RESPONSE TO COMMENTS ON NERA/TRINITY REPORT (*EVALUATION OF ALTERNATIVE PASSENGER CAR AND LIGHT TRUCK CORPORATE AVERAGE FUEL ECONOMY (CAFE) STANDARDS FOR MODEL YEARS 2021-2026*)

April 10, 2019

This document provides responses to three sets of comments on the NERA/Trinity report prepared for the Alliance of Automobile Manufacturers ("Evaluation of Alternative Passenger Car and Light Truck Corporate Average Fuel Economy (CAFE) Standards for Model Years 2021-2026," dated October 26, 2018): (1) comments prepared by the Institute for Policy Integrity, New York University School of Law, dated December 21, 2018 (subsequently "IPI" or "IPI comments;" (2) comments prepared by a group of non-governmental organizations, dated December 20, 2018 (subsequently "NGO" or "NGO comments"); and (3) comments prepared by the California Air Resources Board, dated December 19, 2018 (subsequently "CARB" or "CARB comments"). Full references are provided in Section F (References). Rather than provide point-by-point responses, this document provides responses to the following five principal issues raised in the three sets of comments.[1]

1. *Modeling of the new vehicle market model*. This issue relates to the "nested logit" model developed by NERA to assess new vehicle consumer choice and develop estimates of the value consumers place on fuel economy changes.

2. *Modeling of scrappage effects*. This issue relates to the empirical model that NERA developed to estimate the effects of changes in new vehicle prices on scrappage rates for existing vehicles.

3. *Modeling of changes in vehicle miles of travel ("VMT") due to the rebound effect*. This issue relates to NERA's assessment of the literature on estimates of the "rebound effect" and the determination of an appropriate value to use in the analysis.

4. *Baseline fuel economy*. This issue relates to the methods used by NERA and Trinity to develop estimates of the fuel economy trajectory for passenger cars and light trucks that would occur if no change were made in the CAFE standards beyond model year (MY) 2020, i.e., the baseline fuel economy.

[1] As noted in the NERA/Trinity Report, the NERA/Trinity analysis directly evaluates the stringency range of CAFE standards considered by NHTSA and EPA. Note that NHTSA and EPA also evaluated carbon dioxide ("CO_2") emissions standards for the same model years. We estimate effects of the alternative CAFE standards and do not develop separate estimates for alternative CO_2 standards. Since the two sets of standards are harmonized, however, our comparative results for the alternative CAFE standards in the NERA/Trinity Report should apply to the equivalent CO_2 standards (although the specific estimates would differ). Analogously, this response to comments regarding our modeling of CAFE standards would also apply to the equivalent CO_2 standards.

5. *Valuation of fuel economy gains*. This issue relates to the method NERA used to estimate the dollar value of fuel economy gains to consumers due to alternative CAFE standards.

For each of these issues, we provide the following information: (a) an overview of the treatment of the issue in the NERA/Trinity report to provide context; (b) a summary of the IPI, NGO, and/or CARB criticisms; (c) our responses to these criticisms; and (d) a summary of our conclusions.

A. Modeling of New Vehicle Market

Modeling effects on the new vehicle market model is a critical component of any analysis of the effects of alternative CAFE standards.

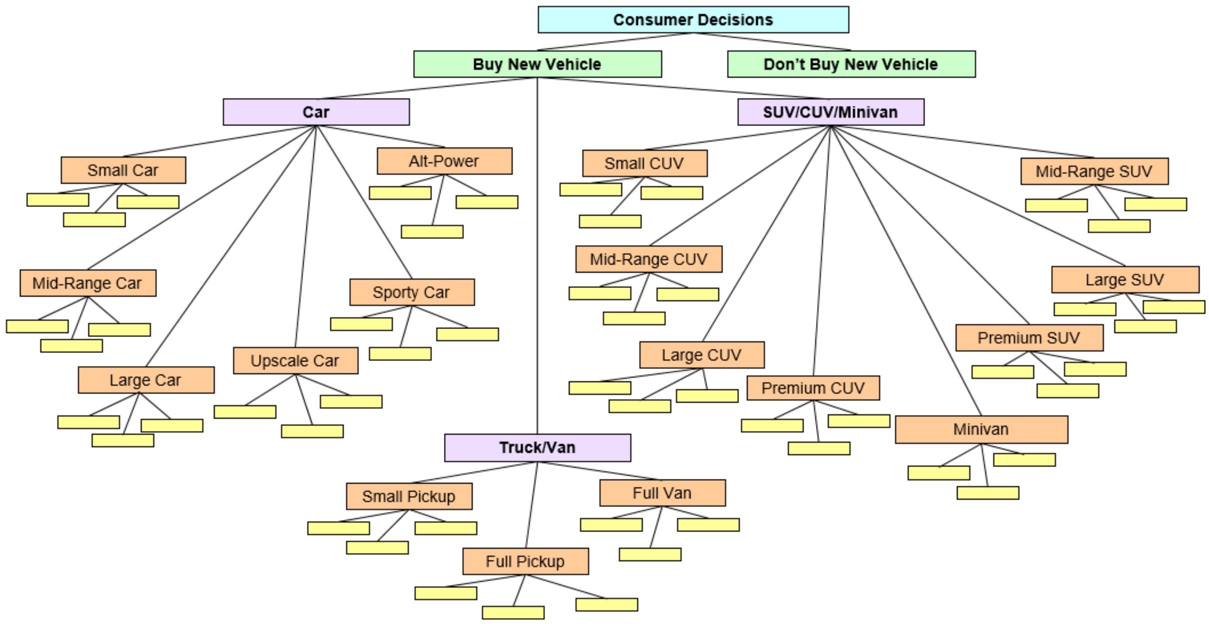
1. Overview of NERA New Vehicle Market Model

NERA developed the New Vehicle Market Model, a model of the U.S. market for new passenger cars and light trucks that we use to analyze the effects of alternative CAFE standards on new vehicle sales and prices. The New Vehicle Market Model has the structure of a nested logit model, a formulation that has been used extensively by economists to characterize motor vehicle markets.[2] Figure 1 shows the detailed nesting structure in our model. We divide the choice problem first into the decision of whether to buy a new vehicle. Conditional upon the choice to purchase a new vehicle, consumers choose the vehicle type—in this case, passenger cars; pickup trucks or full-size vans; and SUVs, CUVs, or minivans. Conditional on the choice of vehicle type, consumers choose the vehicle class—for example, small cars or mid-range cars (among others) in the passenger-car group. Conditional on the vehicle class (e.g., mid-range car, small SUV, etc.), consumers choose one of the individual vehicle models available. The bottom level of the nesting structure includes 296 vehicle models from which consumers may choose.

When using the New Vehicle Market Model to forecast the effects of alternative CAFE standards on new vehicle sales, we integrate strategic pricing responses from manufacturers. That is, vehicle prices and sales adjust to account not only for increased costs of production (from adoption of fuel efficiency-enhancing technologies), but also for the profit-maximizing incentives of multi-product vehicle manufacturers. In particular, the market shares of a manufacturers' vehicle offerings, as well as the own- and cross-price elasticities of demand for those vehicles, affect how prices and sales respond to changes in production costs. The details of this feature of the New Vehicle Market Model are discussed in more detail below.

[2] See, e.g., Bunch et al. (2011); Harrison et al. (2008); Greene et al. (2005); Train (1986); and Ben Akiva and Lerman (1985).

Figure 1. Nesting Structure for New Vehicle Market Model



The model is calibrated and estimated using detailed data on transaction prices and other vehicle characteristics for the almost 300 individual models for vehicles in model year (MY) 2013 to MY 2017. We use the New Vehicle Market Model—along with information on the costs and fuel economy implications—to estimate the effects of alternative CAFE standards on new vehicle prices and sales. Importantly, the New Vehicle Market Model allows us to estimate the value that new vehicle purchasers place on fuel economy improvements based upon observed market behavior. The model also allows us to calculate net price increases for new vehicles—i.e., price increases net of the value that new vehicle purchasers place on fuel economy changes—due to the alternative CAFE standards.

The New Vehicle Market Model is an improvement over using *ad hoc* approaches that do not have empirical verification. These *ad hoc* approaches typically use an arbitrary assumption about the number of years of potential fuel savings that new vehicle purchasers use to calculate potential fuel savings, often referred to as the "payback period." As discussed below, we need to calculate a payback period to implement the CAFE model, but this payback period is based upon empirically-validated estimates of consumer valuation rather than an arbitrary assumed value.

Appendix B of the NERA/Trinity report provides a detailed description of the data and statistical methodologies used to develop the New Vehicle Market Model. Appendix B also provides the results of the model's estimation of consumer willingness-to-pay for fuel economy improvements. We will also provide backup files for the modeling and the data we use, with the exception of data we have purchased from private vendors in which our purchase agreement precludes such distribution; these other data are available for purchase from these vendors.

2. *Overview of Critiques*

IPI and NGO appear to have two major criticisms of the New Vehicle Market Model. First, they claim that the U.S. Environmental Protection Agency ("EPA") and the National Highway Traffic Safety Administration ("NHTSA") (collectively, "the Agencies") have been reluctant to use a consumer choice model and argue that such reluctance represents a reason not to use such a model. Second, both comments claim that the model fails to account for manufacturer decision-making in its predictions of the effects of alternative CAFE standards on new vehicle sales and prices. Importantly, neither of the two sets of comments provide any alternative means of developing estimates of the potential effects of alternative CAFE standards on new vehicle sales or on the value that consumers place on fuel economy improvements.[3]

The following are excerpts from the two comments that illustrate these two criticisms.

> NERA/Trinity use an untested "nested logit" consumer choice model. But that model suffers from several flaws, many of which have caused the agencies to reject use of such models in the past. The economics literature has found that consumer choice models, and particularly nested logit models, are ill-suited to predict consumer purchasing behavior because they fail to account for manufacturer decisions. (IPI 2018a, pp. 2-3)

> In the current NPRM, the Agencies continue to note the uncertainty regarding sales impacts of the standards. Further, they point out that if one were to use a consumer choice model (like what [*sic*] NERA/Trinity have used) to predict sales impacts of the standards, "it would be necessary to include additional relationships about…how manufacturers might strategically price these modified vehicles. This requires a strategic pricing model, which each manufacturer has and would likely be unwilling to share." 83 Fed. Reg. at 43,076-077. (NGO 2018, p. A3)

3. *Responses to Critiques*

We consider the criticisms raised by IPI and NGO related to the New Vehicle Market Model, specifically the following two claims:

- Agencies' lack of a consumer choice model in their analysis is evidence that such models are inappropriate; and
- NERA's New Vehicle Market Model does not include manufacturer behavior.

[3] CARB does not comment on use of a nested logit consumer choice model but does comment on our use of a value of -1.0 for the price elasticity for new vehicles, a parameter included in the New Vehicle Market Model. "In its analysis for the Auto Alliance, NERA/Trinity use a price elasticity for new vehicles of -1.0, which apparently was selected based on a study from nearly two decades ago and is potentially an over-estimate of current and future elasticities." (CARB 2018, p. 22). We note that our value is consistent with the most recent estimate we are aware of in published studies (Fischer, Harrington, and Parry 2007), which estimates a demand elasticity of -1.0.

The following subsections provide our responses to these two criticisms.

a. The Agencies' lack of a consumer choice model is not evidence that such models are inappropriate and, indeed, the Agencies have supported the development of such models.

Both sets of comments point to the Agencies' lack of a consumer choice model as implicit evidence of such models' supposed shortcomings. These comments ignore that positive commentary on such modeling by the Agencies in the background materials as well as by commentators who have been engaged by the Agencies to study the use of such models. In the regulatory impact analysis of the 2017-2025 standards, NHTSA wrote as follows.

> NHTSA also considered developing and using a vehicle choice model to estimate the extent to which sales volumes would shift in response to changes in vehicle prices and fuel economy levels. As discussed in Chapter V, the agency is currently sponsoring research directed toward developing such a model. (NHTSA FRIA 2012, p. 92)

Despite not using a consumer choice model in that analysis, NHTSA expressed an intent to continue development efforts:

> …NHTSA should continue efforts to develop a vehicle choice model suitable for integration with the CAFE modeling system and application toward informing the planned midterm review. (NHTSA FRIA 2012, p. 208)

Note that Agency-sponsored research of consumer choice models, in assessing alternative specifications of potential models, recognized the usefulness of nested logit formulations in particular:

> [Nested multinomial logit (NMNL)] models have been constructed, calibrated, and used in policy analysis of fuel economy issues by Greene et al. (2005), Harrison et al. (2008) and Bunch et al (2011). All three applications modeled vehicle choices at a fine level of detail, ranging from 200 makes and models to more than 800 make/model/engine/transmission combinations. This high level of detail was considered necessary to adequately represent the changes in market shares that might result from fuel economy and emission standards…For the purpose of developing an initial model to test the value of making such estimates the NMNL method appears to be a good compromise between flexibility and simplicity… (Oak Ridge National Laboratory 2012, pp. 18-19)

Though the Agencies still do not employ a consumer choice model in their most recent analysis, this decision seems more related to the computational complexity of these models rather than by conceptual concerns. In the most recent NPRM, the Agencies' discussion on using such models to estimate sales focuses on the difficulties of incorporating particular features of consumer and manufacturer behavior into these models, not on the track record of similar models or their regard in the literature (NHTSA 2018 pp. 195-198).

b. NERA's New Vehicle Market Model does account for the effects of manufacturers' responses on new vehicle sales and prices

Both sets of comments include concerns that the New Vehicle Market Model does not account for manufacturers' decisions and other supply-side effects on the new vehicle market. This concern is not warranted. The New Vehicle Market Model does include supply-side considerations. In particular, manufacturers are assumed to adjust prices based on the market share of its vehicle models, the cost of producing each model, and the pattern of own- and cross-price elasticities of all models produced by a manufacturer. The New Vehicle Market Model incorporates strategic adjustments in prices and sales by automobile manufacturers that account for changes in costs for their different vehicles as well as interactions in demand among the different vehicles in the manufacturer's fleet. Because the details of those adjustments are not described in the NERA/Trinity report, it is useful to provide information on the specifics of our assumptions regarding manufacturers' decisions.

We assume that the motor vehicle market is characterized by Bertrand competition where each manufacturer sets prices to maximize its overall profits, accounting for the fact that it is a multi-product firm.[4] In a Nash equilibrium for this Bertrand competition, the profit-maximizing price for a single-product firm is characterized by the Lerner condition (where mc_j is the marginal cost for alternative j, assumed to be constant):

$$\frac{p_j - mc_j}{p_j} = -\frac{1}{\varepsilon_j} \qquad \textbf{(1)}$$

Observing the elasticity and a change in marginal cost mc_j is sufficient, then, to calculate a change in price.

For a multi-product firm—typical for the major auto firms in the United States—the pricing equations include additional terms that reflect the unit profits on other products made by the firm and the cross-elasticities of demand between good j and these other products. The basic logic is that as the price of good j increases, some of the lost sales of that good will be replaced by increased sales of other goods sold by the same firm. Our model takes these effects into account. Specifically, the profit-maximization condition implies that manufacturers calculate the markup for each product (that is, the value of p-mc) according to the following matrix equation:

$$\mathbf{b} = \Delta^{-1} \cdot s^T$$

Where **b** is a vector of markups for each model, s is a vector of shares for each model, and Δ is a p-by-p matrix (where p is the number of products) whose entries are defined by:

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[4] See, e.g., Carlton and Perloff (1999) for a discussion of the Bertrand-Nash assumptions, which are common modeling assumptions for markets such as automobiles.

$$\Delta_{jk} = \begin{cases} -\dfrac{\partial s_j}{\partial p_k} \text{ if j and k are made by the same firm} \\ \\ 0 \text{ if j and k are made by different firms} \end{cases}$$

The ability to incorporate supply side responses is one of many reasons that researchers use nested logit and other multinomial logit models for assessing consumer and manufacturer behavior in complex markets.[5]

4. Conclusions

Neither of the two major critiques provided by IPI and NGO regarding NERA's modeling of the new vehicle market are valid. EPA and NHTSA have supported the development of consumer choice modeling and, indeed, their contractors have specifically recommended use of the nested logit formulation used in the New Vehicle Market Model. Moreover, in contrast to IPI and NGO concerns, the New Vehicle Market Model includes the effects of manufacturers' decisions. In summary, the New Vehicle Market Model is an appropriate model to estimate (a) effects of alternative CAFE standards on new vehicle prices and sales and (b) the value that consumers place on fuel economy improvements. As noted, neither of the two commentators provide alternative methodologies or data to evaluate these key effects of alternative CAFE standards.

B. Modeling of Scrappage Effects

NERA developed a detailed statistical model to determine the relationships between new vehicle prices and scrappage rates for existing vehicles of different ages. This model is based upon the well-established observation that new vehicles and used vehicles are substitutes, and thus changes in prices for new vehicles will affect prices and scrappage rates for existing vehicles.[6]

1. Overview of NERA Scrappage Model

NERA developed an empirical scrappage model to estimate the effects of new vehicle price increases due to alternative CAFE standards on scrappage of vehicles of different vintages. The vehicle scrappage model is based on well-established economic theory and empirical evidence on the decisions of owners to retire (or "scrap") used vehicles in response to changes in economic factors, including changes in new vehicle prices.[7] The model estimates the relationship between new car and light truck prices and scrappage rates for cars and light trucks of different model year vintages at each age during their lifetimes, holding constant other factors that affect scrappage rates.

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[5] See, e.g., Berry 1994; Klier and Linn 2012; Grigolen and Verboven 2014.

[6] Gruenspecht 1982 is widely credited with the initial analysis of this issue.

[7] See, e.g., Gruenspect 1982; Hahn 1995; Alberini, Harrington, and McConnel 1998; Jacobsen and van Benthem 2015.

NERA estimated the scrappage model using scrappage rates by type (car or light truck) for the individual vehicle model years making up the U.S. passenger vehicle fleet over the 2002-2016 period. Scrappage rates were calculated for ages 4 to 19, with an additional category for vehicles that are 20 years and older. We estimate the model using a rich set of fixed effects similar to those employed in a recent study by Jacobsen and van Benthem (2015). The rich set of fixed effects reflect the complicating effects of various macroeconomic and other factors that affect vehicle scrappage rates, and thus this formulation allows us to estimate the independent effects of changes in new vehicle prices on used vehicle scrappage rates. As explained in the NERA/Trinity report, the resulting model performs well in explaining variation among scrappage rates across the wide range of model years and wide historical period spanned by the underlying data. The coefficient on new vehicle price has the expected direction and is very highly significant. Using the estimated equation, we translate coefficients into elasticities of scrappage with respect to new vehicle price for the 17 age categories for both cars and light trucks. These elasticities range from about -1.3 to about -2.4, i.e., a one percent increase in the new vehicle price leads to a reduction in the scrappage rate of used vehicles in a given cohort (i.e., age and car or light truck) that ranges from 1.3 percent to 2.4 percent.

Appendix C of the NERA/Trinity report provides a detailed description of the data and statistical methodologies used to develop the scrappage model. Appendix C also provides the model results. We will provide backup files for the modeling and the data we use, with the exception of data we have purchased from private vendors in which our purchase agreement precludes such distribution; these other data are available for purchase from these vendors.

2. *Overview of Critiques*

None of the comments dispute the proposition that price changes for new vehicles will influence scrappage rates for the existing fleet. IPI's comments do not provide specific criticisms of the NERA scrappage model, simply claiming that NERA's model suffers from the same flaws as they have alleged for the NHTSA analysis, notably that the model results in unrealistic estimates of changes in the overall vehicle fleet. Similarly, CARB's comments do not have specific criticisms of the specification of the NERA scrappage model but allude to the possibility that the model is producing results "inconsistent with economic theory as the Agencies' model does, i.e., greater demand of used vehicles at a higher price." (CARB 2018, p. 23)

The NGO comments provide more specific comments relating to both the results of the scrappage model (including the scrappage elasticities and the effects on the total vehicle fleet) as well as the empirical specification. As with the IPI and CARB comments, NGO claims that NERA's scrappage model suffers from the same flaws as they allege for the NHTSA analysis (notably unrealistic fleet effects). But they also allege that the NERA empirical specification of the scrappage equation is flawed.

The following are relevant excerpts.

> NERA/Trinity employ a flawed scrappage model that appears to result in an increase in overall fleet size and vehicle miles traveled. (IPI 2018a, p. 2)

> …it is unclear what the total impact of NERA/Trinity's scrappage model is on fleet size…but it appears highly possible that the analysis contains some of the same fundamental flaws as the Agencies' model… (NGO 2018, p. A1)

> …like the agencies' scrappage regression model, the NERA/Trinity analysis also appears to omit several key variables…and also fails to control for several variables that affect used vehicles and are independent of new vehicles…Like the Agencies, NERA/Trinity also fail to index vehicle price by maintenance and repair costs…[T]he NERA/Trinity report significantly modifies the estimation strategy of Jacobsen and van Benthem (2015) to identify the scrappage elasticity…These significant changes invalidate the NERA/Trinity estimation strategy… (NGO 2018, p. A1)

3. *Response to Critiques*

We consider the criticisms raised by IPI, NGO, and CARB related to the scrappage model, specifically the following two major claims:

- Use of the NERA scrappage model may result in unrealistic estimates of changes in the total vehicle fleet, results that are not consistent with economic principles; and
- The NERA specification and estimation of the scrappage model are incorrect.

The following subsections provide our responses to these critiques.

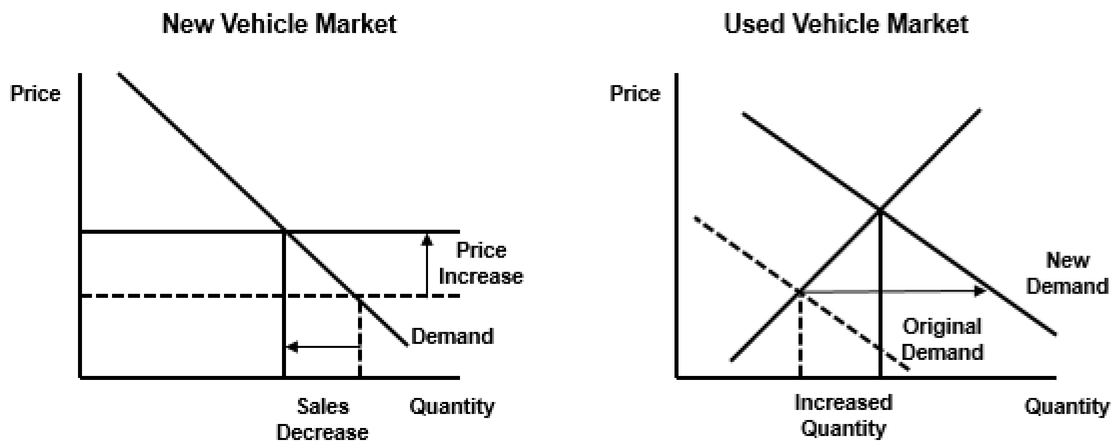
a. Estimated impacts on the motor vehicle fleet using the NERA scrappage model are plausible and consistent with sound economic principles

None of the comments question the basic logic that changes in new vehicle prices affect scrappage rates for existing vehicles. These commenters instead question the implications for the overall fleet of combining results for the new vehicle market and the used vehicle market. In particular, the commenters appear to believe that the net effect of an increase in new vehicle prices must be to decrease the overall fleet. The logic seems to be the following.

- An increase in new vehicle prices will lead to a decrease in new vehicle sales;
- An increase in new vehicle prices will lead to an increase in used vehicle prices;
- An increase in used vehicle prices should lead to a decrease in used vehicles; and
- Because both new vehicle prices and used vehicle prices increase—and because higher prices lead to reduced quantities—the size of the overall fleet must decrease.

This simplistic logic does not properly characterize the effect of an increase in new vehicle prices on the used vehicle market. Figure 2 below (taken from the NERA/Trinity report) shows that an increase in prices of new vehicles leads to a *shift* in the demand for existing vehicles (rather than a movement along the demand curve for existing vehicles). The left-hand figure illustrates the effects of a net increase in the price of new vehicles (i.e., increases in costs greater than the value of fuel economy gains), leading to a decrease in new vehicle sales. Because new vehicles are more expensive, the demand for used vehicles (a substitute good) increases, as illustrated in the shift in demand shown in the right-hand figure. The increased demand for used vehicles leads to increases in their prices, which means that owners will want to retain them longer. Thus, the increase in new vehicle prices leads to increases in the number of existing vehicles (through decreases in scrappage rates).[8]

Figure 2. Effects of Changes in New Vehicles Prices on Prices/Quantities of Used Vehicles



Source: Figure 2 of NERA/Trinity Report.

These market effects mean that an increase in the price of used vehicles is perfectly consistent with (a) an increase in the quantity of used vehicles in the vehicle fleet and (b) a net increase in the number of existing vehicles on the road (combining the effects on new and used vehicles). Indeed, the net effect of these two offsetting effects of a new vehicle price increase on the total vehicle fleet—a decrease in new vehicle sales and an increase in existing vehicles via reduced scrappage—depends upon the parameters of the new vehicle market model and the scrappage model as well as the size of the new vehicle price increase due to more stringent CAFE standards.

Our empirical results indicate that the net effect of more stringent CAFE standards is to increase the overall vehicle fleet—that is, the increase in used vehicles is greater than the decrease in new vehicle sales—although the net effect on the fleet population is very modest.[9] The NERA/Trinity report provides fleet results for 2030, showing changes in the numbers of vehicles in 2030 by

[8] The same process is relevant for changes in the other direction; a decreased demand for used vehicles would lead to decreases in the number of existing vehicles (through increases in scrappage rates).

[9] This net increase in the number of vehicles is plausible because older vehicles tend to be driven fewer miles than newer vehicles.

model year due to alternative CAFE standards. The net effect of a shift from the least stringent standard (Scenario 1) to the most stringent standard (augural scenario) is to increase the overall fleet population in 2030 by 0.25 percent. Moreover, the percentage change in 2030 is the largest for any of the years in our analysis. Thus, use of the NERA scrappage model does not lead to large net changes in the motor vehicle fleet, in contrast to the apparent concerns of IPI and NGO. These modest net changes are fully consistent with economic logic.

b. The empirical specification of the NERA scrappage equations is based upon sound economic and statistical judgments

The empirical specification of NERA's scrappage model employs a rich set of fixed effects terms to capture the many factors that affect scrappage rates, other than new vehicle prices. The fixed effects include 30 "dummy variables" that reflect the effects of interactions between calendar year and vehicle type (passenger car and light truck) and 254 dummy variables that reflect the effects of interactions between calendar year and vehicle age. This rich set of fixed effects is superior to attempting to account for all the other factors that influence vehicle scrappage (e.g., repair costs).

Indeed, this specification is similar to that used in the Jacobsen and van Benthem (2015) study mentioned in the NGO comments, although our estimation method differs somewhat from that of Jacobson and van Benthem. We use ordinary least squares ("OLS") to estimate the scrappage equation, in contrast to Jacobsen-van Benthem's use of instrumental variables ("IV") estimation. Jacobson and van Benthem use IV estimation to overcome potential omitted variable bias, i.e., bias from omitting variables that simultaneously affect both vehicle prices and scrappage rates. In the paper, they use maintenance and repair costs as an example of a problematic omitted variable: greater repair costs may decrease vehicle prices and increase scrappage rates, biasing downward the coefficient on price in any scrappage regression that omits repair cost controls. The results of the Jacobsen-van Benthem regressions, however, show little difference between the OLS and IV estimates, suggesting any bias from omitted variables is not substantial. Moreover, accounting for this effect would lead to greater scrappage elasticities, which would in turn lead to greater net benefits for less stringent CAFE standards.

4. Conclusions

The scrappage model developed by NERA is statistically sound and its results are consistent with sound economic principles, in contrast to concerns raised by IPI, NGO, and CARB. Using the results of the scrappage model (along with the New Vehicle Market Model and cost changes from the CAFE model) leads to estimates that alternative CAFE standards would lead to modest changes in the total motor vehicle fleet. These modest changes are completely consistent with economic theory.

C. Modeling of Effects on Vehicle Miles of Travel (Rebound Effect)

NERA modeled the effects of alternative CAFE standards on vehicle miles of travel (VMT). The VMT impacts are based upon two effects, one related to changes in the vehicle fleet (as discussed previously) and one based upon the effect of changes in fuel efficiency of the vehicles affected by the standards. Improvements in fuel efficiency decrease the cost of energy consumption and thus lead to an increase in energy use; this well-known effect is called the "rebound effect" because its effects on energy use offset the direct effects of energy efficiency programs.[10] In the context of improvements in motor vehicle fuel efficiency, the rebound effect is defined as the elasticity of VMT with respect to fuel efficiency improvements.

1. Overview of NERA Value for the Rebound Effect

The NERA analysis used a rebound value of 20 percent in the VMT Model. This value was determined based on calculation of average and median values from the rebound estimates in the literature, drawing on the lists of studies cited by EPA and NHTSA in NHTSA/EPA (2018) and EPA (2016) and focusing on estimates of the long-run rebound effect. We relied on the Agencies' assessment of the relevant rebound estimates from each of the studies as included in NHTSA/EPA (2018) and EPA (2016a).[11] In instances in which the Agencies presented a range of values for a particular study, we determined an average value or suggested value based on the average value across that range or the central/preferred estimate as identified either by the original report authors or by the Agencies. Using these estimates for each of the 31 studies in the combined list, we calculated median and mean values for the full set of studies. The mean long-term rebound effect is 26 percent and the median rebound effect is 22 percent. As noted, we used a rebound value of 20 percent in the NERA/Trinity study. This is the same value used by the Agencies in their 2018 analysis of the effects of alternative CAFE standards.

[10] See, e.g. Jevons 1865; Greening, Greene, and Difiglio 2000; Sorrell & Dimitropoulos 2008.

[11] See Table 8-8 and discussion in Section 8.9 of NHTSA/EPA (2018) and Section 3.4 of EPA (2016a).

Table 1. Estimates of the Long-Run Rebound Effect in Various Studies (Table E-1 from the NERA/Trinity Report)

Author (Year)	Range	Suggested Value or Average Value	Time Period
Mayo & Mathis (1988)	26%	26%	1958-1984
Gately (1992)	9%	9%	1966-1988
Greene (1992)	5 - 19%	12%	1966-1989
Jones (1993)	30%	30%	1966-1989
Haughton & Sarkar (1996)	22%	22%	1973-1992
Schimek (1996)	21 - 29%	25%	1950-1994
Greene, Kahn & Gibson (1999)	23%	23%	1979-1994
Pickrell & Schimek (1999)	4 - 34%	19%	1995
Puller & Greening (1999)	49%	49%	1980-1990
West (2004)	87%	87%	1997
Small & Van Dender (2005)	22%	22%	1966-2001
Small & Van Dender (2007)	11%	11%	1997-2001
Barla et al. (2009)	20%	20%	1990-2004
Bento (2009)	21 - 38%	34%	2001
Wadud et al. (2009)	1 - 25%	13%	1984-2003
Hymel, Small & Van Dender (2010)	24%	24%	1966-2004
Hymel, Small & Van Dender (2010)	16%	16%	1984-2004
West and Pickrell (2011)	9 - 34%	22%	2009
Su (2012)	13%	13%	2009
Anjovic and Haas (2012)	44%	44%	1970-2007
Greene (2012)	8 - 12%	10%	1967-2006
Linn (2013)	20 - 40%	30%	2009
Frondel and Vance (2013)	46 - 70%	58%	1997-2009
Liu et al. (2014)	40%	40%	2009
Gillingham (2014)	22 - 23%	22%	2001-2003
Weber and Farsi (2014)	19 - 81%	50%	2010
West et al. (2015)	0%	0%	2009
Hymel & Small (2015)	18%	18%	2000-2009
DeBorger (2016)	8 - 10%	9%	2001-2011
Stapleton et al. (2016)	9 - 36%	19%	1970-2011
Stapleton et al. (2017)	14 - 30%	26%	1970-2012
Mean:		**26%**	
Median:		**22%**	

Notes: The mean and median were calculated using mid-points or suggested values for studies in which a range is reported.
Source: Table E-1 of NERA/Trinity report.

2. *Overview of Critiques*

The IPI, NGO, and CARB comments criticize the NERA/Trinity study for using the same value for the rebound effect as NHTSA and EPA, a value that they refer to as "unjustifiable" (NGO 2018, p. A1) and "exaggerated" (CARB 2018, p. 25). Although none of the three comments provide details on why they consider the NERA/Trinity use of the 20 percent value to be unjustifiable, IPI refers to its October 2018 comments on the Agencies' value, which provides some specifics regarding their critique.

The IPI seems to have two major criticisms of the NERA and EPA/NHTSA determination of a representative rebound estimate based upon the relevant literature.[12] First, they argue that some relevant rebound studies are excluded from the lists of literature considered. Second, they argue that some of the studies provide more reliable results than others, and thus that it is not proper to take a simple average (or median) value for all of the studies. In particular, the IPI seems to consider the following study characteristics as providing more reliable/relevant rebound estimates: (a) estimates based upon U.S. rather than non-U.S. data; (b) estimates based upon more recent data; (c) estimates based upon fuel efficiency rather than cost per mile or gasoline price; (d) estimates based upon identification techniques that account for endogeneity; (e) estimates based upon datasets that contain multiple years such as panel datasets, rather than a single cross section; (f) estimates based on modeling that explicitly controls for "capital costs" of new vehicles (i.e., controls for changes in new vehicle prices due to CAFE standards).[13]

The following are relevant excerpts from the IPI comments related to these various study characteristics.

> ***U.S. Data.*** "U.S.-based estimates are far more relevant than foreign estimates for measuring the effects of a policy that would change the cost of driving for U.S. drivers. It is not merely that U.S. drivers and foreign drivers are culturally different. Rather, the U.S. differs substantially from other regions in terms of the price of gasoline, the density of the population, and income levels; each of which has been shown in various studies to affect the rebound effect." (IPI 2018b, p. 114)
>
> ***Recent Data.*** "The agencies should therefore use studies that can project the rebound effect of the 2020-2050 timeframe rather than assume that estimates of historic rebound can be directly applied to the baseline standards. More recent studies that look at more recent data will be more applicable than older studies. In other words, more recent studies are better predictors of future rebound because 'behavioral responses are contingent upon technical, institutional, policy and demographic factors that vary widely between groups and over time.'" (IPI 2018b, p. 114)
>
> ***Fuel Economy.*** "The most relevant rebound estimate for the purposes of the Proposed Rule is the extent to which driving changes due to changes in fuel efficiency— called the 'elasticity of distance travelled with respect to fuel efficiency' or 'fuel efficiency rebound.'" (IPI 2018b, p. 111)

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[12] IPI provides other criticisms on the rebound approach noting (a) that it fails to acknowledge the relationship between the rebound effect and congestion and (b) that the use of a point estimate approach is inconsistent with other components of the analysis that include dynamic effects such as the scrappage modeling. IPI has not indicated how such complexities would be implemented or how their exclusion affects the results of rebound studies.

[13] IPI also identifies that they believe the agencies should rely on studies that develop short-run and medium-run rebound estimates (i.e., 0-3 years) on the basis that they may be more reliable. Considering the lengthy analysis period for the NERA/Trinity study (2017-2050), and the relatively short-term application of short-run and medium-run estimates (0-3 years), we consider the long-run estimates to be more applicable to the policy question at hand.

> ***Endogeneity.*** "Energy efficiency may be correlated with other vehicle attributes, household attributes, and time; some of which are unobservable. As such, the agencies should place greater weight on studies that address this endogeneity, usually using instrumental variables or simultaneous equations. Failure to account for endogeneity means that the study is unable to disentangle to what extent VMT is rising because of fuel efficiency and to what extent it has risen due to changes in other factors (including reverse causality). […] studies that do not address issues with endogeneity may overstate the extent to which fuel efficiency is the cause of extra VMT." (IPI 2018b, pp. 115-116)
>
> ***Multiple Years.*** "[…] cross-sectional studies should be given less weight (or dropped altogether) as they: disagree over appropriate specification; suffer from omitted variable bias making them unreliable; and are only as representative as the year the data was taken." (IPI 2018b, p. 116)
>
> ***Capital Costs***. "Because high capital costs reduce rebound by reducing consumers' income available to purchase other goods, such as driving (the 'capital cost income effect'), analyses that omit capital costs will yield inflated estimates of rebound" (IPI 2018b, p. 113)

3. Response to Critiques

We consider two major criticisms raised by IPI and NGO related to the calculation of the rebound effect, specifically that:

- Additional studies should be added to the list of relevant long-run rebound studies; and
- Average rebound calculation should account for important differences among the studies, including whether the studies use U.S. data, whether they use recent data, whether they use fuel efficiency rather than cost per mile or gasoline price, whether they account for endogeneity, whether they are based on datasets that include multiple years rather than a single cross section, and whether they control for capital costs of new vehicles.

The following subsections provide our conclusions regarding these two major critiques.

a. Including additional studies identified by IPI has little effect on the mean and median values, and thus the rebound value of 20 percent remains reasonable with these additional studies added.

IPI identified six additional studies for inclusion in the list of relevant studies, one of which (Gillingham 2016) is a literature review (and thus does not involve a separate study) and one of which does not provide a long-term rebound value (Dillon et al. 2015). Table 2 provides our list of rebound studies, supplemented by the additional four relevant studies. As with the studies on the original list, for each study we show (a) the range of rebound values, (b) the suggested value or average value; and (c) the time period covered by the study.

Note that we have reviewed the studies included in our original list in order to develop information on the features of the individual studies that can be used to evaluate the effects of focusing on subsets of studies. We also used this opportunity to confirm that the range of values reported reflects the relevant range of statistically significant rebound estimates. Based on this additional review, Table 2 includes slightly modified information on some of the studies in the original list (Table 1, taken from Table E-1 from the NERA/Trinity report); in particular, the "range" reflects the range of statistically significant rebound estimates only. Explanations for each of these modifications are documented in the table notes for Table 2.

The combination of adding these four additional studies and incorporating slight modifications in some results for the original studies does not have a substantial effect on the mean or median values compared to the values calculated in the NERA/Trinity study. The mean and median values for these 35 studies are 25 percent and 22 percent, respectively. These values are very similar to the values calculated in our report (26 percent and 22 percent) and consistent with use of a 20 percent rebound value.

Table 2. Expanded List of Rebound Studies*

Author (Year)	Range[1]	Suggested Value or Average Value[2]	Time Period
Mayo & Mathis (1988)	26%	26%	1958-1984
Gately (1992)	9%	9%	1966-1988
Greene (1992)	5-19%	12%	1966-1989
Jones (1993)	30%	30%	1966-1989
Schimek (1996)	21-29%	25%	1950-1994
Haughton & Sarkar (1996)	22%	22%	1973-1992
Greene, Kahn & Gibson (1999)	23%	23%	1979-1994
Pickrell & Schimek (1999)[3]	29-34%	32%	1995
Puller & Greening (1999)	49%	49%	1980-1990
West (2004)	87%	87%	1997
Small & Van Dender (2007)	22%	22%	1966-2001
Small & Van Dender (2007)	11%	11%	1997-2001
Barla et al. (2009)	20%	20%	1990-2004
Bento (2009)	21-38%	34%	2001
Wadud et al. (2009)	1-25%	13%	1984-2003
Hymel, Small & Van Dender (2010)	24%	24%	1966-2004
Hymel, Small & Van Dender (2010)	16%	16%	1984-2004
West & Pickrell (2011)	9-34%	22%	2009
Gillingham (2011)	6-15%	11%	2001-2009
Su (2012)[4]	11-19%	13%	2009
Anjovic & Haas (2012)	44%	44%	1970-2007
Greene (2012)	8-12%	10%	1967-2006
Frondel & Vance (2013)[5]	44-71%	58%	1997-2009
Liu et al. (2014)	40%	40%	2009
Gillingham (2014)	22-23%	22%	2001-2003
Wang & Chen (2014)	20%	20%	2009
Weber & Farsi (2014)	19-81%	50%	2010
Gillingham et al. (2015)	10%	10%	2000-2010
Hymel & Small (2015)[6]	4-26%	15%	2000-2009
DeBorger (2016)	8-10%	9%	2001-2011
Linn (2016)	20-40%	30%	2009
Stapleton et al. (2016)	9-36%	19%	1970-2011
Stapleton et al. (2017)	14-30%	26%	1970-2012
West et al. (2017)	0%	0%	2010-2011
Wenzel & Fujita (2018)	8-16%	12%	2005-2010
Mean:		**25%**	
Median:		**22%**	

Notes: *Expanded list includes original list (i.e., Table E-1 of the NERA/Trinity report) plus additional studies as described in text. Some of values included in the original list have been modified as noted below.

1. The range reflects the full range of statistically significant long-run rebound estimates.

2. Depending upon the individual study, the suggested value is based upon (a) the only value, (b) the average value across the range of estimates, or (c) the central estimate as identified by the report authors.

3. The Agencies had noted that the relevant range of rebound estimates reported in this study is 4% to 34%. Based on additional review we conclude that the range of statistically significant rebound estimates reported in this study is limited to 29% to 34%

4. We have modified the "range" value to reflect that this study includes a range of rebound estimates from 11% to 19%, rather than a single estimate of 13%.

5. The Agencies had noted that the relevant range of rebound estimates reported in this study is 46% to 70%. Based on additional review we conclude that the range of statistically significant rebound estimates reported is 44% to 71%.

6. The Agencies include a single value of 18% for this study, though the study provides several long-run VMT elasticity estimates (see Table 8 from Hymel & Small 2015).

b. Calculating average rebound values for various subsets of the studies also does not change the conclusion that 20 percent is an appropriate rebound value.

In order to determine whether using subsets of studies would affect the rebound value estimate, we categorized the 35 rebound studies based upon the six features that IPI appeared to consider would lead to more reliable estimates.[14]

- *U.S. Data*. Of the 35 studies, 27 are based upon U.S. data.
- *Recent studies*. Of the 35 studies, 20 are based upon data from 1990 and later.
- *Fuel efficiency*. Of the 35 studies, 13 calculate the rebound elasticity based upon effects of fuel economy.
- *Accounts for Endogeneity*. Of the 35 studies, 19 include estimates based on techniques that control for endogeneity.
- *Multiple Years*. Of the 35 studies, 19 are based upon panel datasets or datasets that contain multiple years.
- *Capital Costs*. Of the 35 studies, 9 include estimates that control for capital costs.

Table 3 shows how the mean and median values change if subsets based upon these six factors are used to calculate the values.

[14] Note that we have not evaluated whether these various features should be used to restrict the sample of rebound studies.

Table 3. Expanded Rebound Estimates Categorized by Various Factors

Author (Year)	Time Period	Suggested Value or Average Value (a)	U.S. Data (b)	Recent Period (c)	Fuel Economy (d)	Accounts for Endogeneity (e)	Multiple Years (f)	Capital Cost (g)
Mayo & Mathis (1988)	1958-1984	26%	26%	-	-	-	26%	-
Gately (1992)	1966-1988	9%	9%	-	-	-	-	-
Greene (1992)	1966-1989	12%	12%	-	-	-	-	-
Jones (1993)	1966-1989	30%	30%	-	-	-	-	-
Schimek (1996)	1950-1994	25%	25%	-	21%	-	-	-
Haughton & Sarkar (1996)	1973-1992	22%	22%	-	-	22%	22%	-
Greene, Kahn & Gibson (1999)	1979-1994	23%	23%	-	-	23%	23%	-
Pickrell & Schimek (1999)	1995	32%	32%	32%	-	-	-	-
Puller & Greening (1999)	1980-1990	49%	49%	-	-	-	49%	49%
West (2004)	1997	87%	87%	87%	-	87%	-	87%
Small & Van Dender (2007)	1966-2001	22%	22%	-	-	22%	22%	22%
Small & Van Dender (2007)	1997-2001	11%	11%	11%	-	11%	11%	11%
Barla et al. (2009)	1990-2004	20%	-	20%	-	-	20%	20%
Bento (2009)	2001	34%	34%	34%	-	-	-	34%
Wadud et al. (2009)	1984-2003	13%	13%	-	13%	-	-	-
Hymel, Small & Van Dender (2010)	1966-2004	24%	24%	-	-	24%	24%	24%
Hymel, Small & Van Dender (2010)	1984-2004	16%	16%	-	-	16%	16%	16%
West & Pickrell (2011)	2009	22%	22%	22%	18%	-	-	-
Gillingham (2011)	2001-2009	11%	11%	11%	6%	11%	11%	-
Su (2012)	2009	13%	13%	13%	-	-	-	-
Anjovic & Haas (2012)	1970-2007	44%	-	-	44%	-	-	-
Greene (2012)	1967-2006	10%	10%	-	-	-	-	-
Frondel & Vance (2013)	1997-2009	58%	-	58%	66%	58%	58%	-
Liu et al. (2014)	2009	40%	40%	40%	40%	40%	-	-
Gillingham (2014)	2001-2003	22%	-	22%	-	23%	22%	-
Wang & Chen (2014)	2009	20%	20%	20%	20%	20%	-	-
Weber & Farsi (2014)	2010	50%	-	50%	50%	78%	-	-
Gillingham et al. (2015)	2000-2010	10%	10%	10%	-	10%	10%	-
Hymel & Small (2015)[1]	2000-2009	15%	15%	15%	4%	15%	15%	15%
De Borger et al. (2016)	2001-2011	9%	-	9%	9%	9%	9%	-
Linn (2016)	2009	30%	30%	30%	30%	30%	-	-
Stapleton et al. (2016)	1970-2011	19%	-	-	-	-	19%	-
Stapleton et al. (2017)	1970-2012	26%	-	-	-	-	26%	-
West et al. (2017)	2010-2011	0%	0%	0%	0%	0%	0%	-
Wenzel & Fujita (2018)	2005-2010	12%	12%	12%	-	12%	12%	-
Mean:		**25%**	**23%**	**26%**	**25%**	**27%**	**21%**	**31%**
Median:		**22%**	**22%**	**20%**	**20%**	**22%**	**20%**	**22%**

Note: (a) Depending upon the individual study, the suggested value is based upon (a) the only value, (b) the average value across the range of estimates, or (c) the central estimate as identified by the report authors.
(b) Estimates based on U.S. data.
(c) Estimates based on data from 1990 or later.
(d) Estimates based on calculating the rebound value using fuel economy, rather than cost per mile or gasoline price. For studies that include multiple measures of the rebound effect (i.e., based on fuel economy, gas price, and/or cost per mile) this value may differ from the value included in the "Suggested or Average Value" column, which would be an average across the various metrics included.
(e) Estimates that account for endogeneity. For studies that include estimates based on multiple modeling techniques, this value may differ from the value included in column (a), which would be an average across the various metrics included.
(f). Estimates based on a data set containing multiple years.
(g). Estimates that explicitly control for capital costs of new vehicles.
1. We rely on the estimates from the "asymmetric model" in Table 8 of Hymel and Small (2015), as we understand that these are the authors preferred estimates (Small 2018).

Source: Rebound studies as described in text.

For each of the six subsets considered in Table 3, the calculated mean and median values are very similar to the values calculated in our report (26 percent and 22 percent) and consistent with use of a 20 percent rebound value. The following are the specific values for the six subsets of rebound estimates.

- *U.S. Data*. Using estimates based on U.S. data only does not have a substantial effect on the mean or median values compared to the values calculated in the NERA/Trinity study. The mean and median values for these 27 studies are 23 percent and 22 percent, respectively.
- *Recent Period*. Using estimates based on more recent data only (1990 and later) does not have a substantial effect on the mean or median values compared to the values calculated in the NERA/Trinity study. The mean and median values for these 20 studies are 26 percent and 20 percent, respectively.
- *Fuel Economy*. Using estimates based on fuel economy only does not have a substantial effect on the mean or median values compared to the values calculated in the NERA/Trinity study. The mean and median values for these 13 studies are 25 percent and 20 percent, respectively.
- *Endogeneity*. Using estimates that account for endogeneity only does not have a substantial effect on the mean or median values compared to the values calculated in the NERA/Trinity study. The mean and median values for these 19 studies are 27 percent and 22 percent, respectively
- *Multiple Years*. Using estimates based on multiple years only does not have a substantial effect on the mean or median values compared to the values calculated in the NERA/Trinity study. The mean and median values for these 19 studies are 21 percent and 22 percent, respectively
- *Capital Costs*. Using estimates that account for capital costs (i.e., new vehicle prices) does not have a substantial effect on the mean or median values compared to the values calculated in the NERA/Trinity study. The mean and median values for these 9 studies are 31 percent and 22 percent, respectively

4. Conclusions

The rebound value of 20 percent used in the NERA/Trinity study reflects average values across the large number of relevant studies. Modifying the list of studies to include those recommended by IPI does not affect the conclusion that 20 percent is a reasonable rebound value. Moreover, restricting studies to subsets based upon the categories mentioned by IPI also does not affect this conclusion. In summary, the rebound value of 20 percent is a reasonable value to use in light of the existing literature, and this choice is robust with respect to using subsets of the studies based upon various criteria.

D. Baseline Fuel Economy

This issue concerns the baseline level of fuel economy included in Trinity's use of the CAFE model. Trinity used NHTSA's CAFE model to evaluate the effects of alternative CAFE standards on costs and fuel economy for the vehicle manufacturers and motor vehicle models included in the CAFE model. For purposes of the CAFE model, the baseline trajectory of fuel economy is the trajectory based upon consumer demand and manufacturers decisions if there were no changes in

CAFE standards beyond MY 2020. These levels represent the baseline for purposes of evaluating the effects of standards more stringent than the MY 2020 standards.[15]

1. *Overview of NERA/Trinity Calculation of Baseline Fuel Economy in the CAFE Model*

Trinity uses the CAFE model to estimate changes in vehicle, manufacturer and fleet compliance costs, technology penetrations and fuel economy levels needed to meet various alternative CAFE standards. The CAFE model was developed by NHTSA to evaluate how manufacturers would comply with various fuel economy standards, which can be specified by the user of the model. The CAFE model evaluates compliance through MY 2032.

The manufacturer compliance simulation within the CAFE model starts with a vehicle model-level baseline fleet (including vehicle attributes such as fuel economy and projected sales). The CAFE model determines future baseline fuel economy values based upon specification of a "payback period," i.e., the number of years of potential future fuel economy savings that new vehicle purchasers are presumed to include in their valuation of fuel economy differences among vehicles. Thus, to implement the CAFE model, Trinity needed to specify a "payback period" for purposes of developing the CAFE model characterization of the baseline trajectory.

NERA calculated a "payback period" that Trinity could use to implement this element of the CAFE model based upon results of the New Vehicle Market Model. The CAFE model then evaluates an array of possible compliance paths that incorporate additional vehicle technologies (beyond those in the initial fleet) that provide various levels of fuel economy improvement. Appendix A of the NERA/Trinity report provides details on Trinity's implementation of the CAFE model.

2. *Overview of Critiques*

The NGO and CARB comments criticize the NERA/Trinity report for using a baseline that assumes that future fuel economy would improve (in the absence of binding fuel economy standards) on the basis of consumer and manufacturer choices. They apparently believe that manufacturers would only improve fuel economy if forced to do so by binding CAFE standards, and not in response to market conditions.

The following are excerpts from the NGO and CARB comments that illustrate these two criticisms.

> NERA/Trinity use their purported 'willingness-to-pay' factor as justification for including in the 'rollback'/preferred alternative fleet any fuel economy technology that pays for itself in 60 months. This exaggerates the Agencies' similarly unjustifiable approach in the NPRM of including all fuel economy technology that

[15] Note that following the NHTSA/EPA reporting of results, the NERA/Trinity report uses the augural (most stringent) standards as the baseline for reporting results of the four CAFE alternatives we evaluate. This use of the term "baseline" is different than the one for this section.

pays for itself in 30 months. …This assumption that manufacturers will improve fuel economy even in the absence of standards grossly warps the cost-benefit analysis by including all the most cost-effective technology in the "business as usual" baseline/preferred alternative scenario, along with the benefits of those fuel savings and emissions reductions. (NGO 2018, p. A4)

…like the Agencies, the NERA-Trinity analysis assumes that automakers will install, without any regulations, available fuel-saving technology that will pay for itself within a specified time. As noted in CARB's Detailed Comments, there is no historical evidence for the assumption that automakers will systematically do so in the absence of standards requiring this technology. (CARB 2018, p. 23)

3. Responses to Critiques

We consider this criticism that baseline fuel economy should be calculated without including the value that consumers place on fuel economy, in particular that:

- Baseline fuel economy in the future motor vehicle fleet should not change based upon consumer and manufacturer responses to future gasoline prices and other market factors;
- In the absence of binding CAFE standards, manufacturers would not improve fuel economy.

The following subsections provide our responses to these critiques.

a. Baseline fuel economy levels in future model years should be based on the levels that would be provided by the market rather than on the assumption that fuel economy would be fixed at levels required by 2020 CAFE standards.

The approach used in the NERA/Trinity report is consistent with general principles establishing a future baseline (or "counterfactual") for purposes of a benefit-cost analysis of alternative regulatory requirements, as articulated in textbooks and in guidelines for preparing economic analyses developed by the EPA. The following text is included in EPA's *Guidelines*.

A baseline is defined as the best assessment of the world absent the proposed regulation or policy action. This "no action" baseline is modeled assuming no change in the regulatory program under consideration. This does not necessarily mean that no change in current conditions will take place, since the economy will change even in the absence of regulation. A proper baseline should incorporate assumptions about exogenous changes in the economy that may affect relevant benefits and costs (e.g., changes in demographics, economic activity, consumer preferences, and technology), industry compliance rates, other regulations promulgated by EPA or other government entities, and behavioral responses to the proposed rule by firms and the public…" (EPA 2016b, p. 5-1)

Consistent with this principle, the baseline developed by Trinity based upon the NERA-estimated "payback period" reflects market effects. The EPA *Guidelines* make clear that factors such as consumer preferences and industry behavior are relevant and should be incorporated into the baseline.

b. Both economic theory and empirical studies indicate that manufacturers would modify future fuel economy levels to reflect consumer valuation.

Economic theory clearly indicates that profit-maximizing manufacturers would "voluntarily" adopt fuel economy-enhancing technologies for reasons other than CAFE requirements. Indeed, profit-maximizing firms have incentives to add such technologies where consumers' valuation is greater than the added production costs. Including such additional technologies adds to consumer and producer welfare.

The academic literature provides empirical evidence that fuel economy changes in response to market forces, and not just in response to the stringency of CAFE standards. For example, Knittel (2012) finds that increases in gasoline prices lead to greater fuel economy. Similarly, Allcott and Wozny (2013) find that higher gasoline prices lead to more fuel-efficient vehicles. These observed responses to gas price fluctuations demonstrate the tendency of manufacturers to adjust the fuel economy characteristics of their vehicle fleets to accommodate consumer preferences for lower fuel costs. It follows that the baseline fuel economy trajectory used to evaluate CAFE alternatives should reflect these market forces.

4. Conclusions

As EPA *Guidelines* clearly establish, the future technology baseline for evaluating CAFE alternatives should account for expected future changes in the new vehicle market rather than freezing technology at the last binding CAFE standard. Both economic theory and empirical results support that these market changes affect the level of fuel economy; these market forces create a baseline trajectory of fuel economy against which CAFE alternatives are evaluated.

E. Valuation of Fuel Economy Benefits

This issue concerns the proper means of determining the value to consumers from increases in fuel economy standards to use in the social net benefits analysis of alternative CAFE standards.

1. Overview of NERA Estimates of the Value to Consumers of Fuel Economy Improvements

NERA developed estimates of the benefits to consumers from improved fuel economy due to CAFE alternatives. We estimated the value that consumers place on three types of gains from improved fuel economy: (a) reductions in the fuel costs per mile; (b) additional mileage driven due to the rebound effect; and (c) reduced time spent refueling given the greater range. We base our estimates for all three categories on consumers' willingness to pay.

We note several preliminary matters relevant for the IPI/NGO critique. First, IPI/NGO only question our calculation of the first type of gain (albeit the largest of the three). Second, the welfare gains we calculate do not account for the fact that potential welfare *losses* of achieving higher fuel-economy standards means sacrificing vehicle characteristics other than fuel economy (e.g., power, acceleration)—an "opportunity cost" of more stringent CAFE standards that has been discussed in the literature but that is not included in our net benefits estimates (or in the estimates developed by the Agencies). Third, as discussed in Section D, these gains are all calculated relative to the baseline future fuel economy levels that are calculated in the CAFE model using a "payback period" based upon the valuation of fuel economy obtained from the results of the New Vehicle Market Model.

a. Consumer Valuation of Fuel Economy Changes to New Vehicle Purchasers

The first component of NERA's estimate of consumers' benefit of fuel economy improvements is consumers' own valuation of expected fuel savings. The CAFE model provides estimates of the changes in fuel efficiency, measured in fuel costs per mile, that vehicles will achieve due to compliance with each CAFE alternative. We use results from the New Vehicle Market Model to estimate consumers' willingness-to-pay for a unit decrease in fuel cost per mile. As discussed in Section A, this model is based upon a conceptually-sound methodology and detailed data. We combine this valuation from the New Vehicle Market Model with the fuel economy gains from the CAFE model to estimate the dollar-value benefit to consumers as measured by their willingness to pay for these gains.

b. Consumer Valuation of Changes in VMT

The second component of consumers' benefit relates to gains in mobility due to improvements in fuel economy. Due to the rebound effect, consumers would change the miles they drive based upon changes in the cost-per-mile of travel. From a baseline level of miles, the decrease in cost-per-mile causes drivers to increase VMT until the marginal benefit of an additional mile decreases sufficiently to once again equal the marginal cost of the next mile. Over the range of "rebound miles," consumers gain because the cost of those miles is less than the value they place on the additional miles. Again, the estimates of the benefits of additional VMT are based on willingness to pay.

c. Valuation of Changes in Driving Range

The third component of consumers' benefit relates to gains in time spent refueling due to an improvement in fuel economy. Assuming the size of the tank does not change, improvements in fuel economy increase the driving range and thus decrease the time spent refueling. We developed estimates of these benefits based on assumptions about the frequency of refueling, the time spent for each refuel, and the value of that time as measured by consumer willingness to pay. Again, the dollar values of benefits for this category are based on willingness to pay.

d. Results

Table 4 shows our estimates of the values of these three components of fuel economy benefits for the three alternative CAFE standards and the two discount rates in our study. Following the format in the Agencies' report, we compare results for the three scenarios with the augural standards, which are the most stringent. Thus, using a 7 percent discount rate, the reduction in fuel economy benefits to consumers (expressed as a present value as of January 1, 2017) ranges from $19.1 billion under Scenario 8 (the closest to the augural standards) to $59.5 billion under Scenario 1 (the furthest from the augural standards).[16] Consumer valuation of fuel cost savings represents about 60 percent of the total estimated consumer benefits.

Table 4. Fuel Economy Benefits Relative to Augural Standards Baseline (billions of 2016$)

	3% Social Discount Rate			7% Social Discount Rate		
	Scen. 8	**Scen. 5**	**Scen. 1**	**Scen. 8**	**Scen. 5**	**Scen. 1**
Valuation of Fuel Cost Savings	-$16.7	-$28.9	-$51.3	-$12.4	-$21.3	-$38.0
Rebound Mobility Benefit	-$9.7	-$17.4	-$31.0	-$5.8	-$10.3	-$18.5
Refueling Time Benefit	-$1.6	-$2.7	-$4.9	-$0.9	-$1.6	-$2.9
Benefits of Fuel Economy Changes	**-$28.0**	**-$49.0**	**-$87.2**	**-$19.1**	**-$33.3**	**-$59.5**

Note: Present values calculated as of January 1, 2017 using 3 percent and 7 percent discount rates for costs/benefits incurred over the 2017-2050 analysis period. The values include effects for model year vehicles up to MY 2029. All values relative to augural standards baseline. All values in billions of 2016 dollars, rounded to the nearest $0.1 billion.

Source: Table 40 of NERA/Trinity 2018.

2. *Overview of Critiques*

As noted, the comments do not question our calculations of two of the three consumer benefits of improved fuel economy—the value of increased travel and the value of increased time—but only the value of reduced fuel costs. In particular, the comments criticize the NERA/Trinity valuation of fuel economy improvements because it is based on consumers' willingness to pay rather than what they contend is a more appropriate method based upon a calculation of the present value of the expected fuel cost savings over time using a social discount rate (3 percent and 7 percent). Moreover, the critiques claim that the NERA method only includes fuel savings for the first 60 months of operation of vehicles, based upon NERA's calculation of a 60-month "payback period" for use in the CAFE model, as explained in Section D.

The commentators contend that the value of fuel economy improvements should be based on a calculation of the future gasoline cost savings, which they refer to as "the full economic value of fuel saved" calculated over the future lifetimes of the vehicles using 3 percent and 7 percent discount rates to determine a present value estimate. IPI points to a list of potential "market failures" that might explain a difference between consumer valuation of fuel economy gains and

[16] Although our WTP estimate represents the value consumers place on potential future fuel savings at the time of purchase, it is still necessary to apply a social discount rate to obtain the present value of that WTP as of a particular analysis date, in this case January 1, 2017.

"the full economic value of fuel saved." (IPI 2018, p. 3) They claim that "the full economic value of fuel saved" measures the resource cost savings from greater fuel efficiency.

The following are excerpts from the three comments that illustrate these criticisms.

> [L]eaving out a component of the economic value of fuel savings—the value that consumers do not consider when making a vehicle purchase decision—ignores the presence of market failures and so is not a rational measure of the social benefits of fuel savings. (IPI 2018a, p. 3).
>
> As the economics literature has explored in detail, consumers often make up-front vehicle purchasing decisions that fail to fully account for future fuel savings…This is termed the "energy paradox" or "energy efficiency gap." The economics literature has identified a number of market failures that contribute to the energy efficiency gap, including consumer myopia, consumer loss aversion, information asymmetries, supply-side market failures, and the positional nature of competing vehicle attributes. (IPI 2018a, p. 3).
>
> [R]egardless of the value consumers appear to place on fuel savings when making vehicle purchase decisions, when they operate more efficient vehicles, they consume fewer real economic resources (e.g., barrels of oil, extraction cost, refining, transportation, etc.) than they would have had they operated less efficient vehicles. These real resource savings are represented by the price of the fuel (i.e., gasoline or diesel) saved. (IPI 2018a, pp. 4-5).
>
> The NERA/Trinity analysis improperly undercounts actual fuel savings in the cost benefit analysis by failing to include the fuel savings beyond those it asserts consumers will value when purchasing a vehicle. … [T]he NERA/Trinity approach argues that Americans value only 60 months of the fuel savings that a relatively more efficient vehicle would deliver when making a vehicle purchasing decision, and that after those 60 months have passed, those drivers will have extra money in their wallets and bank accounts to which they will assign a value of $0. (NGO, p. A5)
>
> …the analysis includes only 60-months' worth of fuel savings rather than all of the savings that actually accrue over the life of a vehicle. While consumers may not value all future fuel savings at the time of a new vehicle purchase, there is no justification provided by the analysis for why *society* should not account for the benefit from all the actual fuel savings that actually occur—savings that leave money in the consumer's pocket and thus produce a real benefit, whether or not the consumer factored those savings into the initial purchase. (CARB 2018, p. 24)

Both sets of comments point to the Agencies' prior analyses, commentary, and directives, which they say provide evidence that present discounted value estimates yield a more accurate measure of consumer benefits.

3. *Response to Critiques*

The following subsections provide our responses to the three critiques.

a. Willingness to pay is the basic criterion for determining the dollar value of benefits to consumers and clear "market failures" are needed to justify using an alternative approach

In estimating benefits to consumers, economists generally rely on consumers' own preferences as revealed by their choices. If consumers choose not to buy a product at a price of $100, that choice reveals that the value they place on the product is less than $100. We use this principle of consumer preference to estimate the benefits for all fuel economy benefits, including additional vehicle miles of travel and additional time as well as reduced fuel costs.

EPA's *Guideline for Preparing Economic Analyses* note that estimating the values of policy effects requires analysts to "estimate willingness to pay (WTP) of all affected individuals for the quantified benefits in each benefit category, and then to aggregate these to estimate the total social benefits of each policy option."[17]

A simple calculation of "the full value of fuel economy savings" abstracts from the many uncertain factors that affect consumers' valuation of future fuel savings—and thus the likely willingness to pay—including the vehicle miles of travel driven per year, projections of future fuel prices, the number of years the vehicle would be in service, the relationship between the measured fuel efficiency and the actual on-road efficiency, and the relevant discount rate to use. Indeed, by rejecting the consumers' own valuation of these future fuel savings, IPI/NGO/CARB are in effect assuming the presence of consumer irrationality or market failures; various commentary suggests that such paternalism may not be appropriate in the context of fuel savings.[18]

b. Neither IPI nor NGO nor CARB have provided any evidence of "market failures" or "consumer irrationality" that would justify overriding market-determined consumer preferences

The commentators argue that consumers' preferences should be overridden—either in the valuation of fuel economy gains directly or indirectly by using a lower discount rate than consumers use—because of references to various types of "market failures." But they provide no empirical evidence for the types of market failures they allege are included in the literature. The list of *potential* market failures provided by IPI does not constitute evidence that such market failures or consumer irrationality exist for consumer choices regarding automobile fuel economy. Indeed, as various commentators have noted, there are a number of alternative reasons that can explain a difference between "consumer valuation" and "the full value of fuel economy savings."

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[17] See U.S. Environmental Protection Agency (2014).

[18] See, e.g., Gayer and Viscusi (2012).

For example, the observed difference could be rational in the presence of high sunk costs and uncertainty over future fuel savings.[19]

Correction of market failures is a well-established basis for regulatory intervention (see, e.g., the EPA *Guidelines*).[20] But the market failure requiring regulation is typically related to some external effect, such as air pollution or other environmental externalities, not criticisms of private decisions as "irrational." Calculating private gains to consumers on the assumption that consumers are irrational when they are observed to value fuel economy gains less than the present discounted value of estimated fuel savings seems inappropriate in a cost benefit analysis for a commodity such as the highly uncertain potential fuel cost savings from CAFE standards.

c. NERA's valuation of fuel economy is based upon the estimated willingness to pay for all future fuel economy gains, not just those in the 60-month payback period used to determine the baseline fuel economy in the CAFE model

The valuation of fuel economy in the New Vehicle Market Model reflects that value that consumers place on *all* future fuel costs, as reflected in the tradeoffs made between vehicle price and fuel economy (as well as the many other vehicle characteristics that are experienced over time, e.g., horsepower, acceleration, interior space). IPI and NGO seem to have confused the calculation of a 60-month payback period for use in the CAFE model as meaning that only 60 months of fuel economy savings are included in the consumer benefits. This inference is not correct.

We developed the calculation of a 60-month payback period so that Trinity could implement the CAFE model; as discussed in Section D the CAFE model uses this payback period to determine the fuel economy technologies to be included in the baseline fuel economy of the motor vehicle fleet. But the value of a reduction in the per mile cost of driving we estimate reflects consumer's willingness to pay for all future cost savings.

d. NERA's estimate of the value of fuel economy can be translated into an estimate of the implicit discount rate that consumers use to calculate the present value of fuel savings; this discount rate is consistent with other studies

Our estimate of the dollar value that consumers assign to fuel economy improvements can be translated into an implicit discount rate that consumers apply to expected future fuel cost savings. Indeed, estimating this implicit discount rate has been a focus of much of the economic literature on the "energy efficiency gap."[21]

For example, two recent studies estimate the discount rate that consumers place on future fuel savings (Allcott and Wozny 2014 and Busse et al. 2013). Indeed, the two sets of authors provide summaries of the other study, allowing for "apples to apples" summaries of the two findings. These results can be considered a "check" on whether the results of our study are consistent with the

[19] See Hassett and Metcalf (1993), cited in Gayer and Viscusi (2013).

[20] U.S. Environmental Protection Agency (2014, Chapter 3).

[21] See, e.g., Busse at al. 2013.

literature. The following is the summary in Allcott and Wozny (2014) of the implications of the Busse et al. (2013) study.

> Busse et al. (2013) estimate how changes in gasoline prices affect equilibrium prices and quantities of new and used vehicles in different quartiles of the fuel economy distribution. They then plug these estimates into an Excel spreadsheet, which outputs the implied discount rates at which the average prices of vehicles in each MPG quartile fully adjust to changes in gasoline costs. Depending upon their assumptions, they find implied discount rates ranging from -6.2 percent to 20.9 percent. When using assumptions that correspond most closely to ours, they find an implied discount rate for used vehicles of 13 percent. (p. 782)

The following is the summary in Busse et al. (2013) of an earlier version of the Allcott and Wozny study.[22]

> We conclude that there is little evidence that consumers dramatically undervalue changes in expected fuel costs, and that the evidence from new and from used cars yields similar messages. Our findings on this are similar to Allcott and Wozny (2011) who calculate that their results correspond to a 16 percent implicit discount rate, and to Sallee, West, and Fan (2009) who find somewhat less undervaluation of future fuel costs than do Allcott and Wozny (2011). It bolsters our confidence in the results of this entire set of papers that different configurations of identifying assumptions yield similar results. In our view, this lessens the worry readers should have that the results in any of these papers arise directly from a particular set of assumptions. (p. 246)

These two papers thus suggest a relevant consumer discount rate in the range of 13 percent to 16 percent. To these results could be added the results of a well-established earlier study by Dreyfus and Viscusi that reports a range of 11-17 percent and a more recent study by Leard et al. that reports a range of 5-15 percent.

We can translate our estimate of the willingness-to-pay for a unit decrease in the cost-per-mile of driving into an implicit discount rate, i.e., the discount that is implicit in the dollar value using various assumptions on future VMT and gasoline prices. In order to make our implicit discount rate calculation consistent with these other values, we use assumptions from Busse et al. (2013) and Leard et al. (2017). These calculations indicate that our estimate is equivalent to an implicit discount rate of between 7 and 19 percent, which is consistent with the range of values from the studies mentioned above.

[22] Note that Busse et al. (2013) are referring to earlier, unpublished versions of papers by Allcott and Wozny, and Sallee, West, and Fan. The Allcott and Wozny paper was later published in 2014 and its conclusions are consistent across versions; the Sallee, West, and Fan paper was later published in 2016. Note that the 2009 version cited by Busse et al. is unavailable; however, the conclusions are ostensibly the same, given the similarity in how the different versions are compared to Allcott and Wozny, 2011 and 2014, by Busse et al. and EPA, respectively. See References provided in Section F for citations.

In addition to comparing a discount rate that is implied by our results to the discount rates in the economics literature, we can also directly compare our valuations to those reported by other econometric studies of the valuation of vehicle attributes. For example, we can compare our estimate of the value of a unit change in cost per mile ($0.01/mile) with results reported in a recent survey article and meta-analysis of the willingness to pay of automobile consumers in numerous studies (Greene et al 2018). This study compared and analyzed willingness-to-pay estimates from 52 U.S. studies. For comparison, the willingness-to-pay value we estimate is $694, i.e., we find that consumers are willing to pay an additional $694 to reduce cost per mile by $0.01. The authors provide mean willingness-to-pay values for many subsets of the various studies. The two values that seem the most appropriate comparisons to our estimate are a mean value $693 (based upon the mean value of market-type studies, excluding survey studies) and a value of $569 (based upon econometric models that account for endogenous determination of the value).[23] Both values are similar to our value, with the first virtually identical to ours and the second about 80 percent of our value.

These various studies thus support the proposition that our estimate of the value that consumers place on fuel economy improvements is broadly consistent with the range of estimates found in the literature.

e. Using the valuation of fuel savings recommended by the critiques would not change the major conclusions of the NERA/Trinity study

Although we believe there are strong reasons to use consumers' willingness to pay—rather than the commentator' preferred method of discounting future expected fuel cost savings at the social discount rate—as the appropriate measure of the social benefits from improved fuel economy, using the alternative calculation would not materially change the conclusions of our study regarding the relative net benefits of alternative CAFE standards.

Table 5 provides estimates of the fuel economy benefits for the three alternative CAFE standards we evaluate, all relative to the (most stringent) augural standards under two methods of valuing fuel cost savings: (a) based upon consumers' willingness to pay as reflected in our detailed study; and (b) based upon the "full value of fuel economy savings" recommended by the critiques. Results are provided for the two discount rates, 3 percent and 7 percent. All of the entries are estimates of the *reductions* in fuel economy benefits of reducing the stringency of the standards relative to the augural standards. Thus, for example, assuming a 7 percent discount rate, adopting the Scenario 5 CAFE standards (rather than the augural standards) is estimated to reduce the benefits of fuel economy changes by $33.3 billion using consumers' willingness to pay and by $42.8 billion using the approach that the comments suggest, a difference of $9.5 billion.

[23] Both values are on p. 271 of Greene et al. (2018), with the first value in Table 6 and the second value in Table 8.

Table 5. Alternative Measures of Fuel Economy Benefits Relative to Augural Standards Baseline (billions of 2016$)

	3% Social Discount Rate			7% Social Discount Rate		
	Scen. 8	Scen. 5	Scen. 1	Scen. 8	Scen. 5	Scen. 1
Valuation of Fuel Cost Savings Based upon WTP						
Valuation of Fuel Cost Savings	-$16.7	-$28.9	-$51.3	-$12.4	-$21.3	-$38.0
Rebound Mobility Benefit	-$9.7	-$17.4	-$31.0	-$5.8	-$10.3	-$18.5
Refueling Time Benefit	-$1.6	-$2.7	-$4.9	-$0.9	-$1.6	-$2.9
Benefits of Fuel Economy Changes	**-$28.0**	**-$49.0**	**-$87.2**	**-$19.1**	**-$33.3**	**-$59.5**
Valuation of Fuel Cost Savings Based upon Expected Savings Using Social Discount Rate						
Valuation of Fuel Cost Savings	-$30.5	-$52.6	-$93.8	-$17.9	-$30.8	-$55.5
Rebound Mobility Benefit	-$9.7	-$17.4	-$31.0	-$5.8	-$10.3	-$18.5
Refueling Time Benefit	-$1.6	-$2.7	-$4.9	-$0.9	-$1.6	-$2.9
Benefits of Fuel Economy Changes	**-$41.8**	**-$72.7**	**-$129.7**	**-$24.7**	**-$42.8**	**-$77.0**

Note: Present values calculated as of January 1, 2017 using 3 percent and 7 percent discount rates for costs/benefits incurred over the 2017-2050 analysis period. The values include effects for model year vehicles up to MY 2029. All values relative to augural standards baseline. All values in billions of 2016 dollars, rounded to the nearest $0.1 billion.

Source: Table 40 of NERA/Trinity (2018) and calculations as explained in text.

Table 6 shows the implications of differences in the dollar of fuel economy benefits on net total benefits for the three CAFE scenarios compared to the augural standards scenario. The top part of the table reproduces results using the same valuation methodology as in the NERA/Trinity report, while the bottom part of the table shows results if the "full value of fuel economy savings" were used to value fuel economy benefits.[24] Social costs are unaffected, so the differences in net benefits are due to the differences in fuel economy benefits.

[24] The values provided in Table 6 are slightly changed from the analogous values reported in the NERA/Trinity Report to reflect minor corrections. A full set of corrected tables and figures is provided in a separate document.

Table 6. Net Benefits Relative to Augural Standards Baseline (billions of 2016$)

	3% Social Discount Rate			7% Social Discount Rate		
	Scen. 8	**Scen. 5**	**Scen. 1**	**Scen. 8**	**Scen. 5**	**Scen. 1**
Valuation of Fuel Cost Savings Based upon WTP						
Social Costs	-$77.7	-$127.6	-$191.1	-$57.8	-$94.4	-$141.8
Social Benefits	-$29.0	-$50.8	-$92.9	-$18.7	-$32.5	-$58.5
Net Total Benefits	**$48.7**	**$76.8**	**$98.3**	**$39.1**	**$61.9**	**$83.2**
Valuation of Fuel Cost Savings Based upon Expected Savings Using Social Discount Rate						
Social Costs	-$77.7	-$127.6	-$191.1	-$57.8	-$94.4	-$141.8
Social Benefits	-$47.1	-$81.9	-$148.6	-$27.0	-$46.9	-$84.8
Net Total Benefits	**$30.6**	**$45.7**	**$42.6**	**$30.7**	**$47.6**	**$57.0**

Note: Present values calculated as of January 1, 2017 using 3 percent and 7 percent discount rates for costs/benefits incurred over the 2017-2050 analysis period. The values include effects for model year vehicles up to MY 2029. All values relative to augural standards baseline. All values in billions of 2016 dollars, rounded to the nearest $0.1 billion.

Source: NERA/Trinity 2018 and calculations as explained in text.

The following are the implications of these comparisons.

- *With 7 percent discount rate, there is no change in conclusions (a) that all three CAFE alternatives lead to net benefits and (b) that Scenario 1 has the largest net benefit.* Using a discount rate of 7 percent to evaluate the present value of social costs and social benefits, none of the conclusions change. The net benefits continue to be positive for all three alternative CAFE scenarios—indicating that the reduction in social costs is greater than the reduction in social benefits for all three scenarios in which CAFE standards would be relaxed relative to the augural standards. The net benefits range from $30.7 billion for Scenario 8 (alternative closest to the augural standards) to $57.0 billion for Scenario 1 (alternative furthest from the augural standards), with net benefits for Scenario 5 equal to $47.6 billion.

- *With 3 percent discount rate, there is no change in the conclusion that all three CAFE alternatives lead to net benefits, but Scenario 5 has slightly greater net benefits than Scenario 1.* Using a discount rate of 3 percent, the net benefits continue to be positive for all three scenarios, indicating that the reduction in social cost is greater than the reduction in social benefits for all three scenarios in which CAFE standards would be relaxed from the augural standards. But with a 3 percent discount rate, the net benefits of Scenario 5 are $45.7 billion, about 8 percent greater than the net benefits of Scenario 1 of $42.6 billion.

As discussed below, the net benefits of the three alternative CAFE standards would likely be substantially greater if account were taken of the effects that binding CAFE standards have on reducing opportunities to improve other vehicle attributes, such as power and acceleration.

f. Recognizing that major adverse consumer effects of the CAFE fuel economy standards are not included in the net benefits—notably the "opportunity costs"

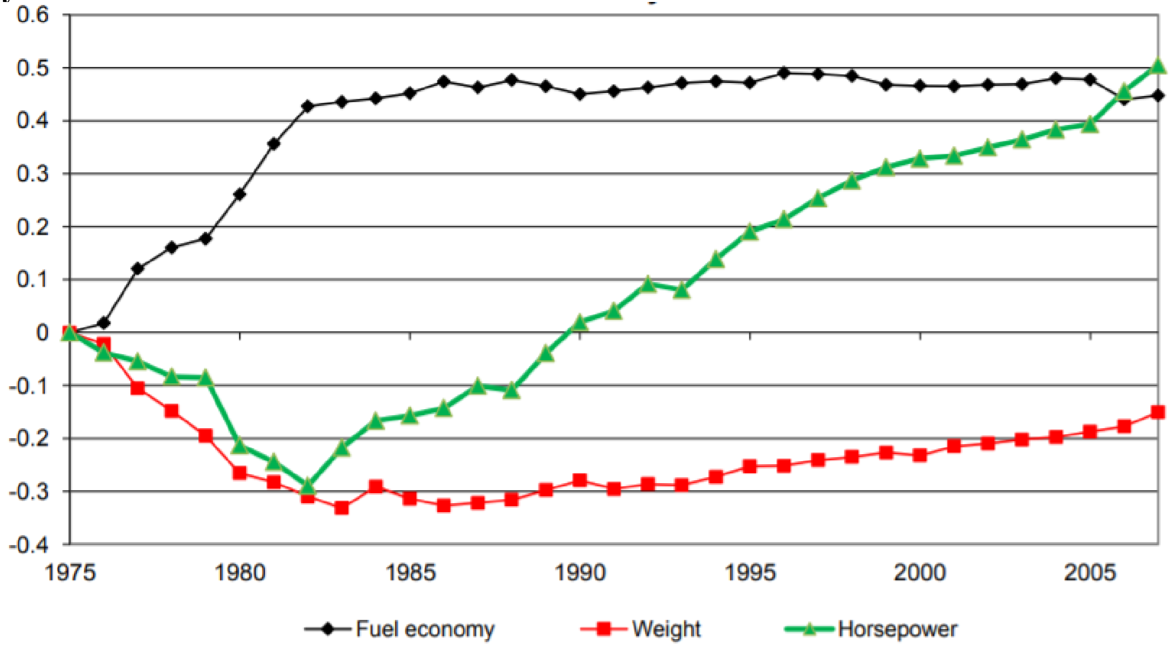
from foregone gains in horsepower and other desirable features—reinforces the conclusion that differences in the valuation of fuel economy would not change the major conclusions of the NERA/Trinity study

Our analyses (as well as those performed by the Agencies) ignore some important negative effects on consumer welfare from CAFE standards—specifically reductions in other desirable vehicle attributes (e.g., horsepower) that otherwise would have been introduced. These reductions in consumer welfare have been documented in numerous studies,[25] although the implications of these studies have not been included in government analyses of the social costs of CAFE standards, and we did not include them in our study. Nevertheless, since the critiques raise issues regarding our alleged *underestimate* of the benefits to consumers from CAFE-induced fuel economy improvements, it seems appropriate to discuss an important effect that means that our analyses (and those of the Agencies) *overestimate* consumers' benefits.

Figure 3, reproduced from Klier and Linn (2013), provides illustration of how CAFE standards can adversely affect other vehicle characteristics and reduce consumer welfare. The figure shows that when U.S. fuel economy standards were constant from about 1985 to 2005, automotive technology improved steadily. In particular, the figure shows that manufacturers used improvements in technology to raise horsepower and weight while holding fuel economy constant. This pattern shows that manufacturers improved vehicle characteristics other than fuel economy when CAFE standards were unchanged.

[25] See, e.g., Klier and Linn (2013), Klier and Linn (2016), Leard et al. (2017).

Figure 3. Fraction Change in Fuel Economy, Weight, and Power 1975 – 2008 for Cars Sold by U.S. Manufacturers



Note: The figure reports the fraction change of sales-weighted mean fuel economy (in mpg), weight (in pounds), and horsepower relative to 1975.
Source: Figure 1 as it appears in Klier and Linn (2013).

Importantly, this historical pattern suggests that if CAFE standards are tightened, manufacturers would reduce the pace of improvement in these other desirable features, reducing consumers' welfare. In economic terms, more stringent CAFE standards create an "opportunity cost" to consumers (beyond the "actual costs" of the technology to achieve the CAFE standards) by not including improvements in vehicle performance that otherwise would have been provided. These opportunity costs offset the gains to consumers from the improved fuel economy. As Klier and Linn (2016) point out, a welfare analysis of CAFE standards should incorporate this effect.[26]

Klier and Linn 2016 provide quantitative estimates of the present discounted value of potential fuel savings from improved fuel economy—using a discount rate of 10 percent—and the offsetting losses from foregoing other vehicle improvements (increased horsepower). Table 7 summarizes their results for an assumed 10 percent decrease in fuel consumption.[27] The results estimate that for purchasers of passenger cars, the loss in potential horsepower offsets about 54 percent of the fuel economy gains. For purchasers of light trucks, the offset is even more dramatic; the loss in potential horsepower offsets about 61 percent of the fuel economy gains. And note that these

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[26] Klier and Linn note a second dynamic factor affecting consumer welfare—the potential for CAFE standards to increase the pace of technology innovation and development. This effect is opposite to the first effect, leading to greater consumer welfare. Empirical evidence indicates that this second effect is smaller than the first effect. The empirical example we provide in this section Table 7 is based upon the net effect on consumer welfare of these two competing dynamic effects.

[27] The authors also provide results for European cars, but these are less relevant than the U.S. results.

results assume that consumers discount potential future fuel savings at 10 percent, which might overstate fuel economy gains if the actual discount rate were higher. The results would be even more dramatic if a higher discount rate were used (and thus the values of the fuel economy gains were lower than shown in this table).

Table 7. Effects on Consumer Welfare of a 10 Percent Fuel Consumption Rate Decrease for U.S. Vehicles Accounting for the Opportunity Costs from Foregone Horsepower Gains

	WTP for MPG Change	WTP for HP Change	Net WTP (MPG + HP)	% Reduction in WTP due to HP
Cars	$725	-$389	$336	54%
Light trucks	$983	-$595	$388	61%

Note: All dollar values are 2005 dollars.
Source: Table 7 from Klier and Linn (2016).

These results cannot be used directly to estimate the offsetting consumer losses from reduced passenger car and light truck performance due to the three CAFE standards we evaluate in the NERA/Trinity report. But it is possible to provide illustrative results assuming these percentage offsets applied, using a value of 57 percent (i.e., rough midpoint for passenger cars and light trucks) to scale the fuel cost savings of new vehicles in each scenario. Table 8 provides these illustrative results, starting with fuel economy values based upon the commentators' suggested approach (see Table 5).

Table 8. Illustrative Application of Klier and Linn (2016) Welfare Effects on Net New Vehicle Fuel Savings Accounting for Opportunity Costs from Foregone Horsepower Gains

	3% Social Discount Rate			7% Social Discount Rate		
	Scen. 8	**Scen. 5**	**Scen. 1**	**Scen. 8**	**Scen. 5**	**Scen. 1**
Benefit of Fuel Economy Improvement						
Expected Fuel Cost Savings using Social Discount Rate	-$30.5	-$52.6	-$93.8	-$17.9	-$30.8	-$55.5
WTP for Horsepower Change	$13.1	$22.6	$40.3	$7.7	$13.3	$23.9
Net WTP for MPG change	**-$17.4**	**-$30.0**	**-$53.5**	**-$10.2**	**-$17.6**	**-$31.6**
Social Costs and Benefits						
Social Costs	-$77.7	-$127.6	-$191.1	-$57.8	-$94.4	-$141.8
Social Benefits	-$34.0	-$59.3	-$108.2	-$19.1	-$33.2	-$60.2
Net Total Benefits	**$43.7**	**$68.3**	**$82.9**	**$38.7**	**$61.2**	**$81.6**

Note: Present values calculated as of January 1, 2017 using 3 percent and 7 percent discount rates for costs/benefits incurred over the 2017-2050 analysis period. The values include effects for model year vehicles up to MY 2029. All values relative to augural standards baseline. All values in billions of 2016 dollars, rounded to the nearest $0.1 billion.
Source: NERA/Trinity 2018 and calculations as explained in text.

While these results are only illustrative, they strongly suggest that incorporating the offsetting negative effects on consumers from losses in vehicle performance would lead to the same two conclusions as the original NERA/Trinity study even if we employed the fuel economy valuation methodology recommended by the critiques: (a) all CAFE alternatives would lead to net social benefits and (b) Scenario 1 would yield the largest net benefits.

4. Conclusions

Contrary to the critiques, the NERA/Trinity study provides estimates for the value that consumers place on all future fuel economy improvements, not just for the first 60 months. Although we calculated a 60-month "payback period" in order for Trinity to implement the CAFE model, the value we obtain from the New Vehicle Market Model does not assume any cut-off date. Our estimate of the value of vehicle fuel economy improvements (based on WTP) could be interpreted as implying a consumer discount rate of about 7-19 percent, a value consistent with the range of discount rates that have been estimated by many researchers using different empirical formulations. Our estimate is also consistent with the results of a recent meta-analysis of studies that have evaluated the marginal willingness to pay for fuel economy improvement.

Although we believe that basing social benefit calculations on estimated consumer willingness to pay—as reflected in our detailed empirical study—has advantages relative to the calculation suggested by the commentators, the major conclusions of our study are not likely to be affected even if their recommended methodology is used. Our calculations show that using their approach with a discount rate of 7 percent does not affect conclusions that all three CAFE alternatives we evaluate lead to net benefits (relative to the augural standards) and that Scenario 1 (the lowest stringency alternative studied) has the largest net benefit. If a 3 percent discount rate is used with their approach, all three CAFE alternatives have net benefits, but Scenario 5 has slightly higher net benefits (about 8 percent greater) than Scenario 1. But when account is taken of the adverse effects of CAFE standards on consumer welfare due to reductions in vehicle performance—an offset that is excluded from our analyses as well as those of the Agencies—Scenario 1 would certainly have the highest net benefit. Although our calculation of this offsetting effect is illustrative, there seems no doubt that this conclusion would hold given the closeness of results for the two scenarios when this effect is excluded.

In summary, although it may be possible to value fuel economy improvements in more than one way that seem consistent with economic theory and EPA and government guidelines, we believe that the principal conclusions of our net benefit study are not affected by this choice. Under either our approach or the commentators' approach, all three CAFE scenarios we evaluate lead to net benefits (relative to the augural standards) and Scenario 1 has the greatest net benefits.

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