POLICY FORUM

ENVIRONMENTAL ECONOMICS

Flawed analyses of U.S. auto fuel economy standards

A 2018 analysis discarded at least $112 billion in benefits

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Corporate Average Fuel Economy (CAFE) and greenhouse gas (GHG) emissions standards for passenger vehicles and light trucks have long been a centerpiece of the U.S. strategy to reduce energy use and GHG emissions and increase energy security. The Energy Independence and Security Act, passed in 2007, mandated that fleet-wide fuel economy reach 35 miles per gallon (mpg) by 2020. In turn, the Environmental Protection Agency (EPA) and National Highway Traffic Safety Administration (NHTSA) jointly set GHG and CAFE standards to achieve this level by 2016 and reach a projected 27 to 55 mpg between 2012 and 2025. A 2016 draft technical assessment report (TAR) affirmed by the EPA in January 2017 concluded that the 2022–2025 standards were technologically feasible and that benefits far exceeded costs. But under the current administration, those agencies are now challenging that conclusion in a 2018 Notice of Proposed Rulemaking (NPRM), which proposes freezing standards at model year (MY) 2020 levels through 2025. Its analysis finds that the costs of the previous standards now exceed benefits. With the agencies currently in the process of determining whether the rule should be finalized, we describe how the 2018 analysis has fundamental flaws and inconsistences, is at odds with basic economic theory and empirical studies, is misleading, and does not improve estimates of costs and benefits of fuel economy standards beyond those in the 2016 analysis.

A COMPREHENSIVE PROTOCOL

A benefit-cost analysis (see table S1) for fuel economy standards grounded on basic economic principles must consider the behavior of consumers and automakers as well as keep account of several externalities (*1*). It must consider a range of parameter values and assumptions to account for inherent uncertainty as well as the impact of related policies that determine the relevant baseline against which the standards are compared.

Modeling consumer behavior should include the purchase of general goods and new or used vehicles. Consumers trade off vehicle prices for various vehicle attributes (for example, performance, safety features, seating capacity, and so on). They also decide how much to drive and whether to keep or scrap their older vehicles.

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A comprehensive analysis would allow automakers to comply with standards by adjusting vehicle prices, improving fuel economy, and altering performance and other vehicle attributes (*2*–*5*). It would also recognize that technology is determined by automaker investments, while accounting for learning-by-doing and knowledge spillovers that, over time, may lower the compliance costs.

Modeling of the interaction between new and used vehicle markets is critical, because it will determine the resulting size of the total fleet and its composition, as well as the prices of vehicles (relative to the price of other goods). Prices, fuel economy, and other attributes determine the total cost of ownership, which affects total vehicle miles traveled (VMT) as well as willingness to pay for vehicles (*1*, *6*).

A comprehensive protocol should also consider costs and benefits that arise from "external effects," including GHG emissions, energy security, local air pollution, safety, and traffic congestion (*7*), which are affected by fleet size and its composition and the total number of miles driven.

In the case of safety, four additional outcomes are relevant: changes in vehicle weights and sizes, distribution of weights and sizes in the entire fleet, distribution of vehicle vintage, and sorting of individuals into vehicles on the basis of their risk preferences, risk profiles, and preferences for other vehicle attributes (*8*–*10*).

Valuation parameters are critical for converting impacts into costs and benefits. The value of a statistical life is used to value fatalities, whereas the social cost of carbon is used for valuing the benefits of reduced gasoline use (*11*, *12*). Other valuation parameters reflect the value of energy security and the health costs of tailpipe emissions. A comprehensive protocol should also account for other factors, including changes in gasoline prices over time.

TWO FLAWED ANALYSES, ONE MORE SO

Both the 2016 and 2018 analyses deviate from the comprehensive protocol outlined above because they do not explicitly model consumer choices and tend to miss important trade-offs between general consumption, vehicle choice, and VMT. On the supply side, the modeling of the new and used car markets does not fully consider important interactions between these markets. As a consequence, multimarket adjustments, and resulting outcomes such as the size of the fleet, fleet composition, and prices of vehicles, are captured imperfectly. Incomplete accounting for such adjustments also affects the magnitudes of the external costs and benefits.

The 2018 analysis did attempt to incorporate several channels of adjustment that were missing from the 2016 TAR (see table S1, fourth column). However, the most im-

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pactful channels were added in an ad hoc way that runs afoul of the proposed protocol outlined above, existing research, and basic economic principles. As a result, the changes in the 2018 NPRM are misleading. Although we do not endorse the 2016 TAR, the 2018 analysis failed to advance our understanding of the true costs and benefits of fuel economy standards.

There are stark differences between the costs and benefits assigned to the current standards in the 2016 and 2018 analyses. The figure shows the costs and benefits from the stricter CAFE standards, relative to the proposed standards [see supplementary materials (SM) section G for GHG emissions standards]. To interpret impacts of a rollback of the standard in the context of the figure, one should change the signs of all costs and benefits. For the CAFE standard, the 2016 review finds a net benefit of $87.6 billion, whereas the 2018 analysis finds a net loss of $176.2 billion; for the GHG emissions standard, the 2016 review finds a net benefit of $97.2 billion, whereas the 2018 analysis finds a net loss of $200.6 billion (see the SM for further details).

The 2018 analysis reports benefits that are roughly twice as high as those in the 2016 analysis, primarily from benefits owing to lower driving costs that increase miles traveled that consumers value (that is, the rebound effect). The 2018 analysis doubles the magnitude of the rebound effect despite recent literature estimating smaller rebound effects (see the SM for further details). Whereas in the NPRM analysis, the higher rebound effect hardly affects net benefits—as additional benefits from avoided car crashes under the rollback are offset by lost benefits from reduced VMT—it doubles the resulting number of avoided fatalities generated by this effect, contributing to a total of 12,700 lives. The assumption regarding the higher rebound effect may lead to unfounded concerns about the unintended safety consequences of the current standards.

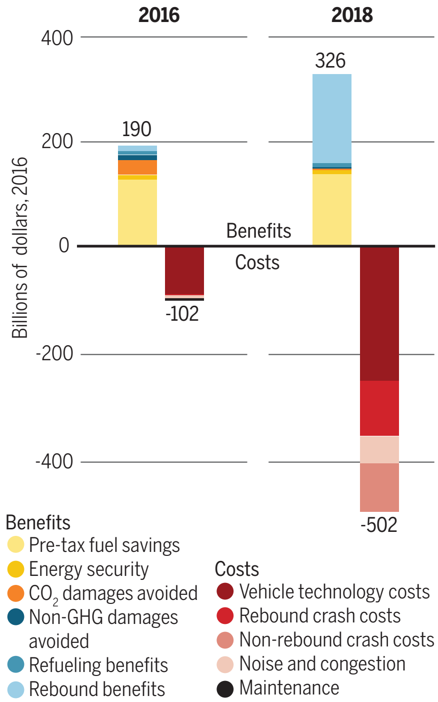
Accounting only for domestic benefits from reducing carbon emissions (ignoring international benefits) scaled down the social cost of carbon from $48 per ton to $7 per ton, reducing GHG benefits from $27.8 billion in 2016 to $4.3 billion in 2018. A more minor difference is that the analyses make slightly different assumptions about the extent to which consumers value future fuel savings from driving a more fuel-efficient car (see SM section C for further discussion of the impact on net benefits).

SIX MILLION MISSING USED CARS

A central difference between the 2016 and 2018 reports is the projection of the total fleet size of cars and light-duty trucks. Economic

2016 and 2018 benefit-cost analyses of CAFE standards

Stark differences between the 2016 and 2018 estimates reflect fundamental flaws and inconsistencies in the 2018 analysis. See supplemental materials.



theory predicts that tighter standards make new vehicles more expensive, on average. This also translates into more expensive used vehicles, on average, because they are substitutes for new vehicles (*6*). As a consequence, as standards increase vehicle prices, total fleet size should decrease over time. Conversely, a rollback should lead to increased demand for vehicles, resulting in a larger fleet that will be newer, on average.

By contrast, the 2018 proposal argues that the rollback in standards will shrink the overall fleet by 6 million vehicles in the year 2029, compared with the current standards. This is inconsistent with basic economic principles. If prices of vehicles decrease (relative to other general-purpose goods), we expect more individuals to purchase vehicles and drive them rather than use other modes of travel. The 2018 NPRM analysis reaches the opposite conclusion based on ad hoc integration of a newly developed vehicle scrappage model with the NHTSA's Volpe model (the CAFE Compliance and Effects Modeling System).

We have identified two major shortcomings of this approach. First, this newly developed model departs substantially from state-of-the-art vehicle scrappage models (*6*, *13*) (see the SM for further details). Second, in relation to the comprehensive framework, the 2018 NPRM does not account for changes in used vehicle prices that result from interactions between new and used car markets as a result of the standard (see the SM for additional discussion). As a result, this new model violates simple economic principles; leads to misleading conclusions related to the overall size of the fleet, fleet composition, and the amount of scrappage; and undermines EPA and NHTSA modeling efforts to improve the understanding of the costs and benefits of fuel economy standards.

These 6 million "missing" vehicles have important implications. A larger fleet leads to higher miles driven, gasoline use, and external costs. Total driving, excluding the rebound effect, should increase (as opposed to decrease) with the rollback relative to keeping the previous standards. Driving scales with fleet size, and newer cars are driven more. As VMT increases, gasoline consumption and the external effects of GHG emissions, local air pollution, traffic fatalities, congestion, and energy security of the rollback will be larger than reported in the 2018 analysis, potentially by considerable amounts.

Crash fatalities and injuries can increase (as opposed to decrease) with the rollback. The 2018 analysis concludes that the rollback will result in a $90.7 billion gain from reduced fatalities and property damages, a result driven almost exclusively by a 2.4% reduction in fleet-wide VMT (changes in fleet composition play a minor role in the 2018 analysis). If we hold fleet size fixed (adding back the missing 6 million used cars), this $90.7 billion gain is likely to fall to near zero. This is a conservative calculation and should be interpreted as a lower bound, because we anticipate that rollback would cause the fleet to grow, possibly driving this term below zero (see the SM for further details).

COMPLIANCE COST INCONSISTENCIES

The EPA and NHTSA estimate costs of hundreds of different fuel-saving technologies and model how manufacturers will add these technologies and combinations of technologies using least-cost algorithms. For the 2016 TAR analysis, the estimates of costs by the EPA for GHG standards are less than half of the costs for the same rule estimated by the NHTSA for CAFE standards. This is in part because the EPA assumes that California and other states' Zero Emission Vehicle (ZEV) mandate will be in place in future years. With many electric vehicles already in the fleet, the incremental cost of meeting the higher fuel economy standards of the federal rule is considerably lower. The NHTSA implicitly assumes that there is no ZEV mandate, which leads to higher calculated costs. The 2018 NPRM does the same.

For a clearer comparison of technology costs, we focus on differences in the NHTSA's

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estimates of costs in the 2016 and 2018 analyses (see the figure). According to the NHTSA, the 2018 costs are more than two times higher than the earlier TAR costs. Some of the cost differences are a result of plausible changes in economic conditions, such as an increase in future new vehicle sales owing to higher income growth and lower gasoline prices. Another important difference, however, is due to the fact that the agencies changed the model years affected by the standards in the 2018 analysis. In the 2016 analysis, the costs of the MY 2022–2025 standards are assessed relative to a baseline fixed at MY 2021 levels. By contrast, the 2018 NPRM argues that the standards should be frozen a year earlier and compares the costs of meeting the existing standards for MY 2021–2025 relative to standards fixed at the MY 2020 level. The agencies claim that the previous standards are no longer feasible and appropriate, but they do not even examine the technology costs for this change in the standards in the 2018 assessment of alternatives. We can show, however, that this change accounts for roughly 12% of the difference in costs for the 2016 and 2018 standards (see the figure; for more discussion of this point, see the SM].

Notwithstanding these differences, we still find that reported per-vehicle costs with the GHG emissions standards are about 80 to 150% higher for MY 2022–2025 vehicles in the 2018 proposal than in the 2016 NHTSA analysis (see fig. S3 for details). In addition to the difference in model years being regulated, four other main factors account for these cost differences.

First, automakers can comply with the regulations by transferring fuel economy "credits" between their passenger car fleet and their light-truck fleet, so that if one fleet overcomplies with the regulations, the other can undercomply within some limit. Credit transferring is also possible across years, so that if an automaker exceeds fuel economy performance in one year, it can meet a less stringent standard in another year. But these flexibilities were not included in the 2018 analysis for MY 2021–2025 (although credit transferring was possible from years before 2021), raising the estimated costs. The NHTSA is currently prohibited by statute from considering all of these flexibilities in their cost analysis of proposed rules. By contrast, neither the NHTSA nor the EPA was subject to this restriction in the 2016 analyses.

Second, the 2018 analysis removed some projected future technology options that were considered in the 2016 analysis (for example, Atkinson engines with cylinder deactivation and exhaust recirculation). Omitting these projected lower-cost options, the 2018 analysis predicts that a substantially higher deployment of more-expensive technologies is necessary to meet the standards: 24% of vehicles in the 2018 analysis are projected to be strong hybrids by MY 2025, whereas only 2.6% are in the 2016 analysis.

Third, the analysis assumes that longer time periods are required to redesign many vehicles to meet the standards in a given year, requiring manufacturers to add fuel-saving technologies earlier, thereby incurring higher costs for more years.

Fourth, the specified costs for electrified vehicles are considerably higher (20 to 50%) than in the 2016 analysis owing to different battery assumptions (for example, electrode thickness limited to 100 microns) and including additional vehicle electrification components (for example, liquid cooling systems) recommended by the National Academies (*14*).

In summary, although some of the changes in technology assumptions in the 2018 analysis are plausible, overall it uses pessimistic assumptions of future technology availability and performance compared with the 2016 analysis.

SAFETY VALVE INSTEAD OF ROLLBACK

We conclude that the 2018 analysis has several fundamental flaws and inconsistencies. In addition to the points we have raised, others have articulated why a global, rather than a domestic, social cost of carbon is the appropriate parameter to value GHG emissions reductions (*11*, *12*), and we agree. Using a global estimate of the social cost of carbon and the correct impact of changes to total fleet size reduces the net benefits of the rollback for the CAFE standard (from $176 billion to $64 billion). Or, in other words, at least $112 billion was discarded in the 2018 analysis. Furthermore, of this, at least $88.3 billion comes from accounting for the missing 6 million cars. For the rollback to have negative net benefits, one only needs to reduce the 2018 technology costs by 26%, which still doubles the costs from the 2016 analysis; using the technology costs from the 2016 analysis implies that the standard will have large positive net benefits. In general, these conclusions also apply to the GHG emissions standard (see the SM for further details).

Under any scenario, the case for a rollback could be made if compliance costs are sufficiently high, but both the 2016 TAR and 2018 NPRM have likely overestimated compliance costs. Neither analysis considers the full extent of options that manufacturers have available to respond to these policies, including changes in vehicle prices, performance, and other attributes. Relative to the 2016 TAR, the 2018 NPRM seems to compound this mistake, leading to greater overestimates of compliance cost by not accounting for the full extent of banking and borrowing credits and by using pessimistic assumptions regarding technology costs.

Given the substantial departure from a comprehensive protocol for benefit-cost analysis, we cannot conclude that the rollback will produce welfare gains, and we instead predict that it will result in unintended consequences. For example, in anticipation of higher standards, automakers accumulated CAFE credits, which they intended to use in the future as a strategy for lowering compliance costs. A rollback of the standard would lead to a de facto devaluation of these credits, penalizing automakers who have been leaders in technological innovation.

Furthermore, economic theory predicts that, for the same level of standard, costs of compliance decline as a result of learning-by-doing and spillover benefits from technology development across automakers. Therefore, we see no economic justification to keep the standard flat from 2020 to 2025, even ignoring the external societal benefits of the standard. Instead, standards should increase over time in stable and predictable ways.

We certainly recognize the inherent uncertainty in estimating costs of compliance through technologies, but we recommend the introduction of a safety valve to address this concern, rather than a rollback. Safety valves, common in cap-and-trade programs, allow firms to purchase compliance credits at a predetermined price, effectively capping compliance costs and allowing for less technology improvement if it turns out to be highly expensive (*15*). A rollback is an unnecessarily blunt way to achieve the same goal and introduces regulatory uncertainty into an industry that needs to make long-run technological investments for the future. ■

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SUPPLEMENTARY MATERIALS

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