Policy Brief

The Rebound Effect and the Proposed Rollback of U.S. Fuel Economy Standards

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Introduction

In August 2018, the Trump administration proposed a rollback of U.S. fuel economy standards. The existing rule, which was finalized in 2012 and affirmed in a Draft Technical Assessment Report in 2016 (EPA/DOT/CARB 2016), was set to substantially tighten standards through 2025, while the proposed rule freezes the standards at 2020 levels through 2026 (DOT/EPA 2018). The legal and political argument for the proposed rule was based on an analysis indicating that rolling back the fuel economy standards would reduce crash fatalities by 12,700 lives over the lifetime of vehicles through model year 2029. A key assumption underpinning this argument is a doubling of the "rebound effect" of fuel economy standards, from 10 percent to 20 percent.[1] In the analysis for the proposed rule, conducted by the U.S. Environmental Protection Agency (EPA) and U.S. Department of Transportation (DOT) (henceforth, the "agencies"), the rebound effect is defined as the percentage increase in driving that occurs when vehicles become more efficient and thus have a lower cost per mile of driving (EPA/DOT 2018). However, the rebound effect is often defined more broadly in the literature as an estimate of the market and behavioral responses to an energy efficiency policy that may reduce the energy savings from the policy (Gillingham, Rapson, and Wagner 2016).

Based on the agencies' 2018 analysis, using a 10 percent rebound effect (instead of 20 percent) would reduce by approximately one-third the 12,700 lives the Trump administration argues would be saved by the rollback. Interestingly, the higher rebound effect has a very small effect on the benefit–cost analysis.[2] Thus it is of primary importance for making

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[1]In this context, a 10 percent rebound implies that there is an increase in fuel use (due to increased driving) that results in 10 percent of the fuel savings from the improved fuel economy being consumed; this means that only 90 percent of the reduction in fuel savings would actually occur.
[2]This is because in both the 2016 and 2018 analyses, the agencies assume that the welfare losses due to increased fatalities are exactly offset by the consumer surplus benefits of additional driving, and that all other welfare changes are also close to offsetting.

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the legal and political argument, rather than the economic argument, for the 2018 proposed rule.

This article seeks to provide guidance to policymakers on the rebound effect of fuel economy standards by reviewing the recent literature on the rebound effect in the United States and assessing the proposed doubling of the central estimate to 20 percent. I find that the recent literature on the fuel price/fuel economy elasticity of driving tends to point to an estimate of around −0.1, which corresponds to a 10 percent rebound effect. I also discuss key factors that should be considered in the choice of a rebound effect in this context—some of which are specific to fuel economy standards and most of which are areas where future research is warranted.

Recent Literature Concerning the Rebound Effect of Fuel Economy Standards

Economists have long used estimates of fuel price elasticities to quantify the direct behavioral response of drivers to the lower cost per mile of driving that results from fuel economy standards (often referred to as the *direct* rebound effect) (Gillingham, Rapson, and Wagner 2016). In the past decade there has been a substantial increase in the number of studies estimating the fuel price elasticity of driving. Some of these studies examine the relationship between the fuel price and driving decisions, others examine the relationship between the cost per mile of driving (the fuel price divided by the fuel economy) and driving decisions, and only a few directly examine the relationship between the *fuel economy* of the vehicle and driving, largely because of the difficulty in finding plausibly exogenous sources of variation in fuel economy. In order to use the relationship between the fuel price and driving to estimate the rebound effect of fuel economy standards, one must implicitly assume that consumers respond to reduced fuel prices in the same way that they respond to improved fuel economy, because both changes reduce the cost per mile of driving. This assumption is often ignored in the literature.

The most recent literature tends to be based on either survey data, largely from the National Household Transportation Survey, or odometer reading data from state vehicle inspection programs. Odometer readings allow for improved estimation strategies, are often considered to be more reliable because they are measured rather than self-reported, and may be more representative by covering nearly the entire light duty fleet in a region. In the 2018 proposed rule, the agencies argue that odometer reading data are the most reliable data when they discuss the relationship between vehicle miles traveled and vehicle age, but they do not make this argument in their discussion of the rebound effect and indeed rely heavily on estimates based on survey data.

Approach to the Literature Review

To provide guidance to policymakers, I reviewed the literature providing the best evidence available for a central estimate of the rebound effect of U.S. fuel economy standards. I considered publicly available U.S.-based literature from the past decade. This review differs from the discussion in the proposed rulemaking in several ways. First, it excludes estimates from outside of the United States, particularly from Europe, as consumer behavior has been shown to be different in Europe because of differences in public transportation access and the configuration of urban areas and public transportation access (Gillingham and Munk-Nielsen 2019). Second, this review excludes estimates from unpublished work that is not publicly available or work that estimates something other than the rebound effect. Third, I excluded estimates that the study authors argue are inappropriate for using as an estimate of the rebound effect.[3] It is important to note that although the 2018 proposed rule states that it reports all long-run elasticity estimates, in fact, it is more accurate to interpret most estimates as short-run or medium-run responses (e.g., a response within 2 years).[4]

Estimates of the Rebound Effect Relevant to U.S. Fuel Economy Standards

The findings of the review are presented in table 1, which lists the studies, including their data sources and rebound estimates. A few findings are clear from table 1, which together cast doubt on the argument for a central estimate of 20 percent for the rebound effect of fuel economy standards. First, there is a relatively wide range of estimates, with studies using survey data tending to have much higher estimates of the rebound effect than those using odometer reading data, which should be given more weight in the choice of the central rebound effect. Second, while simple averages across studies should be interpreted with caution (due to differences in regions, time periods, and methodologies), the average across all studies is 14.1 percent, and the average across studies using the more reliable odometer readings is 8.1 percent. Third, the studies in boldface in table 1 were *not* included in the 2018 proposed rule; in general, these studies not only tend to use odometer readings, but also tend to show smaller rebound effects than those included in the 2018 proposed rule. Indeed, it is by excluding these studies in boldface, weighting studies based on surveys equally with studies based on odometer readings, and including international studies that the agencies are able to argue for a 20 percent rebound.

Additional Factors to Consider in the Choice of the Rebound Effect

The estimates in table 1 form the core of the evidence base for providing guidance on the rebound effect of fuel economy standards. However, the actual rebound effect may be influenced by other factors that are not necessarily reflected in the estimates. More specifically, the ideal estimate of the rebound effect should quantify the consumer response (in terms of the amount driven) to *all* of the changes that occur due to the standards: higher fuel economy vehicles, higher priced vehicles, and vehicles with different attributes such as turbochargers or different aerodynamics (some of which are valued by consumers). Moreover, for policy analysis, we are interested in both the short-run rebound effect and the long-run rebound effect, which accounts for all longer-term adjustments by consumers (e.g., if it is less

[3]For example, Gillingham (2014) examines the response to the 2008 gasoline price shock, an unusual period when gasoline prices were particularly salient to consumers, and thus I excluded this study from my review.

[4]Only two studies claim to provide a long-run rebound effect: Hymel et al. (2010) and Hymel & Small (2015). In table 1, I present the long-run estimates from these studies. The short-run estimates in both studies are near-zero. It is important to note that estimates based on survey data from a single year primarily use variation in gasoline prices over time within that year. Thus it would be inaccurate to refer to these as long-run estimates.

Table 1. Summary of studies presenting the best evidence available for a central estimate of the rebound effect for U.S. fuel economy standards (studies in **boldface** were *not* included in the 2018 proposed rule)

Study	Data	Rebound estimate (%)
Bento et al. (2009)	2001 survey	34[a]
Hymel, Small, and Van Dender (2010)	**State level, 1966–2004**	**9[b]**
Gillingham (2011)	**Odometer, California 2001–2009**	**1**
Greene (2012)	**Aggregate, 1966–2007**	**0**
Su (2012)	2009 survey	11–19
Liu, Tremblay, and Cirillo (2014)	2009 survey, Maryland/DC/Virginia	40
Gillingham, Jenn, and Azevedo (2015)	**Odometer, Pennsylvania 2000–2010**	**10**
Hymel and Small (2015)	State level, 1966–2004	4–18[c]
Leung (2015)	**2009 survey**	**10**
Linn (2016)	2009 survey	20–40
Langer, Maheshri, and Winston (2017)	**Odometer, Ohio 2009–2013**	**11**
West et al. (2017)	Odometer, Texas 2010–2011	0
Knittel and Sandler (2018)	**Odometer, California 1998–2010**	**14.7**
Wenzel and Fujita (2018)	**Odometer, Texas 2005–2010**	**7.5–15.9[d]**

Notes: All of the estimates reported are vehicle miles traveled (VMT) elasticities with respect to the gasoline price or cost per mile of driving with the exception of Gillingham (2011), Greene (2012), and West et al. (2017), which are elasticities with respect to fuel economy. This table converts these elasticity estimates to percentage rebound effects. The following papers are excluded from this table but referenced in the 2018 proposed rule: Wadud, Graham, and Noland (2009), which estimates an elasticity of gasoline consumption; Gillingham (2014), which focuses on a single gasoline price shock; and West and Pickrell (2011), which is not a publicly available study. The 2018 proposed rule incorrectly references Linn (2016) as Linn (2013). Knittel and Sandler (2018) has been available as a working paper since 2013, and Wenzel and Fujita (2018) was reviewed by analysts at the agencies and was published in March 2018, prior to the release of the proposed rule.

[a]The authors present the average VMT elasticity with respect to the price of gasoline as −0.34 (p. 685), which implies a 34 percent rebound. The 2018 proposed rule reports a range of 21–38 percent, but it is unclear where this range comes from.

[b]Estimate was taken from the authors' preferred estimate in the conclusion (p. 1235), with the calculation of variables at 2004 values, but a variety of other estimates were reported.

[c]Estimates are from the authors' preferred estimates in Hymel and Small (2015, table 8). The 2018 proposed rule chooses only the high estimate.

[d]This range is based on a conversation with the authors, who suggest considering both the estimate based on fuel prices and the estimate based on the cost per mile in order to be consistent with the rest of the literature, which uses both.

expensive to commute, some households may choose to live further away in the long run). The discussion that follows identifies several important factors in the choice of the rebound effect that should be considered when relying upon the estimates in table 1.

Changes in Fuel Economy versus Changes in Fuel Prices

First, consumers may respond differently to changes in fuel economy than to changes in fuel prices. For instance, several studies suggest that the response to fuel economy may be less than the response to fuel prices, which implies that the estimates presented in table 1 *overestimate* the rebound effect (Gillingham 2011; Greene 2012; De Borger, Mulalic, and Rouwendal 2016; West et al. 2017). One explanation for the stronger response to fuel prices is that gasoline prices are more visible and thus more salient to consumers. In contrast, Linn (2016) provides evidence suggesting that the response to fuel economy may actually be greater than the response to fuel prices, which implies an *underestimate* of the rebound effect. A possible reason for this finding is that changes in fuel economy are more permanent than fuel price changes. More generally, the strength of the response to fuel economy versus fuel prices may depend on the specific circumstances.

Long-run Response to Fuel Economy Standards

Second, there is likely to be a larger response to fuel economy standards in the long run. Because the estimates in table 1 are mostly short or medium run, they are appropriate for policy analysis for the first few years of the policy, but they likely *underestimate* the rebound effect in the long run. Unfortunately it is extremely difficult to estimate long-run effects. However, the limited evidence available suggests that long-run rebound effects are only modestly larger than short-run effects (e.g., Hymel and Small 2015), suggesting that the estimates in table 1 are fairly close to the mark.

Incomes Growing Over Time

Third, as households become wealthier and roads become more congested, the time value of driving becomes more important than the cost of fuel (Small and Van Dender 2007; Hymel, Small, and Van Dender 2010; Hymel and Small 2015). This suggests that the studies in table 1 may provide useful guidance for today but generally *overestimate* the rebound effect in the future.

Changes in Other Attributes

Fourth, fuel economy will change along with a bundle of attributes (e.g., horsepower, weight), and some of these changes may mean that driving will become less appealing. West et al. (2017) show that drivers induced to buy higher fuel economy vehicles that are lower performing do not drive any more than they had previously. This implies that with the exception of West et al. (2017), the studies in the literature *overestimate* the rebound effect.

Effect of Increased Vehicle Prices

Fifth, if fuel economy standards are met by adding costly technology to vehicles, then vehicle prices may increase, reducing the budget available for driving. Again, this would imply that the studies in table 1 *overestimate* the rebound. Similarly, there may be an indirect rebound effect whereby money saved at the pump by higher fuel economy vehicles may be diverted to other uses that use fuel and create emissions, while the additional money spent on more expensive vehicles may divert money away from these other uses. The net effect could be positive or negative (Borenstein 2015; Gillingham, Rapson, and Wagner 2016); Fullerton and Ta (2018) argue that in general equilibrium the effect could easily be negative. Importantly, although this indirect effect could influence emissions, it would not influence driving, and thus would not change the rebound effect that influences additional crash fatalities.

Macroeconomic Rebound Effect

Finally, there may be a *macro*economic rebound effect if fuel economy standards reduce the global demand for oil, thus lowering the global oil price and leading to more consumption globally in equilibrium (and possibly influencing the direction of innovation). The net effect may be to reduce or increase global emissions, but it is usually expected to increase global emissions (Gillingham, Rapson, and Wagner 2016), which implies that the studies in table 1 *underestimate* the rebound.

Summing Up

The magnitudes of these additional factors are quite uncertain, which means these factors increase the uncertainty bounds around any central estimate of the rebound effect. However, the key point for interpretation is that these factors do not consistently point in one direction—a roughly equal number suggest an upward bias of the literature as suggest a downward bias. Thus, given the current state of evidence, it would be difficult to argue for a higher or lower central rebound effect based on these factors. It is important to note that the 2018 proposed rule does not rely on any of these factors as a rationale for its decision to assume a 20 percent rebound effect.

Concluding Remarks

Although the assumed 20 percent rebound effect plays a major role in the justification of the proposed rollback of fuel economy standards, a review of the most recent literature suggests that this choice is not justified as a central estimate. Indeed, the current evidence points to an estimate on the order of 10 percent. However, it also reveals the wide range of values in the literature, underscoring the uncertainty in the value chosen. Moreover, the review identifies multiple additional factors that influence the rebound effect that are poorly understood and work in opposing directions. This leads to the surprising conclusion that, despite the large amount of literature on the rebound effect, there is still substantial uncertainty concerning the rebound effect in the case of fuel economy standards as well as many issues that require further research, especially those related to the additional factors. The agencies are required to choose a central case estimate that is based on the best evidence available, but the large uncertainty around any central estimate necessitates careful sensitivity analysis.

References

Bento, A., L. Goulder, M. Jacobsen, R. von Haefen. 2009. Distributional and efficiency impacts of increased U.S. gasoline taxes. *American Economic Review* 99:667–99.

Borenstein, S. 2015. A microeconomic framework for evaluating energy efficiency rebound and some implications. *Energy Journal* 36:1–21.

De Borger, B., I. Mulalic, and J. Rouwendal. 2016. Measuring the rebound effect with micro data: a first-difference approach. *Journal of Environmental Economics & Management* 79:1–17.

DOT/EPA. 2018. Notice of proposed rulemaking: the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for model years 2021–2026 passenger cars and light trucks. *Federal Register* 83(165):42986–43500. https://www.govinfo.gov/content/pkg/FR-2018-08-24/pdf/2018-16820.pdf.

EPA/DOT/CARB. 2016. Draft technical assessment report: midterm evaluation of light-duty vehicle greenhouse gas emission standards and corporate average fuel economy standards for model years 2022–2025. EPA-420-D-16-900. U.S. Environmental Protection Agency, U.S. Department of Transportation, California Air Resources Board. https://nepis.epa.gov/Exe/ZyPDF.cgi/P100OXEO.PDF?Dockey=P100OXEO.PDF.

Fullerton, D., and C. Ta. 2018. Costs of energy efficiency mandates can reverse the sign of rebound. Working Paper, University of Illinois at Urbana-Champaign. https://works.bepress.com/don_fullerton/81/download/.

Gillingham, K. 2011. The consumer response to gasoline prices: empirical evidence and policy implications. PhD dissertation, Stanford University. https://stacks.stanford.edu/file/druid:wz808zn3318/Gillingham_Dissertation-augmented.pdf.

———. 2014. Identifying the elasticity of driving: evidence from a gasoline price shock in California. *Regional Science and Urban Economics* 47:13–24.

Gillingham, K., A. Jenn, and I. Azevedo. 2015. Heterogeneity in the response to gasoline prices: evidence from Pennsylvania and implications for the rebound effect. *Energy Economics* 52(Suppl 1):S41–52.

Gillingham, K., and A. Munk-Nielsen. 2019. A tale of two tails: commuting and the fuel price response in driving. *Journal of Urban Economics* 109:27–40.

Gillingham, K., D. Rapson, and G. Wagner. 2016. The rebound effect and energy efficiency policy. *Review of Environmental Economics & Policy* 10:68–88.

Greene, D. 2012. Rebound 2007: analysis of U.S. light-duty vehicle travel statistics. *Energy Policy* 41:14–28.

Hymel, K., and K. Small. 2015. The rebound effect for automobile travel: asymmetric response to price changes and novel features of the 2000s. *Energy Economics* 49:93–103.

Hymel, K., K. Small, and K. Van Dender. 2010. Induced demand and rebound effects in road transport. *Transportation Research B* 44:1220–41.

Knittel, C., and R. Sandler. 2018. The welfare impact of second-best uniform-Pigouvian taxation: evidence from transportation. *American Economic Journal: Economic Policy* 10:211–42.

Langer, A., V. Maheshri, and C. Winston. 2017. From gallons to miles: a disaggregate analysis of automobile travel and externality taxes. *Journal of Public Economics* 152:34–46.

Leung, W. 2015. Three essays in energy economics. PhD dissertation, University of California, San Diego. https://escholarship.org/content/qt3h51364m/qt3h51364m.pdf.

Linn, J. 2016. The rebound effect for passenger vehicles. *Energy Journal* 37:257–88.

Liu, Y., J.-M. Tremblay, and C. Cirillo. 2014. An integrated model for discrete and continuous decisions with application to vehicle ownership, type and usage choices. *Transportation Research A* 69:315–28.

Small, K., and K. Van Dender. 2007. Fuel efficiency and motor vehicle travel: the declining rebound effect. *Energy Journal* 28:25–51.

Su, Q. 2012. A quantile regression analysis of the rebound effect: evidence from the 2009 National Household Transportation Survey in the United States. *Energy Policy* 45:368–77.

Wadud, Z., D. Graham, and R. Noland. 2009. Modelling fuel demand for different socio-economic groups. *Applied Energy* 86:2740–49.

West, R., D. Pickrell. 2011. Factors Affecting Vehicle Use in Multiple-Vehicle Households. U.S. Department of Transportation Working Paper.

West, J., M. Hoekstra, J. Meer, and S. Puller. 2017. Vehicle miles (not) traveled: fuel economy requirements, vehicle characteristics, and household driving. *Journal of Public Economics* 145:65–81.

Wenzel, T., and K. Fujita. 2018. Elasticity of vehicle miles of travel to changes in the price of gasoline and the cost of driving in Texas. LBNL-2001138. https://eln.lbl.gov/publications/elasticity-vehicle-miles-travel.