Appendix B: Review of New Modules and Phase 2 Reviewer Résumés

NHTSA Phase 2 CAFE Model Review Compilation

Introduction

Three modules were added to the Corporate Average Fuel Economy model as part of the analysis supporting the Preliminary Regulatory Impact Analysis (PRIA) of the proposed CAFE rule announced August 2018, as follows.

- Sales Response Model
- Scrappage Model
- Labor Utilization Calculations

Four independent experts were asked to review the new modules for the appropriateness of their specifications and to suggest any modifications or enhancements that might improve the reliability of the estimated market responses to proposed regulatory actions. The four reviewers are:

- Dr. Alicia Birky, Energetics, Inc.;
- Dr. John Graham, Indiana University;
- Dr. Howard Gruenspecht, Massachusetts Institute of Technology; and
- Dr. James Sallee, University of California, – Berkeley.

This document summarizes their reviews. For each topic a brief introduction indicates the particular themes that emerged as generally consistent among the reviewers' responses. Also, although the reviewers address three or four questions related to each topic, some of the reviewers' comments and suggestions applied to both the sales and scrappage models.

Note that the digests of the individual reviewer's comments are paraphrased. The peer reviewers' full, as-received responses are appended to this summary.

Sales Model

Question Number	Question Topic Description
1	**Sales Model**
1a	Please comment on the appropriateness of including a sales response model in the CAFE model as a means to estimate differential sales impacts across regulatory alternatives.
1b	Please comment on the sales model’s specification using an autoregressive distributive lag (ARDL) model time series approach, and comment specifically on the endogeneity of average transaction price.
1c	Please comment on the sales model’s integration in the CAFE model, including interactions with the simulation of multiyear product planning, in combination with the dynamic fleet share model used to allocate total new vehicle sales to the passenger car or light truck market segments.
1d	Please comment on the sales model’s specification as independent of vehicle scrappage, and on the resultant calculation of vehicle miles traveled (VMT).

Summary

The reviewers agree that including sales response and scrappage models is appropriate; however, their analysis raises fundamental issues regarding the model’s specification and implementation. Reviewers suggest that a discrete choice model might be more appropriate in describing the sales response and might have a more solid grounding in economic theory than the aggregate sales/scrappage responses validated on historical data that frames the sales and scrappage models embedded in the CAFE model.

The CAFE model reviewers also note that the automobile ownership profile of consumers appears to be changing and those changes may be quite significant by the end of the period addressed by the model. These changes call into question the assumption that predictions built on past data can predict future consumer response.

A related issue raised by the reviewers is the calculation of VMT based on the vehicle’s vintage. The reviewers suggest that VMT attributable to an additional vehicle in a household may be dependent on the number of vehicles already in the household and may not be only dependent on the vehicle’s vintage as implied by the inputs to the CAFE model. The reviewers indicate that these issues could be better addressed by a household transportation modal choice model.

Reviewers also note that regardless of the model’s formulation, the new and used car markets should be integrated. In other words, the reviewers suggest that more reliable estimates could be generated by integrating the sales and scrappage models and by including the used car market in the specification. If the alternative integrated model is a modal choice model, as suggested above, then a caveat is that vehicle purchase and scrappage decisions are rarely made by the same households. Other specification issues warranting further examination or explication include: the extent to which manufacturers pass-through technology development and manufacturing costs to the consumer; the omission of consequential variables, such as disposable income, that are causally related to the dependent variable; and the method used to determine the distribution of sales across vehicle types.

Reviewers point to the implausibility of the fleet size results where the relaxation of the fuel economy standards of the "preferred alternative" leads to a smaller fleet of cheaper vehicles than the size of the "baseline alternative's" fleet of more expensive vehicles. Along with the independent specifications of sales and scrappage, the reviewers observe that the high degree of simultaneity and endogeneity in the models might lead to the questionable result and call into question the reliability of the models' estimates.

One unanimous reviewer recommendation is to apply sensitivity analyses to test more fully the robustness of the estimates, especially regarding the estimated price elasticity of demand which may be outside the range found in the literature. A further suggestion is to run alternative model specifications and compare resulting estimates. Sensitivity analyses and alternative model specifications may also be used to test for the effects of potential exogenous shocks to the system, such as policy changes not present in the historical data.

Birky

1a.

- Fundamental issue: The PRIA indicates that the model goals are to address consumer and manufacturer behavior, but the sales model is not specified as a choice model.
- The complexity of specifying a model with a high degree of endogeneity requires additional validation and sensitivity analyses.

1b.

- Because the rationale for using ARDL is not explicit, the reviewer assumption is that partial adjustment is the rationale.
- The expectation is that labor force participation (LFP) is positively associated with sales; however, the coefficient of lagged LFP is large and negative, which is counterintuitive and casts doubt on the entire model specification. One missing variable may be disposable income.
- Endogeneity does create difficulties which can only be solved with complex modeling approaches.

1c.

- The specific approach to estimating fleet share of the two vehicle types by determining car share independently of truck share is inappropriate since decisions to purchase are made using a joint determination of the properties of cars and trucks. A possible approach is a single equation for car (or truck) share that includes attributes of both cars and trucks.
- **Recommendation**: Use a logit model that includes at least three (cars, pickups, and vans/cross-overs/ SUVs) or possibly four vehicle types.

1d.

- With the caveat that the decisions to purchase a new vehicle and to scrap an existing vehicle are rarely made by the same household, the model objectives would be better served by a household choice model that includes the used car market. Acknowledges that no existing demand model captures this joint decision.
- Vintaged VMT schedules taken from R. L. Polk & Company are influenced by many trends that may not be valid in the future, including for example ownership rates (which are not reported as part of model results).

  - **Recommendation:** predict national VMT demand based on economic indicators, demographic changes, and characteristics of vehicles, and scale the VMT schedules to determine VMT by age. Scaling has the potential to obscure a shift in VMT between older and newer vehicles that accompanies changes in vehicle stock or fuel prices.

Graham

1a

- The sales response model is appropriate. The high cost/impact of regulations requires analysis even more so than in previous instances of emissions, safety, and fuel economy standards.
- An engineering approach to the problem is not sufficient; a model must also consider consumer responses to policy changes.

1b

- The pass-through assumption is reasonable, but the explication should offer more justification as to why that is the case:
  - **Recommendation**: Add references to the extensive literature on pass-through in the automobile industry.
  - Pass-through pricing is more germane in the long run than in the short run, which is critical given the time span of the model.
  - The footprint adjustments to the regulations, which affect the entire industry rather than only a subset of manufacturers, will lead to a higher degree of pass-through.
  - Pass-through pricing is a feature of competitive markets; today's automobile market exhibits a higher degree of competitiveness than in the late 20th century.
- One aspect of the model specification is the omission of indicators of consumer access to credit (e.g., average interest rates). Also missing is used car pricing. **Recommendation**: Add these two omitted variables.
- A related result is that variables measuring fuel economy do not increase the explanatory power of the model. **Recommendation**: Use a net-price approach, similar to that used in past RIAs, to estimating the future impacts of fuel-economy regulation with the assumption that the net price includes just 2.5 years of consumer valuation of future fuel savings. This is consistent with the model's treatment of how manufacturers choose which fuel savings technologies to develop. Sensitivity analyses using 1 and 4 years should be performed.
- **Recommendation**: Rewrite Section 8.3, "Consumer Valuation of Improved Fuel Economy," to highlight the literature documenting consumer undervaluation of fuel economy when purchasing vehicles.
- Endogeneity can be addressed in the write-up by a qualitative discussion of bias that considers the direction of the bias. This discussion will relate to the reasonableness of the value of the coefficient indicating the price elasticity of demand. The model may be used to control for reverse causation. (Although high prices may decrease sales volume, high sales volume may increase average prices.)
- **Recommendation**: Use a literature-based coefficient of the long-term impact of vehicle price on demand and then use the model to apportion the total effect across the years in the time frame.

1c

- The model does not account for the economic and environmental effects of the preferred alternative's elimination of the State-level zero-emission vehicle (ZEV) standards.
- **Recommendation**: Include the elimination of the ZEV standards in the sales-response model.
- **Recommendation**: Include the cost savings from elimination of the State-level ZEV requirements

1d - No response

Gruenspecht

The reviewer performed a close analysis of model output of both the CAFE and CAFE_ss runs. The latter set of runs incorporate statutory constraints on possible compliance responses.

1a.

- The overall light-duty vehicle (LDV) sales response reported in the model is plausible.
- However, sales outcomes of the Baseline (B) and Preferred (P) Alternatives do not diverge until MY2022 despite the difference in prices between the two cases. Why is there a lag?
- In addition, the CAFE and CAFE_ss runs, which use different price paths, produce the same sales differences between the B and P cases for MY2022 through MY 2032. This implies that other factors are driving sales outcomes other than pricing. What are these additional factors?
- The price elasticity of sales in the model run is markedly below the -0.2 - -0.3 range documented in the accompanying analyses, which itself is below the range of estimated price elasticities most often cited in the literature.
    - **Recommendation**: Perform a sensitivity analysis to test the sales response at higher price elasticities.
- The passenger car/light truck (PC/LT) sales distribution model results is consistent with other results showing that sales by vehicle type responds to different fuel economy standards by vehicle type and fuel prices. However, if standards are fully phased in by MY2025 in the Baseline, why does the difference in LT share of sales continue to grow between the B and P cases?
- The addition of sales response makes the CAFE model more "thorough and up-to-date." However, given the issues indicated above, especially those with regard to price elasticity, the wrong sales response model could lead to less accurate estimates than a model totally excluding sales response.

1b. - No response

1c.

- The reviewer could not assess the multi-year planning feature of the model and its interaction with the market effects questioned in 1a.
- Model validation based on historical data may reduce the ability of the model to distinguish the results of different policy options (which by definition are not reflected in the historical record). The effects of the policy options could be overwhelmed by underlying factors that are present in the history.
- Modeling of product planning at the manufacturer's level could present a risk of mischaracterizing the aggregate picture.

1d.

- Sales response and scrappage response are not independent processes.
- The CAFE_ss model results in a fleet that is markedly larger in the Baseline condition by 2037 than in the Preferred alternative. This is an unexpected result that may be a result of sales and scrappage being analyzed independently rather than in a comprehensive transportation mode choice model.
- The current sales model framework does not consider the demand side of the used car market, which will directly affect scrappage decisions.
    - **Recommendation**: Hold the total number of vehicles constant in both the B and P cases.
- The model posits that VMT per year drops as vehicles age with a rapid decline between ages 6 and 11. No justification is given for the assumption that a consumer's VMT will change given the age of a newly acquired vehicle. The model also accounts for the rebound effect where more efficient vehicles induce additional trips. Examining the CAFE_ss_NOREBOUND runs, the reviewer finds that the percent differences in VMT over the simulated years is much smaller than runs that include the rebound effect.
    - **Recommendation**: Increase the VMTs assigned to older vehicles in the B case versus the P case such that total non-rebound VMT would remain constant between the two cases.
- There are significant advantages to integrating scrappage and sales models, including a reconsideration of how VMTs are accumulated in the modeling.

Sallee

1a.

- The sales response parameter is highly uncertain and difficult to estimate; therefore, it should be subject to sensitivity analyses.
- Possible approaches to improving the estimate include using varying scenarios of the sales response rather estimating than a suspect (due to endogeneity) single-regression coefficient.
- The CAFE model analysis does not isolate exogenous cost increases which contributes to the difficulty of estimating the parameter; an additional difficulty is that the cost increase affects the entire market.
- **Recommendation:** Present an ensemble of results using different values for the magnitude of new car sales response rather than the current approach.
- Discrete choice models are bounded by the choice of an "outside good" (e.g., not buying a car); what are the estimates of these bounds and how might they affect overall fleet size? However, a caveat is that the literature reports the results from static models of short-term effects.
- The pass-through reported in the CAFE model likely overstates the effects of technology deployment costs on new car sales. Economic theory indicates that only true marginal costs of technology would be reflected in the price. Fixed costs are properly included in the cost-benefit analysis, but they distort the sales response model.
- A microeconomic choice model of the vehicle purchasing decision takes into account price net the benefits to the consumer. Using gross prices is misleading. However, producing better (and presumably more expensive) cars could provide a net benefit to consumers and nevertheless expand sales. However, the effect of CAFE standards on overall market size is ambiguous.

- The reviewer distinguishes “steeply sloped” footprint rules from relatively flat regulatory regime schedules. In the flatter case the market size analysis may be misleading.
- The reviewer notes that the ownership model is changing due to new transportation options such as ride share and vehicle subscriptions.

1b

- There is no clear “identification strategy” behind the model specification, so it is difficult to interpret the coefficients.
- Use the econometric model presented to inform alternative scenarios rather than treat it as a conclusive estimate.
- Price endogeneity leads to a biased estimate of the parameter. Prices and quantities are positively correlated in the raw data. Price also is related in the data to changes in the composition of the fleet. The dearth of macro variables in the specification, e.g., interest rates or exchange rates, that affect the automobile market likely leads to bias.
- The model’s goodness of fit with historical data is not enough to indicate an unbiased causal relationship. In addition, the length of the time series lessens the likelihood that the price coefficient is stable over time.
- The model documentation indicates that price changes affect the level of sales, which the reviewer finds to be “peculiar.”
- **Recommendation**: Apply the Newey-West correction to HAC in the standard errors.
- **Recommendation**: Use a vector autoregression rather than ARDL.
- Quarterly data may not be an improvement on annual data given the possibility that seasonal effects are biasing the results.

1c

- New and used car markets interact, but the model does not integrate them.
- The model produces counterintuitive results for the net impacts on fleet size.
- The reviewer has no issues (in contrast to Birky) of estimating total fleet size in one step and the light truck share in a second step.

1d

- New and used car markets should be integrated.
- VMT likely scales less proportionately with fleet size.
- Adding more vehicles to the fleet should cause age-specific VMT to decline.
- **Recommendation**: Start with a fundamental classic economic choice model where the input to utility is VMT to determine the effect of adding an additional vehicle to a household on VMT.

Scrappage Model

2	Scrappage Model
2a	Please comment on the appropriateness of including a scrappage model in the CAFE model as a means to estimate the potential impact of CAFE standards on used vehicle retention.
2b	Please comment on the scrappage model's specification using a form common in the relevant literature. Are there better approaches that allow for both projection (as is necessary in this context) and a focus on new vehicle prices (exclusively)?
2c	Please comment on the scrappage model's integration in the CAFE model, addressing the vehicles affected by the scrappage model, and the extent to which changes in expected vehicle lifetimes are consistent with other assumptions.

Summary

The reviewers pose a related and analogous set of questions and issues for the scrappage model as the sales response model, including issues related to counterintuitive results, endogeneity, missing variables, and the use of a reduced form predictive model rather than a structural causal model. While inclusion of a scrappage model is deemed appropriate, the reviewers note that specifying the two models independently and without direct inclusion of used car prices results in coefficients and aggregate fleet size effects that may not represent causal relationships.

Reviewers point out that the scrappage model does not account for consumer preference for performance, the relationship of performance to fuel consumption, nor the resulting total price of fuel to the consumer. In addition, the model omits repair and maintenance in scrappage decisions. One reviewer notes that the use of scrap metal prices is not completely representative of the markets for scrapped vehicles since used cars also have value in the export market, as well as scrap metal.

Birky

2a

- Scrappage has been neglected in the literature and "a realistic representation of scrappage is an excellent contribution." Adds the caveat that an ideal model would be responsive to demographic variables, as well as existing and new vehicle attributes.

2b

- Fuel consumption is associated with performance variables that consumers value. Inconsistent estimates of the fuel price coefficients in the model may be due to omitting vehicle performance-related variables from the specification.
- **Recommendation**: Use additional statistics to select variables that might add more predictive power to the model, i.e., determining whether to use average price per vehicle or the aggregate price of a manufacturer's vehicles.
- **Recommendation**: Consider export value, which is captured by National Automobile Dealers Association (NADA) residual values and auction prices rather than the value of scrap metal.
- **Recommendation**: Consider other income variables as alternative to gross domestic product (GDP) to increase the explanatory power of the model since income gains have has been less than GDP growth.
- Incremental fleet size is unintuitive; worries about total VMT.

    - **Recommendation:** Consider some measure of accumulated VMT within the scrappage model.

2c

- **Recommendation**: Perform sensitivity analyses of the impact of the scrappage model on expected lifetime vehicle mileage.
- **Recommendation**: Explore the counter-intuitive finding of fleet-size decrease with the reduction of CAFE stringency. The decrease may result from the independence of the scrappage and sales models in the CAFE model specification.

Graham

2a

- Scrappage model is appropriate and supports existence of "Gruenspecht Effect." Suggests several papers as basis for how this should be modelled.

2b, 2c

- Appreciated the effort to describe relative magnitudes of sales and scrappage responses, and does not expect them to be equal. Not surprised by differing fleet sizes across alternatives.
- Would have expected the scrappage effect to be largest for oldest vehicles.
    - **Recommendation**: Perform sensitivity analysis on the vintage in which the scrappage rates are most affected by the regulations.
- The fuel economy regulations should not affect household demand for travel so the VMT effect could be zero.
    - **Recommendation**: Hold VMT constant, but vary share of VMT allocated to differently aged vehicles.
- Thinks that is important to consider impact of potential vehicle upsizing due to footprint based standards.
    - **Recommendation**: Add a qualitative discussion of consumer upsizing to SUVs and provide a quantitative assessment of whether the upsizing results from the current regulations.

Gruenspecht

2a

- Scrappage behavior is important to consider for safety, emissions and fuel consumption outcomes.
- Historical data show scrappage rates are related to fuel prices and fuel economy; there would be a reduction of scrappage rates in augural standards compared to preferred alternative, as shown in the NPRM and PRIA.
- The scrappage model does not account for maintenance and repair costs, which are a part of the scrappage decision.
- Although the model uses new vehicle prices, they do not directly affect scrappage.

- The Baseline fleet size increase over the preferred alternative is due to a larger scrappage response than sales response; this is implausible as all vehicles are more expensive and fleet size should shrink.
- Further, scrappage rates respond to new vehicle price differences in the augural and preferred alternative 2 years earlier than new light-duty vehicle sales response.
- The assumption that repair events related to VMT accumulation do not affect the scrappage decision seems “extreme,” and may partially account for the large scrappage response as new car prices increase.

2b, c – No response

Sallee

2a

- The scrappage model warranted; however, the scrappage model as implemented may not increase the accuracy of the model.
- Misidentification of the causal chain omits the intermediate effect of new car prices on used car prices which then affects scrappage rates.
- Model specification is exposed to simultaneity and omitted variable biases; however, this is a difficult problem to address.
    - **Recommendation**: Use existing evidence to estimate the new vehicle sales response which is then linked to scrappage by an equilibrium choice model.
- The choice in model specification should be based on economic theory, not goodness of fit, to produce a causal model rather than a predictive one.
- Price should be net of changes in quality.
- Use of ad hoc adjustment on future survival rates is problematic.
- Sallee would prefer the use of a data-informed equilibrium model based on theory.
- The presentation of model results does not provide enough information about the estimates for the reader to judge their robustness.
  The sales response model does include a discussion of stationarity (e.g., are the estimators stable over the time period of the model?), but there is not enough discussion of the time series properties of the measures included in the scrappage model. Further, there is insufficient discussion of the use of 3-year lags and why this was thought to be optimal.
- Fleet size results are problematic; are cars Giffen goods as implied by the model?
- Thinks that durability is important to consider, but that the scrappage model may not have captured how new vehicle prices *cause* changes in scrappage rates.
    - **Recommendation**: Separate the analysis of future trends in the longevity of vehicles from the determination of the price coefficients.

2b

- Used vehicles are an intermediate causal step, which the model needs to incorporate directly into its specification.
    - **Recommendation**: Specify a consumer choice model following economic principles that recognizes the flow of once new cars into the used car market over time. The model needs to include the "outside good" – i.e., not owning a car.
- Starting with new cars prices cascade through the vintages, which does not comport with the PRIA's suggestion that there will be a larger scrappage effect on middle-aged used vehicles than on those older or younger.

2c

- VMT schedule is related to fleet size. More vehicles in the fleet leads to lower VMT per vehicle. Current methodology likely overestimates VMT per vehicle.
- The heterogeneity of the Gruenspecht effect across fuel economy levels within a model year probably matters for VMT and fuel leakage, and should be better considered.
- **Recommendation**: in specifying the model, consider that better technology leads to more turnover of the fleet.

Labor Utilization Calculations

3	Labor Utilization Calculations
3a	Please comment on the inclusion of each source of employment related to automobile production and sales.
3b	Please comment on assumptions regarding labor hours, production location (domestic/foreign), and supplier impacts.
3c	Please comment on methods used to calculate changes across alternatives.

Summary

The reviewers provided a smaller volume of responses regarding labor utilization. The comments note that the model takes a piecemeal approach to specifying the labor utilization model and omits downstream effects on labor of changes in the fleet due to fuel economy regulations. The downstream effects would include, for example, labor related to repair and maintenance. Another suggestion for the model is the incorporation of the effects of State-level ZEV requirements on employment. A further proposal is to change the entire modeling approach and use a macroeconomic input-output model to better track changes in employment through all labor market sectors.

Birky

3a

- Downstream employment for maintenance and repair is not included.

3b

- The impact of CAFE on labor hours and costs may not be constant over time as is assumed by the model.

3c - No response

Graham

3a, b, c

- **Recommendation**: Consider the macroanalysis by Carley, Duncan, Graham, Siddiki, and Zirogiannis (2017).
- The PRIA omits the positive and negative impacts of State-level ZEV requirements.

Gruenspecht

3a, b, c - No response

Sallee

3a

- Model takes a piecemeal approach and only considers some of the pieces of automobile-related economic activity
- Alternatives to CAFE model approach include and reviewer discusses each approach in more detail and salience for the current modeling effort
    - Omit labor from the model altogether

    - Use a standard input-output model of economic impact to capture multiplier effects throughout the economy
    - Capture a different set of "pieces" using the current approach
    - Calculate the net real income effect of the policy and apply a generic macro multiplier
- Recommends contrasting the current approach with a more general economic impact multiplier approach

3b

- **Recommendation**: Perform sensitivity analyses, so as not to imply a point estimate.
- Sallee likes the location-specific approach used in the model.
- The following are observations and suggestions:
    - Include more discussion of the use of average rather marginal labor hours to calculate the impact on jobs of changes in sales; however, the use of average labor hours seems appropriate.
    - Use natural experiments to estimate job inputs because of the lumpiness and localization of labor adjustments in the automobile industry.
    - Study long-term trends in labor hours per unit produced.
    - Note that revenue per worker for technology costs is problematic; it is likely that revenues will rise less than costs, thus lowering revenue per worker.
    - Check whether analysis double counts some workers in the production value chain when calculating revenue per worker.
    - Provide additional discussion about the location of the production of advanced technologies; the assumption that the location of the work is fixed (i.e., not affected by the CAFE regulations) is warranted.
    - Consider that it is misleading to separate analysis from the employment rate context.

3c

- The model's general approach for estimating differentials seems reasonable.

Peer Review Charge

"CAFE Model"

Introduction

The 1975 Energy Policy Conservation Act (EPCA) requires that the Secretary of the Department of Transportation set Corporate Average Fuel Economy (CAFE) standards for passenger cars, light trucks and medium-duty passenger vehicles at the maximum feasible levels and enforce compliance with these standards. The Secretary has delegated these responsibilities to the National Highway Traffic Safety Administration, an agency of the U.S. Department of Transportation. Another DOT organization, the Volpe National Transportation Systems Center, provides related analytical support.

In 2002 the Volpe Center and NHTSA staff collaborated to develop a modeling system—referred to here as the "CAFE model"—to analyze how manufacturers could comply with potential standards, and estimate the impacts of regulatory alternatives to inform rulemaking actions that establish CAFE standards. Since that time, DOT staff have collaborated to significantly expand, refine, and update the CAFE model, using the model to inform major rules in 2003, 2006, 2009, 2010, 2012, and 2016. To inform the proposed rule announced August 2018, DOT staff introduced significant new elements to the model, including methods to estimate changes in vehicles sales volumes, vehicle scrappage, and automotive sector labor usage.

Each of these regulatory actions involved consideration of and response to significant public comment on model results, as well as comments on the model itself. In addition to DOT staff's own observations, these comments led DOT staff to make a range of improvements to the model. Insofar as a formal peer review could identify additional potential opportunities to improve the model, DOT sponsored a review of the entire model in 2017. At this time, DOT seeks review of some of the significant new elements added to the model after that review.

Overview of Task

The peer review charge is to identify potential opportunities to improve specific capabilities recently added to the CAFE model. Past comments have sometimes conflated the model with inputs to the model. The peer review charge is limited to the model itself; in particular, rather than addressing specific model inputs which are provided by DOT staff to facilitate review of the model, peer reviewers should address only the model's application of and response to those inputs. However, an evaluation of new relationships within the model is expected to require evaluation of the model's characterization of those relationships – through statistical model coefficients, for example. While those enter the model as "inputs" that can be modified by the user, they are a critical component of the relationships within the model. Thus, it is appropriate to evaluate those coefficients – as they relate to the sales response, scrappage response, and employment response on which this review is focused – as part of this review.

Additional Background

CAFE standards determine the minimum average fuel economy levels required of each manufacturer's fleets of vehicles produced for sale in the United States in each model year. The 2007 Energy Independence and Security Act (EISA) amended EPCA such that these standards must be expressed as mathematical functions of one or more vehicle attributes related to fuel economy. DOT must set CAFE standards separately for passenger cars and light trucks, and must set each standard at the maximum feasible level separately for each model year. Compliance is determined separately for fleets of domestic and imported passenger cars, and domestic passenger car fleets are also subject to a minimum standard based on the projected characteristics of the overall passenger car fleet. A fleet that exceeds the applicable standard in a model year earns CAFE "credits," and subject to a range of conditions, manufacturers can use these credits to offset other model years' and fleets' (including other manufacturers' fleets) CAFE "shortfalls." If a fleet does not meet a requirement, and the manufacturer does not obtain and apply enough credit to cover the shortfall, the manufacturer is required to pay civil penalties.

The purpose of the CAFE model is to estimate the potential impact of new CAFE standards specified in an input file that can contain a range of potential regulatory alternatives to be evaluated. The process involves estimating ways each manufacture could (not "should" or "is projected to") respond to standards, and then estimating the range of impacts that could result from those responses. A detailed representation of the current new vehicle market, specified in another input file, describes that current state of fuel economy technology among all new vehicles offered for sale in the model year (the most recent model year characterized in this way is MY2016). A third file houses a range of inputs defining key characteristics of the range of fuel-saving technologies to be considered—characteristics such as the applicability to specific types of vehicles and costs. The fuel economy improvement associated with a given combination of fuel economy technologies (when applied to a particular class of vehicle) is now contained within the CAFE model itself. While it can be viewed, and even modified, by the user, it is not required as an input to the model. A fourth file contains a wide range of economic and other inputs, such as vehicle survival and mileage accumulation rates (by vehicle age), projected future fuel prices, fuel properties (e.g., carbon content), air pollutant emission factors, coefficients defining potential impact of mass reduction on highway safety, and the social value of various externalities (e.g., petroleum market factors, criteria pollutant and greenhouse gas emissions, fatalities). Considering each manufacturers' projected production, the CAFE standards under consideration, the projected characteristics of the included fuel-saving technologies, and several other input assumptions (e.g., fuel prices and buyers' effective willingness to pay for fuel economy), the model iteratively applies increasing amounts of fuel-saving technology in response to these inputs, and then calculates impacts such as costs to vehicle purchasers, fuel savings, avoided emissions, and monetized costs and benefits to society.

Several elements that appear in the input files reflect earlier versions of the CAFE model, which relied more heavily on static inputs rather than the endogenous relationships present in the current version. In particular, the input files contain remnants from the now-outdated implementation of both sales and scrappage.

While the market data file still contains a static sales "forecast," it is merely a continuation of MY2016 volumes and is used only computationally (and mostly for testing). Rather, the current model defines sales in a given model year based on a function in the code (and described in the suggested documentation). This model relies on a set of exogenous economic factors (GDP growth rate and labor force participation – in both the current and previous periods) to estimate the total unit sales of new light duty vehicles in a given model year. That total is then apportioned to body-style groups based on a “dynamic fleet share” model – essentially a series of difference equations that is also present in EIA’s National Energy Modeling System (NEMS), though which we apply slightly differently. Once the share of each vehicle style, either car-style or truck-style, is determined, new sales are apportioned to each group and then distributed to each vehicle model based on their relative share of each style in the 2016 new vehicle market. It is worth noting that this does not necessarily preserve the market share of each of NHTSA’s regulatory classes because many vehicle models (over 20% of the current market) have both “car” and “light truck” versions for regulatory purposes. We choose to preserve the market definitions rather than the regulatory definitions in assigning sales.

Similarly, the “parameters” input file contains a set of vehicle survival rates that are also vestigial. Vehicle survival is now determined endogenously within the model run in a way that is responsive to changes in new vehicle prices, cost per mile of travel, and a set of exogenous economic factors. As the model calculates the lifetime mileage accumulation, fuel consumption, fuel expenditures, and various emissions values, it does so using these dynamically defined scrappage rates.

Finally, the employment calculations produced in the CAFE model are not only new in the current version, they are unlike the other two components in this review in that they do not contribute to the benefit cost calculations performed by the model (or subsequently by NHTSA based on changes in employment). The employment calculations are a function of new vehicle sales, as one would expect, but also on technology expenditures by manufacturers that influence upstream employment in the supplier network.

Charge Questions

In your written comments, please provide a detailed response to all of the following questions that are within your area of expertise. Reviewers will be expected to identify additional topics or depart from these examples as necessary to best apply their particular areas of expertise. Comments shall be sufficiently clear and detailed to allow readers to thoroughly understand their relevance to the CAFE model.

1	**Sales Model**
1a	Please comment on the appropriateness of including a sales response model in the CAFE model as a means to estimate differential sales impacts across regulatory alternatives.
e1b	Please comment on the sales model’s specification using an ADRL model time series approach, and comment specifically on the endogeneity of average transaction price.
1c	Please comment on the sales model’s integration in the CAFE model, including interactions with the simulation of multiyear product planning, in combination with the dynamic fleet share model used to allocate total new vehicle sales to the passenger car or light truck market segments.
1d	Please comment on the sales model’s specification as independent of vehicle scrappage, and on the resultant calculation of VMT.
2	**Scrappage Model**
2a	Please comment on the appropriateness of including a scrappage model in the CAFE model as a means to estimate the potential impact of CAFE standards on used vehicle retention.
2b	Please comment on the scrappage model’s specification using a form common in the relevant literature. Are there better approaches that allow for both projection (as is necessary in this context) and a focus on new vehicle prices (exclusively).

2c	Please comment on the scrappage model's integration in the CAFE model, addressing the vehicles affected by the scrappage model, and the extent to which changes in expected vehicle lifetimes are consistent with other assumptions.
3	**Labor Utilization Calculations**
3a	Please comment on the inclusion of each source of employment related to automobile production and sales.
3b	Please comment on assumptions regarding labor hours, production location (domestic/foreign), and supplier impacts.
3c	Please comment on methods used to calculate changes across alternatives.

Reviewer Name: Alicia K Birky

Review Question Number: 1a

Review Question Topic Description: Sales Model

1a Please comment on the appropriateness of including a sales response model in the CAFE model as a means to estimate differential sales impacts across regulatory alternatives.

Ideally, regulatory impact would be considered in a systems framework in order to capture important feedbacks. Therefore, including response of vehicles sales to *both* increased vehicle price and decreased fuel economy is highly appropriate. However, it seems that the analysts are tackling issues that are outside the original intent of the model and that current needs may be better met with alternative modeling methodologies and structures. In particular, the PRIA clearly states that the goals of the model changes are to address manufacturer and consumer behavior, yet the model components and system are not choice models. For further details, see answer to question 1d.

At the same time, when increasing the realism and complexity of models, analysts must always weigh the increased power of the model against increased uncertainty and error. These issues can and should be explored with validation and sensitivity analyses.

Reviewer Name: Alicia K Birky

Review Question Number: 1b

Review Question Topic Description: Sales Model

1b Please comment on the sales model's specification using an autoregressive distributive lag (ARDL) model time series approach, and comment specifically on the endogeneity of average transaction price.

The rationale for the ARDL approach is not described in the model documentation or the PRIA. Here I assume the rationale is an assumption of partial adjustment.

Since the equation estimates total sales (rather than change in sales) in response to a *change* in vehicle price and a *change* in GDP growth rate (per the PRIA), the impacts of these changes are temporary if the sum of the coefficients on lagged sales is less than one (as it is in table 8-1). However, the labor force participation enters the equation as a value, rather than a change in value. Therefore, a change in one year (followed by a constant value) leads to a permanently different level of sales. This seems theoretically supportable.

However, based on the resulting coefficients shown in table 8-1, it appears there may be an issue with the specification of the model. I would expect the net impact of labor force participation to be positive – an increase in participation should increase sales. While the coefficient on LFP is positive as expected, the coefficient on lagged LFP is negative and an order of magnitude larger, indicating a net inverse relationship for a sustained change in LFP. This calls into question the results of the other coefficients and indicates possible misspecification. One possible missing variable is disposable income which may not track with changes in GDP or LFP.

Regarding the simultaneity of average vehicle transaction price and sales: Sales prices of individual models or vehicle body styles and sales volumes are definitely jointly determined, with manufacturers and dealers adjusting price incentives as volumes fluctuate. This does create difficulties that can only be accounted for with complex modeling approaches. In competitive markets and in the long run, I would expect market average prices to track changes in manufacturing costs fairly closely.

Reviewer Name: Alicia K Birky

Review Question Number: 1c

Review Question Topic Description: Sales Model

1c Please comment on the sales model's integration in the CAFE model, including interactions with the simulation of multiyear product planning, in combination with the dynamic fleet share model used to allocate total new vehicle sales to the passenger car or light truck market segments.

Using a dynamic fleet share model is highly appropriate since the light truck share in both the short and long run has historically been responsive to fuel price and theoretically should be responsive to cost of driving and vehicle price. However, the specific fleet share approach -- determining the car share independently of truck share, then renormalizing -- seems inappropriate. Clearly these are joint determinations and the properties of both cars and trucks influence the decision to purchase one versus the other. A single model should be used to determine both. An alternative that would be similar to the approach currently in use would be to use a single equation for car (or truck) share but alter it to include both car and truck attributes to capture the cross elasticities of demand.

A more ideal approach would be a logit formulation that includes all modeled body styles. Unfortunately, a large amount of choice among body styles does not relate to economics but rather is more hedonic and subject to transients in consumer tastes. Given the fluid definition of some body styles as either cars or light trucks (i.e., cross-overs and car-based SUVs) as well as shifts in consumer tastes, a logit that uses three – cars, pickups, and vans/cross-overs/SUVs – or perhaps four body styles may prove more tractable.

Reviewer Name: Alicia K Birky

Review Question Number: 1d

Review Question Topic Description: Sales Model

1d Please comment on the sales model's specification as independent of vehicle scrappage, and on the resultant calculation of VMT.

The PRIA states that regulatory impact assessments should "reflect how alternative regulations are anticipated to change the behavior of producers and consumers." Yet at the same time, it also states that neither the dynamic scrappage model nor revised sales response model "are consumer choice models." VMT demand, the decision to purchase a new vehicle, which vehicle to purchase, and whether to use the purchase to replace an existing vehicle, are joint consumer decisions made at the household level. Therefore, the feedbacks of interest likely are better addressed in a household choice model that includes a market for used vehicles. That said, the decision to *scrap* a vehicle (remove it from the national in-use fleet) and the decision to purchase a new vehicle often are not made by the same household. No national-level transportation demand models (that this reviewer is aware of) tackle the issue with this level of complexity.

However, the vehicle-focused method used to calculate total VMT -- using historically derived, vintage specific, per-vehicle VMT – neglects important determinants of demand that are central to the issues this update is attempting to address. The IHS/Polk data used to derive the vintaged VMT schedules include an array of economic and demographic trends that may or may not be representative of future VMT demand, including ownership rates. The independent sales and scrappage functions determine ownership rates, but this result is not reported nor compared to historical trends, so it is not possible to assess how consistent the model is with these trends or with trends in VMT per household or per capita. For example, in response to a decrease in vehicle price, a household could decide to purchase a new vehicle that they otherwise would not, yet keep all currently owned vehicles. The additional vehicle could spur additional household VMT as some multiple occupant trips are now taken independently or as some foregone trips are now possible. However, it is unlikely that the total household VMT would increase by the total annual VMT of a new vehicle.

In the absence of a household-choice model, an alternative approach would be to calculate national VMT demand as a function of economic and demographic variables, including ownership rates, as well as vehicle fleet attributes. The vintaged VMT schedules could be scaled accordingly to achieve the calculated total VMT. Unfortunately, this approach does not address the potential shift of VMT between older and newer vehicles that could occur with changes in the vehicle stock composition and with changes in fuel prices. This latter effect is important in short run responses to fuel price changes, where multi-vehicle households are able to choose which vehicle is used or to adjust overall vehicle usage based on per-mile costs.

Reviewer Name: Alicia K Birky

Review Question Number: 2a

Review Question Topic Description: Scrappage Model

2a Please comment on the appropriateness of including a scrappage model in the CAFE model as a means to estimate the potential impact of CAFE standards on used vehicle retention.

Ideally, regulatory impact would be considered in a systems framework in order to capture important feedbacks. The VMT "rebound" effect has been fairly well covered in the literature, but other feedbacks, both positive and negative, have received less attention. Response of scrappage rates and vehicle turnover are important and often neglected components of the impact of fuel economy standards on in-use fleet fuel consumption. Therefore, a realistic representation of scrappage is an excellent contribution. Ideally, scrappage should be responsive to existing and new vehicle attributes as well as demographic variables.

Reviewer Name: Alicia K Birky

Review Question Number: 2b

Review Question Topic Description: Scrappage Model

2b Please comment on the scrappage model's specification using a form common in the relevant literature. Are there better approaches that allow for both projection (as is necessary in this context) and a focus on new vehicle prices (exclusively)?

While the focus is on the impact of new vehicle price on scrappage at each vintage, other factors are appropriately included. However, I believe there are some issues with the specification (model used to derive coefficients as described in PRIA section 8.10).

While the intent is to measure the impact of a vehicle price increase that arises from an increase in CAFE, it is important to control for other vehicle attributes that also relate to vehicle price and fuel cost per mile. While the model controls for new vehicle fuel cost per mile, there are other attributes valued by customers that are correlated with fuel consumption (e.g. horsepower, weight, acceleration time, torque, etc.). By not controlling for these other vehicle attributes, the price and cost per mile metrics are capturing these other feature differences that are positively valued and that could influence the scrappage rate of used vehicles in different directions. Where increases in performance are correlated with higher fuel consumption, an increase in new vehicle fuel cost/mile could increase rather than decrease scrappage (and vice versa), particularly of any vintages that may be deemed "under-performing." I believe the inconsistent and sometimes counter-intuitive behavior of the fuel price coefficients among the vehicle classes is likely due to this oversight.

The interpretations of the coefficients on fuel cost and lagged fuel cost seem somewhat confused in the PRIA discussion. The mechanism of impact on scrappage generally relates to the comparison of fuel cost between the vintage vehicle and the new vehicle. However, the model includes these 2 measures separately and the interpretation is complex. In the case of the vintage vehicle (same) fuel cost per mile coefficients, the sum of the two coefficients is the scrappage response in the situation where fuel price does not change. All else being equal, I would expect higher scrappage to be related to higher cost per mile, i.e., positive coefficients. However, the sum of the coefficients is negative for all body styles, though only weakly so for cars. I believe the counter-intuitive behavior likely relates to the issue discussed above.

The model documentation indicates that other vehicle attributes are included in the scrappage model values worksheet but it was not clear (given the scope of this review) how they figure into the model.

A few additional comments:

- The model uses average new vehicle prices as a measure of general price trends, partly due to data availability. However, the PRIA states that aggregate prices may be most appropriate because "it is likely manufacturers will cross-subsidize costs." I agree that the cross-subsidization problem is an issue and aggregate price could therefore be more appropriate than model- or even body-specific data. However, I wonder if additional statistics might provide additional predictive power, such as indicators of variation/spread.

- I agree that future models should definitely consider incorporating separate price series by body style (cars, SUVs, and vans, and pickups; PRIA, p. 1009) since these trends are not necessarily the same and manufacturers may “subsidize” across body styles.
- Transaction prices do not include trade-in values which clearly are very important. In addition, only the value of scrap metal is discussed in conjunction with scrappage decisions. However, many older used vehicles are scrapped from the U.S. vehicle stock but are exported to other countries. For many vintages, the export value would be a better indicator of this decision point. Possible measures to consider that capture trends in resale and scrappage values include NADA residual values and auction prices.
- GDP growth and unemployment rates were explored as indicators of economic activity, with only GDP used in the final models. Given that salaries have not kept pace with economic growth, other income variables might improve explanatory power.
- Scrappage decisions also depend on accumulated VMT while annual VMT will respond to scrappage (lower scrappage due to higher cost could lead higher annual VMT in older vehicles). It doesn’t appear that the impact of changes in VMT are considered in the scrappage. This effect is likely to be significant for system changes that could arise if ride-hailing services and automated vehicles become commonplace. On the other hand, this effect may be small in aggregate for the purposes and use of this model.

Reviewer Name: Alicia K Birky

Review Question Number: 2c

Review Question Topic Description: Scrappage Model

2c Please comment on the scrappage model's integration in the CAFE model, addressing the vehicles affected by the scrappage model, and the extent to which changes in expected vehicle lifetimes are consistent with other assumptions.

The dynamic scrappage model affects scrappage at all vehicle ages but is formulated to allow differential response to new vehicle price depending on age, with increasing impact on older vehicles. Over the scenarios analyzed, the impact of the dynamic scrappage model on expected vehicle lifetime mileage is small. Given the relatively small changes in vehicle price and fuel economy, small changes are within expectations. To fully comment on the model implementation, it would be necessary to see the results of sensitivity analyses over a larger variation in inputs. Examining the modeling differences (PRIA, section 8.10.10), the impact on expected lifetime mileage is within the realm of expectations as well.

The decrease in the size of the in-use vehicle fleet as a result of reducing the CAFE stringency is not an intuitive finding and is worth additional exploration. This may solely be the result of scrappage and sales models that were derived and operate independently. This counter-intuitive finding is even more important since total VMT is determined using age-specific VMT curves rather than a demand function. The impact of the change in vehicle stock (both total number and average age) on total VMT should be vetted against expected trends in VMT demand.

Reviewer Name: Alicia K Birky

Review Question Number: 3a

Review Question Topic Description: Labor Utilization Calculations

3a Please comment on the inclusion of each source of employment related to automobile production and sales.

Labor economics is outside my area of expertise so my comments here are very limited.

The PRIA indicates that only direct employment changes were included while vehicle maintenance and repair was not, though it recognizes that used vehicle sales, parts, and maintenance and repair are the major revenue source for dealerships. It seems like changes to the parts, maintenance, and repair labor, revenue, and profitability could be significant.

Reviewer Name: Alicia K Birky

Review Question Number: 3b

Review Question Topic Description: Labor Utilization Calculations

3b Please comment on assumptions regarding labor hours, production location (domestic/foreign), and supplier impacts.

Labor economics is outside my area of expertise so my comments here are very limited.

A number of assumptions are made regarding values that are held constant at 2016 values but the validity of some of these assumptions is not substantiated. In particular, assembly labor hours per unit for vehicles, engines, and transmissions; and the factor between direct assembly labor and parts production jobs are held constant. These assumptions may not hold for two reasons:

1) As CAFE standards become ever more stringent, the technologies used to meet them will increase powertrain complexity (at an increasing rate). This will likely have different impacts on product design, fabrication, and assembly.
2) The cost of new technologies is expected to decrease over time as a function of learning, typically in fabrication and assembly. Reduction of these costs likely includes reduction in labor hours and learning may reduce some labor components more than others.

Reviewer Name: Alicia K Birky

Review Question Number: 3c

Review Question Topic Description: Labor Utilization Calculations

3c Please comment on methods used to calculate changes across alternatives.

This topic is outside of my expertise.

Peer Review Comments on CAFE Model by John D. Graham, Ph.D. (October 10, 2018)

1. Sales Model.
a. Appropriateness of a sales-response model in the CAFE model.

It is entirely appropriate – indeed necessary – for DOT/EPA to include a sales-response model in the CAFE model. Without a sales-response model, it is not feasible to perform a valid benefit-cost analysis of this regulation, or to make valid projections of this regulation's potential impacts on gasoline consumption, oil consumption, greenhouse gas emissions, and emissions of other pollutants related to smog and soot. Since the energy and environmental outcomes relate directly to the statutory goals of the regulatory programs in question, it is apparent that the potential impacts of regulations on vehicle sales must be addressed analytically by DOT/EPA.

If the 2021-2025 CAFE/GHG standards were projected to have only a slight impact on vehicle production costs and vehicle prices, then it might be defensible for DOT/EPA to perform only a qualitative analysis of the impacts on vehicle sales, and proceed with an engineering-oriented estimate of the energy and environmental outcomes of interest. In this rulemaking, however, DOT/EPA are projecting a cumulative cost/price impact of almost $2,000 per vehicle in 2025 compared to vehicle costs/prices associated with a freeze of the 2020 Federal standards.

By way of comparison, there is no previous rulemaking in the history of DOT or EPA that has been predicted to have a cost/price impact in the range of $2,000 per vehicle. In fact, I recently prepared a report for the University of Pennsylvania where I catalogued the estimated vehicle cost/price impacts of every significant DOT and EPA standard covering vehicle emissions, safety, and fuel economy since the 1960s (N = 39). (I can share this report, which will soon appear in a book to be published by the Brookings Institution). The average cost/price impacts were never in excess of $1,000 per vehicle except for the 2011-2016 CAFE/GHG standards, where the cost/price impact exceeded $1,000 when adjustments were made to express the monetary impact in 2016 dollars. (In that rulemaking, DOT/EPA did include a quantitative analysis of sales response, though it was more simplified than the analysis included in this PRIA). There were only 4 rulemakings of the 39 where the cost/price impact was greater than $500 per vehicle, and the median cost/price impact per vehicle for the 39 rulemakings was about $100 per vehicle. Thus, a sales-response model is much more crucial in this rulemaking than it has been in previous EPA and DOT rulemakings on vehicle emissions, safety, and fuel economy standards.

A $2,000 vehicle price increase is more than a 5 percent rise in the average transactions price for a new passenger vehicle in the U.S. market (currently the average transactions price is about $35,000 per new vehicle). A 5 percent rise in new vehicle price will not influence the sales decisions of all, most, or a majority of consumers but it could certainly impact the purchasing decisions of a significant number of consumers in the market. The issue here is not whether the price increment would cause a household to go from owning a car to not owning a car. The issue is whether the price increase on new vehicles might cause some households to delay their purchase of a new car, hold on to their existing car longer, consider a used car instead of a new car, or own one fewer car than they would otherwise own. (Another possibility that DOT/EPA do not address quantitatively – but does mention on p. 950 -- is that the consumer might downgrade the quality of new car that they purchase, due to the affordability issue).
An engineering approach to this regulation is simply insufficient. Behavioral changes by consumers can have important impacts on how fast the DOT/EPA regulations achieve their statutory objectives (since new vehicles are generally cleaner and more fuel efficient than old vehicles), and the

behavioral choices by consumers can have potentially perverse consequences for safety and other important public and private outcomes.

Moreover, there is a stream of academic literature, beginning with Gruenspecht (1982) and extending to Jacobsen and van Bentham (2015), demonstrating the importance of considering sales response in economic models of CAFE and GHG standards. The PRIA on p. 922 (footnote 480) appropriately cites those two classic papers as academic foundation for the modeling that has been performed.

Thus, without question, a sales-response model should be incorporated into the CAFE model, especially for this relatively high-cost rulemaking.

b. Time-series model.

In order to establish the impact of changes in vehicle price on volume of vehicle sales, DOT and EPA presume that regulation-induced increases in the costs of vehicle production will be reflected in average new vehicle prices, and that those changes in new vehicles prices will have impacts on new vehicle sales that are equivalent to what time-series modeling suggests has occurred in the 1979-2015 period. There are some important assumptions here that need to be teased out, discussed, and justified by DOT/EPA.

Are Changes in Vehicle Production Costs Fully Reflected in New Vehicle Prices?

First, there is the question as to whether regulation-induced costs will be reflected in average new vehicle prices. The time-series analysis assumes this relationship rather than establishing this relationship. As far as I can tell, the PRIA addresses this matter only once and only very briefly. On p. 929, the PRIA states that "manufacturers will attempt to recover these additional costs by raising selling prices for those or other models that they offer." The PRIA does not present any evidence that auto manufacturers will be successful in raising prices in response to regulatory cost impositions. The alternative possibilities are the manufacturers finance these costs by reducing labor compensation and/or reducing returns to owners/investors or squeezing dealers or suppliers.

There is a strong theoretical foundation, explained in OMB Circular A-4, for the assumption that regulatory costs will be passed through to consumers in the form of higher prices when markets are competitive (meaning lots of producers and lots of consumers, and good market information and so forth). However, the academic literature on the U.S. automotive industry has not historically treated this industry as classically competitive. Indeed, most of early modeling of the U.S. auto sector used oligopolistic assumptions rather than perfectly competitive assumptions (see Bresnahan, 1981; Berry et al., 1995; Goldberg, 1995 and 1998; and Kleit, 2004). The dominant theories of oligopoly pricing do not lead to a strong prediction on price impacts due to regulation, and it has been established that this issue needs to be addressed empirically on a case-by-case basis rather than be resolved by reference to theory alone (Davis & Knittel, 2016).
A substantial economics literature addresses how manufacturing companies handle changes in their costs of inputs. Dornbusch (1987) theorized that firms operating in a competitive setting increase the amount of "pass-through" as the proportion of the market that is exposed to the cost increase grows. If only one of many firms experiences the cost increase, pass-through pricing may not occur. Ashenfelter, Ashmore, Baker, and McKernan. (1998) confirmed the theoretical prediction in their study of the office supply retail sector. A large stream of literature has confirmed the "pass-through" hypothesis as it relates to the auto industry (Knetter, 1989 and 1993; Feenstra, 1989; Gagnon & Knetter, 1994; Goldberg, 1995; Feenstra, Gagnon, & Knetter, 1996; Goldberg, 1997and 1998; Gron

& Swenson, 2000; Kleit, 1990). I recommend that the final PRIA include appropriate references to this literature.

In a classic study Gron and Swenson (2000) examined list prices of automobiles at the model level in the United States from 1984 to 1994, coupled with data on production, vehicle characteristics, foreign versus domestic firm ownership, wages of employees, exchange rates, imported parts content, tariffs, and other variables. Although their work rejects the hypothesis of 100 percent pass-through of cost to consumer price, they find higher rates of pass-through than previous studies, and much of the incomplete pass-through occurs when cost increases impact only a few models or firms. Confirming earlier studies, they show that U.S. auto manufacturers engage in more aggressive pass-through pricing than Asian and European manufacturers (greater than 100% in some specifications), possibly due to the eagerness of importers to enlarge market share in lieu of recovering regulatory costs, at least in the short run (see Dinopolous & Kreinin, 1988; Froot, 1989). This study helps explain why pass-through pricing is a more viable hypothesis in the long run than in the short run.

The original design of the CAFE program is a contrasting case where pass-through pricing was difficult for some automakers. All auto makers, regardless of their product mix, were subject to the same fleet-wide average CAFE standard, such as 27.5 miles per gallon for cars in 1990. In practice, those standards impacted only three high-volume companies (General Motors, Ford, and Chrysler) because the Big Three produced a higher proportion of large and performance-oriented vehicles than did Japanese companies. As a result, Toyota and Honda consistently surpassed the Federal fleet-wide standard for cars without any regulatory cost (i.e., partly due to their smaller product mix). In the 1975-2007 period, the Big Three were not able to pass on all of their compliance costs to consumers and thus experienced some declines in profitability due to CAFE (Kleit, 1990 and 2004; Jacobsen, 2013a).

When the CAFE program was reformed for light trucks in 2008 (and for cars in 2011) on the basis of vehicle size (the so-called “footprint” adjustments to CAFE stringency), the technology costs of CAFE standards were spread more evenly among automakers, although the overall societal efficiency of the regulation diminished (due to the removal of downsizing as a compliance option) (see Ito & Sallee, 2018). Given that the size-based CAFE/GHG programs are not concentrating the costs of compliance on one or two automakers, it is reasonable to predict a fairly high degree of pass-through pricing for the 2021-2025 CAFE /GHG standards. In a related literature on manufacturer pricing responses to a national carbon tax, Bento and Jacobsen (2007) and Bento (2013) report high rates of pass-through pricing (on the order of 85%). Carbon taxes are more efficient than footprint-based CAFE standards but both instruments are likely to impact a wide range of companies in the auto sector and result in a high degree of pass-through pricing by impacted companies.

It should also be noted that the U.S. automotive industry is much more competitive today than it was in the 1970-2000 period. The market share of General Motors, once the dominant, majority producer in the U.S. market, has declined dramatically, and a variety of Japanese and Korean companies have captured market share. Moreover, the rise of startups (e.g., Tesla and other electric vehicle start-ups) and ride-sharing services (e.g., Uber) are adding a new, competitive dimension in the U.S. industry. As a result some of the most recent auto regulatory studies have given more emphasis to analytic results based on competitive models than oligopolistic models (e.g., Davis & Knittel, 2016). Thus, the assumptions being made in the PRIA about pass-through pricing are defensible but they do need to be defended. Hopefully this discussion, and the related references, have helped in this regard.

Are Consumers Likely to React the Same to CAFE-Induced Price Increases as They Do to the General Price Increases Observed in a National Time Series Model From 1979 to 2016?

The big issue here is how to address price increases caused by the addition of fuel-saving technologies induced by regulation, as it is reasonable to believe that consumers will value the enhanced fuel economy to some degree. In contrast, a consumer does not necessarily value the additional costs of wages paid to executives or workers, or the additional prices for raw materials that impact the cost of vehicle production. The typical consumer might value an extra 5 miles per gallon of fuel economy, since that will translate into lower operating costs for the vehicle when the vehicle is used by the consumer.

In previous RIAs where DOT/EPA analysts have quantified sales impacts of CAFE /GHG standards, a price elasticity of demand of -1.0 has been applied to the net vehicle price increase, where net vehicle price is equal to the gross average technology cost per vehicle minus the present value of fuel savings for the consumer who purchases the vehicle. (Actually, the present value of fuel savings is computed for the original ownership period and then a standard resale value is added for the rest of the vehicle life). As far as I know, the -1.0 elasticity figure does not have a solid grounding in economic evidence and was used simply for illustrative purposes. Moreover, previous RIAs did not present evidence to support the assumption that resale value for fuel-economy technology is similar to resale value for the vehicle as a whole. Thus, DOT/EPA are well justified in taking new evidenced-based approaches to the price elasticity, consumer valuation, and resale questions.

The PRIA contains a new autoregressive distributed-lag (ARDL) model that relates lagged national values of vehicle sales to changes in average vehicle price, changes in GDP growth, and measures of consumer confidence. Aggregate quarterly data is used for the 1979-2015 period. The model fits the data reasonably well, the explanatory variables behave as expected based on theory and prior evidence, and statistical analysis revealed little evidence of autocorrelation or other statistical problems. Based on the model, a $1,000 increase in average new vehicle price is associated with a loss of 170,000 units of sales in year 1, followed by an additional 600,000 losses in vehicle sales over the next 10 years – in effect, the adverse effect of the $1,000 price increase tapers with time. The PRIA characterizes this response as a price elasticity of demand in the range of -0.2 to -0.3.

A weakness in the model is that it does not include important variables concerning consumer access to credit such as average interest rates on car loans. A focus on subprime buyers might be appropriate since they are likely to be the marginal consumer (as they are the most credit constrained). It also does not address movements in used car prices, a surprising omission given that used cars are a prominent potential substitute for new cars.

Both of these variables (interest rates on car loans and used car prices) have been shown to be significant in recent national time-series modeling – interest rates on car loans are negatively associated with new vehicle demand and used car prices are positively associated with new vehicle demand (McAlinden, Chen, Schultz, & Andrea, 2016). Since both of these variables are well known to affect new vehicle sales, the sales-response model would be more credible if these two variables were included and if their estimated coefficients exhibited the theoretically expected behavior.

The omission of used vehicle prices is particularly concerning since the linkage between consumer demand for new versus used vehicles is a key theme of the PRIA and the preamble's case for less stringent standards. DOT/EPA should explore adding these variables and report what they learn.

While these variables may also be endogenous (like new vehicle prices may be endogenous), that is not an argument for ignoring them. They should be analyzed and discussed.
A paradox of the national time-series modeling is that inclusion of fuel-economy variables did not improve the explanatory power of the model. This analytic outcome is troubling because DOT/EPA analysts also review (pp. 938-939) several recent large-sample vehicle transactions-price studies that find that that consumers value highly the fuel-economy of vehicles, as fuel economy is capitalized (reflected) in the prices of used and new vehicles (Busse, Knittel, & Zettelmeyer, 2013; Allcott, Mullainathan, & Taubinsky, 2014; and Sallee, West, & Fan, 2016). While it is encouraging that DOT/EPA analysts explored several variants of fuel-economy variables, it is concerning that none of these variables improved the time-series model statistically. Thus, the time-series findings that are reported and discussed in the PRIA on p. 949 (Table 8-1) – and subsequent outcomes from the CAFE model -- do not account for the potential effects of changes in average fuel economy on new vehicle demand. This omission leaves the sales-response model vulnerable to the allegation that it overstates the adverse effect of fuel-economy regulation on new vehicle demand, since it incorporates only gross technology costs and ignores consumer interest in fuel economy.

I recommend that the paradox be resolved in the following way in the final RIA. The national time series model should be used by DOT/EPA as one approach to estimating the price-elasticity of demand but the future impacts of fuel-economy regulation on new vehicle sales should be based on a net-price concept rather than the gross costs of technology. This approach is similar to the net-price concept that DOT/EPA have used in the past in previous RIAs except, in this and future rulemakings, the net vehicle price should assume substantial consumer undervaluation of fuel economy. Specifically, the net price should assume 2.5 years of consumer valuation (not full valuation) of future fuel savings (since the date of original purchase), the same limited valuation period that the CAFE model is already using to establish which fuel-saving technologies will be adopted voluntarily in the market, without any regulatory pressure. This net-price recommendation will account for limited consumer demand for fuel economy while also bringing analytic consistency to what DOT/EPA are assuming in another module of the CAFE model.

The PRIA exposes itself to this paradox by giving inappropriate emphasis to the recent econometric studies showing high consumer valuation of fuel economy. It is already well known throughout the industry that consumers do not fully value fuel-saving technologies offered on new or old vehicles (see National Research Council, 2015, and Carley et al., 2017). The 2015 National Academies study undertook a survey of industry experience with fuel saving technologies. The authors concluded with the observation that the industry experts believe that consumers behave as if they value only 1 to 4 years of fuel economy (i.e., serious undervaluation of fuel economy) when purchasing new vehicles. Since 2.5 years is the middle of this range, I recommend that 2.5 years be used in computing the net per-vehicle price of regulation and in projecting impacts on vehicle sales. Sensitivity analyses should be performed using 1 and 4 years.

The full-valuation results reported by Busse, Knittel, and Zettelmeyer (2013) and Sallee et al. (2016) are based on changes in fuel prices, not changes in fuel-economy technology. (The results reported by Allcott, Mullainathan, & Taubinsky, 2014, again based on changes in fuel prices, do not support full valuation). The CAFE /GHG standards operate by changing vehicle characteristics, not by changing fuel prices. The two mechanisms of change can have equivalent effects in a rational-choice model but may not be viewed the same way in a behavioral assessment of consumer choice. Consumers may be more cautious about changes in technology than changes in fuel price, even when the two mechanisms have the same present-value financial impact on the consumer.

A recent study by Leard, Linn, and Zhou (2017), using data and methods similar to Busse, Knittel, and Zettelmeyer (2013) and Sallee et al. (2016), does not find full consumer valuation of fuel economy. Importantly, this study focuses on changes in technology as well as changes in fuel price. Moreover, our group at IU recently completed a study of HEVs – using a paired-comparison method with gasoline vehicles -- where we found that several HEV models have had very little consumer uptake even though they are financially attractive from a total cost of ownership perspective. The poor uptake of affordable HEVs cannot be fully explained by shortfalls in other vehicle attributes such as performance and fuel economy. Thus some of the real-world experience with HEVs also suggests consumer undervaluation of fuel economy.

I recommend that section 8.3, "Consumer Valuation of Improved Fuel Economy" (pp. 934-940), be reconsidered and rewritten to reflect the decades of industry marketing experience with fuel economy technology, as reviewed by the National Research Council (2015), the stated preference studies that address directly the limited extent of consumer interest in fuel-economy technology (see the citations in Carley et al., 2017), the fact that Busse, Knittel, and Zettelmeyer. (2013) and Sallee et al. (2016) address consumer response to fuel price changes rather than technology changes, the fact that Allcott, Mullainathan, and Taubinsky (2014) did not find full consumer valuation (even when studying fuel price changes), the fact that Leard et al. (2017) find consumer undervaluation with technology changes, and the fact that HEVs have very limited consumer uptake, even when they are financially attractive from a total cost-of-ownership perspective (Duncan et al., 2019).
The inability of the national time-serious model to find a significant impact of fuel economy on vehicle sales is not difficult to understand if the average consumer is assumed to undervalue fuel economy to a substantial degree. The "signal" provided by the quarterly differences in vehicle fuel economy, when dampened by consumer undervaluation, may simply be too small to find a fuel-economy effect, given the quarter-to-quarter "noise" (random movement) in national vehicle sales. On the other hand, the lack of a significant fuel-economy effect in the national time series model does not mean that the effect is zero. We already have plenty of evidence from better research designs that the effect is nonzero, though consumer demand is substantially less than full valuation as defined by rational-choice theory.

With respect to the endogeneity issue, I think the national time series model is vulnerable to the criticism that average vehicle transactions prices and average volumes of new vehicle sales are determined simultaneously in the market. When sales are low (e.g., in recessionary periods), transactions prices likely fall (e.g., due to dealer and manufacturer discounts); when sales volumes are high, discounts off list prices may diminish, keeping transactions prices relatively high (see PRIA, p. 947, paragraph 2, sentence #2). Transactions prices surely do have a negative causative effect on vehicles sales, but this causative relationship could be mis-estimated in the national time series model due to a failure to control for the reverse causation -- the positive causative effect of sales volume on average transactions price. This omission may help explain why the estimated coefficient on vehicle price in Table 8-1 is so modestly sized and close to zero.

It is doubtful that the endogeneity concern can be addressed convincingly within the national time-series modeling framework. I recommend instead that DOT/EPA analyze the likely direction of the bias, and discuss this limitation qualitatively in the final RIA. In addition, DOT/EPA should not rely entirely on the national time series model to estimate the price-elasticity of demand for use in the CAFE model. Instead, DOT/NHTSA should also explore the price-elasticity studies published in the literature and reviewed by McAlinden et al. (2016), Appendix II, 63-64. I believe that this literature, with a proper focus on long-term price elasticity of demand, provides support for a price elasticity of demand that is well below -1.0 (in absolute value) but probably a bit higher than -0.2. This literature-based estimate can provide an alternative estimate for use in the sales response module of the CAFE model. I recognize, as explained on p. 952 of the PRIA, that the CAFE model requires dynamic projections of vehicle sales and a point estimate of long-term price elasticity of demand from the literature does not provide the desired dynamic property. However, it might be feasible to use a literature-based estimate to define the total long-term impact of vehicle price on new vehicle demand, and then use the national time-series model to allocate the total effect to different years within the ten-year time horizon. In this way, the national time-series model is being used in a more limited way than it is currently used.

c. Integration of sales-response model in the CAFE model.

The sales-response model is generally integrated into the CAFE model in a logical fashion. An exception may be that the regulatory alternatives discussed in the preamble are not reflected accurately in either the sales-response model or the CAFE model. As I understand the preamble and the regulatory alternatives under consideration, DOT/EPA's preferred option is to freeze the Federal standards at 2020 levels and preempt separate State-level GHG and ZEV standards.

If instead the status quo policy is maintained, it should be assumed that the 2021-2025 Federal standards would be supplemented by the California ZEV standards in States representing approximately 30 percent of the new vehicle population in the United States. The California GHG standards would have no incremental economic or environmental effects since compliance with the Federal standards is recognized as per se evidence of compliance with the California GHG standards.

The preferred regulatory proposal would then alter the status quo by freezing the Federal standards at 2020 levels and eliminating the State-level ZEV standards. As currently designed, the sales-response and CAFE models are well designed to address the Federal freeze but they ignore the economic and environmental impacts of removing the State-level ZEV requirements. Removing the State-level ZEV requirements can certainly be expected to have national ramifications since the State-level ZEV requirements cover approximately 30 percent of the national market for new vehicles and since the ZEV requirements are a de facto electric-vehicle requirement of 5 percent to 20 percent of an automaker's State-specific new vehicle fleet in 2025. Technically, the ZEV requirements are not a market-share requirement; they are a compliance credit requirement but both CARB and the stakeholder community view the credit requirements as a tool to boost the commercialization of electric vehicles.

The final RIA needs to incorporate the proposed elimination of the ZEV program into both the sales-response model and the CAFE model. The analytic complications for the RIA are less complex on the benefit side of the ledger than on the cost side of the ledger.

On the benefit side of the ledger, it is unlikely that the ZEV program contributes any significant GHG and energy security benefits, since national GHG emissions and oil-consumption levels are not influenced by a State-level policy nested within a binding Federal performance standard. Insofar as the electric vehicles produced and sold in response to the State-level ZEV requirements are counted by vehicle manufacturers in Federal compliance statistics, the practical effect of the ZEV requirements is to ease the compliance burdens of the Federal standards, allowing vehicle manufacturers to sell gasoline-powered vehicles nationally with a somewhat higher level of GHG emissions and gasoline consumption than would occur if the State-level ZEV requirements did not exist.

It is possible but doubtful that ZEV States will accomplish some incremental control of smog and soot pollution from the ZEV requirements. For sure, the ZEV program was launched in 1990 by CARB with an eye toward helping California cities (especially Los Angeles) come into compliance with EPA's national ambient air quality standards for criteria air pollutants. However, the EPA LEV II and LEV III standards (and the sister standards adopted by CARB) for gasoline vehicles adopted since 1990 reduce dramatically the amount of pollution from new passenger vehicles that contributes to smog and soot. Those standards, which operate in conjunction with low-sulfur gasoline requirements on refiners/blenders, increase the longevity of catalysts and ensure that vehicles did not contribute significantly to smog or soot for 150,000 miles of vehicle lifetime. Since 2008-9, CARB has recognized that GHG control may be a more compelling rationale for the ZEV program than is control of residual pollution related to smog and soot. For sure, Los Angeles and some other communities in ZEV States will not comply with EPA's health-based air quality standards for the forseeable future. However, this noncompliance is related not to conventional emissions (e.g., NOx) from new passenger vehicles (which are quite small) but from the large volume of older, dirtier passenger vehicles in the fleet as well as the large volume of heavy trucks, construction/agricultural vehicles, and stationary sources that are not covered by the ZEV program.

Some analysts in California and other ZEV States may see the ZEV program not as a short-term effort to control GHG emissions but as a long-term technology-forcing policy to stimulate technological innovation and commercialization in the auto sector. However, ZEV requirements are not necessary to stimulate technological innovation and commercialization of electric vehicles. California can make greater progress in this regard by taking the same steps that Norway has already taken: Subsidize consumer demand for electric vehicles to the point where 30 percent of new passenger vehicles in Norway are electric in their propulsion system. Norway has launched this policy without adopting a ZEV requirement and without shifting the costs of the policy to consumers in other countries in Europe.

On the cost side of the ledger, the State-level ZEV requirements can be predicted to cause a distortion in the pricing of new passenger vehicles in the United States. In order to sell an adequate number of ZEVs in California and other States that require ZEVs, auto makers cannot price an electric vehicle at its incremental cost of production (roughly $10,000 per vehicle in 2025 according to EPA/DOT, assuming driving range of 200+ miles). Instead, CARB and EPA generally assume that automakers will treat the costs of the ZEV program as an R&D expense, and spread those costs across all of the new vehicles that automakers sell in the U.S. market. The pass-through effect of the ZEV requirements on new vehicle prices in the United States has not been estimated in the PRIA, even though the preamble to the proposed rule asserts Federal preemption of the ZEV requirements.

With regard to the average cost of producing a new vehicle, the presence of the State-level ZEV requirements have offsetting effects on automakers. The incremental cost of the Federal programs will be smaller in the presence of State-level ZEV requirements than without the State-level ZEV requirements, since the electric vehicles produced to comply with the State-level ZEV requirements count toward an automaker's Federal compliance statistics. However, the combined cost of the Federal and State-level requirements will be greater than the Federal requirements alone, since most automakers would not produce costly electric vehicles in the absence of State-level ZEV requirements. In a recent study of the interaction of the Federal CAFE /GHG and State-level ZEV requirements, we found that the net effect of the addition of the State-level ZEV requirements to the Federal regulations was to increase the average cost of vehicle production (nationwide) by $400 to $700 per vehicle. Those extra costs are large enough to have a significant impact on the results of the sales-response model, the fleet-turnover model and the CAFE model as a whole. Thus, I recommend that DOT/EPA include the cost savings from the elimination of the State-level ZEV requirements in the final RIA for this rulemaking.

1d. Sales-model's specification as independent of vehicle scrappage and impacts on VMT.

No comment.

2. Scrappage Model
   a. Appropriateness of including a scrappage model in the CAFE model.

As explained above, the transportation sector's impact on national GHG emissions and national petroleum consumption is triggered by the use of both used and new vehicles. Vehicle use is operationalized in the PRIA through the metric of vehicle miles of travel (VMT). Thus, DOT/EPA need to know how long a vehicle will be driven (before it is scrapped), and the expected number of VMT for each anticipated year of the vehicle's lifetime. Those mileage schedules may change subtly yet significantly under different CAFE /GHG standards.

In order to appreciate why a scrappage model is needed for the CAFE model, consider how CAFE /GHG standards are likely to impact the average prices of new and used vehicles. If the national volume of new vehicle sales rises due to costly CAFE /GHG regulations, then it should be expected that the demand for new passenger vehicles will decline while the demand for used vehicles will rise (other factors held constant). Unless there is a supply response in the market for used vehicles, the greater demand for used vehicles will bid up prices for used vehicles (Gruenspect, 1982). The opposing effects occur because a used (old) vehicle is a potential substitute for a new vehicle. Ultimately, more VMT will occur in used vehicles relative to new vehicles compared to what would have occurred without stricter CAFE /GHG regulation. Likewise, a freeze on Federal CAFE /GHG standards will tend to allocate more VMT to new vehicles than to old vehicles.

The market dynamics do not end here because there is also a supply response in the used vehicle market due to a rise in average prices of used vehicles. The supply response operates through the scrappage rates on older vehicles.

Consider the recurring decision problem faced by the owner of an old vehicle (Jacobsen & van Bentham, 2015). Each time a vehicle breaks down, the owner must decide whether to repair and keep the vehicle, repair and sell the vehicle, or scrap the vehicle. Rational choice theory predicts that he/she will choose to scrap it if and only if the prevailing price in the used-car market falls below the repair cost plus any residual value. As the prices of used vehicles rise, scrapping an old vehicle becomes less attractive. Thus, a supply response to higher used car prices operates through a tapering in the rate at which owners of old vehicles scrap their vehicles.

Scrap rates, which are usually expressed on an annual basis, follow familiar patterns. They increase with vehicle age from about 1-2 percent for 2 year-old vehicles to almost 15 percent for 20-year old vehicles. The adjustments to scrappage rates due to CAFE /GHG standards will tend to be marginal changes to the age-specific scrappage rates mentioned here. Without knowing the change in scrappage rates, it is not feasible for DOT/EPA analysts to figure out how many total vehicles will be used or the age distribution of those vehicles.

> Fortunately, there is a useful recent literature in economics that provides intellectual guidance on how DOT/EPA should analyze scrappage rate changes and the associated changes in the age-distribution of the vehicle fleet (e.g., see Jacobsen, 2013b; Jacobsen & van Bentham, 2015; Davis & Knittel, 2016). It is appropriate and important for the final RIA to include a scrappage model, since it helps quantify accurately the impacts of the CAFE /GHG standards on GHG emissions, oil consumption, and safety outcomes.

b and c. Specification of the scrappage model and integration into the CAFE model.

The key issue in the specification of the scrappage model is how to allocate changes in scrappage rates due to regulatory policy to vehicles of different ages. The draft PRIA makes a plausible argument that the changes in scrappage rates are likely to be larger for vehicles in the middle of the average lifespan (6 to 14 years old) than for vehicles early in the lifespan (1 to 5 years old) and very old vehicles (15 or more years old). Before reading the PRIA, I would have thought the effect might be greatest for the oldest vehicles. It might be useful, in the final RIA, to report some sensitivity analysis on this assumption.

In assessing the plausibility and implications of the scrappage effect, I appreciated the PRIA's effort on pp. 1056-1059 to compare the relative size of the sales-response and scrappage effects. For each additional new model that is sold due to tighter CAFE /GHG standards, somewhere between 2 and 4 used vehicles are removed from the fleet. I did not expect the ratio to be 1 to 1 (in part for the reasons explained on p. 1057 of the PRIA) and thus was not expecting a constantly-sized vehicle population under different regulatory alternatives. It is also useful to remember, as explained on p. 1058, that average VMT per year is much larger for new vehicles than for old vehicles, and retained used vehicles will have few years remaining compared to a new vehicle. It is reassuring that the overall impact on national VMT, ignoring the rebound effect, of the various regulatory alternatives is quite small (0.4% larger in the baseline 2025 standards than in the preferred "freeze" proposal) but I might have predicted that any overall change to VMT would be effectively zero, since the regulatory alternatives don't have much obvious impact on the average household's demand for travel. It might make sense to consider a scenario analysis where total VMT is fixed with and without the regulatory alternatives but the share of VMT allocated to vehicles of different ages is allowed to vary. Leakage in GHG control (or gasoline consumption) that is attributable to shifting the shares of VMT by vehicle ages strikes me as more plausible than leakage in GHG control (or gasoline consumption) that is generated by changes in overall VMT in the country. Nonetheless, my impressions here are more intuitive than they are based on hard analysis.

I conclude with a technical comment that does not fit neatly into the structure of the questions but seems highly relevant to the CAFE model. There is a small but growing body of literature suggesting that the current structure of CAFE standards, coupled with rapidly growing stringency within footprint categories, is causing a phenomenon that is sometimes called "vehicle upsizing." A simple form of upsizing is a shift from passenger cars to light trucks; a more complicated form is a shift upward in average footprint within the categories of cars and trucks. The upsizing phenomenon is seen as negative from a societal perspective because it creates leakage in energy and GHG savings, and because it may have adverse safety consequences due to aggressivity.

If upsizing is actually occurring to a significant extent due to the current schedule of CAFE /GHG standards, it would seem that a CAFE freeze (or any attenuation of the planned hikes in regulatory stringency) would have the qualitative effect of moderating the extent of upsizing in the U.S. market.

As I read the PRIA, it does not consider this unintended but potentially beneficial side effects of reducing the rate at which CAFE /GHG standards become more stringent. I recommend that the final RIA include at least a qualitative discussion of this matter, and possibly a scenario analysis that gives some quantitative weight to the upsizing story.
One could argue that the perverse effects of upsizing, if they are large and important, might be best addressed – not by reductions in regulatory stringency but – by another redesign of the CAFE /GHG standards to discourage upsizing. That strikes me as an entirely different rulemaking. But there may be merit in pointing out that perverse effects of upsizing are attenuated with less stringent standards, such as those considered in this rulemaking.

3. Labor Utilization Calculations

The best way for me to comment on this section of the PRIA is to simply urge DOT/EPA to consider the macroeconomic analysis produced by Carley et al. (2017). This analysis is much broader and richer than the analysis presented in the PRIA, and it shows that the employment impacts of causal mechanisms not considered in the PRIA (e.g., gasoline savings) are potentially much larger than the employment impacts considered in the PRIA. It is encouraging that the PRIA considers the employment stimulus in the supply chain; it is concerning that that the PRIA does not consider the positive and negative employment impacts of the State-level ZEV requirements, especially since much of the supply chain for electric vehicles is likely to be located outside the United States for the foreseeable future.

a. Sources of employment related to auto production and sales.
b. Assumptions about labor hours, location, supplier impacts.
c. Calculating changes across alternatives.

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Reviewer Name: Howard Gruenspecht

Review Question Number: 1a

Review Question Topic Description: Please comment on the appropriateness of including a sales response model in the CAFE model as a means to estimate differential sales impacts across regulatory alternatives.

Response:

Inclusion of a well-specified sales response model to consider differential sales impact across regulatory alternatives is useful. Extensive research referenced in the documents that are the subject of this review (the NPRM, the PRIA, and the draft model documentation) cite significant evidence that, holding other factors constant, the overall level of motor vehicle sales is inversely related to the level of new vehicle prices. Consumers are free to adjust both the quantity and composition of their new vehicle purchases in response to fuel economy policies that affect the price and other characteristics of new vehicle offerings.[1] A well-specified sales response model will improve the ability of the CAFE model to reflect the implications of regulatory alternatives on vehicle purchase decisions and the resulting implications for fuel consumption, emissions of CO2 and other pollutants, and safety.

Following a discussion of relevant literature, the documents provided for review estimate a regression model for new light-duty vehicle (LDV) sales. According to the documents, the price elasticity of new vehicle sales implied by the estimated regression is in the range of -0.2 to -0.3. The discussion of the literature also indicates that some research suggests a higher sensitivity of sales to prices, which is consistent with my understanding. One issue here is that higher prices arising from manufacturers' application of fuel economy technologies to comply with CAFE standards also provide savings in consumer fuel costs, which as discussed elsewhere in the documents has private value to consumers. The documents discuss a range of views in the literature regarding the extent to which vehicle buyers consider potential fuel savings that may soften the effect of higher prices on sales. Because of this, price changes associated with increased use of fuel saving technologies may have a different effect on sales than price changes of equal magnitude that are driven by labor and materials costs or by other policies, such as regulations to limit conventional pollutants that address externalities but do not provide private savings directly to vehicle owners.

In reviewing the model results, I compared the baseline (B) case incorporating the augural standards and the preferred alternative (P) case that freezes CAFE standards at the model year 2020 level. As discussed in the documents, consumer price increases between these cases are equal to the sum of average incremental technology costs and civil penalties per vehicle (compare, for example, tables 12-75 and 9-56 in the PRIA). However, those numbers do not match the results in the Excel run reports for the central analysis "CAFE" runs. I raised this with the technical lead for the review, who explained that the results used in the rulemaking documents were from the "CAFE_ss" runs, which

[1] There is also ample empirical evidence that changes in fuel prices also affect the perceived value of fuel efficiency in relation to other vehicle characteristics.

take account of statutory constraints that preclude consideration of some possible real-world compliance strategies. Thereafter, I refocused my review on the “CAFE_ss” cases.

(a) Overall light duty vehicle (LDV) sales response

The overall sales responses in the model runs are qualitatively plausible. First, the difference in sales between the B and P cases over time is consistent with the growing difference in vehicle prices as the difference across the cases in fuel economy standards grows over the 2022-25 period. Specifically, as fuel economy standards and their effect on vehicle prices grow over 2022-25, there are a larger number of LDV sales in the P case where vehicle prices are lower. Over 2022-32, overall LDV sales in the P case exceed those in the B case by about 1.18 million vehicles (0.6%).

While the new vehicle sales response patterns are broadly plausible, there are some issues that merit further attention or explanation.

- Table 12-75 and the output files show a significant difference in LDV prices between the B and P cases, with LDVs being more expensive in the in the B case where fuel economy standards continue to increase after model year (MY) 2020. The price difference start at low levels in MY 2017 and grow over time, reaching $1,350 in MY 2021, the first year when the applicable fuel economy standards differ between the B and P cases. Despite the discrepancy in prices, and statements in the documents that each $1,000 increase in the average new vehicle price causes approximately 170,000 lost units in the first year, followed by a reduction of another 600,000 units over the next ten years as the initial sales decrease propagates over time through the lagged variables and their coefficients. The output files show identical sales outcomes in the B and P cases for LDVs through MY 2021.

- Differences in sales between the P and B cases do not begin until MY2022 even though the reported price differences start in MY 2017. Unless I have misread the output files, it would be useful to explain why differences in price levels do not affect sales prior to MY2022 or, if the model code is faulty, to update it to address this problem.

- Another concern arises from comparisons between the CAFE and CAFE_ss versions of the model runs. Although there are differences between the price paths between these two runs, representing different interpretations of limitations on manufacturers’ CAFE compliance strategies, the reported sales differences between the B and P cases for MY2022 through MY2032 are identical in the CAFE and CAFE_ss output reports for total LDVs, passenger cars (PCs), and light trucks (LTs) in each year. This outcome suggests that something other than the difference in new LDV prices is driving sales differences across cases representing the B and P policy alternatives. Unless I have misread the model results, it would be useful to understand why the difference in prices between these two cases does not lead to corresponding differences in LDV sales results.

- A third observation is that the price elasticity of sales in the model run results appears to fall well below the -0.2 to -0.3 range discussed in the documents. The average price impact reported over MY2022 through MY2028 for all LDVs averages over $1,800 per vehicle, more than 5 percent of the average new vehicle price which is roughly $35,000. Annual vehicle sales in the runs over this period are about 17.9 million. Based on the percentage change in vehicle prices, the elasticity range of -0.2

to -0.3 translates into a range of annual sales impacts from 184,000 on the low end to 276,000 on the high end. In looking at the run results, however, sales impacts over MY2023-2028 average only 118,000 and even in their peak year, MY2027, are only 173,000, below the range implied by the low end of the cited elasticity range. The bottom line is that the run results seem to imply price elasticities in the range of -0.1 to -0.2, well below the -0.2 to -0.3 range mentioned in the documentation. As noted in the documents, even the cited range is below many other published estimates. It might be useful to look into this and provide a sensitivity analysis to consider the implications of a sales response at the high end, or even above, -0.2 to -0.3 range.

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(b) New LDV sales mix response

Another relevant aspect of the new vehicle sales response is the effect of CAFE standards on the sales mix. The run results show that freezing standards at their MY2020 level in the P case raises overall sales above those in the B case, increasing PC sales by more than it reduces LT sales. Over 2022-2032, lower LT sales (-2.11 million vehicles, -2.3%) in the P case compared to the B case are more than offset by higher PC sales (+3.28 million vehicles, +3.1%). Such an outcome is consistent with the notion that higher fuel economy standards in the B case serve to push the new vehicle market mix towards a higher sales share for LTs as a part of the consumer behavioral response.

The PC/LT sales mix response in the model runs is consistent with other evidence that the sales mix responds to differential fuel economy standards across vehicle classes as well as fuel prices. The share of light trucks in sales data as reported by the Commerce Department's Bureau of Economic Analysis was generally below 25 percent through the mid-1980s. When oil prices fell sharply in the mid-1980s, new vehicle buyers shied away from passenger cars whose size and performance was constrained by CAFE standards. The sales share of light trucks grew dramatically as consumers adopted minivans and then sport utility vehicles, which were subject to less stringent fuel economy requirements. By the early 2000s, light trucks regularly accounted for more than half of all light duty vehicle sales. From the mid-2000s through 2014, the light truck share of sales moved in a relatively narrow band influenced by both economic and oil price developments. From mid-2014 on however, the light truck sales share has again risen during a time of falling oil prices and increasingly stringent CAFE standards. It is worth noting that BEA and NHTSA use a different approach to categorizing cars and light trucks – for example, BEA counts all crossover utility vehicles (CUVs) as light trucks, while NHTSA counts some as cars and others as light trucks (Stone & Hamilton, 2017). However, whether the NHTSA or BEA categorization scheme is considered, the relationship identified above generally holds.

The model run results show a relatively modest reduction in the LT share of sales in the P case relative to the B case, with the LT share of sales in MY 2026 about 1 percentage point lower in the P case, where fuel economy standards are frozen at the MY 2020 level, than in the B case, where they continue to increase (45.4% in P versus 46.5% in B). This seems qualitatively reasonable. However, given that the standards are fully phased in by MY2025 in the B case, it would be helpful to explain why the difference in the LT share of sales between the B and P cases continues to grow, reaching nearly 2.5 percentage points by MY 2032.

(c) Additional comments relevant to review question 1a

The prior version of the CAFE model assumed that both the overall level of sales and the sales mix was invariant across the regulatory alternatives being evaluated. The treatment of the literature related to sales response in the model documentation and the PRIA seems to be more thorough and more up to date than that in that presented in documents supporting earlier analyses of this matter.

Given the weight of evidence in the literature on the price elasticity of new car demand and consumer valuation of fuel economy, it is definitely worthwhile to take account of sales response in modeling and analysis supporting CAFE rulemaking. However, one cannot arrive at a categorical conclusion that ANY sales response model is better than none. For example, a model that significantly overstated the responsiveness of the level and mix of new LDV sales to changes in the cost and pricing of new vehicles could conceivably lead to estimates that are less accurate than a model that entirely ignores the sales response.

My reading of the literature, including both recent work and earlier studies of the price elasticity of new care demand is that the -0.2 to -0.3 range cited in the model and rulemaking documents is likely to be a more reasonable view of sales response than the zero response assumption used in the prior version of the CAFE model. As noted above, the results of the CAFE_ss model runs appear to be consistent with a price elasticity below that range, suggesting the need to consider sensitivity runs using alternative parameter values that raise the modeled sales elasticity into, or even slightly above, the identified range.

Reviewer Name: Howard Gruenspecht

Review Question Number: 1c

Review Question Topic Description: Please comment on the sales model's integration in the CAFE model, including interactions with the simulation of multiyear product planning, in combination with the dynamic fleet share model used to allocate total new vehicle sales to the passenger car or light truck market segments.

Response:

The integration of the sales model into the CAFE model is important. The reduction in the LT share of total LDV sales in the P case compared to the B case has an effect on fuel consumption outcomes that would not be considered if the effect of alternative regulatory choices on the sales mix is ignored. Similarly, the shift towards accumulation of more VMT by older vehicles that on average are less fuel efficient and also less safe than newer models, would also be missed absent consideration of the sales response.

I could not assess the multiyear product planning aspect of the model. It is possible that the planning mechanism is at least partially responsible for some of the apparent lags and attenuation of market responses identified in some of my other responses to this review request.

Two additional observations may also be relevant. First, modelers understandably have an interest in developing code that can replicate historical data, as the ability of a model to replicate history, especially out-of-sample historical data, can help to validate models and increase confidence in model projections. Inevitably, however, both the past and future evolution of the market will be heavily influenced by factors other than the policy paths under evaluation. Given that the primary purpose of the present model is to compare the implications of alternative policy paths, the accuracy of estimated projection levels over the historical data period, particularly when the full historical data set is used to estimate the model, could weaken the model's ability to reflect differences across prospective policy cases.

Second, there can also be a tradeoff between the amount of detail that a model seeks to provide and the risk of mischaracterizing the big picture. In the present context, some of the modeling of product planning at the individual manufacturer level may present this risk, although it may be necessary to the extent that certain details must be considered given the statute that governs the rulemaking process.

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Reviewer Name: Howard Gruenspecht

Review Question Number: 1d

Review Question Topic Description: Please comment on the sales model's specification as independent of vehicle scrappage, and on the resultant calculation of vehicle miles traveled (VMT).

Response:

It is important to take account of both sales and scrappage changes, since existing vehicles and new vehicles are substitutes. Personally-owned vehicles (POVs), whether new or used, also compete with other less-similar transportation modes, including public transportation and ride-sharing options, although for many purposes and locations alternatives to POVs may be very limited. The literature on transportation mode choice, stemming from seminal work by Daniel McFadden and others, suggests a nested structure. Decisions about where to live, where to work, mode choice for non-discretionary travel, and the amount and mode of discretionary travel are at the top level. Conditional on choices made regarding location of residence and work locations, which in many cases are unlikely to be significantly affected by CAFE policies, transportation mode choices then consider options such as POVs, ride sharing, public transit (where available), biking, and walking. Within the set of POVs, the next level of the decision problem involves choices among vehicles of different makes, model, and age. Generally, one would expect different POVs (for example a new car and a used car within that is a few years older) to be closer substitutes for each other than a POV and another mode of transit.

Within this standard framework, the consideration of sales responses and scrappage responses as independent processes is problematic, because it fails to use important information regarding the total demand to operate POVs, which has implications for projections of the fleet size.

The sales response model takes the reasonable view that the technology costs of CAFE compliance serve to raise new car prices. Notwithstanding savings in fuel costs from higher vehicle efficiency, which several recent articles suggest are mostly or fully factored into vehicle purchase decisions, consumers respond by reducing their new LDV purchases. This is supported by the literature and also by the observation that even in the absence of higher fuel efficiency standards manufacturers retain the option to incorporate fuel efficient technology at higher cost (and price) and increase their sales volume if customers actually preferred to purchase more expensive high-efficiency vehicles to lower-price, lower-efficiency options. Past experience shows that consumers have moved in this direction during past periods of high gasoline prices, but available data suggest that today's fuel economy standards, let alone the further increases through MY 2025 under the augural standards, are already binding under current market conditions.

While some reduction in new LDV sales under increasingly stringent standards could be reflected in decisions to entirely forego the use of POVs, it difficult to envision that higher new vehicle prices associated with more stringent standards would induce consumers to hold a larger total fleet of POVs. Despite this, the CAFE_ss model run results report a "many for one" replacement. By 2030, the fleet is nearly 5.9 million vehicles (1.9%) larger in the baseline (B) case with the augural standards than in the preferred alternative (P) case where new care fuel economy standards and new car prices are lower, a difference that grows to 7.1 million vehicles (2.2%) by 2037. This outcome occurs notwithstanding important costs, including registration fees and required insurance for each vehicle held as discussed in the documents, as well as time-consuming and costly safety and emissions inspection requirements in many jurisdictions that make it extremely awkward and costly to substitute several existing vehicles for a new purchase that is foregone. This unexpected and unlikely result seems directly tied to the use of empirical sales and scrappage models that are independently derived rather than jointly developed within the context of a transportation mode choice model.

What appears to be missing in the current model is a framework to determine how many existing vehicles consumers wish to hold. While new car prices can be used as an explanatory variable in a scrappage model, it is used car prices that directly enter into economic scrappage decisions that are made following the incidence of an event that requires repairs to be made to restore a vehicle to operable condition The price of used cars is definitely influenced by new car prices, but ultimately depends on the balance between supply and demand for used vehicles. The independent scrappage model used in the CAFE model, however, does not consider the demand side of the market for used cars. In particular, it is difficult to understand why an increase in the price of new cars in the B case – accompanied by some increase in the price of used cars as consumers substitute towards them and used car prices rise to reduce the scrappage rate – would lead to a situation in which consumers want to hold more cars than they do in the P case. A useful case to consider would hold the total number of vehicles is held constant across the P and B cases. Such as case could still slightly overstate the reduction in scrappage, since there could be some shifting to other modes, or away from transportation services entirely, as new car prices rise between in moving from the P case to the B case.

The topic question also refers to the calculation of VMT. It appears that the present CAFE model, like prior versions, holds the distribution of VMT accumulation by age and vintage fixed over time other than its consideration of the rebound effect. As shown by figure 8-6 of the PRIA, there is a substantial reduction in average VMT accumulation with age, with an increasingly steep drop off beginning at age 6. For example, new passenger cars average nearly 16,000 VMT per year, decreasing to about 12,000 VMT per year by age 6, followed by a more rapid decline to an average near 5,000 VMT per year by age 11, with continued declines thereafter. This model feature causes a significant disconnect in the relationship between the overall fleet size change and aggregate VMT traveled across the B and P cases. By 2030, the fleet size is nearly 5.9 million vehicles (1.9%) higher in the B case than in the P case, a difference that grows to 7.1 million vehicles (2.2%) by 2037. In the CAFE_ss results, total VMT in the B case is also significantly higher than in the P case – with a difference of 2.6 percent in 2030 and 3.4 percent by 2037. However, this difference in VMT is mainly driven by the rebound effect, as the shift to more efficient vehicles in the B case encourages additional marginal trips by lowering incremental fuel cost per mile traveled. The rebound effect is extensively discussed in the document, but is beyond the scope of this review question.

One can separate the effect of the rebound from that associated with substituting existing vehicles for new ones by looking at the CAFE _ss_NOREBOUND cases that assume the absence of any rebound effect. Percentage differences in aggregate VMT between the "no rebound" versions of B and P cases are much smaller – only 0.5 percent in 2030 and 0.7 percent difference in 2037.

While it does seem plausible that higher new car prices will lead consumers to substitute existing vehicles for some new car purchases, it does not seem plausible that decisions to reduce new car purchases, accompanied by delays in the trade-in of existing vehicles with further impacts among users who might have purchased a relatively young used vehicle that was traded in to replace an older existing vehicle, there is little apparent justification for the model's implicit assumption that when a consumer substitutes an older vehicle for a newer one, he or she is making a simultaneous decision to reduce annual VMT based on the average VMT schedule for each age of vehicle. A useful case for VMT, which could be combined with the case holding the total number of vehicles in use constant across the P and B cases recommended above, would be to adjust the distribution of VMT accumulation by age to increase the VMT accumulation of older vehicles in the B case relative to that in the P case in a manner that would hold total non-rebound VMT constant across the two cases. Much of the mechanics to implement this case could be carried out using an approach similar to that that is already used to incorporate the rebound effect – see discussion in section 8.9.2 of the PRIA. The constant non-rebound aggregate travel case could slightly overstate non-rebound VMT, but is likely to be closer to reality than the present modeling approach, which assumes that consumers' annual travel changes dramatically when an older car is substituted for a newer one even without the consideration of any rebound from more fuel-efficient new vehicles.

Note that the lack of an adjustment to account for increase in average VMT/year for existing vehicles to reflect their increased use in applications that would be served by additional new vehicle sales in the P case, where lower new LDV prices would result in higher sales of new LDVs, largely, but not completely, offsets the effects of "the many for one" substitution of existing vehicles for new ones.

In sum, there could be significant advantages in more closely integrating the analysis of scrappage and new vehicle sales in the CAFE model. Moreover, this integration could be further extended to specifically consider VMT.

Reviewer Name: Howard Gruenspecht

Review Question Number: 2a

Review Question Topic Description: Please comment on the appropriateness of including a scrappage model in the CAFE model as a means to estimate the potential impact of CAFE standards on used vehicle retention.

Response:

If CAFE standards affect the level of new vehicle sales, adjustment to scrappage of existing vehicles can be an important part of the overall behavioral response to CAFE standards. Given differences in fuel economy, emissions, and safety performance across vehicle vintages, consideration of scrappage can have important implications for safety, emissions, and fuel consumption outcomes.

As discussed in the documents, there have been significant changes in scrappage patterns over time. There are two distinct challenges: characterizing absolute scrappage behavior and properly representing differences in scrapping decisions across alternative policies. Both are important, but the latter is most important in the present context. For example, some of the literature cited in the documents shows that both historical and prospective scrappage patterns for existing vehicles are sensitive to fuel prices, as the market value of existing vehicles with lower/higher fuel economy are differentially impacted by realized fuel price outcomes. Absent an ability to accurately project the trends and volatility in fuel prices, it is extremely difficult to accurately project scrappage levels, although one could still be confident that for any fuel price scenario, there would be a reduction in overall scrappage in the case with the augural standards relative to the preferred alternative that freezes fuel economy standards at their MY2020 level as discussed in the NPRM and the PRIA.

Scrappage decisions are driven by the economics of vehicle repair decisions. A vehicle is typically scrapped when the cost of repairing it, which can range from trivial (replacement of a bulb, wiper, or gas cap) to expensive (engine or transmission replacement) exceeds the difference between the post-repair and scrappage value of the vehicle. While the incidence and severity of breakdowns for existing vehicles is not influenced by the cost of regulatory compliance for new vehicles, the ability to substitute existing vehicles for new ones suggests that higher new vehicle prices will be reflected in higher used vehicle prices, resulting in reduced scrappage.

The scrappage equation estimated in the CAFE model uses new vehicle prices as an explanatory variable. Although new vehicle prices do affect used vehicle prices, they do not enter directly into scrappage decisions. Presumably, when new vehicle prices are lower, used vehicle prices are also lower. Therefore, given incidence of repair for existing vehicles in a given vintage/age bucket, lower new vehicle prices should lead to an INCREASE in scrappage in the P case relative to the B case, with less retention of existing vehicles. However, it appears from the reported results that this effect appears to be much larger than the effect on new car sales, with the result that there is significant shrinkage in the overall fleet associated with lower new car prices. This seems implausible, in that LDVs are now less expensive from the consumer perspective.

In reviewing the analysis, I compared results for cases representing the augural standards (baseline) and the proposed alternative, referred to as B and P cases respectively. As discussed in my response for review question number 1a (RQN 1a), I focused on the CAFE_ss runs, which match the results reported in the documents. According to the technical monitor for the review, this set of runs reflect statutory constraints that preclude certain compliance strategies.

As noted in my response to RQN1a, there is a very significant difference in the vehicle fleet size in the baseline and proposed cases, with the baseline fleet being noticeably larger than the proposed fleet, with the gap growing to 5.9 million vehicles by 2030 (B:306.0 million, P:300.1 million). At the same time, cumulative new vehicle sales from 2018 to 2030 are 984,000 less in the B case than in the P case (B:230.24 million, P:231.23 million). Starting from the 2017 fleet that is reported as 234 million vehicles for both cases, the difference in implied cumulative scrappage over 2018-30 is 7.45 million vehicles (B:158.20 million, P: 165.65 million), nearly 4.5 percent. On its face, this result is puzzling.

Endogenous scrapping reflects the notion that consumers respond to the higher price of new vehicles in the B scenario by reducing new vehicle purchases and increasing the retention of existing vehicles to provide personal mobility. If higher new vehicle prices in the B case do not result in lower sales of new LDVs than would occur in the P case, there is no reason for the B case to have higher retention of existing vehicles than the P case, and markets for used vehicles should balance at the same used vehicle price level in both cases, leading to identical scrappage behavior. However, contrary to this observation, the reported results for scrappage generated by the model are not actually synchronized. While differences in new LDV prices between the B and P cases do not cause the affect new LDV sales until 2022, scrappage starts to be affected by new vehicle price differences starting in 2018. As a result, with no change in new vehicle sales, the in-use fleet reported is already 1.18 million vehicles larger in the B case than in the P case.

While substitution between new and existing vehicles in providing services is well established in the literature, the notion that one new LDV would be replaced with multiple existing ones, as suggested by comparison of the B and P case fleet sizes, seems implausible, as discussed above and in my response to RQN1d.

The basic economic model of scrappage outlined above generally applies without regard to the cause of a repair event, which may arise due to an accident, wear/failure related to age, wear/failure related to VMT accumulation, or wear/failure related to the extent and quality of prior maintenance activity. To the extent that wear/failure linked to VMT accumulation plays a significant role, the comment in my response to RQN1d regarding the likely increase in average annual VMT accumulation for existing vehicles as they are increasingly used in place of new vehicles would, holding other factors constant, would tend to partially offset the decrease in scrappage resulting from higher used vehicle prices.

As previously noted, the model includes code to adjust VMT resulting from the rebound effect. However, there appears to be no difference in comparing scrappage outcomes between the B case that incorporates rebound (CAFE_ss) and the alternative version with no rebound effect (CAFE_ss_NOREBOUND). Thus, even when the code that adjusts VMT for rebound is used to reflect rebound itself or, as recommended in a previous response, to reflect the repurposing of existing vehicles for more intensive use, scrappage schedules by age appear to be unaffected. The implicit assumption that wear/failure related to VMT accumulation does not play a role in shifting the distribution of required repairs for vehicles within a given vintage/age bucket seems extreme, and could provide a partial explanation for why the scrappage equation may be showing too large a scrappage response to higher new car prices.

Reference

Stone, D., & Hamilton, M. (2017, May 24). Crossover utility vehicles blur distinction between passenger cars and light trucks (Web page in "Today in Energy" series). Washington, DC: Energy Information Administration. Available at www.eia.gov/todayinenergy/detail.php?id=31352

Reviewer Name: James Sallee

Review Question Number: 1a

Review Question Topic Description: Please comment on the appropriateness of including a sales response model in the CAFE model as a means to estimate differential sales impacts across regulatory alternatives.

In brief, it is conceptually correct to include a sales response. It is important for the analysis to demonstrate how changes in new vehicle sales can impact the analysis, in particular allowing this to affect fleet VMT and alter the used vehicle market.

In practice, however, the merits of including this margin are unclear. The econometric estimates used are not credible by modern academic standards. Thus presenting results based only on the sales response coefficients estimated is potentially misleading. A number of factors (specified below) suggest that the sales response coefficient is likely overstated, though bias in the coefficient could go either way.

The central parameter (how new vehicle sales will change when new vehicle prices are increased) is difficult to estimate reliably. As a result, it is critical to conduct (and exhibit) sensitivity analysis. My opinion is that it would be better to present an ensemble of results using different scenarios about the magnitude of the new car sales response, rather than the current approach, which relies on a problematic coefficient from a single regression.

Challenges for estimating the necessary parameter: Conceptually, the parameter of interest is the slope of aggregate demand for new automobile: that is, by how much will sales change under a long-run exogenous cost increase that impacts the entire automobile market.

The econometric analysis does not have a strategy for isolating exogenous cost increases, but instead measures the correlation between endogenous price changes and new vehicle quantities. This endogenous variation in price embodies changes in fleet composition and other attributes, and it represents equilibrium outcomes influenced by both supply and demand factors. I say more about this fundamental limitation in my response to review question 1b. Here I mention the inherent difficulty in estimating this parameter, as well as concerns about how CAFE is assumed to influence cost, and finally how cost changes translate into price.

The effect of a cost shock on new vehicle sales is unknown: Unfortunately, I am not aware of any credible estimates of the causal effect of an aggregate (i.e., market wide) cost (or price) shock in the new vehicle market on new vehicle sales. In principle, one could look to tax policies, exchange rate fluctuations, wage rates or commodity price shocks. For example, U.S. States often have specific sales tax rates that apply to vehicle purchases—changes in those rates (if they exist) could be used in a difference-in-differences analysis to test for sales impacts.

But even in these situations, much of what is more credibly estimable is likely to represent shorter-run responses, and many sources of variation will have other issues of interpretation. For example, one might argue that sales tax rates are not salient and so an analysis of State tax rates will yield a too conservative estimate.

In discrete choice models of the automobile market, the choice of the "outside good" represents the same conceptual margin (the decision not to buy a car). Thus another approach to grounding the fleet size effects is to study the outside good margin estimates from that literature. This margin, however, tends to be sensitive to modeler choices, and much of the literature relies on static models that capture only one year.

Thus, the point of this comment is not to be critical of the model chosen in the current PRIA per se, but instead to reaffirm the idea that this parameter is highly uncertain and should be added into a model only in way that allows for sensitivity analysis.

Pass-through is uncertain: The technology component of the CAFE model outputs *cost* changes. These need to be translated into *price* changes in order to be multiplied through the coefficients from the sales regression.

The modeled approach assumes that all cost increases are passed through into consumer prices—i.e., the CAFE model takes projected cost changes and multiplies them by the price coefficient from the regression in Table 8-1. For welfare analysis with a fixed fleet size (i.e., no sales response), this is palatable because in terms of economic welfare, whether consumers or producers bear the burden is not material for the overall cost-benefit ratio (though it of course matters for any distributional analysis).

The pass-through assumption matters, however, for estimating the sales quantity response. It is likely that some of the burden of additional technology deployment will be borne by producers in the form of lost profits (especially any fixed costs, as discussed below), suggesting that the sales response model likely overstates the size of any effects on the new car market.

There is a literature on cost pass-through, which is focused largely on exchange rates and trade, in the automobile industry. That literature tends to find incomplete pass-through. See Gron and Swenson, (2000) for relevant estimates and a discussion of the prior literature.

Are fixed (indirect) costs contaminating the analysis? The technology cost estimates described in Chapter 9 of the PRIA imply that the CAFE model passes indirect costs (e.g., research and development) into prices. Economic theory would predict that only true marginal costs (i.e., costs that scale directly with each new unit sold) would impact strategic pricing. The automobile market is typically understood as a market with imperfect competition, in which firms exercise pricing power. As a result, true fixed costs (costs that do not scale with the number of units sold) will be irrelevant to a firm's strategic pricing considerations, except as it ultimately impacts entry and exit. Instead, fixed costs will simply reduce manufacturer profits without passing through into prices, and therefore will not impact sales quantities in equilibrium. Again, indirect costs that are induced by the regulation belong in the cost-benefit analysis—they are a cost to society—but assuming they are passed fully into prices likely leads to an exaggeration of the magnitude of impacts on new vehicle sales.

The relevant price effect for the analysis is the technology cost net of the perceived benefits of any improved attributes (including fuel economy): Any conventional microeconomic choice model of the new vehicle purchasing decision would take into account not only the retail price of an automobile, but also its attributes and its expected operating costs. If CAFE makes cars more expensive, but also better, then the net impact on demand will be the difference between the two. Driving sales estimates from the *gross* price changes, as the PRIA does, is misleading.

Theory predicts that a tighter regulation has a net negative impact on vehicles because, assuming that the standard is binding, it forces the market away from the bundle of price-fuel economy-performance attributes that the consumer most wanted. As such, a view of how regulation should affect sales can be well grounded in theory. For a discussion of how a binding standard can be understood as raising the net price of vehicles, taking into account changes in attributes, see Fullerton and Ta (2019).

(There are two caveats to this related to constant technology and imperfect competition. The Fullerton and Ta analysis is a perfect competition model. See Fischer (2010) for a discussion of how automakers may not provide the optimal bundle in order to exercise price discrimination. Second, this reasoning assumes a constant technology space available. If regulation accelerates technological progress, then it is possible cars are made better faster as a result of the policy, which could expand sales.)

Performance standards have uncertain impacts on market size: The academic literature has considered how fleet average performance standards such as CAFE affect the overall size of a market. Such standards act as implicit subsidies to products that exceed the standard and implicit taxes on products that are below it. This has a net ambiguous sign on the size of the market, such that tighter standards can actually increase market size, rather than shrink it (see Holland, Hughes, & Knittel, 2009).

The CAFE model deployed in the current PRIA takes a different view, which is to minimize the "mix shifting" implications and model the automaker compliance response to a tighter CAFE standard as being entirely of the form of technology deployment. This view assumes that *all* models are being made more expensive, in which case it is clear the total car market would shrink as the standard tightened. This might be a reasonable approach if the CAFE standard is very tight, and if the standard is attribute-based (e.g., footprint based).

If the standard is not especially tight, however, or if the standard is flat (not attribute based), then there will be a substantial number of products that are above the standard in the baseline scenario, so that those products are implicitly *subsidized* by CAFE. This makes the overall market size impacts ambiguous. This points to two concerns.

First, NHTSA's CAFE model seems to minimize mix shifting channels as a compliance strategy, which implies that it is likely to overstate the market size quantity affects by overstating the technology costs that are deployed and passed through into prices in equilibrium. Second, while the most important cases for the regulatory analysis are of steeply sloped footprint rules, the CAFE model is designed to run on alternative flat schedules as well. When used to consider flatter schedules, the market size analysis can be quite misleading if it assumes all vehicles have price increases.

Changing ownership model for vehicles: Finally, as something of a tangent, I would note that this industry is poised for significant change in the near future as the ownership model of vehicles undergoes experimentation. Automakers are introducing vehicle subscriptions, and ride-sharing is growing exponentially (though from a small base as a share of all travel). It is not clear how this would be modeled because it is not clear how this would impact the *difference* between two regulatory scenarios, but it may become a relevant consideration moving forward.

Reviewer Name: James Sallee

Review Question Number: 1b

Review Question Topic Description: Please comment on the sales model's specification using an autoregressive distributive lag (ARDL) model time series approach, and comment specifically on the endogeneity of average transaction price.

The regression approach is described throughout section 8.6, and the estimates are included in a single Table 8-1. Some information is not included that limits my ability to assess the details of the estimation (more on this below), but a high level assessment is possible.

Most importantly, the regression estimated in the PRIA lacks an "identification strategy"; that is, there is no attempt to isolate plausibly exogenous variation in prices that can nail down the desired interpretation of a movement along a long-run demand curve. This muddles the interpretation of the coefficient, and implies that it should be used with extreme caution (if at all).

At the same time, as mentioned in my response to review item 1a, I do not know of a truly reliable way to estimate the new vehicle sales quantity impacts of exogenous aggregate price changes. I think that the model estimated is useful in establishing plausible magnitudes of the new vehicle sales effects, but should be presented as a guiding heuristic and used to inform several alternative scenarios, rather than treated as a precise, conclusive estimate.

Price is endogenous, leading to likely bias in the estimated parameter: The regression results reported in Table 8-1 regress quantity on price. This is literally the textbook example of simultaneity bias presented in most econometrics texts. To identify the slope of the demand curve accurately, one needs an instrumental variable or a natural experiment that shifts supply.

As the PRIA notes (p. 947), in the raw data, prices and quantities correlate positively. This is exactly what happens when price and quantity data are due more to shifts in demand than supply—movements of the demand curve along a (relatively) constant supply curve yield a positive correlation between prices and quantities in the observed data. The fact that the specification reported in Table 8-1 happens to find a negative effect of prices on sales in no way alleviates the broader concern about causal identification.

(The article by Busse, Knittel, & Zettelmeyer [2013], which cited elsewhere in the PRIA for its results on fuel economy valuation, is perhaps instructive. That paper shows that gasoline price shocks that shift demand lead to larger changes in price than quantities in new vehicle transactions. Prices and quantities move together, but it is predominantly a change in prices that restores equilibrium.)

Price also changes in the data due to compositional changes. For example, the PRIA notes (p. 947) that prices were highest from 1996-2006. This is the time period in the auto market when SUV sales peaked. The higher prices in that era are likely due in no small measure to this composition effect. The regression takes no steps to control for composition, which muddles the interpretation of the coefficient further.

Finally, garden variety omitted variable bias is likely present in some degree. The specification includes a very sparse number of macroeconomic controls, not taking into account, for example, interest rates or exchange rates, both of which have important effects on the automobile market.

For all of these reasons, the basic approach of using a time series regression over a long history is subject to biases. (Note that all of the same problems exist for the econometric analysis that relates new vehicle prices to scrap rates, and many of my comments here echo my comments on the scrap response estimation.)

The goal here is causal inference, not prediction: In assessing the model, the PRIA refers only to its time series properties and goodness of fit (see p. 949 for the latter). The goal of this regression, however, is to identify the causal effect of prices on sales, not to achieve forecast accuracy. The critical concern should be whether the coefficient is consistently estimated. Perfect prediction in sample is not evidence of unbiased (consistent) causal identification.

Time trends in the effect size: Economic theory says that it is likely (though not certain) that as people get wealthier, they would be less price sensitive. This suggests that there might logically be a time trend in the price coefficient. This could again dampen the sales price effects of CAFE projected in future vintages. (This is similar to the way that the rebound effect is modeled in the Small and Van Dender (2006), as well as others, and is related to the fact that most discrete choice models of car purchasing use price divided by income as a regressor.) More generally, the time series covers a very long history, and there is little reason to believe that the price coefficient is stable over that time. This can be tested within the data.

Challenges in evaluating the ARDL regression approach: Some essential information is not displayed, which means that it is impossible to fully assess the model. In particular, the dependent variable is not defined. Is this regression estimated in first differences? The right hand side regressors are also not labeled clearly. Are the sales lags differenced as well, or are they in levels? Basically none of the regressors are labeled clearly enough to be sure of how the regression was run based on the PRIA.

The CAFE model documentation offers an additional representation of the same model on p. 77 which seems to indicate that all of the variables are in levels, except for price, which is run in first differences. This then suggests a model where price *changes* are supposed to have an effect on the level of sales. This seems to be a peculiar specification. If one starts with an equation in which level sales are influenced by level prices (as is standard), then it is logical to take first differences and regress changes of quantities on changes of prices. Lagging the dependent variable but differencing the independent variable is unusual.

Building on this last point, only a single specification is reported. It matters a great deal for assessment of the model whether the price coefficient is fairly robust to alternative modeling choices and specifications, such as changes in lag length and inclusion of alternative controls.

The table also does not include the number of observations, or explain how standard errors were adjusted. The standard errors reported imply implausibly precise coefficient estimates. Likely this is due to not adjusting the standard errors for autocorrelation. The PRIA does not mention any correction to the standard errors. Newey-West corrections should be used.

A vector autogression might be better than the ARDL for attempting to deal with the supply and demand simultaneity. But note that such an approach does not fully overcome the threats to causal inference noted above.

The PRIA states that a variety of alternative approaches were considered, but none "offered a significant improvement" (p. 948). But, it is not stated how an improvement is defined. Perhaps it was based on prediction accuracy, but as noted above, the overriding concern here is causal identification, not prediction.

Quarterly data: It is not at all obvious that quarterly data represent an improvement over annual data, especially if the autocorrelation in the data is not being accounted for in the standard errors. The first-difference regression in quarterly time risks conflating short-term intertemporal fluctuations in quantity with the desired long-run demand response, i.e., seasonal effects (which are large for automobiles) could be biasing the regression.

Reviewer Name: James Sallee

Review Question Number: 1c

Review Question Topic Description: Please comment on the sales model's integration in the CAFE model, including interactions with the simulation of multiyear product planning, in combination with the dynamic fleet share model used to allocate total new vehicle sales to the passenger car or light truck market segments.

In reality, new and used vehicle markets interact. Economic theory predicts that the price of used cars influences the demand for new cars, and vice versa. The CAFE model does not integrate these two markets, however, but instead estimates reduced form regressions that determine the relationship between new vehicle prices and new sales, and separately new vehicle prices impact on scrappage.

This is potentially problematic because any errors in the two analyses could compound, rather than counteract each other, yielding net impacts on the size of the fleet that are at odds with economic theory. This appears to have happened in the PRIA, where less expensive new vehicles are projected to shrink the car market, implying that consumers, faced with cheaper cars, choose to substitute away from cars towards other forms of transportation.

I discuss this further in my review items 2a and 2b regarding the scrap model, as well as in item 1d. Here I mention briefly the specific points of integration raised in the question.

Regarding multiyear product planning: I was unable to find discussion in the PRIA or CAFE model documentation about how the sales results impacted the multiyear product planning schedules, or vice versa. I speculate that the concern was whether or not sales volume fluctuations should be assumed to influence the planning schedule, whereas in the current model they are not connected. I suspect that this is not a critical concern: the sales volume changes, while important, are probably not so large as to cause major changes to the product refresh/redesign cycle for most vehicles.

Regarding the fleet share: I have no objection to the separate estimation of the total fleet size in one step and the share of the fleet projected to be a light truck in a second step.

Reviewer Name: James Sallee

Review Question Number: 1d

Review Question Topic Description: Please comment on the sales model's specification as independent of vehicle scrappage, and on the resultant calculation of VMT.

As stated in my response to review questions 1c, 2a and 2b, it is important that the new and used markets interact within the CAFE model. If the CAFE model wishes to fully incorporate fleet size effects into the cost-benefit analysis, it needs to do so in a way that is internally consistent with economic theory. This will require some theoretical equilibrium bridge between the markets, rather than two parallel reduced form econometric exercises.

Even so, one could argue that the new vehicle cost shocks are the initial shock to the market, and that the effect of this shock can be taken in isolation. It does make sense to think that some consumers may be driven primarily by economic fundamentals—like income growth, fuel prices and interest rates—when deciding whether or not to buy a new vehicle. But, the equilibrium price of used vehicles will matter to others. Think for instance of how consumers coming off lease will make a decision of whether to purchase the leased vehicle or return it and lease (or buy) a new model. The residual value is central to this decision.

New vehicle sales will influence the VMT schedule: Much of the final cost-benefit analysis depends on the total VMT in the fleet. This depends on the fleet size (and its age distribution, because the VMT schedule is age dependent) and the VMT per vehicle schedule.

The current model assumes that the fleet VMT schedule is independent of fleet size. This is unlikely. All else equal, adding more and more vehicles to the fleet will surely cause the age-specific VMT per vehicle schedule to decline. That is, the marginal driver induced to own a car (or to divest) likely drives far less than the average. Put differently, total VMT likely scales less than proportionately with the fleet size.

(Note that this is a claim about the marginal person who in equilibrium owns a vehicle under one CAFE scenario but would not under another, who in the end is likely someone owning an inexpensive used car. The marginal person who buys a new car likely moves from a young new car to a new car, with ownership impacts cascading through the markets.)

It seems entirely possible to start with a more fundamental economic choice model where the key input to utility is VMT. The cost of VMT depends on the number of vehicles available, as well as the cost per mile of those vehicles and other attributes that determine vehicle quality. Data could be used to calibrate such a model. At the household level, it is certainly possible to imagine identifying the causal impact of adding an additional vehicle to the household's total travel. Panel data from emissions control systems that include odometer readings could likely be used to detect some of these relationships. This has significant conceptual appeal as a "top down" model that recognizes the interactions between fleet size and the variable that ultimately matters, which is aggregate VMT.

I make related observations in my response to review question 2c.

Reviewer Name: James Sallee

Review Question Number: 2a

Review Question Topic Description: Please comment on the appropriateness of including a scrappage model in the CAFE model as a means to estimate the potential impact of CAFE standards on used vehicle retention.

The PRIA is certainly right in stating that the interaction of the new and used vehicle fleets is an important margin and can have a significant impact on the cost-benefit analysis of fuel economy regulations. As such, including a scrap model is a great idea and could improve the regulatory analysis substantially.

As with any modeling consideration, however, it is important that the addition of a feature to a model makes the model's output more accurate towards its purpose. This may not be the case for the scrap model, given the limitations on how it is derived and integrated.

My concern is based on three issues: (1) the reduced form method employed; (2) the risk of unreliable coefficient estimates central to the exercise; and (3) the fact that the model produces outcomes that seem to be at odds with economic theory. Additional comments are organized by these three issues.

1. The reduced form model exposes the model to a risk of illogical outcomes: The CAFE model uses shocks to new vehicle prices in two separate analyses, one of which determines scrappage, and the other of which determines the new vehicle sales response. As the PRIA itself notes, in reality, these two processes are inherently linked—the causal chain is that new vehicle cost shocks impact new vehicle sales, which changes used vehicle prices, which changes used vehicle scrap rates. In other words, the new vehicle sales outcome is an *intermediate* step in the chain affecting scrappage.

The model skips over this causal chain, letting new vehicle cost shocks act on scrap directly. This means that misspecification, or even just uncertainty around the coefficients, can lead to logically inconsistent results on total fleet size. For example, suppose that the estimated effect of new vehicle prices on new vehicle sales is lower than the truth, and the estimated effect of new vehicle prices on scrap rates is greater than the truth. This can create a compounding error, where the net fleet size effects are grossly wrong.

I offer more detailed comments on this issue in my response to question 2b. Briefly, a model that explicitly that imposes equilibrium conditions and directly links the new sales and scrap decisions would protect against some of the most significant possible errors. There is some precedent in the literature for this which points to a better approach.

2. The estimation of the causal effect of new vehicle prices on scrap rates is subject to biases: The PRIA shows time series (panel) regressions that relate scrappage rates to new vehicle prices. Put simply, this regression lacks an "identification strategy"—that is, the PRIA does not make a positive case as to why this regression ought to be expected to deliver a consistent coefficient estimate. Given that prices are clearly an endogenous variable, the regression is exposed to garden variety simultaneity and omitted variable biases. This regression would not pass muster in an academic research article.

To be clear, this comment is not meant to be overly critical of the panel analysis in the PRIA. The regressions run are sensible and the results are interesting. The point is that this is a difficult problem to solve reliably.

As a result, it is all too easy for both of these analyses to contain substantial errors that compound each other. Thus, instead of relying on these coefficients per se, I would prefer an approach that uses whatever evidence is available to estimate new vehicle sales responses and then links them to scrap rates via an equilibrium choice model, rather than attempting two decoupled reduced form estimations.

The model requires a causal effect of prices on scrappage: The counterfactual policies are modeled as producing a shock to prices, ceteris paribus. Thus, conceptually, the CAFE model requires an estimate of the causal effect of permanent increases (changes) in the average new vehicle price on the longevity of the used fleet.

Many of the features of the regression are discussed as if the goal is *prediction* rather than *causal inference*. The key here is not prediction. Specifications should be chosen based on economic theory and a concern over eliminating biases, rather than on goodness of fit. The former issue is essentially not discussed in the PRIA, and nearly all specification decisions are described as driven entirely by goodness of fit statistics.

Price is endogenous: At the most basic level, new vehicle prices are an equilibrium outcome. A regression of quantity on price is literally the textbook example for simultaneity bias in nearly every econometrics textbook. There is just no reason to believe that this regression delivers unbiased (consistent) estimates of the causal relationship.

New vehicle price variation in the time series reflects lots of things—shifts in demand, changes in vehicle attributes, changing composition of vehicles across classes, etc.

Price should be net of quality changes: The PRIA uses estimates of price that do not account for changes in vehicle quality, including fuel economy. This seems to me deeply problematic, as the right conceptual idea is to ask how a change in the desirability of vehicles, taking price and attributes into consideration, changes ownership. The PRIA argues that the ideal specification ignores quality changes, but I do not understand or agree with the arguments made. For example, on p. 1010, the PRIA argues that the purpose of the analysis is to test whether consumers fully value attributes (namely fuel economy) so it is improper to assume valuation and adjust for it. But I see no way in which the regressions run test this question, nor do I see how that is being *tested* anywhere else in the CAFE model.

Price data is lacking: The scrappage data assembled for this estimation seem quite appropriate, and I know of no better data. The new vehicle price data, however, are coarse. At least in recent years, much more granular price series exist (the best are from J. D. Power or NADA) that could account for price trends in different vehicle classes and that can account for attribute differences.

Out of sample projections of trends are central to the analysis: By necessity, the model must make predictions far into the future, but this is nearly always puts an economic model uncomfortably out on a limb. In this case, a really impactful parameter is the projection of a trend in vehicle durability.

The model produces such implausible survival rates in future cohorts that the modelers chose to add an ad hoc adjustment (the exponential function patch for survival after age 20) to force all vehicles into a (subjectively defined) reasonable scrap pattern. If such an adjustment is required to the regression coefficient outputs, it begs the question of whether the coefficients should be put used in lieu of a reasonable approximation in the first place.

Some signs of concern: A few variables of interest perform strangely in at least some of the vehicle classes—namely the maintenance cost variable and interest rates. These anomalies could just be due to poor data, but they do point to the possibility that the regressions are simply not reliable causal estimators.

There are some alternatives: In contrast, note that the heavily referenced study by Jacobsen and van Benthem (2015), as well as some other studies of scrappage, are based on using gasoline price shocks or other identification strategies. Thus, there are ways of disciplining a model with data, i.e., using econometric analysis to inform the parameters of an equilibrium model based on theory.

There are some challenges in evaluating the econometric estimation: There were some modeling choices that I simply could not evaluate with the given information.

As a minor (but important) point, the main estimating equation does not specify the unit of observation, nor does any table list the number of observations or unit of observation. Tables also do not present standard errors, which makes it difficult to assess many coefficient estimates. Standard errors need to be adjusted for serial correlation, and perhaps two-way clustered to allow correlation in the errors by age.

More significantly, nearly all of the relationships of interest are polynomials. There are no summary statistics reported, so it is nearly impossible for the reader to judge the economic magnitude of the effects given what is reported (i.e., to assess marginal effects at the mean of the sample.)

There are very few alternative specifications shown, with the major difference being the polynomial shape of the age variable. It is simply impossible from the given set of results to judge how robust these estimates are.

In contrast to the new vehicle sales regression reported in the PRIA's section 8.6, the discussion of the scrappage regressions does not include any discussion of the time series properties of the estimators. It is important to test for non-stationarity, for example.

In many cases, the most important impact of new vehicle prices are in three year lags, and contemporaneous prices are often economically and statistically insignificant. The PRIA argues that the largest effects at three years is logical given the prominence of three year leases. This is plausible, but there are also lots of five year leases, and customers who buy their vehicles tend to put them back on the market later than three years on average. Thus, it begs the question of why all the specifications include only 3 lags. No information is given about what happens at higher lags. In one or two places, it is asserted that 3 lags is "optimal" but what this means is not explained.

Is this model dynamically consistent? The reduced form approach does not necessarily build in the dynamic relationships between shocks today and how that impacts the fleet tomorrow. In reality, if a shock today causes a lot of scrappage of a particular cohort today, then another shock tomorrow can be expected to have an attenuated effect, because there is already a smaller remaining population.

The CAFE model produces permanent (growing) shocks to the new vehicle prices. This makes it essential that the model correctly understand these "harvesting" effects. I do not believe that the current reduced form approach solves this problem correctly. This is an important issue. An equilibrium model, in which supply and demand for each type of vehicle is equated, will naturally account for these types of considerations, but a reduced form regression does not.

A very minor point on scrap metal: Many "scrapped" vehicles are in fact exported to Mexico or some other country. This will (correctly) be measured as "scrapped" in the data. For this reason, the value of scrap metal is probably not a particularly critical variable.

3. The results on net fleet size are problematic: The PRIA documents final model results that imply that more expensive new vehicles lead to a larger total vehicle fleet. This is problematic.

A generic economic model of this situation is that there are two goods, A and B, which are close substitutes for each other, and a third good X, which represents all other goods in the economy (i.e., some composite). A decrease in the price of A is said to reduce demand for B. This leads to a decrease in the price of good B. Now, the price of both A and B have fallen. But, the model posits that the reduction in prices of A and B causes net substitution toward X. Basic economics suggests that this is unlikely to make sense.

To say it another way, a CAFE rollback makes vehicle ownership less expensive (for both used and new vehicles), which means that we should expect more vehicles. Yet the analysis predicts that consumers will substitute away from vehicle ownership as vehicles become cheaper. This in essence states that cars are Giffen goods.[2]

The PRIA argues at points that the counterintuitive net effect on fleet size is logical. In those discussions, the document emphasizes that a reduction in new vehicle prices (e.g., from a rollback) will reduce demand for used vehicles, thereby lowering prices. This is true, but the discussion fails to recognize that it also reduces the supply of used vehicles (in the next period). This supply shift will lead to increases in used car quantities, more so as supply is relatively inelastic.

A note on the distinction between longevity trends and causal impacts of CAFE: A major point of discussion (and interesting finding) is the very strong trend over time in vehicle durability. Cars last longer now than they used to. The model predicts that this trend will continue.

Many of the main results of the PRIA are driven by this projected future trend in vehicle longevity. While there are certainly concerns with using a time trend that essentially must be based on twenty year old vintages (as the more recent vehicles have not reached old ages to ensure that they will truly last longer), the evidence that longevity is changing is compelling and this should be integrated into the analysis.

But note that the analysis can model the longevity of future cohorts of vehicles using these estimates without also using the new vehicle price causal impact coefficients. That is, the impact of new vehicle prices on scrappage and the time trends in cohort durability are simply separate issues. The analysis could eschew reliance on the more dubious causal price coefficients while preserving a future-projected longevity.

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[2] [Editor's note: A "Giffen good" in economics and consumer theory is a product whose consumption increases as the price rises -- and vice versa—violating the basic law of demand in microeconomics. Named for 19th century Scottish economist Sir Robert Giffen.]

Reviewer Name: James Sallee

Review Question Number: 2b

Review Question Topic Description: Please comment on the scrappage model's specification using a form common in the relevant literature. Are there better approaches that allow for both projection (as is necessary in this context) and a focus on new vehicle prices (exclusively)?

Used vehicle quantities should be an equilibrium outcome: The ideal model will involve an equilibrium in which vehicle supplies and demands are equated at each moment in time, and supplies are updated dynamically as the fleet ages. This disciplines the model to produce certain intuitive relationships.

In contrast, the current CAFE model is restricted (for practical reasons) to derive only a reduced form (econometric) relationship using historical data between new vehicle prices and scrap rates. The review question specifically asks whether a model can be better if it exclusively focuses on new vehicle prices. My view is that a reduced form econometric exercise that relies solely on new vehicle prices to determine scrappage is inherently problematic. But, the results of this econometric analysis can be used to inform a model that is designed to constrain outcomes to follow economic principles, such as the closer substitutability of similar aged vehicles. What seems most critical is that the new vehicle sales and scrap results be forced into a relationship in a theoretical model, with parameters potentially informed by the type of econometric analysis produced in the PRIA.

It is possible and desirable to build a model that accounts for used vehicle prices. In such a model, the shock of a new vehicle cost change will reverberate through the market and influence scrap rates *through its impact on used vehicle prices.* Such a model is preferable to the current approach that directly posits a reduced form effect of new vehicle prices on scrap rates using econometrics for the reasons discussed in my response to question 2a—namely that any errors in this analysis can be compounded with errors in the new sales forecast when the two streams of analysis are not explicitly linked.

Note also that there is plenty of quality data on used vehicle prices. In recent years, there is very detailed data available from J. D. Power, from wholesale auctions (Manheim or AuctionNet), or Edmunds. Stretching even further back are Blue Book and Black Book estimates.

To improve the current analysis, it is not necessary to have reliable econometric estimates of all of the various channels (though this would of course be ideal). What is important is that the model be derived from a consumer choice model that follows economic principles. Such a model would recognize the mechanical relationship between new vehicle sales today and the supply of used vehicles tomorrow, as well as modeling new vehicles as substitutes for used vehicles. Critical also is an explicit representation of the "outside good"—that is, the choice to not own a car. It is this margin that links to the overall fleet size, which is the key outcome of the scrap model.

The preferred "equilibrium first" approach is used in some of the existing literature, including the Jacobsen and van Benthem (2015) study cited in the PRIA, as well as some papers not cited in the PRIA, such as Adda and Cooper's *Balladurette and Juppette: A Discrete Analysis of Scrapping Subsidies,* (2000). Thus, while it may not be easy to build upon, there are existing studies that lay a foundation for analysis that links used and new vehicle markets through a more fundamental structure.

A minor point of the discussion of scrappage and age: The discussion on pages 995-7 suggests that there will be a larger effect on middle-aged vehicles than on older vehicles or younger used vehicles based on the degree to which new vehicles are substitutes (as well as the number that are close to the margin of scrap). This discussion seems to miss the fundamental point that prices will “cascade”—that new vehicle prices will impact the prices of young used vehicles, but those prices in turn impact the prices of middle used vehicles, which in turn impacts the prices of older used vehicles.

Reviewer Name: James Sallee

Review Question Number: 2c

Review Question Topic Description: Please comment on the scrappage model's integration in the CAFE model, addressing the vehicles affected by the scrappage model, and the extent to which changes in expected vehicle lifetimes are consistent with other assumptions.

As stated in my responses to review questions 2a and 2b, the critical issue of integration is that the new vehicle sales projections and the scrap results should be constrained to relate to each other in a way that matches economic reasoning. Details of this view are included in the answers to those questions. Here I make three other points.

The VMT schedule will be influenced by the fleet size: When we add more vehicles to the fleet, it makes sense to expect that this will lead to a decrease in the VMT-per-vehicle schedule. This is acknowledged very briefly on p. 1059, but left as future work.

Imagine a household with multiple drivers but one car. Suppose they add a second car. It is intuitive to expect that total driving in the household (including both cars) will rise. But, it seems very unlikely that VMT would double. Similarly, as the fleet continues to rise faster than the population (as noted in the PRIA), one would not expect the total VMT to rise at the same proportional rate as the number of registered vehicles, but instead to rise more slowly. This of course is a testable hypothesis historically in the aggregate. One could also use the National Household Travel Survey to look for within household patterns for how total VMT scales with fleet size in order to assess how important this issue is.

Another way to state the same concern is that the marginal driver—i.e., the person who decides to own a vehicle or not as a result of changes in CAFE—is very likely to have a lower VMT demand than the average. This means that we should expect the fleet size changes to be overestimates of real changes in aggregate VMT under the current methodology.

This exaggeration could very well be substantial. Thus my concern about this issue rivals the central concern about how the new vehicle sales and scrap responses are implemented separately. It is quite possible that modeling a change in total fleet size, where the VMT-age schedule per vehicle is held fixed, could lead model output to be less accurate than a model with static fleet sizes, even if the dynamic fleet size model correctly predicts the number of registered vehicles.

Heterogeneity (probably) matters: The Gruensprecht effect for fuel economy regulations implies not only that used vehicles will last longer when new vehicles become less desirable (net of price), but also that there will be a shift towards greater longevity that is especially pronounced for less efficient used cars. The reason is that regulations will impose a bigger burden on the least efficient new vehicles.

The Jacobsen and van Benthem (2015) study finds not only that the overall effect on used vehicles is important, but also that the relative effect of tighter fuel economy standards on the longevity of inefficient vehicles is important.

Note that footprint-based standards may mute this difference substantially. The CAFE model is designed to be run with a flat standard as well, however, and this modeling issue would clearly be important in that case.

If CAFE accelerates technology, the improvement in future cohorts will accelerate turnover through a quality dimension: Analysts have described the move to footprint based standards as something that ensures that more of the compliance efforts of automakers comes through technology deployment, rather than mix shifting. Let us suppose that a tighter CAFE rule will not just force existing technologies to be deployed, but will also lead to more research and development and/or technology cost reductions from learning by doing.

If true, this will mean that successive vehicle cohorts will be "better" (i.e., on a higher technology frontier). As new vehicles are "more better" than existing vehicles, the used fleet will represent a less close substitute, leading to more demand for new vehicles and faster turnover, all else equal. Thus, if tighter fuel economy rules do in fact accelerate technological progress (some suggestive evidence of endogenous technological progress rates is found in Knittel's *Automobiles on Steroids,* (2011) and in Reynaert's *Abatement Strategies and the Cost of Environmental Regulation: Emission Standards on the European Car Market* (2014), then there could be an important "quality" channel that influences turnover rates. Given that the CAFE model includes a very detailed assessment of technology, consideration of this channel seems feasible.

Reviewer Name: James Sallee

Review Question Number: 3a

Review Question Topic Description: Please comment on the inclusion of each source of employment related to automobile production and sales.

This review question essentially asks whether the labor market impacts calculations are correctly scoped—that is, whether the appropriate markets and channels are included. What the labor market analysis does is capture a specific set of effects in the *automobile supply chain*. It uses a piecemeal approach: it decides to include specific sectors and omits others. There are alternatives.

One alternative is to not quantify job impacts. This is a defensible choice because of the uncertainties involved and because the jobs impact is not a necessary component of the cost-benefit analysis.

A second alternative is to conduct a more general economic impact assessment using a standard model (like REMI or IMPLAN). These tools, while imperfect, are widely used and can be useful in characterizing the likely impact of the regulation throughout the wider economy, not just the most directly related automobile markets.

A third alternative is to attempt to capture more or fewer pieces of the automobile industry in the existing piecemeal approach, i.e., one could attempt to model how the change in total VMT would impact expenditures on induced travel, maintenance, gasoline station workers, etc.

A fourth alternative is to attempt to calculate only a net overall real income impact of the policy, and then apply a generic macroeconomic multiplier.

All of these alternatives have merit. At the end of the day, my own judgment is that the scope of the analysis described in the current PRIA is useful, but potentially misleading. It should be described carefully as an "incomplete sectoral effect" and should perhaps be shown in parallel with a more general economic impact multiplier approach. That is, it should be characterized as the impact of the regulation on the automobile sector, not as the overall jobs impact of the regulation. In addition, it would be ideal to conduct analysis that confirms that the auto sector impacts are in fact the most significant channels. More details follow.

The case against showing job impacts (alternative 1): Past analyses have eschewed quantification of jobs impacts because it is extremely difficult to predict the full set of ways that a shock to the economy will propagate through various markets. In my response to review question 1a-c, I assert that the sales quantity impact of CAFE is not well estimated. That sales effect is the input to this exercise. That uncertainty is compounded by the fact that it is inherently difficult to model an equilibrium jobs impact for any case, and that, as discussed in review item 3.b, in this market there are lots of reasons to worry about the jobs impacts described here.

As a result, it is not clear that quantifying a jobs number is better than not quantifying one at all. At a minimum, the uncertainty here implies that it is essential to offer a set of scenarios about jobs impacts that correspond to alternative assumptions about the size of sales impacts.

The case for using an input-output tool (alternative 2): It is perhaps natural to simply include the most directly impacted sectors (i.e., dealers and auto assembly). It is, however, potentially misleading to do so because it risks compounding a bias among policy analysts to think only of the direct effects of a regulation on the regulated sector itself.

General equilibrium economic impact tools (like REMI) exist and are used on a regular basis. These tools are highly imperfect (because modeling counterfactual economies is extremely difficult), but I see no reason that they are not as valid as the jobs impact that is included in the current analysis. It may thus be useful to include them alongside the values focused solely on the automobile supply chain.

What are the largest labor market impacts of the regulation? (alternative 3): If one wishes to stick with a piecemeal approach, the current approach seems sensible, but my concern is (again) that it plays into an overly narrow understanding of how regulation affects the economy.

In principle, there are many other jobs impacts possible. For example, higher fuel economy reduces the cost of travel, which could lower job search costs and otherwise spur economic growth through induced travel (the magnitude of which is also an output of the CAFE model). In a standard economic impact model like IMPLAN, one could posit shocks to the economy from the regulation due to both auto sales and fuel sales or transportation services. I would not be surprised if the latter dominated the calculation.

It is appealing to begin with the most direct impacts on the production sector itself, but if these jobs numbers are meant to play a serious role in the policy analysis, then it might be valuable to conduct a scoping analysis that would consider how large the economic impacts might be of all of the channels. That is, even if they cannot be reliably pinned down, it would be valuable to assess whether a focus on the auto value chain is actually where the largest effects should reside.

The case for a generic income effect to calculate jobs (alternative 4): On theoretical grounds, the general equilibrium impact of shifting resources from one sector to another can be quite minimal, depending on labor market conditions and how easily factor allocations can adjust. What is better grounded in theory regarding CAFE regulations is that, if regulations are binding—that is, they force consumers to move from a more desired set of vehicles towards vehicles that, net of fuel savings, are not what they wanted—then consumers experience a real income loss as a result of the policy. (This logic is described in Fullerton & Ta,[2019])

Thus, a final alternative would be to skip any focus on the auto industry but instead calculate the real income loss of the policy using the consumer choice and technology cost components of the CAFE model, then using macro estimates of the multiplier effects of real income shocks from the literature to characterize an overall effect on jobs.

Reviewer Name: James Sallee

Review Question Number: 3b

Review Question Topic Description: Please comment on assumptions regarding labor hours, production location (domestic/foreign), and supplier impacts.

This review question essentially asks whether the key parameters and assumptions used in the jobs impact are appropriate. In sum, there are many reasons to doubt the parameters used, especially the technology cost jobs effect. However, I am not aware of more reliable estimates, and the approaches taken seem to use common and sensible methods for calculating jobs impacts. As a result, I would again emphasize the value in *conducting and reporting sensitivity analysis* around the jobs impact numbers, rather than reporting a single number as it if were a reliable point estimate.

One nice feature of the approach is that it uses the model-specific vector of quantity changes, linking each model to its production location. This is useful because there is an important average difference between the production location of light trucks and passenger cars (given trade barriers for the former), and because the CAFE model is attentive to these different regulatory classes in its quantity analysis.

Average versus marginal: The assembly, dealer and supplier impacts rely on calculations of average labor hours per vehicle produced. It then implicitly assumes that average labor hours are the same as marginal labor hours in calculating the jobs impact of a change in vehicle sales. Little to nothing is said about the reliability of that assumption, which ought at least to be recognized.

I see little reason to believe that average and marginal labor hours are necessarily the same, though perhaps they are not too far apart.

One possible concern is that prior research has demonstrated that adjustment in the automobile assembly sector tends to be "lumpy"—that is, rather than making small gradual adjustments, many changes are large scale (i.e., adding a shift, canceling overtime, repurposing a plant) (e.g., Bresnahan & Ramey [1994]), This means that small shocks may lead to no labor market impacts, but larger shocks may lead to much bigger changes. That paper uses demand shocks for particular models to study labor at a given plant, which is a viable strategy for directly estimating the marginal labor effects—though the estimated parameter may have a shorter-run interpretation than is ideal for the CAFE analysis. In other words, in this particular market, there is hope for directly estimating the jobs impact induced by changing quantities using natural experiment methodologies.

In terms of the upstream supply "multiplier" that is used, there is a similar question of marginal versus average inputs. The same question arises yet again for employment at dealerships. Do dealerships readily scale up the salesperson hours as modeled, or do small fluctuations in demand simply change the arrival rate of interested customers that changes their efficiency (e.g., labor hours per unit sold)? Direct estimation of how auto market fluctuations translate into dealership labor hours should be feasible using employment data.

All of this is more to make the point that there is substantial uncertainty about the relevant parameter, rather than to levy criticism on the approach used. The use of the average labor hours is a standard and sensible approach in economic impact analysis. It seems broadly appropriate in this context. There may be some scope for using natural experiments to directly identify marginal effects, but the approach taken for estimating dealership, assembly and upstream supply hours per unit seems reasonable.

Add a historical reality check: This industry has undergone several waves of change in terms of the role of workers, with a long-term decline in the number of workers required to produce a unit. It would be worth describing these trends. If there has been a change in labor hours per unit in the last 10 to 15 years, then it would likely be worth scaling down the expected impacts in the near future years under the assumption that this trend would likely continue. (This is not an assertion that the CAFE policy itself is likely to impact the trend, but rather an assertion that today's value of labor hours per unit might be misleading for even the near future.)

Revenue per worker for technology costs more problematic: In addition to the automobile production value chain, the model estimates the change in jobs due to the need to develop and bring to market new technologies. The approach taken is to calculate annual revenue at OEMs and major auto supply companies and then divide by their labor hours in order to calculate a revenue per worker measure. A change in revenue caused by CAFE is then assumed to change the number of workers so as to maintain the original revenue per worker metric. CAFE impacts revenue in two ways—firstly through changing quantities, and secondly through changes in vehicle production costs (which are assumed equal to changes in prices, thereby impacting revenue per unit sold).

Here the proposition that average and marginal effects are equal is even more dubious than in the case above. This analysis seems intended to capture things like design engineering, contracting with suppliers, or tweaks to the assembly line. Many of these things are fixed costs—e.g., if Ford has to deploy a new part on the 2019 Fusion, it will have to employ an engineer to design, test and calibrate the part regardless of how many Fusions it sells that year. It seems likely that the marginal jobs impacts due to an increase in technology deployment costs would exceed the impact implied by the average revenue per worker parameter. Likely revenues would rise by less than costs, squeezing profits and lowering revenue per worker. (In contrast, this is less obvious for revenue changes due to quantity changes, which perhaps suggests that the two should be decomposed.)

Also, the calculation of revenue labor hours is explained only in a footnote (footnote 510, p. 962 of the PRIA) that simply says public documents for a non-random sample of firms was analyzed to come up with revenue per worker. There is not enough detail in this information to fully assess the credibility of the chosen parameter.

Chance of double counting in the technology cost values: The revenue per worker calculations for the OEMs and the parts makers would seem to include the assembly/production workers that are also analyzed in the production value chain analysis. This therefore appears to involve double counting of some workers.

Location uncertainty: An important question is whether alternative CAFE rules might alter the location of production (e.g., inside or outside of the United States). But, there does not seem to be a direct and credible way to make claims about how the location of production would change, so that assuming locations are fixed (as is done in the analysis) seems like the best approach.

The analysis could include some statistics on the location of production of the most advanced technologies, if that is available. It seems possible that more advanced technologies are more likely to be produced in the United States.

The other consideration is to analyze trends in foreign shares and production locations. If there is an important trend, this could be used to adjust the numbers used for future years. The point is not to establish different jobs multipliers for different policy counterfactuals, but instead to project forward a common multiplier to be used for all policy alternatives.

Full employment: In the midst of a discussion of how the net jobs impact depends on labor market tightness, the PRIA asserts that "no assumption" about full employment was made. But, this is not true. Implicitly it is being assumed that there is sufficient labor supply slack so that additional employment in the sector is not directly offsetting labor in another sector. It seems misleading to assert that the analysis is able to abstract from the employment rate context.

Reviewer Name: James Sallee

Review Question Number: 3c

Review Question Topic Description: Please comment on methods used to calculate changes across alternatives.

As I understand the calculation of labor market impacts, each policy alternative produces a vector of technology adoption choices and a vector of model quantities. These outcomes, along with measures of production location and percent foreign content, are then plugged directly into the labor impact equations. A variety of assumptions about the production process, location of production, etc. are held fixed in a common way across all scenario alternatives.

For the purposes of this exercise, and given the lack of detailed information available to speculate on how labor input or production location decisions would be sensitive to policy details, this approach seems to be the best available.

In other words, my concerns—which I detail in review questions 3.a and 3.b—are with the overall approach to calculating jobs impacts in all cases, not how the approach generates *different* results across scenario alternatives. Using the same equations and holding fixed most of the key parameters across scenarios and driving changes strictly from vehicle technology and quantity vectors seems appropriate.

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Reynaert, M. (2014, October). *Abatement strategies and the cost of environmental regulation: emission standards on the European car market* (Discussion Paper Series DPS14.31). Leuven, Belgium: KU Leuven Center for Economic Studies. Available at https://ssrn.com/abstract=2523841 or http://dx.doi.org/10.2139/ssrn.2523841

Small, K. A., & Van Dender, K. (2006, April 10). *Fuel efficiency and motor vehicle travel: the declining rebound effect* (UC Irvine Economics Working Paper #05-06-03). Irvine: University of California. [Corrected July 17, 2006, and August 18, 2007; shorter version published in *Energy Journal*, 28(1), pp. 25-51.] Available at www.economics.uci.edu/files/docs/workingpapers/2005-06/Small-03.pdf

Phase 2 Reviewer Résumés

Alicia Birky
Analysis Team Lead

EDUCATION

Accredited Institutions

Ph.D., Policy Studies, University of MD College Park, 2008.
B.S., Aerospace Engineering, University of MD College Park, 1988, Summa Cum Laude.

Security Clearance

NA

Employment

Energetics Incorporated
TA Engineering, Inc.
PNNL Joint Global Change Research Institute
NASA Headquarters
University of MD, College Park
National Renewable Energy Laboratory
Swales Aerospace

SUMMARY

Dr. Birky is an engineer and policy analyst with more than 16 years of academic and professional experience at the intersection of science, technology, policy, and markets relating to global climate change, energy conservation, and criteria emission reduction. She has developed a working knowledge of policy-making and analysis, as well as strategic planning and program development, management, implementation, and evaluation. Her broad range of experience results in excellent cross-disciplinary technical and communication skills. She has experience working with clients and stakeholders from private industry, federal and state government, independent laboratories, and non-profit organizations. Clients have included Oak Ridge National Laboratory, DOE, Argonne National Laboratory, the National Petroleum Council, EPA, the Baltimore Port Authority, the Maryland Environmental Service, and Constellation Energy. She has collaborated with the National Renewable Energy Laboratory, Sandia National Laboratory, the Maryland Department of the Environment, the Baltimore Port Alliance, the Maryland Environmental Finance Center, and the Maryland Motor Truck Association.

Dr. Birky's main area of expertise is transportation, including light and heavy highway vehicles, non-road equipment, harbor craft, and ocean vessels. Her skills include quantitative and qualitative analysis of technologies, programs, and policies, including assessment of technical, economic, operational, political, social, and market opportunities and constraints. She is skilled in the development and application of econometric, systems dynamics, cost-benefit, emissions, consumer choice, market adoption, and stock accounting models. She has applied these skills to energy demand modeling and to program evaluation, verification, and measurement. She also is adept at communication of technical information in written and oral formats for technical and non-technical audiences.

EXPERIENCE

Energetics Incorporated, Columbia, Maryland
09/2014 – Present

Dr. Birky is the Analysis Team Lead within Energetics' Sustainable Transportation Solutions Division where she supports the Department of Energy's (DOE) Energy Information Administration (EIA) and Office of Energy Efficiency and Renewable Energy (EERE). She collaborates with staff from DOE and the National Laboratories, including Argonne, Oak Ridge, Sandia, and the National Renewable Energy Laboratories. She provides analytical, technical, and management support for research and development programs with a main focus within the EERE Vehicle Technologies Office (VTO). She is responsible for conducting technical and policy analysis on the costs and benefits of technologies being developed by EERE and applies existing analytical models and develops custom tools where necessary. Her duties include assisting EERE staff in responding to requests for information from Congress, EERE management, and other program stakeholders; preparing data in support of program budget development; and supporting the DOE peer and merit review processes. She is responsible for the management of tasks, projects, and team members.

Dr. Birky recently completed a modeling effort with EIA to integrate highly automated vehicles (HAVs) and Mobility as a Service (MaaS) into the National Energy Modeling System (NEMS) Transportation Module (TRAN). Technical work included estimating the impact of vehicle automation on vehicle cost, weight, fuel economy, and other attributes; determining the technology applicability in various vehicle type and end-use markets, including MaaS and transit; and estimating vehicle and transportation system impacts including vehicle use and life, travel demand by various modes, vehicle efficiency, system efficiency, and energy use. She conceptualized new NEMS model components to estimate HAV vehicle cost and adoption by ride-hailing fleets; developed the model approach, structure, and algorithms to integrate HAVs; tested/validated the model equations and inputs in Microsoft Excel; then developed FORTRAN code to include the new HAV components in the TRAN module. She also assisted EIA with conceptualizing modeling approaches (to be pursued in future work) for private consumer adoption, estimation of impact on passenger miles of travel, and mode choice.

Dr. Birky also currently supports the VTO Analysis Team with a primary focus on heavy highway vehicles. She is leading a study of the potential impact of connected and automated vehicle technology on the future energy demand of freight trucks. She leads the heavy vehicle portion of the VTO program benefits analysis, which includes developing advanced technology deployment scenarios; assessing technology fuel consumption benefits over defined duty schedules; estimating technology costs; performing a market adoption analysis; and projecting future fleet fuel savings. For this project, she is currently leading efforts to update the heavy vehicle market adoption and stock accounting models to incorporate regulatory classes and new technology options, such as plug-in hybrid, battery electric, and hydrogen fuel cell trucks. Dr. Birky developed the ASCENTT tool (Assessment of Cycle Energy for Truck Technologies), an engineering-based "road loads" model that estimates the fuel consumption of heavy trucks and assesses the fuel savings of advanced technologies deployed in various duty cycles defined by speed, distance, and grade. She recently completed development of a heavy vehicle choice modeling framework that incorporates payback analysis in a logit model structure. To capture the heterogeneity of the commercial vehicle market, this model includes characterization of vehicles by weight class, body style, and usage, as well as characterization of a range of fleet vehicle purchasers.

Dr. Birky led an analysis of the potential for electrification of the transportation system "beyond light duty." The scope of this study included all highway vehicles in weight classes 2b-8 as well as non-road mobile equipment used for goods and people movement. Dr. Birky employed both qualitative and quantitative analysis techniques to perform a market and industry assessment, determine the state of electrification, identify high potential applications, identify barriers to widespread adoption, and develop possible strategies to overcome these barriers. Dr. Birky and her team assisted in the development and facilitation of, as well as presentation in, a stakeholder workshop to solicit manufacturer and user perspectives. Based on the results of the workshop, Dr. Birky is led a follow-on study of electrification of class 2b-3 pickup trucks and vans.

Dr. Birky developed the LVCFlex light vehicle consumer choice model for VTO and has been responsible for model maintenance, application, and development. This spreadsheet tool utilizes the nested multi-nomial logit methodology found in NEMS to project market share of advanced and alternative technology vehicles. This simplified version of the NEMS Consumer Vehicle Choice Component allows the user to flexibly define vehicle technologies within five vehicle size classes and five technology groups in the nesting structure. It allows investigation of the NEMS model assumptions and methodologies and evaluation of various scenarios for technology development and deployment. She developed an Excel VBA application to translate vehicle attribute data from a standard data file into the input format required by the LVCFlex model. This application automates development of market scenarios based on vehicle simulation results. She is collaborated with an inter-laboratory team, led by ANL, to compare the results of consumer light vehicle choice models under a consistent set of input assumptions. She assists VTO in exploring alternative approaches for modeling and studying consumer behavior, technology diffusion, and market transformation as it applies to highway vehicles.

TA Engineering, Inc., Baltimore, MD
07/2008 – 09/2014

As a Senior Technical Analyst, Dr. Birky was responsible for leading the analysis of technologies, policies, and programs to reduce energy consumption and emission of greenhouse gases and criteria pollutants from mobile sources. She supported compliance of US DOE VTO with the requirements of the Government Performance, Reporting and Accountability Act (GPRA) and held primary responsibility for evaluation of VTO's heavy vehicle program elements. She served as Lead Analyst for the evaluation of the energy saving benefits associated with the US DOE's SuperTruck research and development program. She interfaced with the SuperTruck industry partners to gather information on research elements and expected benefits; developed truck platforms representative of these elements and achievement of program goals; developed technology cost projections; modified analytical tools to incorporate these research findings; performed a market analysis of the representative platforms; and projected future petroleum and emission savings.

Dr. Birky provided technical assistance to the National Petroleum Council (NPC) for their study titled Advancing Technology for America's Transportation, published in 2012. She developed a light vehicle consumer choice model in Excel that applies the methodology found in the Energy Information Administration's (EIA's) NEMS Consumer Vehicle Choice Component. She was asked to give a presentation on the model to DOE's Undersecretary for Science, Dr. Steve Koonin. She also made modifications to the TRUCK heavy vehicle market penetration model to accommodate the NPC's analytical requirements and provided technical assistance in employing the model.

In support of VTOs program benefits analysis, Dr. Birky developed an engineering-based model to assess the fuel consumption benefits due to heavy truck technologies deployed in various duty cycles. The Heavy Truck Energy Balance (HTEBdyn) model estimates vehicle power requirements and fuel consumption of conventional and advanced technologies, including advanced combustion technologies; turbo-compounding; organic Rankine cycle waste heat recover; and regenerative braking in hybrid drivetrains. Dr. Birky has made numerous improvements to VTO's TRUCK heavy vehicle market penetration model and developed a national heavy truck stock accounting model to project future fuel and carbon emission savings from deployment of advanced technology vehicles. Dr. Birky also utilized the data extracted from the US EPA's NONROAD model to develop a tool for the projection of energy use and carbon emissions from the national stock of non-highway equipment.

Dr. Birky served as Lead Analyst for the Port of Baltimore Clean Diesel Program which awarded grants to private equipment owners to upgrade drayage trucks, cargo handling equipment, locomotives, and harbor craft. The program was funded by the American Recovery and Reinvestment Act through the EPA National Clean Diesel Campaign. She provided technical support during program development and implementation and held lead responsibility for technical evaluation of applications and estimation of program benefits and outcomes. She developed a model to evaluate the emission of criteria pollutants from specific non-road equipment and utilized this model to assess the emission savings potential of applicants' proposed measures. She also developed tools for assessing reductions in fuel consumption and criteria emissions from installation of exhaust treatment devices and from repowering or replacing drayage trucks, locomotives, and harbor craft. Finally, she developed tools to apply the program's technical evaluation criteria to all applications.

Dr. Birky served as Project Manager for the Port of Baltimore Diesel Emissions Reduction Opportunities study performed on behalf of the Port and funded by the US EPA. She collaborated with Port officials and equipment owners and operators to assess technical and operational issues and strategies for transoceanic vessels, heavy trucks, locomotives, and cargo handling equipment serving the Port. She supervised junior staff and served as lead author on all project documentation.

Dr. Birky also supported analysis of building energy efficiency upgrades and was responsible for the development of a Measurement and Verification Plan for a major retailer and developed an eQuest energy consumption simulation model of an educational facility.

PNNL Joint Global Change Research Center, College Park, MD
03/2004 – 10/2004

Dr. Birky served as a graduate research intern and performed research on the sources and process of technological change in energy production systems and its representation in integrated assessment models. She also researched learning / progress curves and the underlying mechanisms of organizational learning with an emphasis on energy technologies and industries. While employed at JGCRI, Dr. Birky developed a research agenda on sources of innovation in automotive energy saving technologies.

NASA Headquarters, Washington, DC
09/2001 – 11/2002

As a Program Planning Specialist, Dr. Birky participated in strategic planning and program evaluation activities. She provided direct support to the Associate Administrator for Earth Science and other senior executive staff and assisted with budget preparation, strategic planning, and development of research program roadmaps and implementation plans. She was responsible for the communication of Office of Earth Science mission, goals, strategies, implementation plans, and projected benefits to internal and external stakeholders, including the NASA Administrator; OMB; Congress; national and international professional and scientific organizations; and the public. She developed content for senior executive staff presentations, program factsheets, web pages, Congressional testimony, budget submissions, performance and accountability reports, policy summaries, and various internal reports. She drafted the OES section of the FY 2001 President's Report on Aeronautics and Space. She received a NASA Fast Award for developing a one-page template to communicate to OMB examiners complex OES science program goals and projected benefits. This template allowed OES to overcome a communication barrier that had caused a great deal of tension between OES and OMB.

National Renewable Energy Laboratory, Washington, DC
08/1998 – 08/2001

Dr. Birky served as a Senior Analyst and provided direct support to the U.S. DOE Office of Transportation Technologies. She was responsible for the evaluation of program benefits and performed research on policies and technologies to improve vehicle fuel economy, promote alternative fuel use, reduce dependence on imported oil, and reduce emission of greenhouse gases. Her duties included assessment of environmental and economic impacts; research on consumer preferences; development of strategic plans; and preparation of technical reports, conference papers, and presentations. She developed models and tools for market-based policy and program analysis, including consumer choice, econometric, cost-benefit, input-output, demand forecasting, and stock accounting models.

University of Maryland, College Park, MD
08/1997 – 05/1999

While pursuing her PhD in Policy Studies, Dr. Birky supported the Maryland School of Public Affairs in various teaching and research positions. She served as an Adjunct Lecturer for Quantitative Analysis of Policy Issues, an econometric modeling course for graduate policy students. In collaboration with a co-lecturer, she developed the syllabus and course materials; led lectures and held office hours; and administered all grades. As a Teaching Assistant for Quantitative Aspects of Global Environmental Problems, she led discussion sessions, assisted students on request, and graded homework assignments and exams. She held the position of Instructor for the School's summer Math Immersion class for three years. She was responsible for selecting the course text; developing the syllabus and lecture materials;

and holding lectures and office hours. She also served as a Research Assistant for the Chesapeake Biological Laboratory's Patuxent Landscape Modeling Project where she supported dynamic model calibration through use of remotely sensed data, specifically Normalized Difference Vegetation Index (NDVI) data obtained from various satellite archives.

Swales Aerospace, Beltsville, MD
08/1988 – 09/1997

As a Spacecraft and Instrument Systems Senior Engineer, Dr. Birky provided mechanical and spacecraft systems engineering support to NASA Goddard Spaceflight Center (GSFC) Earth science missions. She served as the interface among project scientists and engineers and performed technical feasibility studies and failure modes and effects analyses (FMEA). As an Engineer in the Structural Dynamics and Loads group, she provided comprehensive structural dynamics support to GSFC missions from preliminary design through launch and on-orbit support. She developed Finite Element Models (FEMs); performed flight loads, jitter, and structural-thermal-optical (STOP) analyses; specified dynamic and static test levels; correlated models to test data; and supported structural and environmental tests. She was responsible for presenting analysis methodology and results at preliminary and critical design reviews.

AWARDS, HONORS, AND SPECIAL RECOGNITON

NASA Fast Award, 2002
Tau Beta Pi
Sigma Gamma Tau

PROFESSIONAL AFFILIATIONS

SAE Member
Transportation Research Board (TRB) Member

PUBLICATIONS

1. Gao, Z., A. Lin, S.C. Davis, A.K. Birky, and R. Nealer (2018) Quantitative Evaluation of MD/HD Vehicle Electrification using Statistical Data, presented at the Transportation Research Board 2018 Annual Meeting, January.
2. Birky, A.K., M. Laughlin, K. Tartaglia, R. Price, B. Lim, and Z. Lin (2017) Electrification Beyond Light Duty: Class 2b-3 Commercial Vehicles. ORNL/TM-2017/744, December.
3. Stephens, T.S., A. Birky and D. Gohlke (2017) Vehicle Technologies and Fuel Cell Technologies Office Research and Development Programs: Prospective Benefits Assessment Report for FY 2018. ANL/ESD-17/22, November.
4. Stephens, T.S., R.S. Levinson, A. Brooker, C. Liu, Z. Lin, A. Birky, and E. Kontou (2017) Comparison of Vehicle Choice Models. ANL/ESD-17/19, October.
5. Birky, A.K., M. Laughlin, K. Tartaglia, R. Price, and Z. Lin (2017) Transportation Electrification Beyond Light Duty: Technology and Market Assessment. ORNL/TM-2017/77-R1, September.
6. Gao, Z., Z. Lin, T.J. La Clair, C. Liu, Jan-Mou Li, A. Birky, and J. Ward (2017) Battery capacity and recharging needs for electric buses in city transit service. Energy, 122: 588-600.
7. Stephens, T.S., A.K. Birky, J. and Ward (2014) Vehicle Technologies Program Government Performance and Results Act (GPRA) Report for Fiscal Year 2015, Argonne National Laboratory report ANL/ESD-14/3.
8. TA Engineering, Inc. (2012) DOE SuperTruck Program Benefits Analysis, Final Report, prepared for U.S. DOE and Argonne National Laboratory, lead author, December 20.
9. Birky, A.K., M. Miller and J.S. Moore (2010) Emission Reductions from Port of Baltimore Maritime

Vessels and Cargo Handling Equipment, DRAFT Final Report. Prepared by TA Engineering, Inc., for the Maryland Port Administration, Maryland Department of the Environment, and the Maryland Environmental Service. September 27.

10. Birky, A.K., M. Miller, and J.S. Moore (2010) Emission Reductions from Port of Baltimore Drayage Trucks, DRAFT Final Report. Prepared by TA Engineering, Inc., for the Maryland Port Administration, Maryland Department of the Environment, and the Maryland Environmental Service. March 10. Birky, A.K., M. Laughlin, K. Tartaglia, R. Price, B. Lim, and Z. Lin (forthcoming) Electrification Beyond Light Duty: Class 2b-3 Commercial Vehicles, ORNL/TM-xxxx/xx.
11. Clarke, L., J. Weyant, and A. Birky (2006) On the sources of technological change: Assessing the evidence, *Energy Economics* 28, 579-595.
12. Johnson, L., D. Greene and A. Birky (2003) Is the barrel half full or half empty? Implications of transitioning to a new transportation energy future, in Transportation, Energy, and Environmental Policy: Managing Transitions, report of the VIII Biennial Asilomar Conference, September, 2001, 104-129. Washington, DC: National Academies Transportation Research Board.
13. Birky, A.K. (2001) NDVI and a simple model of deciduous forest dynamics, *Ecological Modeling* 143, 43-58.
14. Birky, A.K., J.D. Maples, J.S. Moore Jr, and P.D. Patterson (2000) Future world oil prices and the potential for new transportation fuels, Transportation Research Record 1738, 94-99.

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Education

Post-Doctoral Fellow (1984), Environmental Science and Public Policy, Harvard School of Public Health. Advisors: Professors Donald Hornig, Marc Roberts, and Howard Raiffa.

Ph.D. in Urban and Public Affairs (1983), The Heinz School, Carnegie-Mellon University.
Dissertation: "Automobile Safety: An Investigation of Occupant-Protection Policies."
Committee: Professors M. Granger Morgan, Steven Garber and Alfred Blumstein.

M.A. in Public Affairs (1980), Duke University.
Thesis: "The Value of a Life: What Difference Does It Make?"
Advisor: Professor James W. Vaupel.

B.A. with Honors in Economics and Politics (1978), Wake Forest University.
Honors Paper: "A Cost-Benefit Analysis of the 55 MPH Speed Limit."
Honors Paper: "A Theory of Criminal Punishment."
Advisor: Professor Jack Fleer.

Recent Positions

Dean, School of Public and Environmental Affairs, Indiana University, Bloomington and Indianapolis, Indiana, 2008 to present

Leads innovative, two-campus $64-million professional school with programs in arts administration, criminal justice, environmental science and policy, health care management, public budgeting and finance, non-profit management, and public affairs. Orchestrated strategic planning processes with faculty, staff, students, alumni and donors, leading to publication of "SPEA 2015" and "SPEA 2020." Accomplishments to date: (1) hired fifty one new tenure-line faculty on the two campuses (Bloomington and Indianapolis); (2) raised $17 million in philanthropic support from individuals, corporations, and foundations; (3) Master's in Public Affairs Program (Bloomington) rose to #1 out of 272 programs in the 2019 *U.S. News and World Report* national survey; (4) launched the "Indiana Futures Project" through the School's Public Policy Institute, a community-based deliberation prior to Indiana's state-level elections in November 2012 and November 2016; and (5) tripled the rate of student enrollment in overseas study programs, including newly added SPEA programs in Beijing, Berlin, Croatia, Hanoi, Kenya, London, Moscow, Pamplona, Siberia, Speyer, Australia, Caribbean-Bonaire and Mexico to the already robust course offerings in 12 other locations; (6) launched SPEA Connect, the first fully on-line MPA program offered by a top graduate program in public affairs; (7) expanded by 75% (to more than 2,500) the number of undergraduate majors on the Bloomington campus; (8)

secured new laboratory space for SPEA's environmental science faculty while renovating existing space to meet the needs of public affairs faculty and staff on both campuses. A $12 million addition to the main SPEA building, named after former U.S. Treasury Secretary Paul O'Neill, opened in early 2017 to serve the needs of graduate students.

Dean, The Pardee RAND Graduate School, RAND Corporation, Santa Monica, California, 2006 to 2008

Led innovative policy-analysis Ph.D. program based on apprenticeship relationships with RAND researchers. Responsible for curricula, faculty oversight, student recruitment and placement, fundraising, commencement exercises and disciplinary issues. Streamlined the core curriculum, established new analytic concentrations, expanded recruitment of female and minority students, added a weeklong workshop on American culture for international fellows, and revamped the dissertation process to enable students to start the dissertation process earlier. Raised $3.4 million in philanthropic gifts from individuals and corporations to support scholarships, dissertations and other educational expenses.

Administrator, Office of Information and Regulatory Affairs, US Office of Management and Budget, Executive Office of the President, Washington, D.C., 2001 to 2006

Oversaw for President George W. Bush federal regulatory policy, statistical policy and information policy. As Senate-confirmed political appointee, directed a staff of 50 career policy analysts with backgrounds in science, engineering, economics, statistics and law. Strengthened the role of benefit – cost considerations in federal regulation while establishing new information-quality procedures in the federal government. Simplified hundreds of regulations and helped design valuable new rules on clean air, auto fuel economy and food safety.

Founding Director, Center for Risk Analysis, Harvard School of Public Health, Boston, MA, 1989 to 2001

Created mission-oriented Center with programs in automotive safety, environmental health, and medical technology. Raised over $10 million in governmental and private support. Financed eight new faculty positions, new course development, and numerous doctoral students.

Deputy Chairman, Department of Health Policy and Management, Harvard School of Public Health, Boston, MA, 1987 to 1992

Supported Department Chairman in curriculum reform, faculty recruitment and evaluation, budgeting and student recruitment and placement.

Staff Associate, Committee on Risk and Decision Making, National Research Council/National Academy of Sciences, Washington D.C., 1979 to 1981

Supported Study Director and Committee Chairman in preparation of an NAS report on the future of risk analysis in national policy.

<u>Academic Appointments</u>

Professor of Public Affairs (with tenure), School of Public and Environmental Affairs, Indiana University, Bloomington and Indianapolis, IN (2008 to present).

Professor of Policy Analysis, Pardee RAND Graduate School, Santa Monica, CA (2006 to 2008).

Professor of Policy and Decision Sciences (with tenure), Department of Health Policy and Management, Harvard School of Public Health, Boston, MA (1991 to 2003).

Associate Professor of Policy and Decision Sciences, Department of Health Policy and Management, Harvard School of Public Health, Boston, MA (1988 to 1991).

Assistant Professor of Policy and Decision Sciences, Department of Health Policy and Management, Harvard School of Public Health, Boston, MA (1985 to 1988).

Assistant Professor, School of Urban and Public Affairs, Carnegie-Mellon University, Pittsburgh, PA (1984 to 1985).

Doctoral Students and Fellows

Adam Abelkop (Ph.D.)	Jill Morris (Ph.D.)
Jessica Alcorn (Ph.D.)	Doreen Neville (Sc.D.)
Sandra Baird (Fellow)	Naveed Paydar (Ph.D.)
Agi Botos (Ph.D.)	Susan Putnam (Sc.D.)
Phaedra Corso (Ph.D.)	Alon Rosenthal (Sc.D.)
Joshua T. Cohen (Ph.D.)	Dana Gelb Safran (Sc.D.)
Alison Taylor Cullen (Sc.D.)	Mary Jean Sawey (Fellow)
Diana Epstein (Ph.D.)	Maria Seguí-Gómez (Sc.D.)
George Gray (Fellow)	Joanna Siegel (Sc.D.)
Sara Hajiamiri (Ph.D.)	Andrew Smith (Sc.D.)
Evridiki Hatziandreu (Sc.D.)	Tammy Tengs (Sc.D.)
Neil Hawkins (Sc.D.)	Kimberly Thompson (Sc.D.)
David Holtgrave (Fellow)	Edmond Toy (Ph.D.)
Nancy Isaac (Fellow)	Eve Wittenberg (Ph.D.)
Bruce Kennedy (Fellow)	Zach Wendling (Ph.D.)
Michelle Lee (Ph.D.)	Scott Wolff (Sc.D.)
Younghee Lee (Ph.D.)	Fumie Yokota (Ph.D.)
Ying Liu (Ph.D.)	Yu Zhang (Ph.D.)
Arthur Ku Lin (Ph.D.)	

Extramural Grant Support from the Federal Government

Principal Investigator. Evaluation of Countermeasures to Reduce Drinking and Driving. U.S. Centers for Disease Control. $75,000. 1990-91.

Co-Investigator. Harvard Injury Control Research Center. U.S. Centers for Disease Control. $2.0 million per year. 1990-94.

Principal Investigator. The Determinants of Lifesaving Investments. U.S. National Science Foundation. $150,000. 1993-95.

Principal Investigator. Harvard Injury Control Research Center. U.S. Centers for Disease Control. $1.2 million per year. 1995-97.

Principal Investigator. Community-Based Intervention to Encourage Rear Seating of Young Child Passengers. U.S. Centers for Disease Control. $200,000. 1998-00.

Awards

Elected Fellow, National Academy of Public Administration (2009).

Distinguished Lifetime Achievement Award, Society for Risk Analysis (2008).

Co-Recipient (with Ryan Keefe and Jay Griffin) of the annual Best Paper Award in Risk Analysis (2008), vol. 28.

Alumni Merit Award, Carnegie Mellon University (2002).

Annual Public Service Award for Achievements in Risk Communication to the American People, Annapolis Center, Annapolis, Maryland (1998).

Award for Outstanding Service in Helping to Develop and Support the National Agenda for Injury Control, U.S. Centers for Disease Control (April 25, 1991).

Outstanding Oral Presentation, "The Case for Motor Vehicle Injury Control", Society for Automotive Engineers, Industry-Government Meetings (May 16, 1991).

Co-Recipient (with Steven Garber) of the annual Herbert Salzman Award for the "Outstanding Paper" in Volume 3 of the Journal of Policy Analysis and Management (1984).

Service

Member, U.S. Environmental Protection Agency Chartered Science Advisory Board, Washington, D.C. (2017-2020.

Member, National Association for Urban Debate Leagues Governing Board, Chicago, IL (2017 to present).

Member, Committee on Preparing the Next Generation of Policy Makers for Science-Based Decisions. National Research Council/National Academy of Sciences (March 2014 to June 30, 2016).

Director, National Science Foundation International, Ann Arbor, MI (2013 to present).

Expert Witness, Boies, Schiller, Flexner, Table Saw Safety (2009 to 2013).

Faculty Advisor to IU Ballroom Dance Club (2011 to present).

Faculty Advisor to IU Debate Team (2009 to present).

Member, International Advisory Board of Germany's Helmholtz-Programme "Technology, Innovation and Society" (2010 to 2015).

Member, Administrative Conference of the United States (2011 to 2012).

Chairperson, Regulatory Occupations Evaluation Committee (ROEC), State of Indiana (2010 to 2014).

Member, The B. John Garrick Foundation for the Advancement of the Risk Sciences, Advisory Board (2010 to 2015).

Member, Dow AgroSciences Advisory Committee (2010 to 2013).

Member, American Chemistry Society (2008 to present).

Member, Board of Scholars, American Council for Capital Formation (1995 to 2000 & 2007 to present).

Member, Scientific and Technology Council, International Risk Governance Council, Lausanne, Switzerland (2008 to 2015).

Member, Board of Directors, International Risk Governance Council, Geneva, Switzerland (2006 to 2008).

Member, Committee on the Status and Future of Federal e-Rulemaking (2008).

Member of the Scientific Advisory Panel, Green Chemistry Initiative, State of California (2007 to 2008).

Member, Public Health Policy Advisory Board (1997 to 2001).
Member, National Council on Radiation Protection and Measurement (1997 to 2001).

Member, Editorial Board, Risk: Health, Safety and Environment (1990 to 2001).

Member, Editorial Board, Journal of Risk Research (1990 to 2001).

Member, Editorial Board, Risk Analysis: An International Journal (1989 to 2001, 2008 to present).

Member, Editorial Board, Injury Control and Safety Promotion (1999).

Member, Editorial Board, Accident Analysis and Prevention: An International Journal (1990 to 1999).

Member, Editorial Board, Journal of Benefit-Cost Analysis (2001 to present).

Elected President, Society for Risk Analysis (1995 to 1996).

Member, Ad Hoc Committee on Risk Analysis, Advisory Body to the President of the National Academy of Sciences (1994).

Member, Board of Visitors, Wake Forest University (1991 to 1994).

Member, Committee to Review the Structure and Performance of the Health Effects Institute, Board on Environmental Studies and Toxicology, National Research Council (1992 to 1993).

Member, Motor Vehicle Safety Research Advisory Committee, U.S. Department of Transportation, Washington, D.C. (1990 to 1993).

Member, Highway Safety Study, Strategic Transportation Research Committee, Transportation Research Board, (1989 to 1991).

Member, Committee to Identify Measures that May Improve the Safety of School Bus Transportation, Transportation Research Board, (1987 to 1988).

Books

John D. Graham, Laura Green, and Marc J. Roberts, In Search of Safety: Chemicals and Cancer Risk, Harvard University Press, Cambridge, MA, 1988.

John D. Graham (ed.), Preventing Automobile Injury: Recent Findings of Evaluation Research, Auburn House Publishing Company, Dover, MA, 1988.

John D. Graham, Auto Safety: Assessing America's Performance, Auburn House Publishing Company, Dover, MA, 1989.

John D. Graham (ed.), Harnessing Science for Environmental Regulation, Praeger, Westport, CT, 1991.

John D. Graham and Jonathan B. Wiener (eds.), Risk versus Risk: Tradeoffs in Protecting Health and the Environment, Harvard University Press, Cambridge, MA, 1995.

John D. Graham & Jonathan B. Wiener, eds., Risk vs. Risk: Tradeoffs in Protecting Health and the Environment (Chinese edition, translated by XU Jianhua & XUE Lan, Tsinghua University Press, 2018)

John D. Graham (ed.), The Role of Epidemiology in Regulatory Risk Assessment, Elsevier Science, Amsterdam, NL, 1995.

John D. Graham and Jennifer K. Hartwell (eds.), The Greening of Industry: A Risk Management Approach, Harvard University Press, Cambridge, MA, 1997.

John D. Graham, Bush on the Home Front: Domestic Policy Triumphs and Setbacks, Indiana University Press, Bloomington, IN, 2010.

Kristin S. Seefeldt and John D. Graham, America's Poor and the Great Recession, Indiana University Press, Bloomington, IN, 2013.

Eberhard Bohne, John D. Graham, Jos C.N. Raadschelders in collaboration with Jesse Paul Lehrke, Public Administration and the Modern State: Assessing Trends and Impact, Palgrave Macmillan, Houndsmills, Basingstoke, Hampshire, 2014.

Adam Abelkop, John D. Graham, and Todd Royer, Persistent, Bioaccumulative, and Toxic (PBT) Chemicals, CRC Press, Boca Raton, FL, 2015.

John D. Graham, Obama on the Home Front: Domestic Policy Triumphs and Setbacks, Indiana University Press, Bloomington, IN, 2016.

Published Papers and Reports (* indicates peer reviewed)

1. Vaupel, James W. and Graham, John D., "Egg in Your Bier?" Public Interest, Winter 1980, 3-17.

2.* Graham, John D. and Vaupel, James W., "The Value of a Life: What Difference Does It Make?" Risk Analysis, Volume 1, 1981, 89-95; reprinted with revision, What Role for Government? eds., Richard Zeckhauser and Derek Leebauert, Durham, NC: Duke University Press, 1983, 176-186; reprinted, Risk Benefit Analysis in Water Resource Planning and Management, ed., Yacov Y. Haimes, New York: Plenum Press, 1981, 233-244.

3.* Graham, John D., "Some Explanations of Disparities in Life Saving Investments", Policy Studies Review, Volume 1, 1982, 692-704.

4.* Graham, John D., "On Wilde's Theory of Risk Homeostasis", Risk Analysis, Volume 2, 1982, 235-237.

5. Graham, John D. and Gorham, Patricia, "NHTSA and Passive Restraints: A Case of Arbitrary and Capricious Deregulation", Administrative Law Review, Volume 35, 1983, 193-252.

6. Graham, John D., "Automobile Crash Protection: Institutional Responses to Self-Hazardous Behavior", Risk Analysis, Institutions, and Public Policy, ed., Susan G. Hadden, Associated Faculty Press, 1984, 39-59.

7.* Graham, John D. and Garber, Steven, "Evaluating the Effects of Automobile Safety Regulation", Journal of Policy Analysis and Management, Volume 3, No. 2, 1984, 206-224.

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9. Crandall, Robert W., and Graham, John D., "Automobile Safety Regulation and Offsetting Behavior: Some New Empirical Estimates", American Economic Review, Volume 74, No. 2, May 1984, 328-331.

10.* Graham, John D., "Technology, Behavior, and Safety: An Empirical Study of Automobile Occupant-Protection Regulation", Policy Sciences, Volume 17, 1984, 141-151.

11. Graham, John D., "The Failure of Agency-Forcing: The Regulation of Airborne Carcinogens Under Section 112 of the Clean Air Act", Duke Law Journal, February 1985, 100-150; selected for republication in Land and Environment Law Review, ed., Stuart L. Deutsch, 1986.

12. Graham, John D., "Secretary Dole and the Future of Automobile Airbags", Brookings Review, Summer 1985, 10-15.

13. Graham, John D., Raiffa, Howard and Vaupel, James W., "Science and Analysis: Roles in Risk and Decision Making", Risk Evaluation and Management, eds., Vincent Covello, Joshua Menkes, and Jeryl L. Mumpower, New York: Plenum Press, 1986, 503-518.

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53. Gray, George M., Cohen, Joshua T., and Graham, John D., "The Challenge of Risk Characterization: Current Practice and Future Directions", Environmental Health Perspectives Supplements, Volume 101 (Suppl. 6), 1993, 203-208.

54. Graham, John D., "An Economic Perspective on Air Bag Regulation for Canada", Chronic Diseases in Canada, Volume 14, No. 4 (Suppl.) 1993, sl25-sl28.

55. Graham, John D., "The Economics of Controlling Outdoor and Indoor Air Pollution" in Indoor and Outdoor Air Pollution and Human Cancer, ed., U. Veronesi, European School of Oncology, Springer-Verlag, Berlin, 1993, 149-162.

56. Putman, Susan W. and Graham, John D., "Chemicals vs. Microbials in Drinking Water: A Decision Sciences Perspective", Journal of the American Water Works Association, Volume 85, 1993, 57-61.

57. Graham, John D., "Incorporating Scientific Judgment into Quantitative Risk Assessment", The Toxicology Forum, Winter 1993, 51-62.

58. Gray, George M. and Graham, John D., "Intuitive Toxicology: Comments on Public Perceptions and the Role of Institutional Affiliation in Expert Opinions", Comments on Toxicology: A Journal of Critical Discussion on the Current Literature, Volume 4, 1993, 501-504.

59.* Putman, Susan W. and Graham, John D., "Formaldehyde Science: From the Laboratory to the Regulatory Arena" in Keeping Pace with Science and Engineering, ed., Myron F. Uman, National Academy Press, Washington, D.C., 1993, 189-220.

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61. Graham, John D., “The Fate of the Maximally Exposed Individual Under the 1990 Amendments to the Clean Air Act”, a paper presented to the Committee on Risk Assessment Methodology, National Research Council, National Academy of Sciences, Washington, D.C., August 1993.

62. Graham, John D., "Making Sense of Risk", AG in Perspective, Volume 1, No. 1, September 1993.

63.* Evans, John, Graham, John, Gray, George and Sielken, Jr., Robert, "A Distributional Approach to Characterizing Low-Dose Cancer Risk", Risk Analysis, Volume 14, No. 1, 1994, 25-34.

64.* Safran, Dana Gelb, Graham, John D., and Osberg, J. Scott, "Social Supports as a Determinant of Community-Based Care Utilization Among Rehabilitation Patients", Health Services Research, Volume 28, No. 6, 1994, 729-750.

65. Putman, Susan W. and Graham, John D., "Environmental Regulation", Essay in The Encyclopedia of the Environment, Boston: Houghton Mifflin Company, 1994, p. 224.

66. Graham, John D., "Synopsis of the BELLE Conference on Chemicals and Radiation" in Biological Effects of Low Level Exposures: Dose-Response Relationships, ed., E.J. Calabrese, Lewis Publishers, Ann Arbor, MI, 1994, 271-274.

67. Graham, John D. and Sadowitz, March, "Superfund Reform: Reducing Risk through Community Choice", Issues in Science and Technology, Summer, 1994, 35-40.

68. Graham, John D., "Hammers Don't Cut Wood: We Need Pollution Prevention and Comparative Risk Assessment" in Worst Things First? The Debate over Risk-Based National Environmental Priorities, eds., Adam M. Finkel and D. Golding, Johns Hopkins University Press, 1994, 229-236.

69.* Evans, John S., Gray, George M., Robert L. Sielken, Jr., Smith, Andrew E., Flores, Ciriaco Valdez, and Graham, John D., "Use of Probabilistic Expert Judgment in Uncertainty Analysis of Carcinogenic Potency", Regulatory Toxicology and Pharmacology, Volume 20, 1994, 15-36.

70. Graham, John D., "The Risk Not Reduced", New York University Environmental Law Journal, Volume 3, No. 2, 1994, 382-404.

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University School of Law Conference, Superfund Reauthorization: Theoretical and Empirical Issues, December 3, 1993.

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Executive Courses

Course Director, Risk Analysis, Office of Continuing Education, Harvard School of Public Health (1991 to 2001).

Course Director, Risk Communication, Office of Continuing Education, Harvard School of Public Health (1995 to 2001).

Teaching Experience

Quantitative Policy Analysis, Graduate Level, Harvard School of Public Health, 1985 to 1990.

Methods of Cost-Benefit Analysis and Cost-Effectiveness Analysis for Health and Medicine, Graduate Level, 1991 to 2000.

Principles of Risk Analysis, Executive Education, Harvard School of Public Health, 1992 to 2000.

Principles of Risk Communication, Executive Education Harvard School of Public Health (Boston and Brussels), 1998 to 2000.

Introduction to Policy Analysis, Graduate Level, Pardee RAND Graduate School, 2006 to 2008.
Hazard Management in the U.S. and Europe, IU Overseas Study Course, Undergraduate Level (King's College – London), Indiana University, 2009 to 2017.

Case Studies in Policy Analysis, Undergraduate Level, Indiana University, 2012.

Introduction to National and International Policy, Undergraduate Level, Indiana University, 2013 to 2014.

Energy Policy from a Nation-State Perspective, Graduate Level, Indiana University, 2014, 2016.
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John D. Graham, "Green But Unsafe", Wall Street Journal, Europe Edition, April 18, 2007.

John D. Graham and Laura Cavagnaro, Commentary: "Save Big 3 by Making Buyers See Green for Fuel-Sipping Cars", Detroit Free Press, March 11, 2009.

John D. Graham, "Obama's Auto Pitfalls", The Journal of the American Enterprise Institute, August 16, 2009.

John D. Graham, "President Obama Can Shore Up His Popularity by Pushing Immigration Reform", appeared in 33 different newspapers including Taiwan News//Taipei, May 1, 2010; Fresno Sunday Bee, May 2, 2010; Contra Costa Sunday Times, May 9, 2010.

John D. Graham, "Small Cars and Personal Responsibility", The New York Times, May 27, 2010.

John D. Graham, "Can Obama Learn from Bush's Domestic Playbook?" The Washington Post, Political Bookworm by Steven Levingston, May 14, 2010. *http://voices.washingtonpost.com/political-bookworm/2010/05/can_obama_learn_from_bushs_dom.html*

Denvil R. Duncan and John D. Graham, "Replacing the Gasoline Tax with a Road User Fee", The Ripon Forum, Vol. 47, No. 3, Summer 2013, p. 22.

Congressional and Administrative Testimony

John D. Graham, Testimony on "Clean Air Act Amendments of 1990", S.816: The Toxics Release Prevention Act of 1989, Subcommittee on Environmental Protection, Committee on Environment and Public Works, U. S. Senate, Washington, D.C., 101st Congress, Second Session, 1989.

John D. Graham, "Recommendations for Improving Cancer Risk Assessment", comments submitted to the National Academy of Sciences, California's Environmental Protection Agency and the U. S. Environmental Protection Agency, July 1, 1992.

John D. Graham, Testimony on S. 3373, "The Bullet, Death, and Family Dissolution Act", Subcommittee on Social Security and Family Policy, Finance Committee, U. S. Senate, Washington, D.C. 102nd Congress, Second Session, October 23, 1992.

John D. Graham, Comments submitted to Ms. Dorothy Strunk, OSHA, regarding Risk-Risk Analysis, October 23, 1992.

John D. Graham, Comments submitted to Mr. Orron Kee and Mr. Barry Felrice, NHTSA, regarding CAFÉ and Safety, January 4, 1993.

Susan Putnam, John D. Graham, George Gray, Sandy Baird, Katy Walker, and Kim Thompson, Comments on EPA's Integrated Risk Information System, submitted to the U. S. Environmental Protection Agency, April 15, 1993.

John D. Graham, Testimony on "Reform of the Delaney Clause", Subcommittee on Department Operations and Nutrition, Committee on Agriculture, U. S. House of Representatives, Washington, D.C., 103rd Congress, First Session, July 14, 1993.

John D. Graham, Testimony on "Reform of the Delaney Clause", Joint Hearing, House Subcommittee on Health and Environment and Senate Committee on Labor and Human Resources, Washington, D.C., 103rd Congress, First Session, September 21, 1993.

John D. Graham, Testimony on "The Role of Risk Analysis in Environmental Policy Making", Committee on Energy and Natural Resources, U. S. Senate, Washington, D.C., 103rd Congress, Second Session, November 9, 1993.

John D. Graham, Testimony on "The Role of Risk Assessment in Environmental Protection", Subcommittee on Transportation and Hazardous Materials, Committee on Energy and Commerce, U. S. House of Representatives, Washington, D.C., 103rd Congress, Second Session, November 17, 1993.

John D. Graham, "The Role of Risk Analysis in Environmental Protection", Subcommittee on Environment, Energy, and Natural Resources, Subcommittee on Legislation and National Security, Committee on Government Operations, U. S. House of Representatives, Washington, D.C., 103rd Congress, Second Session, February 1, 1994.

John D. Graham, Testimony on Title III, H.R. 9, "Risk Assessment and Cost-Benefit Analysis of New Regulations", Committee on Science, U. S. House of Representatives, Washington, D.C., 104th Congress, First Session, January 31, 1995.

John D. Graham, Testimony on Title III, H.R. 9, "Risk Assessment and Cost-Benefit Analysis of New Regulations", Committee on Commerce, U. S. House of Representatives, Washington, D.C., 104th Congress, First Session, February 2, 1995.

John D. Graham, Testimony on S. 291, "Regulatory Reform Act of 1995", Governmental Affairs Committee, U. S. Senate, Washington, D.C., 104th Congress, First Session, February 15, 1995.

John D. Graham, Testimony on S. 123, S. 229, S. 333, and S. 343, "Impacts of Regulatory Reform on Environmental Law", Committee on Environment and Public Works, U. S. Senate, Washington, D.C., 104th Congress, First Session, March 22, 1995.

John D. Graham, Statement to the National Transportation Safety Board, Supplemental Restraint Panel, Washington, D.C., March 17, 1997.

John D. Graham, Statement to the National Transportation Safety Board, Effectiveness Panel, Washington, D.C., March 19, 1997.

John D. Graham, Testimony on S. 981, "Regulatory Improvement Act of 1997, " Committee on Governmental Affairs, U. S. Senate, Washington, D.C., 105th Congress, First Session, September 12, 1997.

John D. Graham, Testimony on "The Role of Risk Science in Decision Making", Committee on Science, U. S. House of Representatives, Washington, D.C., 105th Congress, June 10, 1998.
John D. Graham, Testimony on the "Regulatory Improvement Act of 1999" (S. 746), Committee on Governmental Affairs, U. S. Senate, Washington, D.C., April 21, 1999.

John D. Graham, Testimony on "Reauthorization of the Clean Air Act", Committee on Governmental Affairs, U. S. Senate, Washington D.C., October 14, 1999.

John D. Graham, Testimony on "Biotechnology in the Year 2000 and Beyond", U. S. Food and Drug Administration, Washington, D.C., November 30, 1999.

John D. Graham, Testimony on "Comparative Risk Assessment and Environmental Decision Making", Committee on Environment and Public Works, U. S. Senate, July 27, 2000.

John D. Graham, Testimony on "Cost-Justifying Regulations: Protecting Jobs and the Economy by Presidential and Judicial Review of Costs and Benefits", Subcommittee on Courts, Commercial and Administrative Law, House Judiciary Committee, U.S. Congress, May 4, 2011.

John D. Graham, Testimony on "How A Broken Process Leads to Flawed Regulations", OMB-OIRA Oversight Hearing, Committee on Oversight and Government Reform, House of Representatives, United States Congress, September 14, 2011.

John D. Graham, Testimony on the "Office of Information and Regulatory Affairs: Federal Regulations and Regulatory Reform under the Obama Administration", Committee on the Judiciary, House of Representatives, United States Congress, March 21, 2012.

John D. Graham, Testimony on "Regulatory Aspects of Trans-Atlantic Trade and Investment Partnership (TTIP)", U.S.-EU Free Trade Agreement, Committee on Trade, European

Parliament, Brussels, Belgium, October 14, 2013.

John D. Graham, Testimony on “Secret Science Reform Act of 2014”, Committee on Science, Space and Technology, Secret Science Reform Act of 2014, U.S. House of Representatives, Washington, D.C., February 11, 2014.

John D. Graham, Testimony on “The First Step to Cutting Red Tape: Better Analysis”, Joint Economic Committee, U.S. Congress, Washington, D.C., April 30, 2014.

John D. Graham, Testimony on “A Regulatory Budget and the U.S. Economy”, Committee on the Budget, United States Senate, Washington, D.C., December 9, 2015.

John D. Graham, Testimony on “Examining Federal Rulemaking Challenges and Areas of Improvement Within the Existing Regulatory Process”, Subcommittee on Regulatory Affairs and Federal Management, Committee on Homeland Security and Governmental Affairs, United States Senate, Washington, D.C., March 19, 2015.

John D. Graham, Testimony on “Surface Transportation Reauthorization: Performance, not Prescription”, Subcommittee on Surface Transportation, Committee on Commerce, United States Senate, Washington, DC., March 24, 2015.

John D. Graham, Testimony on “The Federal Government on Autopilot: Delegation of Regulatory Authority to an Unaccountable Bureaucracy”, Committee on the Judiciary, U.S. House of Representatives, Washington, D.C., May 24, 2016.

John D. Graham, Testimony on “Proposed Crew-Staffing Rule”, Federal Railroad Association, Docket No: FRA-2014-0033, U.S. Department of Transportation, Washington, D.C., July 15, 2016.

John D. Graham, Testimony on “Midterm Review and an Update on the Corporate Average Fuel Economy Program and Greenhouse Gas Emissions Standards for Motor Vehicles”, Subcommittee on Commerce, Manufacturing, and Trade and the Subcommittee on Energy and Power, U.S. House of Representatives, Washington, D.C., September 22, 2016.

Personal Facts

Born October 3, 1956 (Pittsburgh, PA); married to Susan W. Graham; daughters, Jennifer Ann Staver and Kathryn Graham; granddaughters Louisa and Isabella; hobbies include golf, ballroom dancing and bridge. Home address: 2417 Boston Road, Bloomington, IN 47401

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Education:

1979-1981 and 1976-1977 YALE UNIVERSITY, New Haven, CT
Ph.D. in Economics, 1982
· Dissertation: "Differentiated Regulation: The Case of Auto Emissions Standards"
· Brookings Research Fellow 1979-1980

1972-1975 McGILL UNIVERSITY, Montreal, P.Q., CANADA
B.A. in Economics 1975
· Allan Oliver Gold Medal
·

Professional Experience:

2017- MASSACHUSETTS INSTITUTE OF TECHNOLOGY ENERGY INTIATIVE
Senior Energy Economist
Conducts research on energy storage and energy use in electricity generation and transportation

2003-2017 U.S. ENERGY INFORMATION ADMINISTRATION
Deputy Administrator
· Chief operating officer of $122 million energy analysis and data program
· Responsibilities include oversight of energy data and analysis programs, budget formulation and execution, frequent testimony before Congressional committees, interagency deliberations and public speaking engagements.
· Presidential Distinguished Executive Rank Award, 2007
Adelman-Frankel Award, U.S. Association for Energy Economics, 2015

2000- 2003 RESOURCES FOR THE FUTURE, Washington, DC
Resident Scholar
· Conducted policy-relevant research on energy and environmental issues.

1991- 2000 U.S. DEPARTMENT OF ENERGY, Washington, DC
Director, Office of Economic, Electricity and Natural Gas Analysis
Deputy Assistant Secretary for Economic and Environmental Policy
· Developed positions on energy, regulatory, and environmental policy issues, including electricity restructuring and climate change.
· Represented the Department in testimony before Congressional committees, legislative negotiations for 1992 National Energy Policy Act, international scientific and negotiations on the Framework Convention on Climate Change and the Intergovernmental Panel on Climate Change, interagency deliberations and public speaking engagements.
· Presidential Distinguished Executive Rank Award, 1999

1989-1991 EXECUTIVE OFFICE OF THE PRESIDENT, Washington, DC

Senior Staff Economist, Council of Economic Advisers

- Developed CEA positions on energy, environmental, regulatory, and trade policy issues, including the Clean Air Act and global change.
- Drafted environment sections of 1990 Economic Report of the President and Interagency White Paper on the Economics of Long-term Climate Change.
- Represented CEA in interagency deliberations, congressional negotiations and public speaking engagements.

1988-1989 U.S. INTERNATIONAL TRADE COMMISSION, Washington, DC

Economic Adviser to the Chairman

- Executed economic analyses of antidumping, countervailing duty, and escape clause cases as a primary input to the Chairman's injury determinations.
- Directed staff regarding the structure and content of reports prepared in response to requests from the Office of the Trade Representative and Congress.
- Advised the Chairman on personnel matters involving senior economics positions inside the Commission.

1982-1988 TEPPER SCHOOL OF BUSINESS

CARNEGIE MELLON UNIVERSITY, Pittsburgh PA

Assistant Professor of Economics

- Responsibilities included research, publication, and teaching in economic and social regulation and international trade and competitiveness.
- Courses taught included Energy and Environmental Economics, Microeconomics, International Trade and Competitiveness, and Political Economy.

1984-1985 THE BROOKINGS INSTITUTION, Washington DC

Associated Staff

- Co-authored Regulating the Automobile, a study of safety, emissions, and fuel economy regulation and its impact on the automobile industry.

1978-1979 THE WHITE HOUSE, Washington, DC

Assistant Director, Economics and Business, Domestic Policy Staff

- Advised the Assistant to the President for Domestic Affairs and Policy on regulatory, economic, and trade policy issues.
- Negotiated policy positions on regulatory, economic and trade issues within the Administration and with senior congressional staff.
- Drafted decision memos presenting agency positions to the President.

Other Professional Activities:

Guest lecturer on energy issues for classes at Yale, Carnegie Mellon, and George Washington universities – usually 1 class or seminar per year at each institution over the last several years

Author or co-author of academic and policy papers – list of selected papers is attached

Referee for several professional journals.

HOWARD K. GRUENSPECHT: Selected Publications and Working Papers
(Note: excludes book reviews, testimonies, presentations, published comments, etc.)

Portney, Paul, Ian Parry, Howard Gruenspecht, and Winston Harrington. "The Economics of Fuel Economy Standards." *The Journal of Economic Perspectives*, vol. 17, no. 4, pp 203-217 (2003)

Gruenspecht, Howard. Regulatory Tailoring, Reliability, and Price Volatility with Stochastic Breakdowns. RFF Discussion Paper 02-37. September 2002

Gruenspecht, Howard and Robert Stavins. "New Source Review Under the Clean Air Act: Ripe for Reform" *Resources*, Winter 2002.

Gruenspecht, Howard. "Zero Emissions Vehicles: A Dirty Little Secret" *Resources* Winter 2001.

Gruenspecht, Howard and Tracy Terry. Horizontal Market Power in Restructured Electricity Markets, Office of Policy, Department of Energy, PO-0060, March 2000.

Gruenspecht, Howard and John Conti. Supporting Analysis for the Comprehensive Electricity Competition Act, Office of Policy, Department of Energy, PO-0058, May 1999.

Richels, Richard., Jae Edmonds, Howard Gruenspecht, and Tom Wigley. The Berlin Mandate: The Design of Cost-effective Mitigation Strategies. (In) *Report on the Regional Distribution of the Costs and Benefits of Climate Change Policy Proposals*, Energy Modeling Forum-14, Stanford University, Stanford, California, 1996

Gruenspecht, Howard. "Trade and Environment: A Tale of Two Paradigms," in Agriculture, Trade, and the Environment: Discovering and Measuring the Critical Linkages, M. Bredahl, ed., Westview Press (1996).

Rosenthal, Donald, Howard Gruenspecht, and Emily Moran. "Effects of Global Warming on Energy Use for Space Heating and Space Cooling in the United States," *The Energy Journal*, vol. 16, no. 2, pp.77-96 (1995).

Lave, Lester and Gruenspecht, H.K. Benefit-cost analysis and effluent fees: A Critical Review. *Journal of the Air and Waste Management Association*, vol 41, no. 5 pp. 679-701 (1991).

Gruenspecht, Howard. "Forging New Links With Economic Policy," *EPA Journal*, vol. 16, no. 5, pp.36-38 (1990).

Gruenspecht, Howard, John Antle, Richard Schmalensee. "The Economy and the Environment," in Economic Report of the President, Council of Economic Advisers, Washington, DC 1990.

Gruenspecht, Howard, and Lester Lave. "The Economics of Health, Safety and Environmental Regulation," in Handbook of Industrial Organization, vol II, R. Schmalensee, R.D. Willig, eds., Elsevier, New York, 1989.

Gruenspecht, Howard. "Export Subsidies for Differentiated Products," *Journal of International Economics*, vol.24 pp.331-344 (1988).

Gruenspecht, Howard. "Dumping and Dynamic Competition," *Journal of International Economics*, vol 25. pp.225-248 (1988).

Crandall, Robert, Howard Gruenspecht, Ted Keeler, Lester Lave, Regulating the Automobile Brookings Institution, Washington, DC 1986.

Gruenspecht, Howard. "Differentiated Regulation: The Case of Automobile Emissions Standards," *American Economic Review*, vol 72, no.2, pp.328-331 (1982)

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CURRENT EMPLOYMENT AND AFFILIATIONS

Assistant Professor, Department of Agricultural and Resource Economics (July 2015—present)
University of California, Berkeley
Faculty Research Fellow, National Bureau of Economic Research (April 2010—present)
Public Economics and Energy and Environmental Economics Programs
Research Associate, Energy Institute at Haas (March 2016—present)
Faculty Affiliate, E2e Program (January 2014—present)
Faculty Affiliate, Institute for Research on Labor and Employment (July 2016—present)

PAST EMPLOYMENT

Assistant Professor, Harris School of Public Policy Studies (July 2008 – June 2015)
University of Chicago
Visiting Researcher, University of California Energy Institute (August 2010 – December 2010)

EDUCATION

University of Michigan, Ph.D. in Economics (2008)
Dissertation: *Three Essays in Public Economics*
Committee: Joel Slemrod (Chair), Rebecca Blank, James Hines, Jeffrey Smith
University of Michigan, M.A. in Economics (2005)
Macalester College, B.A. in Economics and Political Science, *Summa Cum Laude*, ΦΒΚ (2001)

PUBLISHED ARTICLES (peer reviewed unless otherwise noted)

"The Use of Regression Statistics to Analyze Imperfect Pricing Policies" (with Mark R. Jacobsen, Christopher R. Knittel and Arthur van Benthem) *Journal of Political Economy* conditionally accepted.

"The Economics of Attribute-Based Regulation: Theory and Evidence from Fuel-Economy Standards" (with Koichiro Ito) *Review of Economics and Statistics* 100, May 2018, pp. 319-336.

"Tax Incidence with Endogenous Quality and Costly Bargaining: Theory and Evidence from Hybrid Vehicle Sales" (with Sumeet Gulati and Carol McAusland) *Journal of Public Economics* 155, November 2017, pp. 93-107.

"Disparities in Complex Price Negotiations: The Role of Consumer Age and Gender" (with Ambarish Chandra and Sumeet Gulati). *Journal of Industrial Economics* 64(2), June 2017, pp. 235-74.

"Do Consumers Recognize the Value of Fuel Economy? Evidence from Used Car Prices and Gasoline Price Fluctuations" (with Sarah West and Wei Fan) *Journal of Public Economics* 134, March 2016, pp. 61-73.

"Designing Policies to Make Cars Greener: A Review of the Literature" (with Soren T. Anderson) *Annual Review of Resource Economics* 8, 2016, 157-80.

"The Intergenerational Transmission of Automobile Brand Preferences: Empirical Evidence and Implications for Firm Strategy" (with Soren T. Anderson, Ryan Kellogg and Ashley Langer) *Journal of Industrial Economics*, 63(4), December 2015, pp. 763-793.

"New Evidence on Taxes and the Timing of Birth" (with Sara LaLumia and Nicholas Turner) *American Economic Journal: Economic Policy*, 7(2), May 2015, pp. 258-293.

"Rational Inattention and Energy Efficiency" *Journal of Law and Economics*, 57(3), August 2014, pp. 781-820.

"What Do Consumers Believe About Future Gasoline Prices? (with Soren T. Anderson and Ryan Kellogg) *Journal of Environmental Economics and Management*, 66(3), November 2013, pp. 383-403.

"The Value of Honesty: Empirical Estimates from the Case of the Missing Children" (with Sara LaLumia) *International Tax and Public Finance*, 20(2), April 2013, pp. 192-224.

"Car Notches: Strategic Automaker Responses to Fuel Economy Policy" (with Joel Slemrod) *Journal of Public Economics*, 96(11-12), December 2012, pp. 981-999.
*Awarded the 2015 Atkinson Award (Best Paper in the *Journal of Public Economics* 2012-4)

"Financial Reporting, Tax, and Real Decisions: Toward a Unifying Framework" (with Douglas A. Shackelford and Joel Slemrod), *International Tax and Public Finance*, 18(4), August 2011, pp. 461-494.

"Using Loopholes to Reveal the Marginal Cost of Regulation: The Case of Fuel-Economy Standards" (with Soren T. Anderson) *American Economic Review* 101(4), June 2011, pp. 1375-1409.

"The Surprising Incidence of Tax Credits for the Toyota Prius" *American Economic Journal: Economic Policy*, 3(2), May 2011, pp. 189-219.

"Forecasting Gasoline Prices Using Consumer Surveys" (with Soren T. Anderson, Ryan Kellogg and Richard M. Curtin) *American Economic Review Papers & Proceedings* 101(3), May 2011, pp. 110-114. (Not Peer Reviewed)

"Fuel Economy Standards: Impacts, Efficiency, and Alternatives" (with Soren Anderson, Carolyn Fischer and Ian Parry), *Review of Environmental Economics and Policy*, 5(1), Winter 2011, pp. 89-108.

"The Taxation of Fuel Economy" *Tax Policy and the Economy* v. 25, Editor Jeffrey R. Brown, NBER: University of Chicago Press, 2011, pp. 1-38. (Not Peer Reviewed)

"A Cautionary Tale About the Use of Administrative Data: Evidence from Age of Marriage Laws" (with Rebecca M. Blank and Kerwin Kofi Charles), *American Economic Journal: Applied Microeconomics,*1(2), April 2009, pp. 128 - 149.

"On the Optimal Allocation of Students and Resources in a System of Higher Education" (with Alexandra M. Resch and Paul N. Courant) *The B.E. Journal of Economic Analysis & Policy* (Advances Tier), 8(1), Article 11.

WORKING PAPERS

"Who Benefits When Firms Game Corrective Policies?" (with Mathias Reynaert) *Submitted*.

SELECTED WORK IN PROGRESS

"Pigou Creates Losers: On the Implausibility of Pareto Improvements from Pigouvian Taxation"

"Are Local Air Pollution Regulations for New Vehicles Effective and Efficient?" (with Mark Jacobsen, Joseph Shapiro and Arthur van Benthem)

"Durable Goods Demand and the Rationality of Consumers' Price Expectations: Evidence from Gasoline and Diesel" (with Ryan Kellogg)

AWARDS AND HONORS

Sloan Foundation Grant (*Heterogeneity, Equity and Energy Policy* 2017-8)
Club Six (2017, recognition for teaching scores above 6 out of possible 7, Haas MBA)
Hellman Family Faculty Fund Award (2017)
UC Regents' Junior Faculty Fellowship (2016)
France-Berkeley Fund Award (2016)
Atkinson Award (2015, for best Paper in the *Journal of Public Economics* between 2012-2014)
Best Teacher in a Core Course, The Harris School (2012, 2013)
W.E. Upjohn Institute Early Career Research Grant (with Reed Walker) (2012)
Certificate of Excellence in Reviewing, *Journal of Public Economics* (2012)
John V. Krutilla Research Award from Resources for the Future (2009 - 2010)
National Tax Association Dissertation Award (2008)
National Science Foundation Graduate Research Fellowship (awarded 2003)
Population Studies Center Trainee Fellowship, University of Michigan (2003-2008)

TEACHING

University of California, Berkeley
Environmental and Resource Economics, ARE 261 (PhD)
Environmental Economics, EEP 101/ECON 125 (Undergraduate)
Economic Analysis for Business Decisions (Core micro for MBAs), MBA201A
taught at Haas School of Business

University of Chicago (all for MPP students)
Policy Approaches to Mitigating Climate Change
Topics in U.S. Tax Policy
Empirical Methods in Policy Analysis II
Science, Technology and Policy

REFEREE

Editorial Council Member (2014-) *Journal of the Association of Environment and Resource Economists*

American Economic Review, Journal of Political Economy, Quarterly Journal of Economics, Econometrica, American Economic Review: Insights, Journal of Public Economics, American Economic Journal: Economic Policy, American Economic Journal: Applied Economics, Review of Economics and Statistics, RAND Journal of Economics, Journal of Environmental Economics and Management, National Tax Journal, Journal of the Association of Environment and Resource Economists, Journal of Labor Economics, International Economic Review, European Economic Review, International Tax and Public Finance, Journal of Law & Economics, Economic Journal, Energy Journal, Canadian Journal of Economics, Nature, B.E. Journal of Economic Analysis & Policy, Economic Inquiry, Journal of Human Resources, Economic Letters, Energy Economics, Environmental and Resource Economics, Journal of Urban Economics, Journal of Policy Analysis and Management, Transportation Research Part A, Journal of Population Economics, Environmental Policy and Governance, Scottish Journal of Political Economy ***Grants:*** *National Science Foundation, European Science Foundation, Sloan Foundation, Smith Richardson Foundation, Time-Sharing Experiments for the Social Sciences*

SELECTED PRESENTATIONS

Invited **2017:** UC Santa Cruz (Economics) **2016:** Berkeley (Economics), UC Davis (ARE), Texas A&M (Economics), FGV Rio de Janeiro (Economics), Resources for the Future, Arizona State **2015:** LSE (Economics), Berkeley (Goldman), UCLA (Luskin), Colorado School of Mines (Economics), Universidad de Chile (Business School), Pontificia Universidad Catolica de Chile (Economics) **2014:** Michigan (Ross), Berkeley (ARE), University of Pennsylvania (Wharton), Berkeley (POWER Conference), Yale (FES), Illinois (Economics), National Tax Association Spring Symposium, Federal Trade Commission, EPA, University of Leuven (Economics), Universidad de Chile (Business School), Pontificia Universidad Catolica de Chile (Economics) **2013:** Georgetown (Economics), Illinois (Economics), Wisconsin (Economics) **2012:** Maryland (Economics), Northwestern (Law), Universidad de Chile (Business School), Oxford (Business School); **2011:** Columbia (Economics), Maryland (AREC), Syracuse (Maxwell), Illinois (Finance), Ohio State (Economics), Illinois (Sustainability Center), NYU (Law conference), University of Illinois at Chicago (Sustainability workshop), Treasury, EPA, Resources for the Future (Conference); **2010:** MIT (Economics), Yale (FES), Berkeley (ARE), Berkeley (UCEI), NBER Tax Policy and the Economy, University of Chile; **2009:** Cornell (Economics), Minnesota (Applied Economics), North Carolina State University (Economics), Berkeley (POWER Conference), University of Illinois at Chicago (Economics), Macalester College (Economics); **2008:** Resources for the Future, University of Chicago (Harris), University of Pennsylvania (Wharton), University of British Columbia (Economics), University of Kentucky (Martin/Economics), University of Indiana (SPEA), University of California, Irvine (Economics), Treasury, Ford Motor Company

Conference **2018:** ASSA (AEA) **2017:** National Tax Association, ASSA (AEA) **2016:** NBER EEE Summer Institute, Stanford Institute for Theoretical Economics, National Tax Association, Heartland Environmental and Resource Economics **2015:** NBER EEE **2014:** ASSA (AEA and AERE), NBER EEE, NBER Public Economics, Oxford Tax Systems Conference, Michigan Tax Invitational **2012:** NBER Public Economics, National Tax Association, Michigan Tax Invitational **2011:** National Tax Association, ASSA, Association of Environmental and Resource Economics, International Institute of Public Finance, University of California Energy Institute; **2010:** NBER Public Economics, Iowa State Bioenergy Camp; **2009:** ASSA, National Tax Association, Heartland Environmental and Resource Economics; **2008:** APPAM, National Tax Association; **2007:** NBER Summer Institute (EEE), National Tax Association, APPAM

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National Highway
Traffic Safety
Administration

NHTSA

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