compliance trading. Third, it includes multiple increases and decreases in gas prices (Leard, Linn, and McConnell 2017), helping to account for short-term changes in demand for mpg or VMT. Fourth, this is the period for which all relevant data on fuel economy, production shares, and VMT are available for each scenario. Lastly, 2017 marks the first year in which light-duty trucks made up the majority of VMT driven on American roads (Davis and Boundy 2020). The analysis includes emissions from all LDVs produced during this period, divided into two phases: 2000-2017 and 2018-2047. The former quantifies the impact of the shift towards light trucks, particularly SUVs, that has already occurred. The latter estimates the lifetime emissions of these LDVs, some of which will remain on the road for up to 30 years.

Data Sources

Data for this paper come from multiple sources. Vehicle production numbers and production shares by vehicle class (sedan/wagon, car SUV, truck SUV, minivan/van, and pickup) are from the EPA's *2018 Automotive Trends Report* (2019d). The report also provides real-world data on mpg and CO2 gpm by vehicle class for all LDVs since MY1978. I utilize these data to develop average fuel economy across vehicle classes for each MY. Vehicle production data by class for the EU come from the International Council on Clean Transportation's (ICCT) *Pocketbook* for 2018/2019, which provides comprehensive data on the European vehicle fleet. In order to estimate GHG emissions from vehicles across their lifespans, one needs to incorporate data on VMT and vehicle survival rates (i.e. the percent of MY2000 vehicles still on the road in 2015). I took data on VMT and survival rates by vehicle age for cars and light trucks from US EPA's Motor Vehicle Emissions Simulator (MOVES) model, version 2014a. These data are included in the Agency's draft *Technical Assessment Report* (TAR) for the MY2022-2025 fuel economy standards (2016).

Methods

To analyse the impact of the trend towards light trucks, I first needed to develop baseline emissions. To do so, I constructed the LDV fleet from MY2000-2017 using the following methodology.

Let c index vehicle class and a index vehicle age. Fleet emissions E are given by

$$E = \sum_c \sum_a \sigma_{ac} \tau_c$$

where σ_{ac} represents vehicle miles travelled by vehicles of age a in class c and τ_c represents average greenhouse gas emissions in grams per mile for vehicles in class c. One could also imagine these things varying by year y, in which case a subscript y would be added to each term in the equation.

Calculating emissions using this equation is straightforward for a given year in which σ and τ are observed. The same equation could be used to calculate lifetime emissions for vehicles in a given model year if σ and τ are observed for all ages and classes. Some adjustment is required, however, if σ and/or τ is not observed for some ages and/or classes, or if the goal is to estimate counterfactual emissions if utilization (i.e. vehicle miles travelled) had been different.

Suppose vehicle miles travelled is known for all classes of vehicles at (but not beyond) age one. Suppose historical average patterns of vehicle usage ε_{ac} across subsequent ages a are also known for all classes c. Let

$$\varepsilon_{ac} = \frac{\overline{\sigma_{ac}}}{\overline{\sigma_{1c}}}$$

where $\overline{\sigma_{ac}}$ represents the historical average vehicle miles travelled for vehicles in class c at age a. This expression could also be described as vehicle miles traveled at age a as a proportion of vehicle miles travelled at age one. One could also think of this as a vehicle miles travelled-weighted vehicle-level survival rate. Then

$$\sigma_{ac} = \sigma_{1c}\varepsilon_{ac}$$

and

$$E = \sum_{c}\sum_{a} \sigma_{1c}\varepsilon_{ac}\tau_{c}$$

This equation can also be used to estimate counterfactual emissions under some alternate path of utilization by changing the definition of ε_{ac} (e.g. using some fixed rate, some multiple of $\overline{\sigma_{ac}}/\overline{\sigma_{ac}}$, etc.). If historical patterns of vehicle miles travelled by age and class are not observed directly but could be estimated from other data (e.g. new car sales, aggregate vehicle miles travelled, etc.), this framework can still be useful with ε_{ac} estimated in some other way.

In order to estimate the emissions from the shift to SUVs, I construct three alternative scenarios. First, I use the composition of the MY1980 fleet and apply it to the MY2000-2017 fleets. MY1980 is the year during which passenger cars had the largest production share of the US fleet (83.5%) since the advent of the CAFE program. Second, I applied the composition of the MY1996 fleet to MY2000-2017 LDVs. MY1996 was the last year in which passenger cars made up at least 60% of vehicles produced in the US. It also marks the beginning of the period during which SUVs began to rapidly gain market share. Third, I developed an alternative vehicle fleet using the shares of passenger cars and light trucks in the EU during each MY. Historically, light trucks have made up a much smaller share of LDVs in the EU. This outcome may be due to the EU’s fuel economy regulations, which, unlike the US, do not distinguish between cars and light trucks. The EU's light truck share during MY2000 (7.7%) was smaller than the light truck share in the US during MY1980. While SUVs have rapidly gained market share in the EU over the past decade, cars still made up 65% of MY2017 LDVs, a share that the US has not seen since MY1992.

Additionally, I divided both the MY1980 and MY1996 scenarios into two sub-scenarios. The first (Fixed) holds the share of each vehicle class constant at their MY1980 and MY1996 levels. In other words, since car SUVs had 0% market share in MY1980, they remained at 0% market share for MY2000-2017. The second sub-scenario (Tech Change) holds the share of passenger cars constant, but allows the relative shares of car SUVs, truck SUVs, minivans/vans, and pickups to reflect their actual market shares during each MY. This provides a more accurate representation of the observed trend towards light trucks in recent years, which has been overwhelmingly due to SUV sales. In MY1980, car SUVs and truck SUVs made up 0% and 1.6% of the LDV fleet, respectively. By MY2017, these numbers had increased to 11.5% and 31.8%, respectively. From MY1975-2017, the market share of SUVs rose by 2,306%, while the respective shares for cars, vans, and pickups fell by 49%, 20%, and 8%, respectively.

Once I constructed my alternative LDV fleets for each of the scenarios, I compared baseline GHG emissions to emissions from these alternative fleets. As noted, the emissions impact is split between two different periods: 2000-2017 and 2018-2047. Projecting the lifetime emissions impact of the trend towards SUVs allows one to capture the impact of the accelerated shift towards SUVs that has occurred in recent years. During MY2011, cars fell below 50% of the LDV fleet for the first time in US history. This long-term trend has continued apace, and automakers have responded. Ford canceled the production of all car models except for the Mustang and Focus

Active, following in the footsteps of GM and Fiat Chrysler (Colias and Rogers 2018). Given that the average age of LDVs in the US increased to 11.8 in 2018 from just 6.5 in 1975, the impact of this trend towards SUVs will continue for years to come.

Results

Comparing the estimated emissions from the baseline scenario to actual GHG emissions from LDVs demonstrates that the modeled vehicle fleet corresponds well to the actual fleet. In 2017, US EPA (2019a) reported that LDVs emitted 1,110.6 MTCO2e; the modeled LDV fleet in the base scenario emits 1,138.8 MTCO2e, 3.5% higher. From 2013-2017, emissions in the base scenario were just 0.5% higher than actual emissions.

Light trucks made up a majority of emissions in the baseline scenario, emitting 8.2 MTCO2e, 57.9% of the total. SUVs accounted for 4.5 MTCO2e, equal to 31.9% of emissions. The average, real-world fuel economy of MY2017 LDVs was 24.9 mpg, 26% higher than MY2000 vehicles. Both cars and light trucks saw significant improvements in fuel economy, with cars increasing from 22.9 mpg to 30.2 mpg and light trucks rising from 16.9 mpg to 22.1 mpg. The difference in fuel economy between cars and light trucks did not decrease, however; the average car was between 23.3% and 27.8% more fuel efficient during this period. This gap may have gotten bigger if not for the shift within the light truck market, with consumers swapping vans and pickups for SUVs, particularly car SUVs. The fuel economy of car and truck SUVs actually grew faster than any other vehicle class from MY2000-2017. While combined SUV fuel economy improved 2.3% per year, the fuel economy for cars, vans, and pickups improved by just 1.8%, 1.1%, and 0.7%, respectively.

From 2000-2017, the average GHG emissions, in grams per mile (g/mi) for the baseline LDV fleet improved by 12.2%, to 399.3 g/mi from 454.5 g/mi. Across this period, the average LDV in the US fleet emitted 432.8 g/mi. The 1996 scenarios see average emissions rates fall to 423.6 g/mi (Fixed) and 422.3 g/mi (Tech Change), improvements of 2.1% and 2.4%, respectively, compared to the baseline. Average fleet emissions rates reach 395.1 g/mi and 389.3 g/mi for the 1980 Fixed and Tech Change scenarios, respectively. These numbers are 8.7% and 10% above the base scenario. Lastly, the EU scenario leads to the lowest average emissions at 383.3 g/mi, an 11.4% improvement over the real world fleet. Figure 3 charts the change in emissions rate over time, by scenario. As it shows, while the EU scenario has the most fuel efficient fleet, overall, the average emissions rate of vehicles in the MY1980 Tech Change fleet actually dips below that of the EU fleet in 2017.

[Figure 3 near here]

While emissions vary across the five scenarios, the impact of the shift towards light trucks in the LDV market is substantial. The 1996 scenario generates the smallest emissions difference from 2000-2017, with the Fixed and Tech Change scenarios producing 404.3 MTCO2e and 449.2 MTCO2e less, respectively. Compared to the baseline, these represent reductions of 2.8% for the Fixed and 3.2% for the Tech Change scenarios. The emissions impact is starker for the 1980 and EU scenarios. When applying the MY1980 vehicle fleet makeup, emissions in the Fixed and Tech Change scenarios were 1,639.2 MTCO2e (11.6%) and 1,799.2 MTCO2e (12.7%) lower, respectively, than the baseline. The EU scenario showed the greatest difference, with emissions more than 2,041.7 MCO2e, or 14.4%, lower than in the baseline scenario.

Putting these emissions in context demonstrates just how large the impact of shifting to light trucks has been in the US. The annual emissions impact ranges from a low of 22.5 MTCO2e for the 1996 Fixed scenario to 113.4 MTCO2e in the EU scenario. The former total is higher than the transportation sector GHG emissions of 22 states and Washington, DC during 2017, while the latter total is higher than transportation emissions from every state but Texas and California in that year (US Energy Information Administration 2019). These emissions are also higher than the total GHG emissions of 138 and 183 countries, respectively, during 2017 (Global Carbon Project 2018).

[Figure 4 near here]

As discussed, the emissions impact from light trucks is not confined to the past, so one must also account for their potential emissions from 2018-2047. In the baseline scenario, total LDV emissions are estimated to reach nearly 9,194.3 MTCO2e. For the 1996 scenario, Fixed and Tech Change emissions are 462.9 MTCO2e (5%) and 493.6 MTCO2e (5.4%) lower, respectively. Emissions under the MY1980 LDV fleet are 1,508.8 MTCO2e (16.4%) and 1,616.4 MTCO2e (17.6%) lower in the Fixed and Tech Change scenarios, respectively. Due to the recent shift towards SUVs in Europe, the EU scenario actually generates a smaller net emissions benefit than the 1980 scenarios from 2018-2047. Using the EU vehicle fleet reduces emissions by just under 1,477.7 MTCO2e, equal to 16.1% of the baseline.

Summing these two values provides the cumulative, lifetime impact of the shift towards light trucks in the US during the analysis period. If the US had retained the MY1996 composition of the LDV market, total emissions for MY2000-2017 LDVs would be 867.2 MTCO2e (Fixed scenario) to 942.7 MTCO2e (Tech Change scenario) lower than they are projected to be. These represent 3.7% and 4% reductions against the baseline, respectively. Had the market shares, instead, reflected the MY1980 fleet, emissions would be 3,148.5 MTCO2e (Fixed scenario) to 3,415.6 MTCO2e (Tech Change scenario) lower than the baseline. Emissions would fall by 13.5% and 14.6% in these scenarios. The largest cumulative emissions impact occurs under the EU LDV fleet; emissions through 2047 would be 3,519.5 MTCO2e, or 15% lower.

[Table 1 near here]

Discussion

Clearly, the total emissions effect of drivers switching to light trucks is substantial. On the low end, total lifetime emissions under the MY1996 Fixed scenario are equal to 79% of total GHG emissions from the US LDV fleet during 2017. At the high end, emissions from the EU scenario are 3.2 times greater than the annual emissions of the LDV fleet. Total emissions exceed those of nearly every country on earth; only the US and China emitted more than 3,519 MTCO2e in 2017. Perhaps, the most appropriate comparison for this analysis is the estimated lifetime emissions benefits from the MY2011-2025 CAFE standards. According to NHTSA (2012), these standards, which would improve the fuel economy of new LDVs by nearly 80%, will save 4,700 MTCO2e. Thus, the observed shift towards light trucks in the US LDV fleet may cancel out some 18.5-74.8% of this total projected benefit. While this analysis looked at all light trucks, SUVs are the dominant driver of this trend. Across all five scenarios, the market shift towards SUVs (both car and truck SUVs) explains the entire difference in emissions from the baseline scenario. On average, emissions from cars, vans, and pickups fall by 1.5-fold, while emissions from SUVs increase more than by 2.5-fold.

To quantify the costs of these additional GHG emissions, I used estimates from the Interagency Working Group on the Social Cost of Greenhouse Gases (2016). Totals are expressed in 2007 US dollars, based upon that report. The total social cost of lifetime GHG emissions from the shift towards light trucks ranges from a low of $34.5 billion for the 1996 Fixed scenario to a high of $132.9 billion for the MY1980 Tech

Change scenario. The average annual cost range is $718 million to $2.8 billion. Applying a higher SCC, as many experts suggest, would increase this total. The Biden administration, for instance, has called for using an interim SCC of $51 per ton, which is nearly 20% higher than the cost under the 2016 guidelines (Interagency Working Group, 2021).

But these estimates only account for GHG emissions, not for other externalities. As noted, light trucks both remain on the road longer and drive farther than passenger cars. Accordingly, the rise of light trucks also places a greater strain on American infrastructure. Under the base scenario, MY2000-2017 LDVs amassed a total of 29.75 trillion VMT through the end of 2017. The 1996, 1980, and EU scenarios, in turn, lead to 227.75 billion (0.77%), 925.94 billion (3.1%), and 990.94 billion (3.3%) fewer VMT. These scenarios significantly lessen damage to roads, mitigate congestion, and reduce the risk of traffic fatalities. Larger vehicles also pose a greater threat to other drives. Li (2012) estimates that the cost of increased traffic fatalities during the lifetimes of light trucks is $2,444 per vehicle. Compared to the five alternative scenarios, there are anywhere from 24.5-89.1 million additional light trucks on the road today. Using these estimates, the crash externality from the shift to light trucks is $59.9-217.8 billion, significantly higher than the SCC. Combined, the total externalities from additional GHGs and traffic fatalities add up to $94.3-350.7 billion, enough to offset 19.3-72.6% of the total net benefits of the MY2011-2025 CAFE standards.

Moreover, this analysis does not include the costs from emissions of conventional air pollutants, like nitrogen oxides and fine particulate matter. There is not an absolute correlation between fuel economy and conventional tailpipe emissions, as they are regulated under different rules and controlled by different systems. But larger vehicles often face less restrictive emissions regulations, as the US EPA averages emissions standards for conventional pollutants across the fleets, much like it does for GHGs. Next to fuel economy data on vehicle window stickers, US EPA includes a Smog Rating, which is an indexed value (1-10) for conventional pollutants. Higher scores indicate that a car is cleaner than others. During MY2017, the first year during which Tier 3 emissions standards were in effect, new cars had an average Smog Rating of 6.43, which was 6.3% higher than the 6.05 rating for SUVs. While this rating does not mean cars release 6.3% fewer emissions, it does suggest that they are, on the whole, cleaner than SUVs. Furthermore, LDVs with lower fuel economy tend to have emissions control systems which deteriorate more rapidly, causing higher lifetime emissions of conventional pollutants (Harrington 1997). These findings suggest that accounting for conventional pollutants would increase the social costs of SUVs considerably.

To help mitigate the costs of this trend, regulators should consider revising fuel economy rules in the US First, the US should follow the EU's model and eliminate the distinction between cars and light trucks in the standards. This distinction has existed since the start of the CAFE program, but it is a relic of a period when light trucks occupied a niche market, rather than making up the majority of passenger vehicles on American roads. Second, NHTSA should end its use of footprint-based standards and consider adopting a weight- or mass-based standard, as Japan currently employs. Footprint-based standards appear to encourage automakers to increase the size of the vehicles they produce, because larger vehicles are subject to less stringent fuel economy requirements (Ullman, 2016). This incentive undermines the central goal of the CAFE program. Third, lawmakers should update the Gas Guzzler Tax, which it has not done since 1991, and index its value to inflation. This tax inexplicably does not apply to light trucks, which distorts the market by incentivizing automakers to reimagine cars as light trucks in order to avoid tax liability (Sallee 2011). This regulatory loophole is at least partially responsible for the growth of crossover utility vehicles, (i.e. car SUVs). The US could also raise gasoline taxes, which it has not done since 1993. According to Anderson and Auffhammer (2014), it would cost $0.97-2.17 per gallon of gasoline to internalize the costs of increased vehicle size. Based on estimates from Linn and McConnell (2019), this gas tax would be equivalent to a carbon price of $87-193 per ton and would have the potential to cut VMT by 7-16%, which would help offset the additional emissions from SUVs.

Policymakers should also consider using additional levers to discourage consumers from purchasing larger vehicles. State governments could raise registration fees for LDVs based on their weight or footprint. They could also work with insurance companies to adjust premiums based on vehicle characteristics (e.g. footprint) or adopt pay as you drive (PAYD) pricing models, which can reduce VMT by up to 8% (Bordoff and Noel 2008). Although these policies will incentivize better fuel economy and help reduce VMT, they may not be enough to lower the number of light trucks on American roads, as it takes 20 years to roll over at least 90% of the LDV fleet (Keith, Houston, and Naumov 2019). Getting LDVs off the road before the end of their useful life is a difficult, expensive proposition. According to Erickson et al. (2015), it would take a carbon price of $1,000 per ton to displace existing LDVs from the road. With this in mind, lawmakers may need to create a vehicle buyback and scrappage program to begin undoing the damage from these additional light trucks. An SUV purchased in 2021 has the potential to remain on the road through 2050, making the urgency of immediately mitigating these additional emissions abundantly clear.

Conclusion

Over the past four decades, the US has focused on strengthening fuel economy standards in order to reduce oil consumption and tailpipe emissions from LDVs. Unfortunately, the market shift away from cars and towards light trucks, particularly SUVs, has undermined this effort. This trend has picked up steam in recent years, with light trucks making up the majority of new LDVs for the first time in MY2011. This study quantified the total impact of the rise of light trucks from MY2000-2017. Based upon this analysis, the additional light trucks on American roads will emit anywhere from 867-3,519 $MTCO_2e$ across their lifetimes, enough to offset 19-75% of the projected emissions savings from the MY2011-2025 CAFE standards. The latter estimate is equal to more than 57% of all GHG emissions in the US during 2017. Combined, the social cost of these additional emissions and the increased risk of traffic fatalities may reach $94.3-350.7 billion through 2047. The staggering costs of this trend demonstrates the need for the federal and state governments to change transportation policy, including amending the CAFE program, raising fuel taxes, and shifting towards weight-based vehicle regulations. While these steps may not be enough to fully counteract he impact of light trucks in the US, they can begin to ameliorate the harm that has been done and rebalance the stakes in favour of a more sustainable transportation system.

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Figures and Tables

Figure 1. US CAFE Standards for Cars and Light Trucks, MY1978-2025

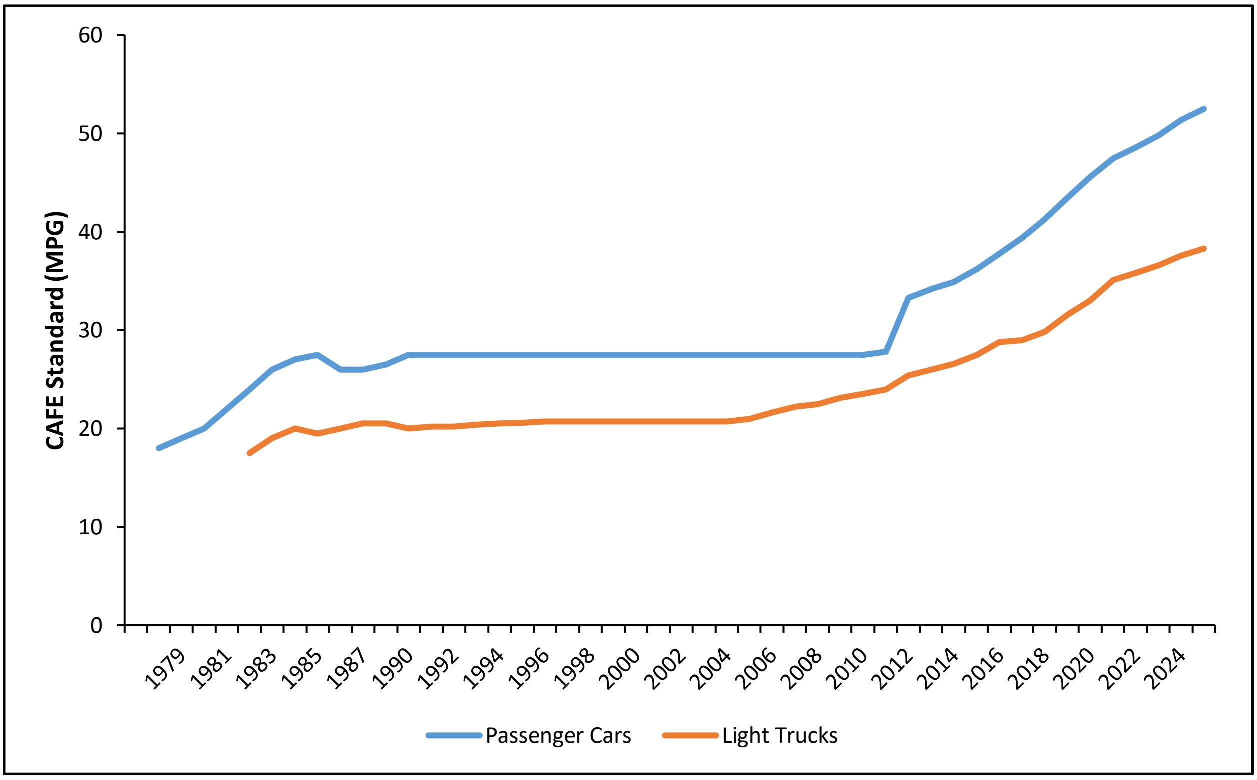

Figure 2. Light-Duty Vehicle Market Shares by Vehicle Class, MY1975-2017

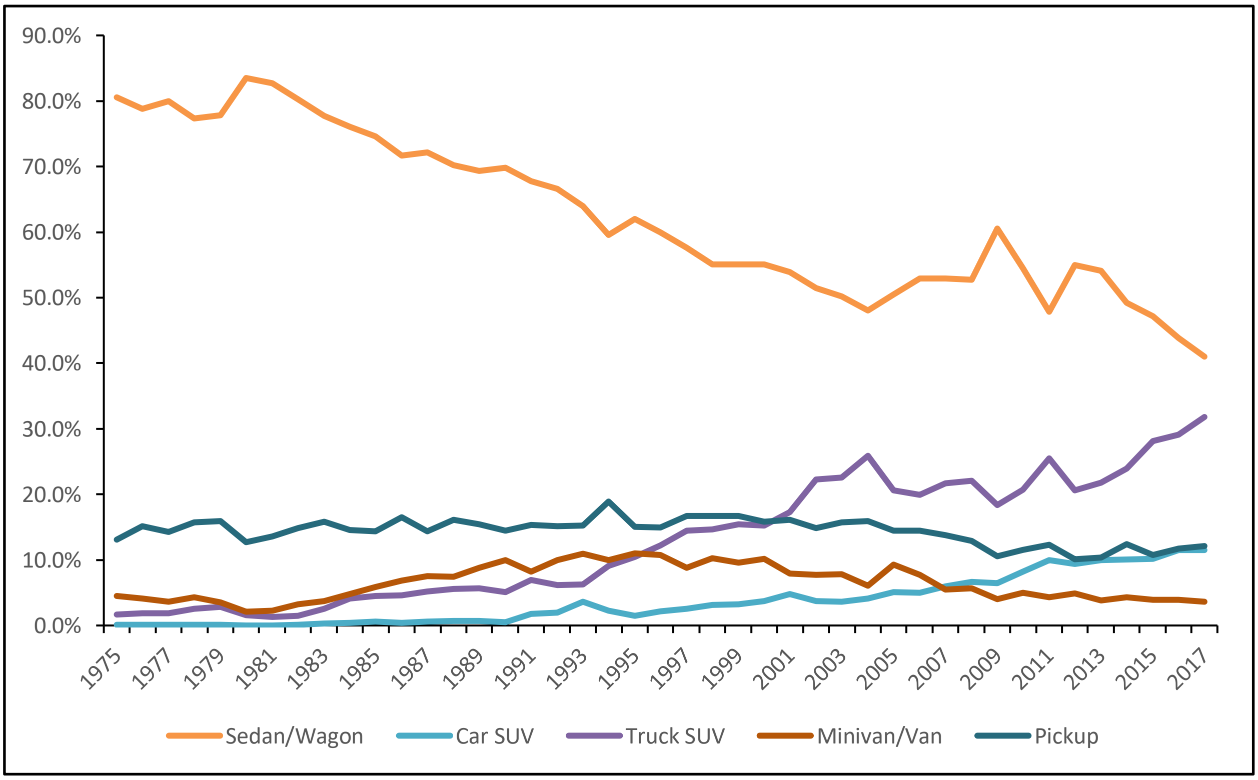

Figure 3. Average Emissions Rates for LDV Fleet by Scenario, 2000-2017

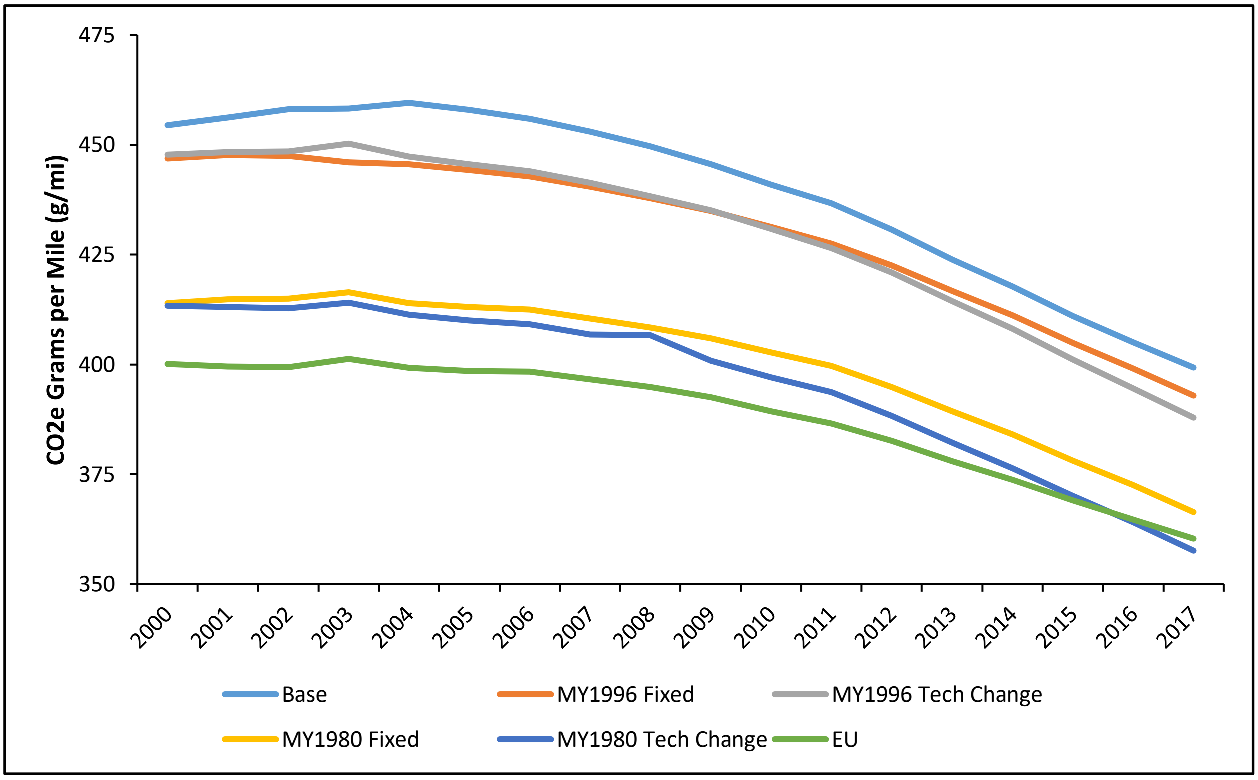

Figure 4. Cumulative Emissions from LDV Fleet by Scenario, 2000-2047

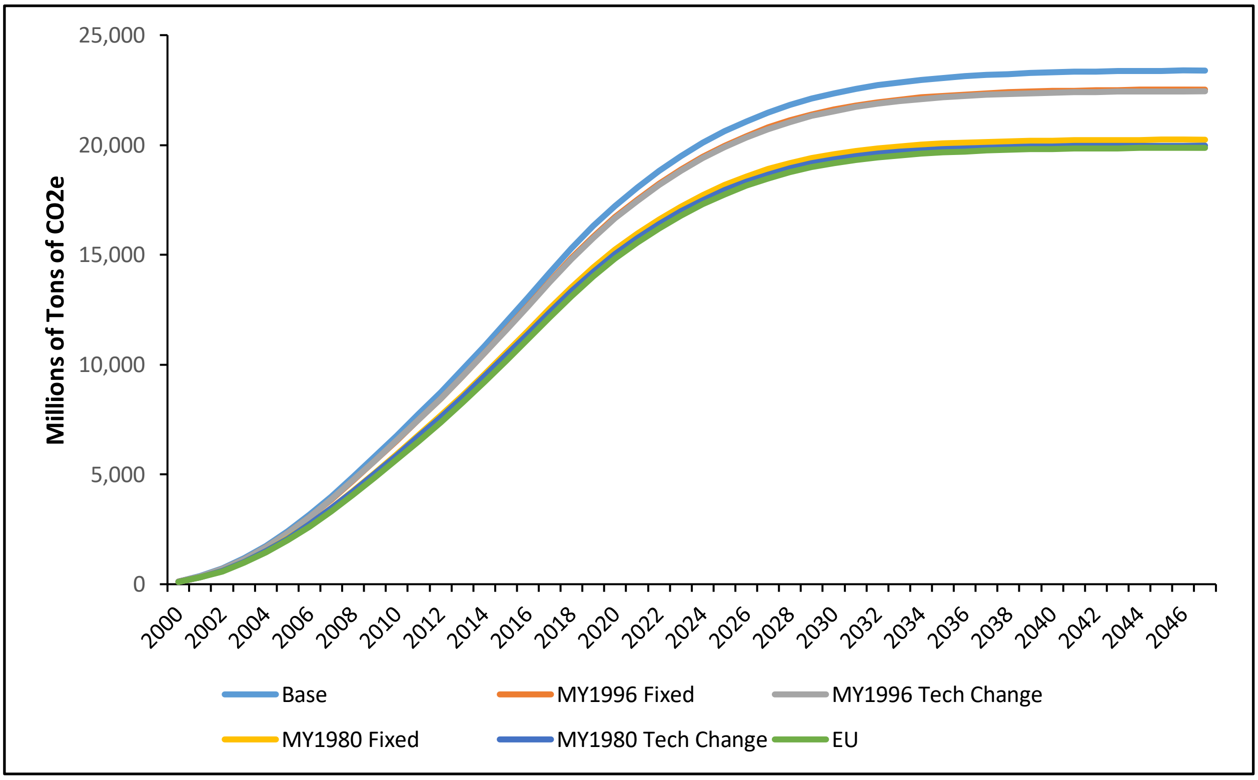

Table 1: Total Greenhouse Gas Emissions from LDV Fleet by Scenario

Scenario	2000-2017 Emissions ($MTCO_2e$)	Percent Change	2018-2047 Emissions ($MTCO_2e$)	Percent Change	Combined Emissions ($MTCO_2e$)	Difference ($MTCO_2e$)	Percent Change
Base Scenario	14,191	N/A	9,194	N/A	23,386	N/A	N/A
MY1980 Fixed	12,552	-11.6%	7,685	-16.4%	20,237	-3,149	-13.5%
MY1980 Tech Change	12,392	-12.7%	7,578	-17.6%	19,970	-3,416	-14.6%
MY1996 Fixed	13,787	-2.8%	8,731	-5.0%	22,518	-867	-3.7%
MY1996 Tech Change	13,742	-3.2%	8,701	-5.4%	22,443	-943	-4.0%
EU Scenario	12,150	-14.4%	7,717	-16.1%	19,866	-3,519	-15.0%

Supplemental Data

Data used in this paper are available at

https://drive.google.com/drive/folders/1fu7XdObgWfats-Bvd9Jydx4-BGHfXolx?usp=sharing.