Peer Review for the Consumer Vehicle Choice Model and Documentation

United States
Environmental Protection
Agency

Peer Review for the Consumer Vehicle Choice Model and Documentation

Assessment and Standards Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

Prepared for EPA by
Systems Research and Applications International, Inc.
EPA Contract No. EP-C-11-007
Work Assignment No. 0-09

NOTICE

This technical report does not necessarily represent final EPA decisions or positions. It is intended to present technical analysis of issues using data that are currently available. The purpose in the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments.

EPA United States Environmental Protection Agency

EPA-420-R-12-013
April 2012

March 2012

MEMORANDUM

SUBJECT: Peer Review for Consumer Vehicle Choice Model and Documentation, developed by David Greene and Changzheng Liu

FROM: Gloria Helfand, Assessment and Standards Division
Office of Transportation and Air Quality, U.S. Environmental Protection Agency

In September 2011, EPA contracted with SRA International (SRA) to conduct a peer review of the Consumer Vehicle Choice Model and associated documentation developed by David Greene and Changzheng Liu of Oak Ridge National laboratory.

The three peer reviewers selected by SRA were Drs. David Bunch (University of California, Davis), Trudy Cameron (University of Oregon), and Walter McManus (University of Michigan, Transportation Research Institute). EPA would like to extend its appreciation to all three reviewers for their efforts in evaluating this survey. The three reviewers brought useful and distinctive views in response to the charge questions.

The first section of this document contains the final SRA report summarizing the peer review of the Consumer Vehicle Choice Model and associated documentation, including the detailed comments of each peer reviewer and a summary of reviewer comments according to the series of specific questions set forth in the peer review charge. The SRA report also contains the peer reviewers' resumes, completed conflict of interest and bias questionnaires for each reviewer, and the peer review charge letter. The second major section contains our responses to the peer reviewers' comments. In this section, we repeat the summarized comments provided by SRA and, after each section of comments, provide our response. We have retained the organization reflected in SRA's summary of the comments to aid the reader in moving from the SRA report to our responses.

CONTENTS

I.

Peer Review of EPA's Consumer Vehicle Choice Model and Associated Documentation, Conducted by SRA International

TO: Kent Helmer, Gloria Helfand, U.S. Environmental Protection Agency, Office of Transportation and Air Quality (OTAQ)

FROM: Brian Menard, SRA International

DATE: November 10, 2011

SUBJECT: Peer Review of the Consumer Choice Vehicle Model and Associated Documentation

1. Background

The U.S. Environmental Protection Agency's (EPA) Office of Transportation and Air Quality (OTAQ) has recently sponsored the development of a Consumer Vehicle Choice Model (CVCM) by the Oak Ridge National Laboratory (ORNL). The specification by OTAQ to ORNL for consumer choice model development was to develop a Nested Multinomial Logit (NMNL) or other appropriate model capable of estimating the consumer surplus impacts and the sales mix effects of greenhouse gas (GHG) emission standards.

The CVCM will use output from the EPA's Optimization Model for reducing Emissions of Greenhouse gases from Automobiles (OMEGA), including changes in retail price equivalents, changes in fuel economy, and changes in emissions, to estimate these impacts. In addition, the CVCM will accept approximately 60 vehicle types, with the flexibility to function with fewer or more vehicle types, and will use a 15 year planning horizon, matching the OMEGA parameters. It will be calibrated to baseline sales projection data provided by the EPA and will include a buy/no-buy option to simulate the possibility that consumers will choose to keep their old vehicle or to buy a used vehicle.

EPA sought a peer review of the CVCM and associated documentation. This report documents the peer review of the CVCM. Section 2 of this memorandum describes the process for selecting reviewers, administering the review process, and closing the peer review. Section 3 summarizes reviewer comments according to the series of specific questions set forth in the peer review charge. The appendices to the memorandum contain the peer reviewers' resumes, completed conflict of interest and bias questionnaires for each reviewer, and the peer review charge letter.

2. Description of Review Process

In August 2011, OTAQ contacted SRA International to facilitate the peer review of EPA's Consumer Vehicle Choice Model and associated documentation. The model and documentation were developed by David Greene and Changzheng Liu of Oak Ridge National laboratory.

EPA provided SRA with a short list of subject matter experts from academia and industry to serve as a "starting point" from which to assemble a list of peer reviewer candidates. SRA selected three independent (as defined in Sections 1.2.6 and 1.2.7 of EPA's *Peer Review Handbook, Third Edition)* subject matter experts to conduct the requested reviews. SRA selected subject matter experts familiar with economic valuation, discrete choice models and the use of these models for valuation, and the use of these models for predicting automobile purchases. To ensure the independence and impartiality of the peer review, SRA was solely responsible for selecting the peer review panel. Appendix A of this report contains the resumes of the three peer reviewers. A crucial element in selecting peer reviewers was to determine whether reviewers had any actual or perceived conflicts of interest or bias that might prevent them from conducting a fair and impartial review of the CVCM and documentation. SRA required each reviewer to complete and sign a conflict of interest and bias questionnaire. Appendix B of this report contains an explanation of the process and standards for judging conflict and bias along with copies of each reviewer's signed questionnaire.

SRA provided the reviewers a copy of the most recent version of the CVCM and associated documentation as well as the peer review charge containing specific questions EPA asked the reviewers to address. Appendix C of this report contains the memo to reviewers from SRA with the peer review charge.

A teleconference between EPA, the reviewers, and SRA was held to allow reviewers the opportunity to raise any questions or concerns they might have about the CVCM or the documentation, and to raise any other related issues with EPA and SRA, including EPA's expectations for the reviewers' final review comments. SRA delivered the final review comments to EPA by the requested date. These reviews, contained in Appendix D of this report, included the reviewers' response to the specific charge questions and any additional comments they might have had.

3. Summary of Review Comments

The Consumer Choice Vehicle Model and associated documentation were reviewed by David Bunch (University of California, Davis), Trudy Cameron (University of Oregon), and Walter McManus (University of Michigan, Transportation Research Institute). Appendix A contains detailed resumes for each of the reviewers. This section provides a summary of their comments. The complete comments may be found in Appendix D.

3.1 Overall Approach and Methodology of Model

Reviewers provide a range of opinion on the model's overall approach and methodology, with one providing detailed comment on the need to reflect the uncertainty in the predictions, and another concluding that the model is flexible enough.

Bunch: "The representative consumer NMNL form, and the inputs and outputs of the model, are an entirely appropriate choice of methodology for this problem. The OMEGA model itself is based on a specific model for manufacturer behavior whereby (1) the vehicle market definition does not change (2) the only changes to vehicles are the fuel economy and purchase price. Using this approach, this type of NMNL model could be readily integrated directly into the OMEGA model if necessary. In addition, this model could be viewed as only a starting point in an ongoing process of future model development. Additional complexity could be incrementally introduced into the model and evaluated."

Cameron: Provides extensive comment on her main substantive concern, which she terms "reflecting the uncertainty in the predictions". She cautions against "spurious precision"; discusses fixed parameters and distributions on parameters; and suggests "honoring the bounds" on elasticities across levels, allowing for some non-zero correlations between parameters, building sampling distributions for output measures, providing richer summaries of model results, enhancing the model to provide access to a pseudo-random number generator, and subjecting key assumptions to systematic sensitivity analysis.

"From a broader social welfare perspective, the model is a bit narrow. Its goal is to explain the mix of vehicles sold and to predict how this mix might change when vehicle prices are affected by the costs of meeting more stringent fuel economy standards. However, this is not part of a full computable general equilibrium model. Instead, the OMEGA model apparently minimizes the costs of achieving a particular carbon dioxide goal across a variety of possible technology packages, and these higher costs are passed (in one direction) to the CVCM to predict the effects of higher vehicle prices on the demand for different vehicle types and therefore on the sales of each company and the resulting corporate average fuel economy effects, to a first approximation." Cameron suggests that there should be a feedback, and she "raises the naïve question of why are there no estimates of *cross-price elasticities* of demand in the model. The market share model, as a function vehicle own-prices and incomes, with no feedback to the supply side, necessarily misses the effects of demand shifts in response to changes in relative prices as a result of the original supply shift. There are likely to be heterogeneous price changes and cross-price elasticities that are different from zero." Cameron expresses worry about the model's "narrow focus on how much vehicle prices go up due to standards and the resulting loss in consumer surplus in vehicle markets." EPA should not conclude that "vehicle buyers will be "hurt" to this extent without considering the potentially countervailing benefits from reduced carbon emissions and fewer emissions of conventional pollutants," and should emphasize that although "some surplus will be lost by consumers of this product," society will benefit in general.

McManus: The model "strikes the right balance between too much and too little flexibility."

3.2 Appropriateness of Model Parameters and Inputs

Reviewers provide a range of opinion on the model parameters and inputs.

Bunch: "Greene and Liu take an approach that is a bit different from what is typical in most of the literature. Specifically, most researchers determine model parameters by obtaining data on vehicle choices (typically at the household level), and then using statistical estimation methods to obtain parameter estimates. In contrast, Greene and Liu use the parsimonious model form described above, and take a "calibration" approach. They make assumptions about the values of price elasticities, which are in turn related to the values of structural parameters (price slopes). The alternative-specific constants, on the other hand, are calibrated using actual sales data for a particular base year. (We say "calibrated" rather than "estimated" because there is a direct deterministic mapping between sales and the constants.) The assumptions on the elasticities are based on a review of the literature, combined with theoretical considerations related to the model. The values of the structural parameters are related to the elasticities, but there is not a deterministic relationship as in the case of the alternative-specific constants. The authors use an *ad hoc* approach to estimating price slopes based on elasticities. Although there could be a better way to do this, under the circumstances it seems reasonable. Finally, the only utility attribute currently required by their model is an estimate of the value of fuel savings from an improvement in fuel economy. This can be computed on the basis of additional assumptions.

Their approach avoids many of the pitfalls of the statistical estimation approach. First, the statistical approach requires access to good data sets (which are frequently not available) and a lot of difficult econometric analysis. When using this approach, revealed preference data are rife with multicollinearity, stated choice methods (which can overcome multicollinearity) are not universally accepted, and all aspects of such analyses are subject to debate and criticism that are a distraction from the main purpose of policy analysis. The literature review by Greene (2010) illustrates that the parameter estimates obtained via this approach are very context dependent, and can vary widely. In particular, there is very little agreement on a key issue: how consumers value fuel economy/fuel savings.

I support the decision by Greene and Liu to use a parsimonious NMNL model with a calibration approach. The assumptions can be debated separately from other parts of the analysis, and can always be changed to test their implications.

With regard to chosen values for model parameters, there is a relationship between price elasticities and NMNL structural parameters (aka "price slopes"), and that the mapping is not one-to-one. The method used by the authors is described on page 29. Although there may be better methods, this one seems sufficient in practice. The other question is how to choose the elasticities. They do this based on values found in the literature, also recognizing that the NMNL requires the type of ordering found in equation (38). They provide a discussion (page 31) to support their selections, which seem reasonable. Having said this, one thing that is missing is an analysis of the distribution of price elasticities produced from actual runs of the Model itself. This would seem to be a useful validation exercise. "

Cameron: "I am greatly concerned about the misleading impression of precision that is created by the use of arbitrary simple point estimates for price elasticities. These point estimates are selected from a sparsely populated range of empirical estimates of just a subset of the needed elasticities. These empirical estimates are typically for more-aggregated categories of vehicles as well. It seems imperative to implement a strategy for capturing the uncertainty about the true parameters that capture price responsiveness. The model cannot predict exact market shares, yet readers will be lulled into thinking that they can be confident in its predictions about changes in market shares and consumer surplus. Consumers of the model's results need to know how sensitive all of its predictions are with respect to the actual state of knowledge about the necessary input quantities.

The documentation for the model is very clear, on page 4, about the list of potential sources for prediction errors, including source number 4, "Errors in NML parameters." Just acknowledging these sources, however, does not reveal the potential sizes of these errors, relative to the predictions of the model. I think it is imperative to try to capture at least some of the noise that is actually in the model, so users are not left with zero information about the sensitivity of the results to at least some of the key subjective inputs. There is not much to be done about "model uncertainty," or "input variable uncertainty" (unless even more layers of randomization are added to the framework in which each single simulation is embedded), but at least some of the parameter uncertainty could be accommodated."

"Also, to the extent that other inputs to the model are also not known with certainty, there could be an additional layer of simulations within each iteration. For example, if forecasts of the population or number of households come with standard errors, those could also be subjected to random draws."

McManus: "Overall the model parameters are appropriate. The consumer value of fuel economy is, as the authors acknowledge, subject to conflicting views and assumptions. The ORNL model amounts to entering (price of fuel) / (fuel economy) in the demand function. This formulation forces the impact of fuel price and fuel economy to have effects that are equal but opposite in sign. Nearly all of the empirical estimates of the "value of fuel economy" also use this formulation, so these estimates might be "appropriate." However, most of the historically observed changes in (price of fuel) / (fuel economy), and almost all of the large changes, have come from variation in the price of fuel, not in fuel economy."

3.3 Information that Can Be Input into the Model

One reviewer highlights the necessary linkage between the CVCM and OMEGA models in understanding inputs, while another provides a detailed review of specific inputs.

Bunch: "Note that the model inputs are *not* "changes in CAFÉ/GHG policy." To produce a complete analysis of changes in CAFÉ/GHG policy requires the use of both the OMEGA model and the Greene and Liu model. . . . To analyze the impact of a change in CAFÉ/GHG policy, the OMEGA model must be used to "predict" the fuel economies and price changes that occur. These, in turn, are passed to the CVCM. Note that this requires some coordination between the two models. For example, both models must be set up to use the same new vehicle market definitions. The reference sales used by OMEGA must be passed along to the CVCM unchanged. . . . There needs to be some coordination and testing that involves both models, including common data for an agreed-upon base year. One concern is that, if the number and/or types of vehicles in the market definition were to change, it could affect how the ORNL model behaves. In particular, if the new market definition, e.g., reduced the number of configurations for each make/model combination to one, this could have implications for the elasticities at the bottom level of the tree."

Cameron: "The assumption about individual discount rates is central to the choice model because it is necessary to express utility from each vehicle as a function of the present value of future fuel savings that accompanies the higher purchase price of a vehicle with improved fuel economy. Assuming one common discount rate for everyone, even if that discount rate can be adjusted, will miss the fact that individual subjective discount rates vary systematically with a number of individual characteristics. Furthermore, when it comes to capital-cost/operating-cost decisions like the ones made in the new automobile market, the fact that capital market constraints can sometime masquerade as higher individual discount rates may be very relevant. People who are heavily capital-market constrained may make very different choices in durable goods markets than people who are not. These vehicles will have different mixes of capital and operating costs at the baseline, and different fuel efficiency requirements will change the capital/operating cost mix as well.

The model is very flexible in terms of the different quantities that can be set by the user, although all of these quantities are entered as point values, rather than likely distributions. For example, the model seems to include gasoline and diesel prices for twenty years into the future, and these individual parameters lend the appearance of being amenable to being very precisely and independently specified. When I clicked on each cell to ascertain how it was being calculated, I expected to see each future cell computed as the starting value subjected to a growth rate, but this is not the case. It seems necessary for the user to propose a price per gallon for each type of fuel in each future year. It is not clear why these settings as flexible as they are (unless the programming merely anticipates that users will ask for such flexibility eventually). Would it be possible for users, alternatively, just to choose a rate of growth or a linear trajectory for these two fuel prices (with confidence bounds, of course)?

Among the global parameters, the user appears to be invited to provide individual independent estimates of the population and average household size from 2010 to 2030, although the note in line 6 suggests that these numbers come from the U.S. Census Bureau's projections of the U.S. population (not “polution”) to 2050. It is not clear from this sheet what might be the Census Bureau’s basis for such precise population estimates over a twenty-year horizon, or for the static value of projected average household sizes over the same period. What about how the baby boom is moving through the demographic landscape? Might it be reasonable to allow the user, alternatively, to commit only to an estimate of growth rates (with confidence bounds)? This could be based on the current actual population estimate in the starting year. Perhaps for flexibility into the future, these years could also be expressed relative to the current year, rather than as absolute time. In short order, the “starting” year of 2010 will definitely be obsolete.

Also among the global parameters, it might make sense to make the contents of “Market Size-CycleX” to be linked to the content of the relevant future population cells, both in this case, with one cycle specified, and when more than one cycle is specified. Perhaps “Input Validation” is a way to make sure that things line up in a foolproof way, but that is not transparent. It should also be made clearer in the column headings how the cycle length (six years, apparently) is related to assumptions about the length of the payback periods (if it is). If there is a relationship, functional relationships among the values for the fields could enforce these relationships.

To keep the program as self-contained as possible, please be clear, among the notes to this sheet, what are the definitions of a “cycle” and what is meant by the “OnRoad Discount” field. We know this is the fraction of advertised MPG that is actually achieved in regular driving, but it might be better to call it something else, unless there is a tradition in the literature of using this terminology. Perhaps “Actual/Rated MPG.”

On the VehicleUse sheet, individual car and truck Survival (not Survial) Rates, by age, need to be specified. Again, I expected that each cell would be a function of the previous one, perhaps until a threshold was reached. Again, however, users are required to be specific about each cell, which probably overstates the precision that is feasible in forecasting these survival rates. Historical survival rates are not really relevant because of the substantial changes in materials and technology in recent decades. It might be preferable to allow users the options to specify a starting survival rate and a parameter according to which the survival rate changes over time (with confidence bounds) so that these cells can alternatively be populated automatically according to that function. The confidence bounds would allow for sensitivity analysis.

Without more information, the column headings in the Target sheet are just too cryptic. It is not clear what is meant by a “cycle,” or what are the units for the “a” and “b” fields, or the “c” and “d” fields for cars and trucks, or why there are lower and higher constraints for both. These sheets could be rendered more self-contained and self-explanatory with more “Notes” as are offered on some other sheets. Since it is desirable to leave room for other “cycles” in this sheet, perhaps the headings could be expanded with “wrap text” invoked so that users could be confidence about what information was needed in each of these cells for each cycle.

The Logit sheet finally invokes the types of cross-sheet and cross-cell functions I expected to see elsewhere in the setup. The rank ordering of the degree of responsiveness of demand to full cost of a vehicle (I assume) is enforced at the level of the “Slope” variable, rather than among the “Elasticity” settings that the user is free to specify. Are there any values for the ingredients to this calculation for which a rank ordering of the elasticities will not produce an identical rank ordering of slopes? That would seem to be a possible problem. Users could specify elasticities that were admissibly rank-ordered, but the relationship among the slopes would then be rejected by the slope-ranking test.

Also in the Logit sheet, the counts of vehicle types at Level 4 (“Number of Members”) are linked directly to the Vehicle sheet where the full range of vehicles is inventoried. However, at level 3, the “Number of Members” seems to be set independently, without reference to the number of Vehicle Classes. Is there a way to make the software robust to the introduction of a user-specified new Vehicle Class? This might require the introduction of a “Type” column next to the “Class” column for Level 4 that shows the mapping from Classes to Types. I am comfortable that we can get along for quite a while before it would be necessary to introduce a new Category, but perhaps an extra column under Level 3 to make the corresponding Categories explicit for each Type would also be helpful. This information is contained in the (verbal) Parent Node, but it might be clearer to have the Parent Node relabeled as “Parent Type” for Level 4 and “Parent Category” for Level 3.

It would be more logical to have Level 1 at the top, progressing down to the most disaggregated levels at the bottom of the sheet. At least in my experience, correlation structure diagrams are not upward-growing “trees” but downward-expanding “root systems.” This could be just a matter of taste, but I had been visualizing the structure as expanding downward (perhaps in the order in which consumers narrow down their vehicle choice), so the reverse ordering of the Logit Sheet came with a bit of cognitive dissonance. Perhaps I was basing my expectations on Figure 1 on page 21 of the document.”

McManus: Although modelers would like to have more input options, simulation options, and output options, the model “strikes the right balance between too much and too little flexibility.”

3.4 Types of Information the Model Produces

One reviewer compares various models and concludes that the chosen model produces sufficiently accurate information. Two reviewers express concerns about the types of information the model produces.

Bunch: Reviewer considers a number of possible models that might have been chosen and writes that most of them “make more detailed behavioral assumptions to explain consumers’ vehicle choices than does the representative consumer NMNL (the only exception being the representative consumer MNL based on equation (2)). In this regard, they could be regarded as potentially superior in terms of more accurately capturing market reaction to changes in vehicle offerings. On the other hand, their model is extremely parsimonious while also capturing important market substitution effects across various types of vehicles, and Occam’s razor could be said to apply.

The fact is that modeling future behavior of the new vehicle market is extraordinarily difficult. There is a relatively large literature on this subject, representing the efforts of many researchers using a variety of modeling approaches. As noted above, it could be argued on theoretical grounds that more complex models have the potential to be more accurate than an aggregate-level model. However, as shown in the review by Greene (2010), the results of more complex model estimation results vary over a wide range. Moreover, we are not aware of any studies that directly compare the accuracy of simpler models versus more complex models in any definitive way. Finally, it is well understood that modeling approaches are chosen based on a variety of factors, including the type of decision problem being addressed, availability of data to perform model estimation, data and computational requirements for using the model when performing scenario analysis, etc.

For this particular project, the ultimate goal is to use the OMEGA-NMNL system to analyze regulations. The most effective way to perform such analyses is by *comparison* of two scenarios (reference versus alternative) in response to specific types of *changes* (leaving all other factors constant). Specifically, the analysis is not predicated on requiring a model give the most accurate *forecast* of what will happen in the future (in an absolute sense). If this were the case, then it would be more important to include the effect of demographic variables over time (which would also require a demographic forecast), to predict structural changes in the vehicle market, and to simulate manufacturer decisions to add or delete various models (including the introduction of advanced technology vehicles).

Cameron: The point estimates of consumer surplus and sales embody spurious precision. "For example, it is hubris to predict industry revenue in hundreds of billions down to the exact dollar. At best, *the predictions of the model should be rounded to no more than two or perhaps three significant digits and confidence bounds of some kind should be provided*. The same goes for all of the other model outputs. The key elasticity settings must be so arbitrarily selected from the extant empirical estimates that it isn't wise to imply so much accuracy in the results file. *The precision in the results can be no greater than the precision in the elasticity estimates that serve as inputs, since these inputs are the weakest ones."*

McManus: "The report points out that aggregate models or modeling NMNL at an aggregate level could miss some important shifts in vehicle mix within the aggregates. Thus the report advises using the most complete level of detail possible. However, the report's authors recognize that the forecast errors at this most complete level of detail possible are uncomfortable large, and that the impacts at this level are too imprecise to be reported. The authors do not put it as strongly as this, of course. They should provide some evidence, possibly from simulations, that aggregated NMNL models indeed miss mix shifts that the most complete level of detail possible captures accurately."

3.5 Accuracy and Appropriateness of Model's Algorithms and Equations

All three reviewers provide extensive and highly specific comment on the model's algorithms and equations.

Bunch: Although the equations and derivations are generally correct, there are concerns about the model notation. "The specific NMNL form used by Greene and Liu has a tree structure that is much more complicated than most applications found in the literature. (Most have two or perhaps three levels, and exhibit a certain amount of symmetry.) In addition, they primarily use a notation developed over the years by Greene and co-authors that is not typically used by the rest of the field. The model parameters are one of two types: alternative-specific constants, and price slopes. The price slopes are the "structural parameters" of the model that relate to correlation among random disturbance terms in the RUM framework.

However, the use of the term "price slope" is potentially misleading, since one might infer that this is a model coefficient that exclusively applies to vehicle price.[1] Generally speaking, this parameter is a conversion factor that converts "generalized cost" (not just price) into "utility." In this approach, all of a choice alternative's attributes must be first expressed as costs (in dollars), and then added up. The resulting sum is then multiplied by a price slope to get "utiles." This works reasonably well for simple

[1] Potentially more confusing, the authors sometimes refer to "price coefficient" (e.g., on page 120.

utility functions where the only entries are price and, e.g., present value of fuel costs. (It is also easier to digest when the model has only two levels.)

However, in the future if other vehicle attributes are added (e.g., performance, vehicle size, etc.) this approach would be cumbersome. In discussing the implications of moving to lower levels of the tree, it is said that price slopes get larger (more negative), and that consumers are more "price sensitive." Again, this is potentially misleading, since consumers are actually becoming more "attribute sensitive."

The authors also include two other notational conventions in various locations in the paper. The other conventions are used more widely in the literature, with more conventional interpretations of the structural parameters as relating either to the scale or the variance of the (conditional) random disturbance term. The can also be used to express the degree of correlation between disturbance terms in the same nest. Overall, the way the notation, equations, and interpretation of parameters are used in the documentation could be said to be "sub-optimal". The authors are attempting to keep things simple (but still technically correct) in some places, but also more complete in other places. This is not an easy job, but depending on how EPA would like to use the documentation going forward, some attention may be required to these issues. "

Cameron: Expresses concern "that *M* in equation (35), annual VMT, is assumed to be exogenous. There seems to be a lot of literature concerned with the "rebound effect." For example, Barla et al. (2009), Eskeland and Mideksa (2008), Frondel et al. (2008; Greene et al. (1999; Greening et al. (2000; Hymel et al. (2010; Jones (1993; Kemel et al. (2011; Small and Van Dender (2007) all discuss this issue. Since Greene is one of these authors, we know he is aware of this. It would seem that *M* should be considered as endogenous, and should be specified as a function of the difference in fuel economy, rather than being treated as a constant that depends only on the age of the vehicle."

"I am accustomed to seeing the qualification that the correlation structure in a nested logit model does not necessarily imply a sequential decision process. All it does is highlight subsets of choices within which there is an error component unique to the group and different from analogous components associated with other groups."

"In the Prelude section, in equation (15), a *vector* of vehicle attributes that is assumed to influence the utility of alternative *j* to individual *n* quietly turns into nothing more than a "sum" G_j that represents a "generalized cost" for alternative *j*. All other attributes of these vehicles besides their price become non-explicit and apparently get soaked up by the alternative-specific constant utility component α_j for that vehicle, which is therefore assumed not to vary with price. It would also seem that the individual and alternative-specific random utility component ε_{nj} must be assumed to be independent of the generalized cost variable if the coefficient β_p is to be unbiased. How does this work? What about the fact that there are reasons for some vehicles to be more expensive than others."

"The parameter *L*, the "assumed payback period, in years," is presumably linked to planned duration of vehicle use (and is inherited from the OMEGA assumptions). However, it seems important to think about the extent to which fuel efficiency is capitalized into the resale value of used cars. If greater fuel efficiency enhances a vehicle's resale value, so that the capitalized value of fuel savings for used cars is fully reflected in their prices, the effective planning horizon is actually a lot longer—perhaps extending to the useful life of the vehicle. The current formulation is implemented with a value of 5 (years) in the

GlobalParameter sheet for the CCM inputs. Allcott and Wozny (2010), for example, find that consumers are willing to pay $0.61 to reduce expected discounted gas expenditures by $1. This estimate undoubtedly hinges on their assumptions about individual discount rates. However, the fact that this WTP estimate is not zero suggests that a finite time horizon, with no "resale-value increment" factored into the model of expected fuel (cost) savings in equation (35), might need some re-thinking."

"Is there evidence to suggest that the "Actual/Rated MPG" is constant across all types of vehicles? Surely this ratio has been established for almost all classes of vehicle. Consumer-contributed data by make/model/year seem to be available at www.fueleconomy.gov, for example, but the data are rather thin. It might be possible to do better here."

It would be helpful to first write the formula for a price elasticity of demand in a conventional Econ 101 format. If a demand equation is linear and additively separable in price, where the derivative of quantity demanded with respect to price is β_c, this formula in the single-equation case should be:

$$\eta_j = \left(\frac{\partial q_j}{\partial p_j}\right)\left(\frac{p_j}{q_j}\right) = \beta_c\left(\frac{p_j}{q_j}\right) = p_j\beta_c\left(\frac{1}{q_j}\right) \quad (1)$$

To help the reader determine whether it is necessary to go find their copy of Train (2009), it would be helpful to explain how we get from $\left(1/q_j\right)$ to $\left(1-S_j\right)$. If this step is transparent, it can go right into the derivation in the text. If it is more complex, explain that the reader really needs to ponder an extended discussion in Train (and give a preview of what is involved there).

Emphasize in the discussion of equation (38) the strong assumption that the underlying β parameter (before normalization on the error dispersion for a given nest) is the same across all levels and branches of the model's correlation structure diagram. It is only the dispersion of the errors in each partitioning that leads to different normalized values of this parameter, B.

McManus: "Bordley's elasticities are derived from second-choice information collected from new vehicle buyers. They were asked to specify the vehicle they would have bought, had the vehicle which they actually bought not been available. (Full disclosure: I was employed as an economist by General Motors for nine years and became well-acquainted with the second-choice information.) A key insight from GM's consumer research is that the new vehicle buyer, in general, has a short shopping list. This means that each vehicle in the market is not considered by all buyers. Vehicles with novel technologies are likely to have low consideration when introduced. Therefore, the NMNL model would overstate their expected market share. There is no easy fix for this, but the issue should be mentioned as a limitation of the NMNL, especially for new advanced technologies.

Another way to look at the impact of willingness to consider on market share in a logit model can be shown mathematically in the two-product case. In the standard logit, the purchase probabilities are given by $\pi_0 = \frac{e^{u_0}}{e^{u_0}+e^{u_1}}$ and $\pi_1 = \frac{e^{u_1}}{e^{u_0}+e^{u_1}}$. Subscripts 0 and 1 refer to "conventional" vehicles and "advanced technology" vehicles respectively. Implicit in this frame is the assumption that the representative consumer considers every possible vehicle model, at least those models in the market. This is how the NMNL model frames things as well.

However, the formulas for purchase probability change if one of the vehicle types has lower consideration that the other. (See Struben and Sterman 2008) Suppose all consumers consider the conventional vehicle, but only fraction w consider the advanced technology vehicle. The probabilities need to be rewritten as $\pi_0 = \frac{e^{u_0}}{e^{u_0}+we^{u_1}}$ and $\pi_1 = \frac{we^{u_1}}{e^{u_0}+we^{u_1}}$. Thus, it should be possible to adjust for consideration. "

3.6 Congruence Between Conceptual Methodologies and Program Execution

Two reviewers provide comment on whether the model functions as suggested in the documentation.

Bunch: "Although it may seem nitpicky, the NMNL model produced by ORNL quite literally does *not* satisfy the specification quoted above (nor should it have). Specifically, the ORNL model we were asked to review *by itself* is not capable of "estimating … effects of greenhouse gas (GHG) emissions standards." Rather, it *is* capable of estimating the effects (consumer surplus impacts and sales mix effects) of changes in two specific vehicle characteristics: sales price, and fuel economy. This is what the software we were given actually does. So, reviewing the ORNL model should presumably address technical aspects of how it does what it actually does."

Cameron: Believes that the software does what it appears to suggest in the documentation.

3.7 Clarity, Completeness, and Accuracy of Model's Calculations

One reviewer indicates that a more detailed analysis including a check of source code and knowledge of accurate data would be required to definitively assess the accuracy of the models calculations, while another states that the model's calculations are "too accurate" and "overstate the precision" of possible forecasts.

Bunch: "Depending on what is meant by "accuracy," I would either need to do a detailed analysis that includes checking the source code of the model (plus program my own version), or, I would need to have some specialized knowledge of what the "true" market shares and elasticities are. Either would not be workable. Having said this, I do recommend that additional test calculations be performed for validation purposes. . . . there is a relationship between price elasticities and NMNL structural parameters (aka "price slopes"), and that the mapping is not one-to-one. The method used by the authors is described on page 29. Although there may be better methods, this one seems sufficient in practice. The other question is how to choose the elasticities. They do this based on values found in the literature, also recognizing that the NMNL requires the type of ordering found in equation (38). They provide a discussion (page 31) to support their selections, which seem reasonable. Having said this, one thing that is missing is an analysis of the distribution of price elasticities produced from actual runs of the Model itself. This would seem to be a useful validation exercise."

Cameron: The model's calculations are too "accurate" and "overstate the precision with which such forecasts can possibly be made." It is important both to incorporate uncertainty and to acknowledge that "the user has to pick and choose between competing options for the point estimates of the elasticities for each level of the nests. Given the gaps in the empirical data, especially the differing vintages and contexts of the studies in which these sparse values have been quantified, the user just has to guess something reasonable for many of the settings, or use some kind of weighted average of the point estimates across different studies. If those studies were competently done, each estimate will come with confidence bounds and that uncertainty about these key ingredients to this program needs to be acknowledged somehow."

3.8 Accuracy of Model's Results and Appropriateness of Conclusions

One reviewer indicates that a more detailed analysis including a check of source code and knowledge of accurate data would be required to definitively assess the accuracy of the model's results. Another reviewer expresses concern about over stating the level of precision attainable.

Bunch: "Depending on what is meant by "accuracy," I would either need to do a detailed analysis that includes checking the source code of the model (plus program my own version), or, I would need to have some specialized knowledge of what the "true" market shares and elasticities are. Either would not be workable. Having said this, I do recommend that additional test calculations be performed for validation purposes. . . . there is a relationship between price elasticities and NMNL structural parameters (aka "price slopes"), and that the mapping is not one-to-one. The method used by the authors is described on page 29. Although there may be better methods, this one seems sufficient in practice. The other question is how to choose the elasticities. They do this based on values found in the literature, also recognizing that the NMNL requires the type of ordering found in equation (38). They provide a discussion (page 31) to support their selections, which seem reasonable. Having said this, one thing that is missing is an analysis of the distribution of price elasticities produced from actual runs of the Model itself. This would seem to be a useful validation exercise."

Cameron: "The model results leave the impression that these redistributions of consumer demand can be calculated, in many cases, to five or more significant figures, with certainty. Conditional on the "point" inputs and current market shares, precise estimates of the alternative-specific constants can be calculated for each Mfr/NamePlate/Model. However, this overstates the precision with which these constants are known because the point values that are inputs to the process are actually random variables which are not known with as much precision as is implied by the program. This sets aside any noise introduced by the various simplifications in the functional form of the model."

McManus: "Large changes in fuel prices over a short period of time have caused significant movement by consumers between vehicle classes. Most recently, the fuel price spike in 2008 caused many buyers to trade in trucks and SUVs for cars. The danger is that we might be applying lessons from changes in behavior involving mix switching to the value of fuel economy at the level of a vehicle."

3.9 Caveats About Using Model for Regulatory Analysis

Reviewers provide a range of opinion concerning use of the model for regulatory analysis.

Bunch: "The suitability of the model for regulatory analysis hinges on how it is used in conjunction with the OMEGA model. . . . The charge we were given also asks us to provide an opinion on the *suitability of the model for analyzing the effects of regulatory programs* on consumer vehicle choices." It is clear that the larger purpose associated with this model is to allow EPA to perform policy analysis related to CAFÉ/GHG regulations. However, this can only be done in conjunction with the OMEGA model. Unfortunately, the materials provided to us were insufficient in describing the relationship between this model and the OMEGA model. . . . It would seem important for regulatory analysis to establish some type of reference (baseline) scenario over the planning *period* (not to be confused with the base year). EIA produces forecasts of new vehicle sales as well as fuel price forecasts. There must be some working assumption about CAFÉ/GHG standards associated with these forecasts. What does EPA regard to be the reference assumptions for future CAFÉ/GHG standards? “

“The introductory material (in both the Charge and the Documentation) talks about OMEGA having “a 15 year planning horizon,” and indicates that the CVCM “will be calibrated to baseline sales projection data provided by the EPA.” This implies that policy analysis would involve establishing a 15-year baseline (reference) scenario under a reference policy, and then running OMEGA under alternative (15-year) policies. It is also the case that analyses of this type typically have a base year (not to be confused with a baseline). How this was handled was not specified.”

Cameron: “There should be heavy caveats that the error bounds on the calculated values are not presently being calculated. Thus it is not possible to know whether any *apparent* differences in the point estimates in the baseline versus the alternative scenarios are actually substantive (statistically significantly different from zero).”

McManus: The model’s authors have covered the salient caveats for regulatory analysis.

3.10 Recommendations and Specific Improvements

Reviewers note a variety of additions, corrections, and typographical errors that should be addressed in subsequent versions of the model and documentation.

Bunch: “There seems to be some murkiness around the changes in vehicle cost/price associated with the technology packages. In at least one place these are called “retail price equivalents” (RPE). In other places they are simply identified as “costs” or perhaps “long-run average costs.” More generally, it seems that manufacturers would be able to change vehicle prices as well as well as fuel economy in order to meet standards. Of course, the current version of OMEGA could not really deal with that because it does not incorporate sales shifts. However, one potential improvement to the ORNL model would be to identify price changes that would put manufacturers back into compliance. (Actually, the authors mention this on page 5.)

The reference to Train 5 is incorrect. It should be 1986. (The third printing was in 1991, but that is not the same thing.)

In the middle of page 5, it is claimed that the nesting structure in CVCM is similar to those used in empirically estimated models. I don’t think this is strictly true, but would welcome a reference. (NERA does a type of estimation, but assumes values for the structural parameters as is done here.)

On page 10 there are problems with equation (6), depending on the interpretation of the U values. The U values in equation (5) are random utilities, which are unknown and cannot be used in equation (6).

On page 11 it is claimed that the NMNL model is “also known as the Generalized Extreme Value (GEV) model.” This is incorrect. NMNL is a special case of the GEV.

On page 12, middle of page, it says “In equation (6) each nest has a different set of coefficients that map vehicle attributes into the utility index. In particular for this model, the price coefficients differ across nests.” This is generally not true for the form of the model they are attempting to use on this page, and represents the type of confusion that can arise based on the discussion in section 2.2.2 of my review.”

Cameron: "Among the global parameters, the user appears to be invited to provide individual independent estimates of the population and average household size from 2010 to 2030, although the note in line 6 suggests that these numbers come from the U.S. Census Bureau's projections of the U.S. population (not "polution") to 2050."

On the VehicleUse sheet, individual car and truck "Survial Rates, by age" should read "Survival".

The most disaggregated alternatives are generally called "elemental" alternatives, as in the Appendix. On page 26, however, they are called "elementary" alternatives.
In the Appendix (Derivation of Nested Logit Model Equations…), include the additional assumption that the error terms ε_c and $\varepsilon_{j|c}$ are independent and hence uncorrelated (so that there is no covariance term in the variance of their sum).

The current version of the CVCM software is desperately in need of some more user-friendly instructions. When you first open the program, the Help button is inactive. (There is a "Contents" button and an "About…" button, but these have not yet been populated/activated.) Clicking on the File button offers two options: "Open" and "Output file to…" as well as an "Exit" option. Those are the only clues the user gets.

Fortunately, the "Open" button takes you to the input folder inside the CVCM_v1.5 folder where the program resides, and it is logical to try the one called "Baseline" first. This action fills the two small boxes in the program's window with just some of the information from the input file.
a.) It is irritating that you cannot drag the corner of the window to expand its size. With a whole widescreen monitor to work with, and with content that must currently have its headings truncated to fit, a re-sizeable window would be great. Right now, if you expand one column, all the others must shrink. A slider at the bottom of each window would be helpful, as in Excel, so that you can keep each column heading fully expanded and scroll to see those which are out of the current window.
b.) There is nothing in the user interface to suggest that there is vastly more information in the Excel spreadsheet in the Input folder than what seems to populate the limited number of boxes in the program window when you choose an Input file.
c.) Even inside the Input file, it took me a while to notice that there were multiple sheets in this spreadsheet. 1130 vehicles in the Vehicle sheet, 18 car companies in the Manufacturer sheet
d.) There is nothing to imply that the automobile icon in the upper right corner is the "execute" button. It just looked like a cute little graphic.

McManus: On page 4, sources of prediction errors should add "unexpected behavior by consumers over time."

4. References

Greene, D. and C. Liu (2011), Consumer Vehicle Choice Model Documentation

Appendix A: Resumes of Peer Reviewers

David S. Bunch

Current address:
Graduate School of Management
One Shields Avenue
University of California, Davis
Davis, CA 95616
USA

Phone: 530-752-2248
Fax: 530-752-2924
Email: dsbunch@ucdavis.edu
Web page: www.gsm.ucdavis.edu/~bunch

Education

Ph. D., Rice University, 1985 (Mathematical Sciences)
Master in Applied Mathematical Sciences, Rice University, 1981
M. S., Northwestern University, 1979 (Chemistry)
B. A. (cum laude), Rice University, 1978 (Chemistry)

Positions

Professor of Management, UC Davis, July 2000-present
Acting Director, 'Center for New Mobility Studies,' Institute of Transportation Studies, UC Davis, October 1999-August 2000.
Associate Professor of Management, UC Davis, July 1992-July 2000.
Visiting Scholar, Department of Marketing, Faculty of Economics, University of Sydney. July 1997-July 1998.
Assistant Professor of Management, UC Davis. July 1985-June 1992.
Visiting Assistant Professor, UC Davis. July 1984-June 1985.
Associate, Rice Center, Houston, Texas. May 1982-August 1983.
Research Associate, The Institute for Rehabilitation and Research, Houston, Texas. February 1980-January 1982.

Courses taught

Product Management
Marketing for E-Commerce
Marketing Research
Management Policy
Decision Making and Management Science
Marketing Models for New Products
Discrete Choice Analysis
Managerial Decision Making
Systems Analysis and Design
Applied Linear Models for Management
Special Topics in Management of Information Systems
Seminar in Management

Publications and Papers

"Fuel Economy and CO2 Emissions: Standards, Manufacturer Pricing Strategies, and Feebates," with C. Liu and D. L. Greene, In Preparation.

"Impacts of Feebates in Combination with Fuel Economy and Emissions Standards on U.S. Light-Duty Vehicle Fuel Use and Greenhouse Gas Emissions," with C. Liu, D. L. Greene, E. C. Cook, Transportation Research Board, Paper 11-2027.

"Potential Design, Implementation, and Benefits of a Feebate Program for New Passenger Vehicles in California" (with D. L. Greene, T. Lipman, E. Martin, S. Shaheen), California Air Resources Board, Final Report on Contract UCD 08-312, University of California, Davis, CA, February, 2011.

"Potential Design, Implementation, and Benefits of a Feebate Program for New Passenger Vehicles in California: Interim Statement of Research Findings" (with David L. Greene). Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-10-13

"Follow-on Development of CARBITS: A Response Model for the California Passenger Vehicle Market," Final Report (Contract 05-303) prepared for State of California Air Resources Board, April 30, 2009.

"Exploring the Consumer Valuation of Organic-Related Properties in Fresh Produce Choice," (with Yuko Onozaka and Doug Larsen), Working Paper.

"Theory-based Functional Forms for Analysis of Dissagregated Scanner Panel Data" Working Paper.

"Behavioral Models and Estimates for Leisure-Passenger Value of Travel-Time Saving in Long-Hall Air Travel Markets Using Stated Choice Experiments" Working Paper.

"Behavioral Frontiers in Choice Modeling" (with Wiktor Adamowicz, Trudy Ann Cameron, Benedict G. C. Dellaert, Michael Hanneman, Michael Keane, Jordan Louviere, Robert Meyer, Thomas Steenburgh and Joffre Swait), Marketing Letters, Volume 19, Numbers 3-4 (December, 2008), pp. 215-228.

"Automobile Demand and Type Choice," Handbook of Transport I: Transport Modeling (Second Edition), with Belinda Chen, in David A. Hensher and Kenneth J. Button, editors, Pergamon, (2008) pp. 463-479.

"Joint mixed logit models of stated and revealed preferences for alternative-fuel vehicles" (with David Brownstone and Kenneth Train) in The Stated Preference Approach to Environmental Valuation, Volume III: Applications: Benefit-Cost Analysis and Natural Resource Damage Assessment, ed. Richard T. Carson, Series: The International Library of Environmental Economics and Policy, Ashgate Publishing (2007).

Publications and Papers -cont.-

"Hybrid Choice Models: Progress and Challenges," (with Moshe Ben-Akiva, Daniel McFadden, Kenneth Train, Joan Walker, Chandra Bhat, Michel Bierlaire, Denis Bolduc, Axel Boersch-Supan, David Brownstone, Andrew Daly, Andre de Palma, Dinesh Gopinath, Anders Karlstrom and Marcela A. Munizaga), Chapter 11 in Transportation Planning, Classics in Planning Series, Volume 7, eds. Yoram Shiftan, Kenneth Button, Peter Nijkamp, Edward Elgar Publishing (May, 2007).

"California Air Resources Board – Institute of Transportation Studies (CARBITS) Vehicle Market Microsimulation Model for California, UC Davis Institute of Transportation Studies Research Report (2004).

"Purchase Pattern Analysis for Organic and Conventional Produce with Detailed Supermarket Scanner Data," Working Paper, with Doug Larson and Yuko Onozaka (2004).

"Hybrid Choice Models: Progress and Challenges," (with Moshe Ben-Akiva, Daniel McFadden, Kenneth Train, Joan Walker, Chandra Bhat, Michel Bierlaire, Denis Bolduc, Axel Borsch-Supan, David Brownstone, Andrew Daly, Andre de Palma, Dinesh Gopinath, Anders Karlstrom, Marcela A. Munizaga), Marketing Letters, 13(3): pp. 163-175 (August 2002).

"Optimal Designs for 2^k Paired Comparison Experiments," (with Deborah J. Street and Beverly Moore), Communications in Statistics - Theory and Methods, 30(10), pp. 2149-2171 (2001).

"Automobile Demand and Type Choice," Handbook of Transport I: Transport Modeling, David A. Hensher and Kenneth J. Button, editors, Pergamon (2000), pp. 463-479.

"The First-Passage Approach to Valuing the American Put," (with Herb Johnson). Journal of Finance, 55 (5), (October 2000), pp. 2333-2356.

"Joint Mixed Logit Models of Stated and Revealed Preferences for Alternative-fuel Vehicles" (with David Brownstone and Kenneth Train). Transportation Research B, Volume 34, Issue 5 (June 2000), pp. 315-449.

"Combining Sources of Preference Data for Modeling Complex Decision Processes" (with Jordan J. Louviere, Robert J. Meyer, Richard Carson, Benedict Delleart, W. Michael Hanemann, David Hensher, and Julie Irwin). Marketing Letters, Volume 10, Issue 3 (August 1999), pp. 205-217.

"Discussion of 'Multi-Featured Products and Services: Analyzing Pricing and Bundling Strategies' by Moshe Ben-Akiva and Shari Gershenfeld" (with Jordan J. Louviere), Journal of Forecasting, Volume 17, Issue 3-4 (1998), pp. 197-201.

Publications and Papers -cont.-

"Determinants of Alternative Fuel Vehicle Choice in the Continental United States" (with Melanie Tompkins, Danilo Santini, Mark Bradley, Anant Vyas, and David Poyer), Transportation Research Record, Number 1641, Energy and Environment: Energy Air Quality, and Fuels 1998, Transportation Research Board, National Research Council.

"Commercial Fleet Demand for Alternative-fuel Vehicles," (with Thomas F. Golob, Jane Torous, David Brownstone, Soheila Crane, and Mark Bradley), Transportation Research A Vol. 31A (1997): 219-233.

"A Vehicle Usage Forecasting Model Based on Revealed and Stated Vehicle Type Choice and Utilization Data," (with Thomas F. Golob and David Brownstone), Journal of Transport Economics and Policy Vol. 31 (1997): 69-92.

"Analysis of the Future Household Market for Alternative Fuel Vehicles in Southern California Using a Microsimulation Forecasting System," (with Camilla Kazimi), University of California-Davis, Graduate School of Management Working Paper UCD GSM WP# 05-96 (1996).

"A Comparison of Experimental Design Strategies for Choice-Based Conjoint Analysis with Generic-Attribute Multinomial Logit Models (with Jordan J. Louviere, and Don Anderson). (1996, revised version of UCD GSM Working Paper 01-94).

"A Dynamic Forecasting System for Vehicle Markets with Clean-Fuel Vehicles," (with David Brownstone and Thomas F. Golob). In D. A. Hensher, J. King, and T. H Oum eds., World Transport Research, Volume 1 (1996): 189-203.

"A Vehicle Transactions Choice Model for Use in Forecasting Demand for Alternative-Fuel Vehicles," (with David Brownstone, Thomas F. Golob, and Weiping Ren), Research in Transportation Economics, Vol. 4 (1996): 87-129.

"A Demand Forecasting System for Clean-Fuel Vehicles," (with David Brownstone and Thomas F. Golob), in Organization for Economic Co-operation and Development (OECD) Towards Clean Transportation: Fuel Efficient and Clean Motor Vehicles, Publications Service, OECD, Paris, France, 1996, 609-624.

"Experimental Analysis of Choice," (with J. Louviere, R. Carson, D. Anderson, P. Arabie, D. Hensher, R. Johnson, W. Kuhfeld, D. Steinberg, J. Swait, H. Timmermans, and J. Wiley), Marketing Letters, Vol 5:4, 351-368.

"Extension of the Four-Parameter Logistic Model for ELISA to Multianalyte Analysis," (with G. Jones M. Wortberg, S. Kreissig, S. Gee, B. Hammock, and D. Rocke), Journal of Immunological Methods, Vol. 177, 1-7.

Publications and Papers -cont.-

"Demand for Clean-Fuel Vehicles in California: A Discrete-Choice Stated Preference Survey" (with Mark Bradley, Thomas F. Golob, Ryuichi Kitamura, Gareth P. Occhiuzzo). Transportation Research A, Vol. 27A, No. 3, pp. 237-253, 1993.

"Predicting the Market Penetration of Electric and Clean-fuel Vehicles" (with Thomas F. Golob, Ryuichi Kitamura, and Mark Bradley), The Science of the Total Environment, 134 (1993) pp. 371-381.

"Subroutines for Maximum Likelihood and Quasi-Likelihood Estimation of Parameters in Nonlinear Regression Models" (with David M. Gay, and Roy E. Welsch). ACM Transactions on Mathematical Software, Vol. 19, No. 1, March 1993, Pages 109-130.

"Who Deters Entry? Evidence on the Use of Strategic Entry Deterrents" (with Robert Smiley). Review of Economics and Statistics, Vol. 74, No. 3 (August 1992), pp. 509-521.

"A Simple and Numerically Efficient Valuation Method for American Puts Using a Modified Geske-Johnson Approach" (with Herb Johnson). Journal of Finance, Vol. XLVII, No. 2 (June 1992), pp. 809-816.

"Estimability in the Multinomial Probit Model," Transportation Research B, 1991, Vol 25B(1), pp. 1-12.

"Statistical Design of ELISA Protocols," Journal of Immunological Methods, 1990, (with David Rocke and Robert Harrison), 132 (1990), 247-254.

"Heterogeneity and State Dependence in Household Car Ownership: A Panel Analysis Using Ordered-Response Probit Models with Error Components," 11th International Symposium on Transportation and Traffic Theory, Elsevier, July 1990 (with Ryuichi Kitamura).

"Multinomial Probit Model Estimation Revisited: Testing Estimable Model Specifications, Maximum Likelihood Algorithms, and Probit Integral Approximations for Trinomial Models of Household Car Ownership," Transportation Research Group Research Report UCD-TRG-RR-4, April 1990, (with Ryuichi Kitamura).

"How Many Choices Are Enough?' The Effect of the Number of Observations on Maximum Likelihood Estimator Performance in the Analysis of Discrete Choice Repeated-Measures Data Sets with the Multinomial Logit Model," UC Davis Graduate School of Management Working Paper UCD-GSM-WP0390, January 24, 1990, (with Richard Batsell).

A Comparison of Algorithms for Maximum Likelihood Estimation of Finite Mixture Density Models. Working paper.

"When Are Additive Models Valid for Evaluating Proposed Research?," Methods of Information in Medicine, 1989, 28, pp. 168-177 (with D. Cardus, M. J. Furher, R. M. Thrall).

Publications and Papers -cont.-

"A Monte Carlo Comparison of Estimators for the Multinomial Logit Model" (with Richard R. Batsell), Journal of Marketing Research, February 1989, pp. 56-68.

"A Comparison of Algorithms for Maximum Likelihood Estimation of Choice Models," Journal of Econometrics, May/June 1988, Vol. 38, No. 1/2, pp. 145-167.

"Efficient Algorithms for Maximum Likelihood Estimation of Probabilistic Choice Models, SIAM Journal of Scientific and Statistical Computing, 1987, 8(1), 56-70.

"Parameter Estimation of Probabilistic Choice Models," Department of Mathematical Sciences Technical Report TR84-5 (Ph.D. Thesis), Rice University, 1984.

Presentations

"Recent Advances in Modeling Multiple Discrete-Continuous Choices," Invited Workshop Presentation, Second International Choice Modelling Conference, Oulton Hall, Leeds, July 5, 2011.

"Potential Impacts of Feebate Programs for New Passenger Vehicles," (with D. L. Greene and T. E. Lipman), California Air Resources Board – Cal/EPA HQ, Sierra Hearing Room, June 14, 2011.

"Economic Incentives for New Vehicle Purchases to Reduce Greenhouse Gas Emissions: Research on Policy Options for California," Transportation Center Seminar Series, Northwestern University Wednesday, August 12, 2009.

"University of California Feebates Research Project," Kitamura Memorial Symposium, June 29, 2009, University of California, Davis.

"University of California Feebates Research Project," presented at the Fuel Economy/Greenhouse Gas Emissions Standards – Technical Meeting, California Air Resources Board, June 17, 2009.

"Feebate Policy Workshop," (with David L. Greene and Tim Lipman) California Air Resources Board, February 26, 2009.

"Theory-based Functional Forms for Analysis of Dissagregated Scanner Panel Data," presented to workshop on Behavioral Frontiers in Choice Models, Seventh Tri-Annual Choice Symposium, Wharton, June 2007.

"Theory-based Functional Forms for Analysis of Dissagregated Scanner Panel Data," presented to the 2007 Bay Area Marketing Consortium, May 11, 2007.

"Recent Advances in Discrete Choice Models," (with Jordan J. Louviere), tutorial workshop, Thirteenth Annual Advanced Research Techniques (A/R/T) Forum, Vail, Colorado (June 2-5, 2002).

Presentations -cont.-

"Identifying Optimal Offerings and Campaigns In Interactive Channels Using Real-Time Experiments and Automated Modelling Procedures," (with Moshe Ben-Akiva, Denis Bolduc, Richard Carson, Jordan Louviere, Hikaru Phillips, Matthew Symons), Thirteenth Annual Advanced Research Techniques (A/R/T) Forum, Vail, Colorado (June 2-5, 2002).

"Information and Sample Size Requirements for Estimating Non-IID Discrete Choice Models Using Stated-Choice Experiments," 2001 UC Berkeley Invitational Choice Symposium, Asilomar Conference Center, Pacific Grove, California, June 1-5, 2001.

"Estimation of Non-IIA Discrete Choice Models," Winter Quarter Econometrics Seminar Series, Department of Economics, UC Davis (February 19, 1999).

"Implications of Choice Task Complexity Effects for Design and Analysis of Discrete Choice Experiments" (with Jeff D. Brazell and Jordan J. Louviere). Presented at 1998 INFORMS Marketing Science Conference, INSEAD, Paris (July 1998).

"Estimating Non-IIA Models Using Discrete Choice Stated-Preference Data: Model Forms, Sample Size Effects, and Simulation Estimation." Presentation to workshop on "Combining Sources of Preference Data for Modeling Complex Decision Processes," HEC Invitational Choice Symposium, Paris (July, 1998).

"Estimating Non-IIA Models Using Discrete Choice Stated-Preference Data: Model Forms, Sample Size Effects, and Simulation Estimation." Presentation to PhD seminar, Department of Marketing, University of Sydney, Australia (May 27, 1998).

"Optimal Designs: Discussion." Presented at "Workshop on Experimental Design and Experimental Data: Alternative Perspectives," Department of Econometrics, University of Sydney, Australia (May 8, 1998).

"Computational Methods for Maximum Likelihood Estimation." Presentations to Ph.D. course in "Bayesian Estimation Methods," AGSM (Australian Graduate School of Management), University of New South Wales, Sydney, Australia (May 1, May 15, 1998).

"Determinants of Alternative Fuel Vehicle Choice in the Continental United States" (with Tompkins, Santini, Bradley, Vyas, and Poyer), Presented at 1998 Transportation Research Board Meetings, Washington, D. C. (January 1998).

"Random Parameter Logit Models to Forecast Vehicle Ownership" (with David Brownstone and Kenneth Train), in preparation. Presented at the Eighth Meeting of the International Association of Travel Behavior Research, September 1997, University of Texas, Austin.

"Analysis and Forecasts of EV Markets: Background and Methods for Multi-Year Household Surveys." Presented at "Electric Vehicle Markets: Conceptual and Analytical Approaches for Understand EV Demand," Institute of Transportation Studies, UC Davis (November 20, 1996).

Presentations -cont.-

"Analysis and Forecasts of EV Markets: Results for Multi-Year Household Surveys." Presented at "Electric Vehicle Markets: Conceptual and Analytical Approaches for Understand EV Demand," Institute of Transportation Studies, UC Davis (November 20, 1996).

"Using Dynamic Microsimulation and an Integrated System of Revealed Preference and Stated Preference Discrete Choice Models to Estimate Penetration of Electric Cars in the California Vehicle Market" (with D. Brownstone and T. F. Golob), presented at the 1996 INFORMS Marketing Science Conference, March 1996, University of Florida, Gainesville.

"Testing a multinomial extension of partial profile choice experiments: Empirical comparisons to full profile choice experiments" (with Keith Chrzan and Daniel C. Lockhart), presented at the 1996 INFORMS Marketing Science Conference, March 1996, University of Florida, Gainesville.

"Forecasting future vehicle usage using a jointly-estimated revealed- and stated-preference model" (with T. F. Golob and D. Brownstone). Presented at the Annual Meeting of Transportation Research Board, National Research Council, National Academy of Sciences, Washington, D.C., January 7-11, 1996.

"The future of alternative fuel vehicles in California: Projections from a microsimulation forecasting system" (with D. Brownstone and T. F. Golob). Presented at the Annual Meeting of Transportation Research Board, National Research Council, National Academy of Sciences, January 7-11, 1996, Washington, DC.

"Using Stated Preference and Intended Transactions to Predict Market Structure Changes for the Personal Vehicle Market in California," (with D. Brownstone, and T. F. Golob), presented at the 1995 Marketing Science Conference, July 1995, University of New South Wales, Sydney, Australia.

"Design strategies for experimental choice sets: Comparison of methods for multinomial logit models," (with J. Louviere and D. Anderson), presented at the 1994 Marketing Science Conference, March 1994, University of Arizona, Tucson, AZ.

"A Demand Forecasting System for Clean-Fuel Vehicles," (D. Brownstone, D. S. Bunch, and T. F. Golob), presented at the OECD Conference "Fuel Efficient and Clean Motor Vehicles," Mexico City, March 28-30, 1994.

"Choice models from experimental choice sets," Workshop 2 Participant at Duke Invitational Symposium on Choice Modeling and Behavior (no-formal-presentation format), August 1993, Fuqua School of Business, Durham, North Carolina.

"Predicting the market penetration of electric and clean-fuel vehicles," (T. F. Golob, R. Kitamura, M. Bradley, D. S. Bunch), presented at International Symposium on Transport and Air Pollution, September 10-13, 1991, Avignon, France.

Presentations -cont.-

"Modelling the choice of clean fuels and clean-fuel vehicles," (R. Kitamura, M. Bradley, D. S. Bunch, and T. F. Golob), presented at the PTRC Annual Meeting, September 9-12, 1991, University of Sussex, England.

"Demand for clean-fuel personal vehicles in California: A discrete-choice stated-preference survey," (with M. Bradley, T. F. Golob, R. Kitamura, and G. Occhiuzzo), presented at the Transportation Research Board Conference on Transportation and Global Climate Change: Long Run Options, August 25-28, 1991, Asilomar Conference Center, Pacific Grove, California.

"Advances in Computation, Statistical Methods and Testing," Workshop 1 participant, Banff Invitational Symposium on Consumer Decision Making and Choice Behavior (no-formal-presentation format), May 8-15, 1990, Banff, Alberta, Canada.

"Heterogeneity and State Dependence in Household Car Ownership: A Panel Analysis Using Ordered-Response Probit Models with Error Components," (with Ryuichi Kitamura) presented at TIMS/ORSA Joint National Meeting, Las Vegas, May 1990.

"Multinomial Probit Model Estimation Revisited: Testing Estimable Model Specifications, Maximum Likelihood Algorithms, and Probit Integral Approximations for Trinomial Models of Household Car Ownership," (with Ryuichi Kitamura), presented at the 69th Annual Meeting of the Transportation Research Board, Washington, D. C., January, 1990.

"A Panel Analysis of Car Ownership Using the Multinomial Probit Model," (with Ryuichi Kitamura) Fall ORSA/TIMS meeting, Denver, October 1988.

"How Many Choices Are Enough? The Effect of Replications on MLE Performance in the Analysis of Discrete Choice Repeated-Measures Data Sets," invited presentation at the Joint Statistical Meetings of the American Statistical Association and the Biometric Society, August, 1988.

"A Monte Carlo Comparison of Estimators for the Multinomial Logit Model," presented at the Fall ORSA/TIMS meeting, St. Louis, October 1987.

"A Comparison of Algorithms for Maximum Likelihood Estimation of Choice Models," presented at the SIAM Conference on Optimization, Houston, May, 1987.

"Efficient Algorithms for Maximum Likelihood Estimation of Probabilistic Choice Models." Invited presentation for Computer Science and Statistics: the 18th Symposium on the Interface, Fort Collins, Colorado, March 1986.

Grants and Contracts -cont.-

University of California Center for Energy and Environmental Economics, 2011-2012. "The Demand for High Fuel Economy Vehicles," (with D. Brownstone).

California Air Resources Board, 2009-2011. Potential Design, Implementation, and Benefits of a Feebate Program for New Passenger Vehicles in California (with David L. Greene).

California Air Resources Board, 2005-2009. Follow-on Development of CARBITS: A Response Model for the California Passenger Vehicle Market.

California Air Resources Board, 2002-2004. Analysis of Auto Industry and Consumer Response to Regulations and Technological Change, and Customization of Consumer Response Models in Support of AB 1493 Rulemaking (with D. Sperling and A. Burke).

University of California Energy Institute, 1996-1997. An Evaluation of Policies Related to Vehicular Energy Use (with Golob and Brownstone).

California Energy Commission, 1995-1996. Development of Policy Sensitive Transportation Forecasting Models for Personal, Commercial Fleet, and Freight Activity (with Golob, Brownstone, and Kitamura).

Pacific Gas and Electric, 1993-1995. Alternative Vehicles in the Pacific Gas and Electric Service Area: A Project for Developing Models and Scenario Simulation Systems for Forecasting AFV Penetration and Usage. (Principal investigator, with Co-PI's Golob, Kitamura, and Brownstone).

Southern California Edison, 1992-1994. Forecasting Electrical Vehicle Ownership and Use in the California South Coast Basin (with Golob, Kitamura, and Brownstone).

United States Department of Transportation, 1992-1993. Improved Designs for Stated Preference Analysis of Transport-Choice Processes (continuation).

United States Department of Transportation, 1991-1992. Improved Designs for Stated Preference Analysis of Transport-Choice Processes.

National Institutes of Health, National Institute of Environmental Health Sciences, 1988-1992. Decision Support System for Statistical Analysis of Toxics Measurement Data (with Rocke). Renewed for 1993-1996 (with Rocke).

California Energy Commission, 1991-1992. Assessing the Potential Acceptance of Alternative Fuels and Vehicles in California's Commercial Fleets (with Golob and Kitamura)

California Energy Commission, 1990-1992. Clean Vehicles/Clean Fuels Stated Preference Pilot Study (with Golob and Kitamura).

Grants and Contracts -cont.-

United States Department of Transportation, 1990-1991. Impact of Telecommuting on T ravel: Accessibility Implications of Working at Home (with Kitamura, Jovanis, and Mokhtarian).

United States Department of Transportation, 1988-1990. Evaluation of the Impact of Telecommuting on Travel Patterns, Road Congestion, Energy Use and Air Quality (with Kitamura).

Professional Societies

INFORMS (Institute for Operations Research and Management Science)
Society for Industrial and Applied Mathematics

Editorial Board Journal of Choice Modeling

Reviewing

Reviewer for:

- ACM Transactions on Mathematical Software
- Annals of Operations Research
- Computational Statistics and Data Analysis
- Department of Transportation (UC Transportation Center)
- IEEE Transactions on Signal Processing
- Journal of the American Statistical Society
- Journal of Computational and Graphical Statistics
- Journal of Business and Economic Statistics
- Journal of Econometrics
- Journal of Forecasting
- Journal of Marketing Research
- Mathematical Programming
- Marketing Science
- National Science Foundation
- SIAM Journal on Optimization
- SIAM Journal on Scientific and Statistical Computing
- Transportation Research
- Transportation Research Board (TRB)
- Transportation Science

CURRICULUM VITA

Trudy Ann Cameron

Department of Economics, University of Oregon

Department of Economics, 435 PLC
1285 University of Oregon
Eugene, OR 97403-1285

(541) 346-1242   (541) 346-4661
FAX: (541) 346-1243
Email: cameron@uoregon.edu

Education
University of British Columbia, B.A. (Honours Economics), 1977
Princeton University, Ph.D. (Economics), 1982

Professional Employment

Jan. 2002 to present	R.F. Mikesell Professor of Environment and Resource Economics, University of Oregon
July 1997 to Feb. 2005	Professor, University of California, Los Angeles
July 1990 to June 1997	Associate Professor, UCLA
July 1985 to June 1990	Assistant Professor, UCLA
July 1984 to June 1985	Visiting Assistant Professor, UCLA
July 1983 to June 1984	Visiting Assistant Professor, Claremont McKenna College
July 1982 to June 1984	Assistant Professor, University of British Columbia
July 1981 to June 1982	Instructor II, University of British Columbia

Fields of Interest

Applied Microeconomics:
- environmental and resource economics
- environmental health; climate; recreational values; migration
- economics of non-market and public goods
- stated versus revealed preferences
- behavioral models of consumer demand, utility

Applied Econometrics:
- qualitative choice modeling
- censored and limited dependent variable models
- alternative distributional assumptions

Research:

Publications
- in print or forthcoming

“Willingness to pay for other species’ well-being,” Brian Vander Naald and Trudy Ann Cameron, *Ecological Economics* (forthcoming 2011)
“Distal order effects in stated preference surveys,” Beilei Cai, Trudy Ann Cameron, Geoffrey R. Gerdes, *Ecological Economics* (forthcoming 2011)
“Scenario adjustment in stated preference research,” Trudy Ann Cameron, J.R. DeShazo and Erica H. Johnson, *Journal of Choice Modelling* (forthcoming 2011).
“Differential attention to attributes in utility-theoretic choice models,” Trudy Ann Cameron and J.R. DeShazo, *Journal of Choice Modelling* 3(3) 73-115 (November 2010).
“Demand for health risk reductions: A cross-national comparison between the U.S. and Canada,”
Trudy Ann Cameron, J.R. DeShazo and Peter Stiffler, *Journal of Risk and Uncertainty* 41(3) 245-273 (December 2010)
“Euthanizing the value of a statistical life,” Trudy Ann Cameron, *Review of Environmental Economics and Policy* 4(2) 161-178 (Summer 2010)

“Is an ounce of prevention worth a pound of cure? Comparing demand for public prevention and treatment policies,” Ryan Bosworth, Trudy Ann Cameron, and J.R. DeShazo, *Medical Decision Making* 30(4) E40-E56 (Jul-Aug 2010)

“Distributional preferences and the incidence of costs and benefits in climate change policy,” Beilei Cai, Trudy Ann Cameron, and Geoffrey R. Gerdes, *Environmental and Resource Economics* 46(4) 429-458 (Aug 2010) (DOI 10.1007/s10640-010-9348-7)

“The effect of children on adult demands for health-risk reductions,” Trudy Ann Cameron, J.R. DeShazo, and Erica H. Johnson, *Journal of Health Economics* 29(3): 364-376, (May 2010)

“The effect of consumers' real-world choice sets on inferences from stated preference surveys,” J.R. DeShazo, Trudy Ann Cameron, and Manrique Saenz, *Environmental & Resource Economics* 42(3) 319-343 (March 2009)

“Demand for environmental policies to improve health: Evaluating community-level policy scenarios,” Ryan Bosworth, Trudy Ann Cameron, and J.R. DeShazo, *Journal of Environmental Economics and Management* **57**(3), 293-308 (May 2009).

“Popular support for climate change mitigation: Evidence from a general population mail survey,” J. Jason Lee and Trudy Ann Cameron, *Environment and Resource Economics* 41(2) 223-248 (October 2008)

“Behavioral frontiers in choice modeling,” Wiktor Adamowicz, David Bunch, Trudy Ann Cameron, Benedict G.C. Dellaert, Michael Hanneman, Michael Keane, Jordan Louviere, Robert Meyer, Thomas Steenburgh, Joffre Swait, *Marketing* Letters **19**(3-4), 215-228, Dec (2008).

“Valuing publicly sponsored research projects: Risks, scenario adjustments, and inattention,” Daniel R. Burghart, Trudy Ann Cameron, and Geoffrey R. Gerdes, *Journal of Risk and Uncertainty*, 35(1), 77-105 (August 2007).

“Can stigma explain large property value losses? The psychology and economics of superfund,” Kent Messer, William Schulze, Katherine F. Hackett, Trudy Ann Cameron, and Gary McClelland; *Environment and Resource Economics*, 33(3), 299-324, 2006. (**Reprinted** in Sigman, Hilary (2008) *The Economics of Hazardous Waste and Contaminated Land*, Edward Elgar.

“Evidence of environmental migration,” Trudy Ann Cameron and Ian McConnaha, *Land Economics*, 82(2), 273-290 (May 2006). (**Reprinted** in Fullerton, D. Distributional Effects of Environmental and Energy Policy, Ashgate Publishing, 2009)

“Directional heterogeneity in distance profiles in hedonic property value models,” Trudy Ann Cameron; *Journal of Environmental Economics and Management*, 51(1),26-45, 2006.

“Recent progress on endogeneity in choice modeling,” Jordan Louviere, Kenneth Train, Moshe Ben-Akiva, Chandra Bhat, David Brownstone, Trudy Ann Cameron, Richard Carson, J.R. DeShazo, Denzil Feibig, William Greene, David Hensher, and Donald Waldman, *Marketing Letters*, 16(3-4), 255-265, 2005

“Updating subjective risks in the presence of conflicting information: An application to climate change,” *Journal of Risk and Uncertainty*, 30(1) 63-97, 2005. “Individual option prices for climate change mitigation,” *Journal of Public Economics,* 2005*,* 89, 283-301.

“Dissecting the random component of utility,” (J. Louviere, D. Street, R. Carson, A. Ainslie, J.R. DeShazo, T. Cameron, D. Hensher, R. Kohn, T. Marley) *Marketing Letters* 13(3) 177- 193, 2002.

"Alternative nonmarket value-elicitation methods: Are the underlying preferences the same?" (T.A. Cameron, W.D. Schulze, R.G. Ethier, and G.L. Poe) *Journal of Environmental Economics and Management* 44(3) 391_425 November 2002 (doi:10.1006/jeem.2001.1210)).

"Nonresponse bias in mail survey data: Salience vs. endogenous survey complexity" (T.A. Cameron, W.D. Shaw, and S. Ragland), in *Valuing the Environment Using Recreation Demand Models*, J.A. Herriges and C.L. Kling (eds.) Edward Elgar Publishing Ltd., (1999) 217-251.

"Estimation using contingent valuation data from a 'Dichotomous Choice with Follow-up' questionnaire: Reply" (T.A.Cameron and J. Quiggin), *Journal of Environmental Economics and Management*, 1998.

"Respondent experience and contingent valuation of environmental goods" (T.A. Cameron and J. Englin) *Journal of Environmental Economics and Management* 33(3), 1997, 296-313.

"Welfare Effects of Changes in Environmental Quality under Individual Uncertainty about Use," (T.A.Cameron and J.Englin) *RAND Journal of Economics*, 28(0) Special Issue, 1997, S45-S70.

"Using actual and contingent behavior data with differing levels of time aggregation to model recreational demand" (T.A. Cameron, W.D. Shaw, S.R. Ragland, J.M.Callaway, and S. Keefe) *Journal of Agricultural and Resource Economics* 21(1) 1996, 130-149.

"Augmenting travel cost models with contingent behaviour data: Poisson regression analyses with individual panel data" (J. Englin and T.A. Cameron), *Environmental and Resource Economics* 7, 1996, 133-147.

"Estimation using contingent valuation data from a 'Dichotomous Choice with Follow-up' questionnaire" (T.A.Cameron and J..Quiggin), *Journal of Environmental Economics and Management*, 27(3) November 1994, pp. 218-234.

"Nonuser resource values," (T.A. Cameron) *American Journal of Agricultural Economics* 74 (December 1992), pp. 1133-1137.

"Combining contingent valuation and travel cost data for the valuation of non-market goods," (T.A. Cameron) *Land Economics* 68 (August 1992). (**Reprinted** in Carson, Richard T. *The Stated Preference Approach to Environmental Valuation, Volume II: Conceptual and Empirical Issues*, Ashgate Publishing Ltd., 2007)

"Energy audit programs versus market incentives as inducements to undertake energy conservation retrofits," (T.A. Cameron and M. Wright) *Natural Resources Modelling* 5 (Winter 1991).

"'Referendum' contingent valuation estimates: Sensitivity to the assignment of offered values," (T.A. Cameron and D.D. Huppert) *Journal of the American Statistical Association* (December 1991) 19-53. (**Reprinted** in Carson, Richard T. *The Stated Preference Approach to Environmental Valuation, Volume I: Foundations, Initial Development, Statistical Approaches*, Ashgate Publishing Ltd., 2007; **Reprinted** in Herriges, Joseph and Cathy Kling, *Revealed Preference Approaches to Environmental Valuation: Volume II: Hedonic Models*, Ashgate Publishing, forthcoming 2008)

"Interval estimates of non-market resource values from referendum contingent valuation surveys," (T.A. Cameron) *Land Economics* (November 1991).

"Cameron's censored logistic regression model: Reply" (T.A. Cameron) *Journal of Environmental Economics and Management*, 20 (1991) 303-4.

"The determinants of household water conservation retrofit activity," (T.A. Cameron and Matthew Wright), *Water Resources Research* (February, 1990). (**Reprinted** in Grafton, R. Quentin, Economics of Water Resources (two-volume set), The International Library of Critical Writings in Economics, Edward Elgar Publishing, Cheltenham, UK, 2008)

"One-stage structural models to explain city size," (T.A. Cameron) *Journal of Urban Economics*, 27 (1990) 294-307.

"OLS versus ML estimation of non-market resource values with payment card interval data," (T.A. Cameron and Daniel D. Huppert), *Journal of Environmental Economics and Management*, 17 (1989) 230-246.

"A new paradigm for valuing non-market goods using referendum data: Maximum likelihood estimation by censored logistic regression," (T.A. Cameron) *Journal of Environmental Economics and Management*, 15 (1988) 355-379. (**Reprinted** in Carson, Richard T. The Stated Preference Approach to Environmental Valuation, Volume I: Foundations, Initial Development, Statistical Approaches, Ashgate Publishing Ltd., 2007)

"Estimating willingness-to-pay from survey data: An alternative pre-test market evaluation procedure," (T.A. Cameron and M.D. James), *Journal of Marketing Research,* 24 (November 1987) 389-395.

"Generalized gamma family regression models for long distance telephone call durations," (T.A. Cameron and K.J. White) in A. de Fontenay, M. Shugard, and D. Sibley (eds.), *Telecommunications Demand Modeling*, Amsterdam: North-Holland (1990) 333-350.

"The impact of grouping coarseness in alternative grouped-data regression models," (T.A. Cameron) *Journal of Econometrics*, 35 (1987) 37-57.

"Efficient estimation methods for 'closed ended' contingent valuation surveys," (T.A. Cameron and M.D. James), *Review of Economics and Statistics*, 69, no. 2 (May 1987) 269-276. (**Reprinted** in Carson, Richard T. The Stated Preference Approach to Environmental Valuation, Volume I: Foundations, Initial Development, Statistical Approaches, Ashgate Publishing Ltd., 2007)

"Permanent and transitory income in models of housing demand," (T.A. Cameron) *Journal of Urban Economics*, 20, no. 2 (September 1986) 205-210.

"Some reflections on comparable worth," (T.A. Cameron) *Contemporary Policy Issues*, 4, no. 2, (April 1986) 33-39.
"Consistent 'multinomial' and 'nested' logit point estimates: A practical note," (T.A. Cameron) *Oxford Bulletin of Economics and Statistics*, 47, no. 1 (February 1985) 83-89.
"Demand models incorporating prices differences across political boundaries," (T.A. Cameron and K.J. White), *Annals of Regional Science*, 19(1) (March 1985) 50-60.
"The demand for computer services: A disaggregate decision model," (T.A. Cameron and K.J. White), *Managerial and Decision Economics*, 7, no. 1, (March 1985) 37-41.
"A nested logit model of energy conservation activity by owners of existing single family dwellings," (T.A. Cameron) *The Review of Economics and Statistics*, 67(2) (May 1985) 205-211.
"Comments on E.R. Berndt: 'From Technocracy to Net Energy Analysis,'" (T.A. Cameron) in *Progress in Natural Resource Economics*, A.D. Scott (ed.), Oxford University Press, 1985.
"Sectoral energy demand in Canadian manufacturing industries," (T.A. Cameron and S.L. Schwartz), *Energy Economics*, April 1979, 112-118.
"Inflationary expectations and the demand for labor, capital, and energy in Canadian Manufacturing Industries," (T.A. Cameron and S.L. Schwartz), Chapter 3 in *Energy Policy Modeling: United States and Canadian Experiences, Volume I: Specialized Energy Policy Models*, W.T. Ziemba and others (eds.), Martinus Nijhoff, Social Sciences Division, Boston, 1980, 50-64.

Papers in Proceedings:
"Issues in Benefits Transfer" in Bingham, T.H., E. David, T. Graham-Tomassi, M.J. Kealy, M. LeBlanc, and R. Leeworthy (eds.) *Benefits Transfer: Procedures, Problems, and Research Needs*, Proceedings of the 1992 Association of Environmental and Resource Economists Workshop, Snowbird, Utah, June 1992.
"Cost-Benefit Analysis for Non-Market Resources: A Utility-Theoretic Empirical Model Incorporating Demand Uncertainty," (T.A. Cameron and Jeffrey Englin) in Kling, C.L. (ed.) *Benefits and Costs in Natural Resources Planning*, Western Regional Research Project W-133, Fourth Interim Report (June, 1991)

Book Review:
Econometric Analysis of discrete choice: With applications on the demand for housing in the U.S. and West Germany. By Axel Borsch-Supan. *Journal of Economic Literature*, June 1989.

Work in Progress:
- under review
"Subjective choice difficulty in stated choice tasks," Eric N. Duquette, Trudy Ann Cameron, and J.R. DeShazo
"Willingness to pay for health risk reductions: Differences by type of illness," Trudy Ann Cameron, J.R. DeShazo, and Erica Johnson (presented 2008 AERE Workshop)
"Willingness to pay for public health policies to treat illnesses" Ryan Bosworth, Trudy Ann Cameron and J.R. DeShazo (presented ASHEcon 2010)
"Comprehensive selectivity assessment for a major consumer panel: attitudes toward government regulation of environment, health and safety risks," Trudy Ann Cameron and J.R. DeShazo

- revise-and-resubmit, or pending submission
"Demand for Health Risk Reductions," Trudy Ann Cameron and J.R. DeShazo (revise-and resubmit)
"Discounting versus risk aversion: the effects of time and risk preferences on individual demands for climate change mitigation," Trudy Ann Cameron and Geoffrey R. Gerdes (revise and- resubmit)
"Individual Subjective Discounting: Form, Context, Format, and Noise," Trudy Ann Cameron and Geoffrey R. Gerdes (revise-and-resubmit)
"Superfund Taint and Neighborhood Change: Ethnicity, Age Distributions, and Household Structure," Trudy Ann Cameron, Graham Crawford, and Ian McConnaha, (revise-and resubmit)
"The effect of health status on willingness to pay for morbidity and mortality risk reductions," J.R. DeShazo and Trudy Ann Cameron (pending submission)
"Two types of age effects in the demand for reductions in mortality risks with differing latencies," J.R. DeShazo and Trudy Ann Cameron (pending submission)

- in draft form

"Note: Competing Nonmarket Value-elicitation Methods: Reinterpreting Open-Ended and Payment Card Responses," Trudy Ann Cameron and Tatiana Raterman

"Thorough Non-response Modeling as an Alternative to Minimum Survey Response Rate Requirements," J. Jason Lee and Trudy Ann Cameron

"Note: Independent dimensions of sociodemographic variability in neighborhood characteristics at the tract level of the 2000 Census," Trudy Ann Cameron and Graham Crawford

Completed Technical Reports:

"The Value of a Statistical Illness," (T.A. Cameron and J.R. DeShazo) Final Report to Health Canada, Economic Analysis and Evaluation Division, Healthy Environments and Consumer Safety Branch (Contract H5431-010041/001/SS) March 2003, 186 pp.

"A Comparison of Hedonic Property Value Models for Four Superfund Sites," (T.A. Cameron and G.D. Crawford), sub-report for US EPA CR 824393-01, PI: William D. Schulze, Cornell University, December 2002, 66 pp.

"Review of the Draft Analytical Plan for EPA's Second Prospective Analysis – Benefits and Costs of the Clean Air Act 1990-2020; An Advisory by a Special Panel of the Advisory Council on Clean Air Compliance Analysis" (Chair: T.A. Cameron) September 2001 (EPA-SABCOUNCIL-ADV-01-004) http://www.epa.gov/sab/pdf/councila01004.pdf, 90pp.

"Revealed/Stated Preference Estimation of the Value of Time Spent for Tax Compliance," white paper prepared for client US Internal Revenue Service on behalf of PricewaterhouseCoopers. March 2000

"User's Guide, BMP Water Savings Simulation Program" (T.A. Cameron, L. Coffin and B. Mandapati) software prepared for the Department of Water Resources, State of California (September 1992).

"Valuation of Damages to Recreational Trout Fishing in the Upper Northeast Due to Acidic Deposition," (J.E. Englin, R.E. Mendelsohn, T.A. Cameron, G.A. Parsons, and S.A. Shankle) prepared by (Battelle) Pacific Northwest Laboratory for National Acid Precipitation Assessment Program, U.S. Department of Energy DE-AC06-76RLO 1830.

"Contingent Valuation Assessment of the Economic Damages of Pollution to Marine Recreational Fishing," (T.A. Cameron) United States Environmental Protection Agency, Policy, Planning, and Evaluation (PM-221), EPA 230-05-90-078 (November 1989)

"The Determinants of Value for a Recreational Fishing Day: Estimates from a Contingent Valuation Survey," (T.A. Cameron and M.D. James), *Canadian Technical Report of Fisheries and Aquatic Sciences*, no. 1503, Department of Fisheries and Oceans, Canada, January 1987.

Dissertation:

"Qualitative Choice Modeling of Energy Conservation Decisions: A Microeconomic Analysis of the Determinants of Residential Space-Heating Energy Demand." (Chair: Richard E. Quandt), 1982.

Working Papers:

"Note: Independent Dimensions of Sociodemographic Variability in Neighborhood Characteristics at the Tract Level of the 2000 Census," Trudy Ann Cameron and Graham D. Crawford, working paper, Department of Economics, University of Oregon (RePEc:ore:uoecwp:2004-10)

"Quintennial Pseudo-panel Data from Five Fishing, Hunting and Wildlife-Associated Recreation (FHWAR) Surveys: Cohort Effects in Recreational Participation and The Implications for Forecasting the Social Benefits of Environmental Protection" (with Jeffrey Englin, mimeo).

"Measuring Taint: The Effect of the Valdez Oil Spill on Alaskan Salmon Prices," (with Robert Mendelsohn) mimeo, Yale School of Forestry and Environmental Studies.

"Weighted Estimation Procedures for Benefits Transfer Applications," mimeo, Department of Economics, UCLA, January 1993 (revision requested by *Water Resources Research*).

"Graduate Admissions and Aid Decisions: Inferring Academic Success based on Admissions Information" (with Laura B. Field) (revision requested by *Journal of Economic Education*).

"Willingness to Pay for Household Water Saving Technology in Two California Service Areas: A Preliminary Report" (by Richard A. Berk, Daniel Schulman, and Trudy Ann Cameron)

"Existence, Option, and User Demands for Non-Market Resources" (with Jeffrey Englin) Department of Economics, University of California at Los Angeles, August 1990.
"Simulation Sensitivity Analysis: Does that Data Problem Matter?" Department of Economics, University of California at Los Angeles, July 1989.
"The Effects of Variations in Gamefish Abundance on Texas Recreational Fishing Demand: Welfare Estimates," Department of Economics, University of California at Los Angeles, June 1989.
"Using the Basic 'Auto-Validation' Model to Assess the Effect of Environmental Quality on Texas Recreational Fishing Demand: Welfare Estimates," Working Paper No. 522, Department of Economics, University of California at Los Angeles, September 1988.
"The Determinants of Value for a Marine Estuarine Sportfishery: The Effects of Water Quality in Texas Bays," Working Paper No. 523, Department of Economics, University of California at Los Angeles, May 1988.
"The Price of Convenience: A Disaggregated Alternative to Two-Market Models," (co-authored with K.J. White) mimeo, University of British Columbia, September 1984.
"The Price of Convenience," (co-authored with K.J. White), Discussion Paper No. 83-14, Department of Economics, University of British Columbia, Vancouver, B.C., June 1983.
"Vertical and Horizontal Divestiture of U.S. Oil Companies: An Examination of the Issues," Working Paper No. 477, Faculty of Commerce and Business Administration, University of British Columbia, Vancouver, B.C., June 1977.

Professional Activities

Past-President: Association of Environmental and Resource Economists (2009-2010)
President: Association of Environmental and Resource Economists (2007-2008)
President-Elect: Association of Environmental and Resource Economists (2006)
Vice-President: Association of Environmental and Resource Economists (1996 - 1997)
Associate Editor: *Journal of Environmental Economics and Management* (1990, 1991).
Associate Editor: *American Journal of Agricultural Economics* (1/92 -12/93, 1/94-12/95)
Editorial Council/Board: *Journal of Environmental Economics and Management* (1989, 1994- 1998); *Review of Environmental Economics and Policy* (2006-); *Journal of Benefit- Cost Analysis (2009-), Journal of Risk and Uncertainty (2011-2015)*
Board of Directors: Association of Environmental and Resource Economists (1992-94), Resources for the Future (2009-2011), Society for Benefit-Cost Analysis (2011-2012)
Chair: Advisory Council on Clean Air Compliance Analysis, Science Advisory Board, US Environmental Protection Agency, FY01-FY06
Member: Executive Committee, Science Advisory Board, US Environmental Protection Agency, FY01-FY07
Environmental Economics Advisory Committee, Science Advisory Board, US Environmental Protection Agency, FY95 through FY96, FY97 - FY98, FY99-FY00
Advisory Council on Clean Air Compliance Analysis, Science Advisory Board, US Environmental Protection Agency, FY00-FY01
Grand Canyon Monitoring and Research Committee, Water Science and Technology Board, Commission on Geosciences, Environment and Resources, National Research Council, National Academy of Sciences,1998-2001
Economics and Assessment Work Group, Children's Health Protection Advisory Committee, Office of Children's Health Protection, U.S. EPA, 1998-1999
Referee: *Econometrica, Journal of Econometrics, Review of Economics and Statistics, American Economic Review, Journal of Political Economy, Economic Journal, RAND Journal of Economics, Canadian Journal of Economics, European Economic Review, Journal of Applied Econometrics, Land Economics, American Journal of Agricultural Economics, Journal of Environmental Economics and Management, Environmental and Resource Economics, Journal of Agricultural and Resource Economics, Journal of Environment and Development, Journal of Environmental Management, Canadian Journal of Agricultural Economics, Journal of Development Economics, Public Opinion Quarterly, Oxford Economic Papers, Economic Inquiry, Journal of Labor Economics, Journal of Law and Economics, Journal of Human Resources, Growth and Change, Regional Science and Urban Economics, Contemporary Policy issues, Water Resources*

Research, Environment and Planning A, Scandinavian Journal of Forest Research, Journal of African Economics, Fishery Bulletin.

Panel Member: National Advisory Board, Long-Term Ecological Research program, 2008-2009
National Science Foundation (Human Dimensions of Global Change Panel), 1992-93, 1993- 94; (Decision Risk and Management Science Panel) 2011-2012.
National Science Foundation site visit team, Directorate for SBES, 1999, 2004
Environmental Protection Agency (Socioeconomics Panel), 1992, 1995, 2006 EPA/NSF Environmental Statistics, 1998
UC Centers for Water and Wildlands Research, 1995-97, 1997-1999

Reviewer: InterAcademy Council, National Science Foundation, Environmental Protection Agency, National Oceanic and Atmospheric Administration, World Bank, Universitywide Energy Research Group, University of California; University of California Energy Institute; Water Resources Research Center, University of California; American Agricultural Economics Association; Western Regional Center, National Institute for Global Environmental Change; Department of Fisheries and Oceans, Government of Canada; U.S. Department of Commerce, National Oceanographic and Atmospheric Administration, National Marine Fisheries Service.

Member: American Economic Association, Association of Environmental and Resource Economists, American Society of Health Economists, American Agricultural Economics Association, International Society for Ecological Economics.

Reviewer: Harper and Row, Publishers; McGraw-Hill Book Company, Business Publications, Inc.

Research Grants

National Science Foundation, 2006-2010
US Environmental Protection Agency/Health Canada (Co-PI with JR DeShazo), 2001-2003, 2003-2005
National Science Foundation (Co-PI with JR DeShazo), 1999-2000
National Science Foundation (PI) 1999-2002
Environmental Protection Agency (Co-PI with William Schulze), 1995-1997
NSF/EPA, (Co-PI with William Schulze), 1995-1997.
Environmental Protection Agency (Co-PI with Hilary Sigman), 1994-96
Water Resources Center, University of California, 1993-94.
California Department of Water Resources (7/92 - 12/93)
Faculty Career Development Grant, University of California, 1988-89.
Water Resources Center Grant, University of California, 7/87 - 6/88.
Faculty Center Development Grant, University of California, 1986-87.
Universitywide Energy Research Group/California Energy Commission. 1986-88.
Academic Senate/Council on Research Grants, University of California, 1985-86 through present.
Universitywide Energy Research Group, California Energy Studies Program, 1985-86.
SHAZAM (A General Computer Program for Econometric Methods), 1984-85.
Social Sciences and Humanities Research Council of Canada/University of British Columbia Faculty Research Grant: 1981-82, 1982-83.

Contracts

Protected Species Branch of the Northeast Fisheries Science Center in Woods Hole, Massachusetts (2005-2007) Reviews of project on Public's WTP for Right Whale Protection.
Harvard University (2005) Review of final EPA report by Viscusi/Huber (water quality study)
Stratus Consulting Inc., (01-02) Survey design/review/estimation advice
PriceWaterhouseCoopers. "Revealed and Stated Preference Estimation of the Value of Time Spent for Tax Compliance." 2000
Expert Review. National Oceanic and Atmospheric Administration. Southern California Bight Study. (4/91 - 9/93).
RCG/Hagler, Bailly, Inc. Survey design/review (93-94).
World Bank, Country Operations Division, Latin American and Caribbean Region. Reviewer (1994).
Environmental Protection Agency. Co-operative Agreement. "Economic Benefits of Environmental Quality: Methodologies, Econometrics, and Benefits Transfer" (1993- 1998).
Environmental Law Institute. Methodologies for Benefits Transfer (9/92-8/93)

Water Resources Research Center, UC Riverside. Assessment of Urban Water Demand Forecasting Models; Quantification of Water Savings Potential due to Best Management Practices (7/92 - 9/92)

Battelle Pacific Northwest Laboratories. Subcontract consultant agreement for work pertaining to the National Acidic Precipitation Assessment Program (2/89-12/90).

California Energy Commission (through UC Irvine Institute for Transportation Studies) (7/89 - 2/90).

Government of Canada, Department of Fisheries and Oceans. "An Econometric Analysis of Responses to the 1985 Survey of Sportfishing in Canada" (3/89-10/89).

U.S. Environmental Protection Agency. Cooperative Agreement. "Contingent Valuation Assessment of the Economic Damages of Pollution to Marine Recreational Fishing." 1987-88.

Government of Canada, Department of Fisheries and Oceans. "Contingent Valuation Study of the Fraser River Sportfishery." 1986-87.

Government of Canada, Department of Fisheries and Oceans. "Contingent Valuation Study of the British Columbia Tidal Sportfishery." 1985-86.

Harper and Row, Publishers. New examples and revisions of end-of-chapter questions for 9th edition of Lipsey, Purvis and Steiner, *Microeconomics*.

Conferences and Presentations since 2000

2011

Pending:

Inaugural summer conference of the Association of Environmental and Resource Economists, Seattle, WA, June 9-10, 2011

2010

ASSA/AERE annual meetings, Atlanta, January (discussant)

Department of Economics, University of Washington, February 26, 2010 (departmental seminar)

8th triennial Invitational Choice Symposium, Key Largo, FL, May Symposium: Towards a Theory of Scale (co-chairs: Joffre Swait and Jordan Louviere), May 12-16

3rd biennial Conference of the American Society of Health Economists (ASHEcon), Cornell University, June 20-23, 2010 (organized two sessions; 2 papers, discussant)

4th World Congress of Environmental and Resource Economists, UQAM, Montreal, June 28-July 2 (2 papers, discussant)

Developing Standards for Benefit-Cost Analysis conference sponsored by the Benefit-Cost Analysis Center of the University of Washington and funded by the MacArthur Foundation; October 18-19, Washington, DC (sponsored participant)

Society for Benefit-Cost Analysis annual meeting, Washington DC, October 19-20, 2010 (paper)

University of Trento, Envirochange, International Research Workshop on Risk Elicitation and Stated Preference Methods for Climate Change Research; Trento, Italy, October 21- 22, 2010 (keynote speaker)

12th Occasional California Workshop on Environmental and Resource Economics, UC Santa Barbara, November 12-13, 2010 (paper, discussant)

2009

UW/MacArthur Foundation 2009 Benefit-Cost Analysis Conference: “Unleashing the Power of Social Benefit-Cost Analysis: Removing Barriers” (panelist)

CREE 2009 Canadian Resource and Environmental Economics Working Group conference, University of Alberta, Edmonton, October 2-4 (paper)

WEA/AERE inaugural sessions, June 30/July 1, 2009 (organized 11 sessions, paper)

US EPA, Estimating the Benefits of Reducing Hazardous Air Pollutants Workshop, Washington DC, April 30-May 1, 2009 (panelist)

2008

North Carolina State University, Raleigh, NC, seminar, March 20, 2008

AAEA/AERE annual conference, July, Orlando, FL (paper)

AERE Workshop, June, Berkeley, CA (paper)

EAERE Annual conference, June, Goteborg, Sweden (paper)

2007
ASSA/AERE annual meetings, January, Chicago, IL (three papers, discussant)
Resources for the Future (RFF) Conference on the Frontiers of Environmental Economics, February 26-27, 2007, Washington, D.C. (discussant)
Seventh Triennial Invitational Choice Symposium, Wharton School and the University of Pennsylvania, June 13-17, 2007, Philadelphia, PA (Member, Session 15: Behavioral Frontiers in Choice Modeling)
EAERE Annual Conference, June 27-30, Thessaloniki, Greece (three papers, three discussions)
AAEA/AERE annual conference, July 28-31, Portland, OR (paper coauthor, discussant)
Oregon Ad Hoc Environmental Economics Workshop, Willamette University, Salem, OR (paper coauthor, participant), December 13, 2007

2006
ASSA/AERE annual meetings, January, Boston, MA (paper, discussant, session chair)
W-1133 Workshop, San Antonio, TX (coauthor participant, two papers)
EPA Environmental Policy and Economics Workshop Series: "Morbidity and Mortality: How Do We Value the Risk of Illness and Death?" April 10-12, Washington, DC (paper, panelist, and full session on work by Cameron/DeShazo http://www.scgcorp.com/morbidity/index.asp)
Oregon Ad Hoc Environmental Economics Workshop, Willamette University, Salem, OR (chair, coauthor participant), May 26, 2006
Resources for the Future (RFF) Workshop: Sample Representativeness: Implications for Administering and Testing Stated Preference Surveys, October 2, 2006, Washington, D.C.
9th Occasional Workshop on Environmental and Resource Economics, UCSB Bren School, November 3-4, 2006; panelist, discussant

2005
ASSA/AERE annual meetings, January, Philadelphia, PA (paper, session chair, discussant)
Workshop on Representation of Dose-Response Relationships for Chemicals Associated with Non-Cancer Effects and Their Policy Implications, sponsored by the Superfund Basic Research Program, School of Public Health, UC Berkeley; National Center for Environmental Economics, US EPA; Office of Environmental Health Hazard Assessment, CalEPA, February, Oakland CA (invited discussant)
UC Berkeley, Econometrics Workshop, April, Berkeley, CA (departmental seminar)
NBER Summer Institute, Environmental Economics, July, Cambridge, MA (discussant)
American Agricultural Economics Association, Summer Meetings, July, Providence, RI (invited roundtable panelist)
Society of Toxicology, Workshop on Probabilistic Risk Assessment, July, Washington, DC (invited expert)
UCLA, Applied Microeconomics Workshop, October, Los Angeles, CA (departmental seminar)
9th Southern California Occasional Workshop in Environmental Economics, October, UC Santa Barbara

2004
NBER Environmental Economics Meeting, Stanford, CA, April 9-10, 2004; paper
University of Florida, conference on "Risk Perception, Valuation, and Policy," April 29-May1, 2004; paper
6th CU-Boulder Invitational Choice Symposium, June 4-8, 2004; workshop member "Endogeneity in Choice Models"

2003
AERE/ASSA 2003 Winter meetings, Washington, DC, January 2003; paper, discussant
Steinhardt Lecture, Lewis & Clark College, Portland OR, February 20, 2003
AERE Workshop, Madison, WI, June 2003, paper
Canadian Resource and Environmental Economics Study Group Workshop, University of Victoria, British Columbia, Canada, October 2003, paper
US Environmental Protection Agency, Environmental Policy and Economics Workshop Series: "Valuing Environmental Health Risk Reductions to Children," October 20-21 2003; paper

Bren School of the Environment, University of California at Santa Barbara, November 2003; departmental seminar
Stanford University, November 2003; departmental seminar

2002
John F. Kennedy School of Government, Harvard University, March 2002; seminar
Department of Economics, Utah State University, Logan, Utah, March 2002; two seminars, public radio interview.
Second World Congress of Environmental Economists, Monterey, CA, June 2002; three papers.

2001
AERE/ASSA 2001 Winter Meetings, New Orleans, LA, January 2001; discussant
AEA/ASSA 2001 Winter Meetings, New Orleans, LA, January 2001; discussant
Department of Economics, University of Oregon, April 2001; seminar
UC Berkeley Invitational Choice Symposium, Asilomar, CA, June 2001; panelist
AERE Workshop, Bar Harbor, ME, June 2001; paper, discussant

2000
Department of Economics, California State University at Fullerton, April 2000; departmental seminar
Environmental and Resource Economics Fifth Occasional Southern California Workshop, University of California at Santa Barbara; May 2000; paper
Congressional Research Service of the Library of Congress. Workshop on Children's Environmental Health. Washington, DC, May 22, 2000; panelist
Environmental Protection Agency. Workshop on Hazardous Air Pollutants; Washington, DC, June 2000; panelist
Canadian Resource and Environmental Economics Study Group Annual Meetings, Guelph, Ontario, Canada; September, 2000; paper.

Teaching

School	Course	Title	Enroll
UO	Econ 607	Environmental Economics (Ph.D.)	3-6
UO	Econ 607	Advanced Econometrics (Ph.D.)	15
UO	Econ 425/525	Econometrics	20
UO	Econ 199	Economics of Environmental Issues	28
UO	Econ 233	Economics of Environmental Issues	15-25
UO	Econ 333	Resource and Environmental Economic Issues	78
UO	Econ 433/533	Environmental and Natural Resource Economics	70
UO	ENVS 399	Allocating Scarce Environmental Resources	50
UCLA	Econ 204F	Natural Resource Economics (Ph.D.)	4
UCLA	Econ 204G	Environmental Economics (Ph.D)	4
UCLA	Econ 203B	Econometrics (Ph.D.) (second half)	35
UCLA	Econ 203C	Applications of Econometrics (Ph.D.)	35
UCLA	Econ 204M	Workshop in Econometric Theory and Applied Econometrics (Ph.D.)	6
UCLA	Econ 204x	Workshop in Environmental and Natural Resource Economics (Ph.D.)	10

UCLA	Econ 221	Urban Economics (Ph.D.)	5
UCLA	Econ 134A	Environmental and Natural Resource Economics	120
UCLA	Econ 134B	Economics of Environmental Regulation	30
UCLA	Econ 143	Applied Regression Analysis	40-70
UCLA	Econ 40	Introduction to Statistical Methods	120
UCLA	Econ 1	Principles of Economics (Micro)	350
UCLA	Econ 2	Principles of Economics (Macro)	250
UCLA	PS 208	Policy Research and Analysis	22

Recipient: Warren C. Scoville Distinguished Teaching Award (Department of Economics, UCLA)
- Fall 1986 (Econ 143 - Applied Regression Analysis)
- Fall 1987 (Econ 143 - Applied Regression Analysis)

UCLA Mortar Board (Senior Honor Society)
Faculty Excellence Award (1990)

CGS	Econ 382	Econometrics II (graduate)	25
CMC	Econ 120	Probability and Statistics	40
CMC	Econ 50	Principles of Economics	35
UBC	Econ 526	Probability and Statistics (graduate)	25
UBC	Econ 326	Regression Theory	45
UBC	Econ 370	Cost-Benefit Analysis	50
UBC	Econ 309	Principles of Economics for non-majors	200
UBC	Econ 100	Principles of Economics	400

Dissertation Committees (since 1990 only):

As Chair or Co-Chair (UO):
Ryan Bosworth (Economics, ’06) (chair) School of Public and Int’l Affairs, NC State; now Utah State University
William Galose (Economics, ’07) (chair); SUNY Fredonia; Drake University; now Lamar University
Dan Burghart (Economics, ’07) (co-chair); postdoc at NYU; now NYU Abu Dhabi
Beilei Cai (Economics, ’08) (chair); on the market in 2010-11 after two-year hiatus
Erica Johnson (Economics, ’09 expected) (chair); Gonzaga University
Peter Stiffler (Economics, ’10) (co-chair); Bonneville Power Authority, Portland OR
Eric Duquette (Economics, ’10) (chair); Economic Research Service, USDA
Toni Sipic (Economics, ’11 expected) (chair)
Brian Vander Naald (Economics, ’12 expected) (chair)
Matthew Taylor (Economics, ’12 expected) (co-chair)

As Chair or Co-Chair (UCLA):
Jae Seung Lee (Economics.’02) (chair) ICF International, VA, CA; now Samsung, South Korea
W. Bowman Cutter (Economics, ‘02) (co-chair) UC Riverside; now Pomona College
Lea Kosnik (Economics, ‘01) (co-chair) PERC; Montana State University; now tenured at University of Missouri at St. Louis
Manrique Saenz (Economics, ‘00) (co-chair), Central Bank of Costa Rica; now IMF

Andres Lerner (Economics,’99) (co-chair) Economic Analysis Corp., LA; Director, LECG; now Senior Vice President, Compass Lexecon, Los Angeles, CA
German Fermo (Economics, ‘99) (co-chair) Ernst & Young, NY; Argentina; now in Switzerland
Kerry Knight (Economics, ‘98) (chair) Oliver, Wyman and Company, NY; now Principal, Biz-Stay Inc, Los Angeles, CA
Kenneth Serwin (Economics, ‘97) (co-chair) A.T. Kearney, Chicago; Director, Intecap, Inc.; Vice President, NERA Economics Consulting; Director, LECG; now Director, Berkeley Research Group, LLC
Michael Kimel (Economics, '96) Alltel Communications, Little Rock; PricewaterhouseCoopers; now Analytic Economics (founder)
Craig Ernest Mitchell (Economics, '95) McKinsey and Company, Atlanta; now Partner, The Exetor Group

As Committee Member (UO)
Edward Birdyshaw (Economics, ’04)
Gretchen Mester (Economics, ‘04)

As Committee Member (UCLA):
- **Economics:**
Matthew Neidell (Economics) 5/02) Post-doc, University of Chicago; now Assistant Professor, Mailman School of Public Health, Columbia University
Geoffrey Gerdes (Economics) 6/99 Board of Governors, Federal Reserve Bank
Luis Alvarado (Economics) 4/95; unknown
Hye-Hoon Lee (Economics) 4/93; now Legislator, Grand National Party, Korea 2004-2008, 2009-
Mark Edward Schweitzer (Economics) 10/91; now Senior Vice President and Director of Research, Federal Reserve Bank of Cleveland
Jorge Ivan Alonso (Economics) 9/91; unknown
James Emmett Harrigan (Economics) 7/91; now Professor of Economics, University of Virginia
Linda Mae Hooks (Economics) 6/91; now Cannan Professor of Economics, Washington and Lee
Ariane Aimaq Schauer (Economics) 10/90; now chair, Division of Business and Economics, Marymount College, Palos Verdes, CA
Kishore Gawande (Economics) 5/90 University of New Mexico; now Roy and Helen Ryu Chair of Economics and Government, Bush School of Government and Public Service, Texas A&M

- Other departments:
C. Scott Wo (Management) 3/98
Daniel Schulman (Sociology) 12/95
Laura Field (Management) 6/97
Miehshan Benson Huang (Environmental Science and Engineering) 2/95
Jianling Li (Urban Planning) 5/95
Diana Vorsatz (Env. Science and Engineering) 4/95
Jih-Wen Lin (Political Science) 11/94
Brian Christy Potter (Political Science) 4/94
Kenneth Philip Green (Environmental Science and Engineering) 3/93
Russell Richard Wermers (Management) 8/93
Marijke Lynne Bekken (Env. Science and Engineering) 6/92
Kwanho Kim (Management) 3/92
Hiromi Ono (Sociology) 12/92
Khashaiar Lashgaribroojerdi (Env. Science and Engineering) 6/92
Juliann Emmons Allison (Political Science) 6/92 qualifying exam
Deborah Skoller Drezner (Environmental Science and Engineering) 7/91
Alyssa Ann Lutz (Management) 9/91
Sanjay Kumar Dhar (Management) 4/91
Marnik Gustaaf Dekimpe (Management) 4/91
Michael David Scott (Biology) 12/88-1/91
Raul P. Lejano (Environmental Science and Engineering) 3/91
Tak-Jun Wong (Management) 1/90

Wai Lin Christina Soh (Management) 5/90

Service Activities
Departmental (UO):
COOF Alumni Newsletter, 2007
Graduate Admissions, 2002-03
Salary Review Committee, 2002-2003
Environmental Studies Liaison
Executive Committee, 2008-09, 2010-11
Recruiting Committee, 2008-09
Micro chair, Recruiting Committee, 2009-10

Extra-departmental (UO):
Graduate Admissions and Fellowships, Environmental Studies 2001-2003
CAS Curriculum Committee, 2008-09 (Chair, 2009-2010)
Undergraduate Council, ex-officio liaison from CAS Curriculum Committee, 2008

Departmental (UCLA):
Undergraduate Advisory Committee, 1997-99;
Executive Committee, 1993-96;
Graduate Committee, 1992-94;
Staffing Committee, 1987-88, 1992-93, 1994-95;
Vice-chair, Department of Economics, UCLA,
Director of Graduate Studies, 1990-91, 1991-92;
Graduate Admissions and Aid Committee, 1985-86, 1998-2001;
Computing Committee Chair, 1986-90, 1994-95;

Extra-departmental (UCLA):
Committee on Undergraduate Admissions and Relations with Schools, 1998-
Teaching and Technology Initiative, 1997-1999
Founding faculty member, Department of Policy Studies,
UCLA School of Public Policy and Social Research (SPPSR); 1994-
Faculty Advisory Committees:
Institute for Social Science Research, 1986-90;
Social Science Data Archive, 1990-94 ;
Program in Applied Econometrics, 1989-94;
Social Science Computing, 1990-94;
Committee on Social Science Curriculum Reform, 1993-94;
Environmental Studies Task Force, 1993-94;
UCLA Global Change Consortium, 1992-94;
Council on Environmental Strategies, UCLA, 1992-98;
Committee on the Teaching of Undergraduate Statistics, 1990-92;
Student Research Program, Faculty Sponsor since 1986.

Search Committees for:
Dean of Natural Sciences, UC Merced (2001)
Director of the Institute for Social Science Research (199?)
Director of Social Science Computing (199?)

Various Ad Hoc committees for personnel reviews, UCLA.

Extra-departmental (UC):
UC Faculty Welfare, Retirement Subcommittee, 1994-96 ;
Member of Coordinating Board of the University of California Water Resources Center, 1995-1999
Advisory Board for the University of California Energy Institute.

Professional:

Committee to select the Publication of Enduring Quality for the Association of Environmental and Resource Economists, 1995-1998. (Chair, 1998)

Reviewer, Selection committee for the 3rd World Congress of Environmental and Resource Economists, Kyoto, 2006

Reviewer, Selection committee for 2008 annual conference of the European Association of Environmental and Resource Economists

Selection Committee chair, WEAI/AERE sessions, 2009 Vancouver, BC, June 30-July 1 (44 papers)

Research Community Workshop Planning Committee, National Climate Assessment Valuation Techniques Workshop December 2010

Additional expert, U.S. Environmental Protection Agency, Science Advisory Board (SAB) Staff Office, Environmental Economics Advisory Committee, Augmented for Valuing Mortality Risk Reduction, Public Meeting, Madison Hotel, 1177 15th Street, Washington, D.C. 20005, January 20-21, 2011

Reviewer, Selection committee for 2011 annual conference of the Association of Environmental and Resource Economists.

Curriculum vitae

Walter McManus
Research Scientist (Economist)
Head, Automotive Analysis Group
University of Michigan Transportation Research Institute
2901 Baxter Rd.
Ann Arbor, MI 48109-2150
(248) 821-0493
watsmcm@umich.edu

Biography

Walter McManus is an economist and head of the Automotive Analysis Group at the University of Michigan's Transportation Research Institute. Before joining the research faculty in March 2005, he was Executive Director of Forecasting and Analytics at the global marketing information company, J.D. Power and Associates. His business experience also includes nine years with General Motors in forecasting, marketing analysis and strategy, and new-product development. (He also spent a year as a production supervisor in a GM manufacturing plant. He began his career as an academic. He was Assistant Professor of Economics at the University of Florida (1983-88) and then Associate Professor of Economics at Baruch College (1988-89). McManus graduated from Louisiana State University (BA 1977) and earned a doctorate in economics from the University of California, Los Angeles (PhD 1983).

A research leader in the behavioral aspects of energy and transportation, McManus has a record of research accomplishments in consumer behavior and market competition in the transportation sector. He has an enthusiasm for working with multiple diverse stakeholders to generate knowledge through excellent research to help design effective policies.

McManus has conducted and managed complex cross-disciplinary research projects throughout his career. Subjects have included the assimilation of immigrants into the US labor market, the importance of researchers' prior beliefs in controversial research topics, the behavior of consumers and firms in the automotive industry, the impacts and effectiveness of energy and environmental policies, and the adoption and diffusion of new technologies.

Research Interests and Skills

Economics and public policy; behavioral and human dimensions of transportation and energy; adoption and diffusion of new technologies; the automotive industry.

Economic analysis (consumer behavior, market models, strategic behavior of firms, economic history), econometrics, forecasting and simulation, finance, public speaking.

Education

PhD, Economics, University of California, Los Angeles, 1983
BA, Economics, Louisiana State University, 1977

Awards

2008 UMTRI Research Excellence Award for the article in *Business Economics* 2007
NABE Abramson Award for the best article published in *Business Economics* 2007
GM Chairman's Honors for innovations enhancing performance in new-product development 1991 & 98
Sidney Stern Fellow, University of California, Los Angeles 1979 – 82

Affiliations

Automotive Industry Expert Panel, U.S. Government Accountability Office, 2009 – present
Ceres Stakeholder Committee on Sustainability, Ford Motor Company, 2009 – present
Fellow, Michigan Memorial Phoenix Energy Research Institute, 2007 – present
Executive Committee, Michigan Center for Advancing Safe Transportation throughout the Lifespan, 2007 – Present

Transportation Energy Committee, Transportation Research Board, 2008 – Present
Transportation Working Group, Energy Futures Coalition, 2003 – 04
American Economic Association
National Association for Business Economics
Society of Automotive Engineers

Professional History
Research Scientist (Economist) and Head, Automotive Analysis Group, University of Michigan Transportation Research Institute, Mar 2005 – Present

Visiting Scholar and Research Engineer, Transportation Sustainability Research Center, Institute of Transportation Studies, University of California, Berkeley, Mar 2009 – Oct 2009

Executive Director of Forecasting and Analytics, J.D. Power and Associates, Oct 1999 – Jan 2005

Director of Marketing, Textron Automotive Company, Dec 1998 – Sept 1999

Leader, Industry Analysis Group, General Motors Corporation, July 1996 – Nov 1998

Manager, North American Market Analysis, General Motors Corporation, Jan 1994 – June 1996

Economist, Delco Remy Division, General Motors Corporation, Anderson, IN, Aug 1991 – Dec 1993
(Memo: included development assignment as Manufacturing Supervisor, Jan 1993 – Dec 1993)

Economist, General Motors Corporation, Detroit, MI, June 1989 – Aug 1991

Associate Professor of Economics and Fellow, Center for the Study of Business and Government, Baruch College, New York, NY, July 1988– May 1989

Assistant Professor of Economics, University of Florida, Gainesville, FL, July 1983 – June 1988

Testimony and Briefings
U.S. EPA and NHTSA Public Hearing, Proposed Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, October 21, 2009

Investor Briefing, Citigroup Investment Research, CAFE Panel Conference Call & Briefing, April 2009.

Testimony, Committee on Assessment of Technologies for Improving Light-Duty Vehicle Fuel Economy, National Research Council, March 16, 2009

Testimony, US EPA, Hearing on California Greenhouse Gas Waiver, March 3, 2009

Testimony, Environmental Regulation Commission Hearing, Greenhouse Gas Emissions Reduction-Florida Clean Car Emission Rule, Florida Department of Environmental Protection, October 29, 2008

US Congressional Briefing, Environmental and Energy Study Institute & Investor Network on Climate Risk, December 4, 2007

Investor Briefing, Citigroup Investment Research, CAFE and the U.S. Auto Industry: A Growing Auto Investor Issue, 2012-2020, October 31, 2007

Public Briefing, National Commission on Energy Policy and the International Council on Clean Transportation, Fuel Economy: Technology Trends and Policy Options, Washington, DC. October 1, 2007.

Congressional Testimony, U.S. Senate Finance Subcommittee on Energy, “Advanced Technology Vehicles: The Road Ahead”, May 1, 2007

Congressional Testimony, U.S. Senate Energy and Natural Resources Committee, “the Consumer Market for Fuel Economy”, January 30, 2007

Publications

Rogozhin, A., Gallaher, M., Helfand, G., and McManus, W. (2010), Using indirect cost multipliers to estimate the total cost of adding new technology in the automobile industry, International Journal of Production Economics 124(2):350-368

McManus, W., Senter, R., Curtin, R., and Garver, S. (2009), The demographic threat to Detroit's automakers, Targeting, Measurement and Analysis for Marketing 17:81-92

Senter, R. and McManus, W. (2009), General Motors in an age of corporate restructuring, in the second automobile revolution: the automobile firms' trajectories at the beginning of the 21st century (Chapter 9), Edited by M. Freyssenet, New York: Palgrave Macmillan

McManus, W. (2007), The link between gasoline prices and vehicle sales: economic theory trumps conventional Detroit wisdom. Business Economics 1.42:54-60

McManus, W. and Griffor, E. (2006), Toward a science of driving: Safety in rules-based versus adaptive self-regulating traffic systems, SAE Convergence, 2006-21-0064

McManus, W. (1985), Estimates of the deterrent effect of capital punishment: the importance of the researcher's prior beliefs, Journal of Political Economy 93:417-25

McManus, W. (1985), Labor market assimilation of immigrants: the importance of language skills, Contemporary Economic Policy 3:77-89

McManus, W. (1985), Labor market costs of language disparity: an interpretation of Hispanic earnings differences, American Economic Review 75:818-27

Theil, H., Rosalsky, M., and McManus, W. (1985), Lp-norm estimation of non-linear systems Economics Letters 17(1-2):123-125

McManus, W. and Rosalsky, M. (1985), Are all asymptotic standard errors awful? Economics Letters 17(3):243-245

McManus, W., Gould, W., and Welch, F. (1983), Earnings of Hispanic men: the role of English language proficiency, Journal of Labor Economics 1:101-30

Technical Reports and Working Papers

Belzowski, B. and W. McManus, Powertrain Strategies For The 21st Century: Alternative Powertrains/Fuels And Fleet Turnover, UMTRI 2010-XX, August 2010.

Rogozhin, A., M. Gallaher, A. Lentz, and W. McManus, Heavy Duty Truck Retail Price Equivalent and Indirect Cost Multipliers, RTI Project Number 0211577.003.002 for EPA, April 2010.

McManus, W. and Senter, R., Market Models for Predicting PHEV Adoption and Diffusion, UMTRI-2009-37, August 2009.

McManus, W. and Kleinbaum, R., Fixing Detroit, How Far, How Fast, How Fuel-Efficient, UMTRI-2009-26, June 2009

Senter, R. and McManus, W., Reshaping the Big Three, GERPISA, June 2009

Rogozhin, A., Gallaher, M., Helfand, G., and McManus, W., Automobile Industry Retail Price Equivalent and Indirect Cost Multipliers, EPA-420-R-09-003, Feb 2009

McManus, W., The Impact of Attribute-Based Corporate Average Fuel Economy (CAFE) Standards: Preliminary Findings, Automotive Analysis Division, University of Michigan Transportation Research Institute (UMTRI), July 2007

McManus, W., Economic Analysis of Feebates to Reduce Greenhouse Gas Emissions from Light Vehicles for California, Automotive Analysis Division, University of Michigan Transportation Research Institute (UMTRI), May 2007

McManus, W., Can Proactive Fuel Economy Strategies Help Automakers Mitigate Fuel-Price Risks? Automotive Analysis Division, University of Michigan Transportation Research Institute (UMTRI), September 2006

McManus, W., Baum, A., Hwang, R., Luria, D., and Baura, G., In The Tank – How Oil Prices Threaten Automakers' Profits and Jobs, Office for the Study of Automotive Transportation, July 2005

McManus, W. and Berman, B., The 2005 OSAT – HybridCars.com Survey of Owners and Shoppers, Office for the Study of Automotive Transportation (OSAT), University of Michigan Transportation Research Institute (UMTRI), 2005.

McManus, W., The Effects of Higher Gasoline Prices on U.S. Light Vehicle Sales, Prices, and Variable Profit by Segment and Manufacturer Group, 2001 and 2004. Office for the Study of Automotive Transportation (OSAT), University of Michigan Transportation Research Institute (UMTRI), June 2005.

Greene, D., Duleep, K., and McManus, W., Future Potential of Hybrid and Diesel Powertrains in the US Light-Duty Vehicle Market, Report to Department of Energy, July 2004.

McManus, W., Consumer Acceptance of Alternative Powertrains, OE Industry Review. Troy, MI: Original Equipment Suppliers Association, 2004.

McManus, W., "Diesel vs. Hybrid-Electric Powertrains: Assessing Dependability," Power Report (July 2004)

McManus, W., "Interest in Diesel Grows—Quietly," Power Report (June 2004)

McManus, W., Consumer Acceptance of Alternative Powertrains Study. Westlake Village, CA: J.D. Power and Associates, 2004.

Malesh, T. and McManus, W., Clean Diesel Market Acceptance Study. Westlake Village, CA: J.D. Power and Associates, 2003.

McManus, W., Analysis of Tax Credits to Stimulate Consumer Demand for Advanced-Technology Fuel-Efficient Vehicles: Final Report to Energy Future Coalition Transportation Working Group. Westlake Village, CA: J.D. Power and Associates, 2003.

McManus, W., Generation Y Automotive Market Assessment. Westlake Village, CA: J.D. Power and Associates, 2002.

McManus, W., Interaction Between New and Used Vehicle Sales in the U.S. Market. Westlake Village, CA: J.D. Power and Associates, 2002.

McManus, W., Telematics Forecast. Westlake Village, CA: J.D. Power and Associates, 2002.

McManus, W., Satellite Radio Forecast. Westlake Village, CA: J.D. Power and Associates, 2002.

McManus, W. and Bussmann, W., Isuzu in the U.S., Westlake Village, CA: J.D. Power and Associates, 2001

McManus, W., Adaptive Cruise Control Forecast, Westlake Village, CA: J.D. Power and Associates, 2001

Appendix B: Conflict of Interest Statements

Conflict of Interest and Bias for Peer Review

Background

Identification and management of potential conflict of interest (COI) and bias issues are vital to the successes and credibility of any peer review consisting of external experts. The questionnaire that follows is consistent with EPA guidance concerning peer reviews.[1]

Definitions

Experts in a particular field will, in many cases, have existing opinions concerning the subject of the peer review. These opinions may be considered bias, but are not necessarily conflicts of interest.

<u>Bias</u>: For a peer review, means a predisposition towards the subject matter to be discussed that could influence the candidate's viewpoint.

Examples of bias would be situations in which a candidate:

1. Has previously expressed a position on the subject(s) under consideration by the panel; or

2. Is affiliated with an industry, governmental, public interest, or other group which has expressed a position concerning the subject(s) under consideration by the panel.

<u>Conflict of Interest</u>: For a peer review, as defined by the National Academy of Sciences,[2] includes any of the following:

1. Affiliation with an organization with financial ties directly related to the outcome;

2. Direct personal/financial investments in the sponsoring organization or related to the subject; or

3. Direct involvement in the documents submitted to the peer review panel... that could impair the individual's objectivity or create an unfair competitive advantage for the individual or organization.

---

[1] U.S. EPA (2009). Science Policy Council Peer Review Handbook. OMB (2004). Final Information Quality Bulletin for Peer Review.

[2] NAS (2003). "Policy and Procedures on Committee Composition and Balance and Conflict or Interest for Committees Used in the Development of Reports" (www.nationalacademies.org/coi).

Policy and Process

- Candidates with COI, as defined above, will not be eligible for membership on those panels where their conflicts apply.

- In general, candidates with bias, as defined above, on a particular issue will be eligible for all panel memberships; however, extreme biases, such as those likely to impair a candidate's ability to contribute to meaningful scientific discourse, will disqualify a candidate.

- Ideally, the composition of each panel will reflect a range of bias for a particular subject, striving for balance.

- Candidates who meet scientific qualifications and other eligibility criteria will be asked to provide written disclosure through a confidential questionnaire of all potential COI and bias issues during the candidate identification and selection process.

- Candidates should be prepared, as necessary, to discuss potential COI and bias issues.

- All bias issues related to selected panelists will be disclosed in writing in the final peer review record.

Conflict of Interest and Bias Questionnaire

Consumer Vehicle Choice Model Peer Review

Instructions to Candidate Reviewers

1. Please check YES/NO/DON'T KNOW in response to each question.

2. If your answer is YES or DON'T KNOW, please provide a brief explanation of the circumstances.

3. Please make a reasonable effort to answer accurately each question. For example, to the extent a question applies to individuals (or entities) other than you (e.g., spouse, dependents, or their employers), you should make a reasonable inquiry, such as emailing the questions to such individuals/entities in an effort to obtain information necessary to accurately answer the questions.

Questions

1. Are you (or your spouse/partner or dependents) or your current employer, an author, contributor, or an earlier reviewer of the document(s) being reviewed by this panel?

   YES___ NO___ DON'T KNOW_X_

   [This depends upon the nature of the documentation provided. Reviewer has previously been asked by Changzeng Liu, involved with development of the present work product being reviewed, to review documentation on nested logit models. Reviewer states that this will not prevent him from being impartial in the present review.]

2. Do you (or you spouse/partner or dependents) or your current employer have current plans to conduct or seek work related to the subject of this peer review following the completion of this peer review panel?

   YES_X_ NO___ DON'T KNOW___

   [Reviewer interprets "subject of this peer review" broadly to include work of a nature that is disclosed following Question 7. Reviewer does not have current plans to conduct or seek work related to the present work product being reviewed.]

3. Do you (or your spouse/partner or dependents) or your current employer have any known financial stake in the outcome of the review *(e.g.,* investment interest in a business related to the subject of peer review)?

   YES___ NO_X_ DON'T KNOW___

4. Have you (or your spouse/partner or dependents) or your current employer commented, reviewed, testified, published, made public statements, or taken positions regarding the subject of this peer review?

   YES_X_ NO___ DON'T KNOW___

   [Reviewer interprets "subject of this peer review" broadly to include work of a nature that is disclosed following Question 7. *Reviewer has not commented, reviewed, testified, published, made public statements, or taken positions regarding the present work product being reviewed.]*

5. Do you hold personal values or beliefs that would preclude you from conducting an objective, scientific evaluation of the subject of the review?

   YES___ NO_X_ DON'T KNOW___

6. Do you know of any reason that you might be unable to provide impartial advice or comments on the subject review of the panel?

   YES___ NO_X_ DON'T KNOW___

7. Are you aware of any other factors that may create potential conflict of interest or bias issues for you as a member of the panel?

   YES___ NO_X_ DON'T KNOW___

Disclosure:

(1) I recently worked closely with David Greene and Changzheng Liu on a large project, and part of it involved doing choice modeling for a similar application. I am under the impression that it is their work you are going to be asking me to review. I already know a fair amount about how their choice model is likely to work, since I helped them with various aspects of a similar development for a feebate project. This could be seen as a plus, in that I am already quite knowledgeable.

(2) I am currently working on a similar project for DOT. That is, based on what I have been able to piece together, I think I have been tasked with doing work for DOT that is "parallel" to the work being done for EPA by David Greene. We are working with folks at Volpe who have a model that projects future technology choices of manufacturers, which as I understand it is the analog to EPA's OMEGA model. A colleague (David Brownstone) and I are working on new vehicle demand models (vehicle choice models) that would be "married" to their model to support CAFÉ analysis. I don't know if this would be perceived as a conflict/problem or not. I feel no sense of "competition" between us and Greene/Liu, and have no motivation to somehow "trash" their work to somehow make our work look "superior."

Acknowledgment

I declare that the disclosed information is true and accurate to the best of my knowledge, and that no real, potential, or apparent conflict of interest or bias is known to me except as disclosed. I further declare that I have made reasonable effort and inquiry to obtain the information needed to answer the questions truthfully, and accurately. I agree to inform SRA promptly of any change in circumstances that would require me to revise the answers that I have provided.

David Bunch________________

Name

9/15/2011______

Signature

Date

Conflict of Interest and Bias Questionnaire

Consumer Vehicle Choice Model Peer Review

Instructions to Candidate Reviewers

1. Please check YES/NO/DON'T KNOW in response to each question.

2. If your answer is YES or DON'T KNOW, please provide a brief explanation of the circumstances.

3. Please make a reasonable effort to answer accurately each question. For example, to the extent a question applies to individuals (or entities) other than you (e.g., spouse, dependents, or their employers), you should make a reasonable inquiry, such as emailing the questions to such individuals/entities in an effort to obtain information necessary to accurately answer the questions.

Questions

1. Are you (or your spouse/partner or dependents) or your current employer, an author, contributor, or an earlier reviewer of the document(s) being reviewed by this panel?

   YES___ NO_X_ DON'T KNOW___

2. Do you (or you spouse/partner or dependents) or your current employer have current plans to conduct or seek work related to the subject of this peer review following the completion of this peer review panel?

   YES___ NO_X_ DON'T KNOW___

3. Do you (or your spouse/partner or dependents) or your current employer have any known financial stake in the outcome of the review *(e.g.,* investment interest in a business related to the subject of peer review)?

   YES___ NO_X_ DON'T KNOW___

4. Have you (or your spouse/partner or dependents) or your current employer commented, reviewed, testified, published, made public statements, or taken positions regarding the subject of this peer review?

   YES___ NO_X_ DON'T KNOW___

5. Do you hold personal values or beliefs that would preclude you from conducting an objective, scientific evaluation of the subject of the review?

   YES___ NO_X_ DON'T KNOW___

6. Do you know of any reason that you might be unable to provide impartial advice or comments on the subject review of the panel?

YES___ NO_X_ DON'T KNOW___

7. Are you aware of any other factors that may create potential conflict of interest or bias issues for you as a member of the panel?

YES___ NO_X_ DON'T KNOW___

Acknowledgment

I declare that the disclosed information is true and accurate to the best of my knowledge, and that no real, potential, or apparent conflict of interest or bias is known to me except as disclosed. I further declare that I have made reasonable effort and inquiry to obtain the information needed to answer the questions truthfully, and accurately. I agree to inform SRA promptly of any change in circumstances that would require me to revise the answers that I have provided.

Trudy Ann Cameron__________

Name

Trudy Ann Cameron

Signature

Sept 17th, 2011____

Date

Conflict of Interest and Bias Questionnaire

Consumer Vehicle Choice Model Peer Review

Instructions to Candidate Reviewers

1. Please check YES/NO/DON'T KNOW in response to each question.

2. If your answer is YES or DON'T KNOW, please provide a brief explanation of the circumstances.

3. Please make a reasonable effort to answer accurately each question. For example, to the extent a question applies to individuals (or entities) other than you (e.g., spouse, dependents, or their employers), you should make a reasonable inquiry, such as emailing the questions to such individuals/entities in an effort to obtain information necessary to accurately answer the questions.

Questions

1. Are you (or your spouse/partner or dependents) or your current employer, an author, contributor, or an earlier reviewer of the document(s) being reviewed by this panel?

   YES___ NO_X_ DON'T KNOW___

2. Do you (or you spouse/partner or dependents) or your current employer have current plans to conduct or seek work related to the subject of this peer review following the completion of this peer review panel?

   YES___ NO_X_ DON'T KNOW___

3. Do you (or your spouse/partner or dependents) or your current employer have any known financial stake in the outcome of the review *(e.g.,* investment interest in a business related to the subject of peer review)?

   YES___ NO_X_ DON'T KNOW___

4. Have you (or your spouse/partner or dependents) or your current employer commented, reviewed, testified, published, made public statements, or taken positions regarding the subject of this peer review?

   YES___ NO_X_ DON'T KNOW___

5. Do you hold personal values or beliefs that would preclude you from conducting an objective, scientific evaluation of the subject of the review?

   YES___ NO_X_ DON'T KNOW___

6. Do you know of any reason that you might be unable to provide impartial advice or comments on the subject review of the panel?

   YES___ NO_X_ DON'T KNOW___

7. Are you aware of any other factors that may create potential conflict of interest or bias issues for you as a member of the panel?

   YES___ NO_X_ DON'T KNOW___

Disclosure:

I did work on a vehicle choice model under a California grant while I was at UC Berkeley. David Greene was working under the same grant at UC Davis. I do not believe that this would in any way prevent me from providing a thorough, unbiased, and impartial review of the present work product being reviewed.

Acknowledgment

I declare that the disclosed information is true and accurate to the best of my knowledge, and that no real, potential, or apparent conflict of interest or bias is known to me except as disclosed. I further declare that I have made reasonable effort and inquiry to obtain the information needed to answer the questions truthfully, and accurately. I agree to inform SRA promptly of any change in circumstances that would require me to revise the answers that I have provided.

Walter McManus_____________
Name

_____________________________ 9/19/2011_____
Signature Date

Appendix C: Peer Review Charge

MEMORANDUM

To: Professors David Bunch, Trudy Cameron, and Walter McManus

From: SRA International

Date: September 9, 2011

Subject: Review of Consumer Choice Model

You have agreed to serve as an expert peer reviewer of the consumer choice model developed by the Oak Ridge National Laboratory (ORNL) through the support of EPA-OTAQ. This memorandum sets out the parameters of your review and expectations for the work product you will deliver at the conclusion of your review.

<u>Background on the Consumer Choice Model</u>

The specification by OTAQ to ORNL for consumer choice model development was:

> "ORNL shall develop a Nested Multinomial Logit (NMNL) or other appropriate model capable of estimating the consumer surplus impacts and the sales mix effects of greenhouse gas (GHG) emission standards. The model will use output from the EPA's Optimization Model for reducing Emissions of Greenhouse gases from Automobiles (OMEGA), including changes in retail price equivalents, changes in fuel economy, and changes in emissions, to estimate these impacts. …The model will accept approximately 60 vehicle types, with the flexibility to function with fewer or more vehicle types, and will use a 15 year planning horizon, matching the OMEGA parameters. It will be calibrated to baseline sales projection data provided by the EPA and will include a buy/no-buy option to simulate the possibility that consumers will choose to keep their old vehicle or to buy a used vehicle."

Most consumer choice models use discrete-choice methods to estimate consumers' vehicle purchases and are, by far, the most common methodology used to mathematically model lightduty passenger vehicle demand, based on both consumer and vehicle characteristics. Baltas and Doyle (2000) succinctly summarize the methodology of discrete choice models, also referred to as random utility (RU) models. "In RU models, preferences for such discrete alternatives are determined by the realization of latent indices of attractiveness, called product utilities. Utility maximization is the objective of the decision process and leads to observed choice in the sense that the consumer chooses the alternative for which the utility is maximal.

Individual preferences depend on characteristics of the alternatives and the tastes of the consumer….The analyst cannot observe all the factors affecting preferences and the latter are treated as random variables."[4]

Since the early applications of random utility models in the 1970s[5], formulations of RU models have proliferated. Baltas and Doyle (2000) identified 14 different methods which they grouped into three fundamentally different approaches depending on the nature of the random utility:

- Unobserved product heterogeneity;
- Taste Variation (consumer heterogeneity);
- Choice Set Heterogeneity.

Nearly all applications of random utility models to automobile choice fall into the first two groups because the availability of different types of automobiles is rarely a significant issue. Randomness in the simple multinomial logit model derives primarily from unobserved attributes. Its error term may also include unobserved variations in taste but the representation of these variations is limited and simplistic. The same applies to Nested Multinomial Logit Models (NMNL), though their ability to represent randomness in unobserved attributes and tastes is much more complex. In these models, heterogeneity in consumers' preferences is commonly represented by explicit functional relationships between product attributes and consumer characteristics. Mixed Logit models allow variations in consumers' preferences to be represented by random coefficients, whose distributions can be inferred either from survey or market shares data.

Materials to Be Reviewed

We will provide you the model contained in a computer program and described in the report documenting the model. The report details the structure, key modeling assumptions, and data inputs utilized in developing this modeling approach to vehicle consumer choice. No independent data analysis will be required for this review.

Focus of Your Review

EPA is seeking your expert opinion on the data, concepts, and methodologies upon which the model relies, whether or not the model will execute the analysis correctly, and the suitability of the model for analyzing the effects of regulatory programs on consumer vehicle choices. Toward this end, we ask that you review and comment on the following items:

(1) in general, the overall approach to the specified modeling purpose and the particular methodology chosen to achieve that purpose;

[4] Baltas, G. and P. Doyle, 2001. "Random utility models in marketing research: a survey", *Journal of Business Research*, vol. 51, pp. 115-125.

[5] McFadden, D., 1973. "Conditional logit analysis of qualitative choice behavior", pp. 105-142 in P. Zarembka, ed., *Frontiers in Econometrics*, Academic Press, New York.

(2) the appropriateness of the model parameters and other inputs;
(3) the types of information that can be inputs to the model;
(4) the types of information that the model produces;
(5) the accuracy and appropriateness of the model's conceptual algorithms and equations;
(6) the congruence between the conceptual methodologies and the program execution;
(7) clarity, completeness and accuracy of the calculations made by the model;
(8) assessment of the accuracy of the model results and appropriateness of conclusions to be drawn from the model; and
(9) any caveats about the use of the model for regulatory analysis.

In your comments, you should distinguish between recommendations for clearly defined improvements that can be readily made based on data or literature reasonably available to EPA, and improvements that are more exploratory or dependent on information not readily available to EPA. Any comment should be sufficiently clear and detailed to allow a thorough understanding by EPA or other parties familiar with the model. EPA requests that you not release the peer review materials or your comments to anyone else until the Agency makes its report and supporting documentation public.

Appendix D: Reviews

Review of:
Consumer Vehicle Choice Model and Documentation
By David L. Greene and Changzheng Liu

Reviewed by
David S. Bunch
October 19, 2011

0. Introductory Remarks

Before proceeding, I would like to remark on the charge given to the reviewers, because there are elements of the charge (and also the review materials provided to us) that created extra challenges in the review process (at least for me). I expressed these concerns prior to agreeing to do the review, but the issues appear to be inherently stubborn, so my approach will be to address them first to provide a clarified context within which to provide a review.

The very first sentence of the specification given by OTAQ to ORNL illustrates the source of my concerns:

> "ORNL shall develop a Nested Multinomial Logit (NMNL) or other appropriate model capable of estimating the consumer surplus impacts and the sales mix effects of greenhouse gas (GHG) emissions standards."

Although it may seem nitpicky, the NMNL model produced by ORNL quite literally does *not* satisfy the specification quoted above (nor should it have). Specifically, the ORNL model we were asked to review *by itself* is not capable of "estimating … effects of greenhouse gas (GHG) emissions standards." Rather, it *is* capable of estimating the effects (consumer surplus impacts and sales mix effects) of changes in two specific vehicle characteristics: sales price, and fuel economy. This is what the software we were given actually does. So, reviewing the ORNL model should presumably address technical aspects of how it does what it actually does.

The charge we were given also asks us to provide an opinion on the *suitability of the model for analyzing the effects of regulatory programs* on consumer vehicle choices." It is clear that the larger purpose associated with this model is to allow EPA to perform policy analysis related to CAFÉ/GHG regulations. However, this can only be done in conjunction with the OMEGA model. Unfortunately, the materials provided to us were insufficient in describing the relationship between this model and the OMEGA model.

My approach to developing this review was to first clarify the role of the OMEGA model. Next, I provide background material on possible discrete choice modeling options that could have been used, and evaluate the particular methodological approach taken by Greene and Liu within the context of the overall modeling purpose. I am generally supportive of their approach under the circumstances, and I am satisfied that it has been implemented correctly. Finally, I provide a collection of comments of various types that could be of value for moving forward with the model and its documentation.

1. Purpose of the Model and Model Development

The overall (general) purpose of the model development is to enhance EPA's ability to analyze alternative CAFÉ/GHG policies and regulations. However, to evaluate the model itself requires a clear understanding of the model's role in this larger process. The model's *specific* purpose is not to be confused with the *overall* purpose to which it contributes. Specifically, this model, on its own, cannot be used effectively to analyze regulations. To provide clarity, we emphasize these distinctions in the following discussion of the model's purpose, inputs, and outputs.

The model developed by Greene and Liu is narrowly focused on producing estimates of consumer demand for new vehicles. These estimates can be used to compute a variety of measures useful for evaluating alternative policies: two specific measures are (1) consumer surplus impacts, and (2) changes in sales mix effects. Note that these measures (which involve changes) require estimates of consumer demand for both a *reference scenario* and an *alternative scenario*. (Note: for now we use the terms "reference" and "alternative." The documentation uses the term "baseline," with the potential for some confusion, as discussed later.)

An important thing to clearly understand is the model's *inputs*. The model requires a definition of the new vehicle market to form the basis for calculations. This consists of a list of individual vehicles that represent the complete set of choice alternatives available to consumers, plus attributes and characteristics of the vehicles. Some characteristics, once defined, cannot be changed and must remain exactly the same for both scenarios (reference and alternative). A key characteristic for definitional purposes is Vehicle Class. Other attributes are allowed to change between the two scenarios: these are the *input variables*. For this model, the key input variables for each vehicle are: sales under the reference scenario, fuel economy under the reference scenario, fuel economy under the alternative scenario, and price change (alternative versus reference).

Note that the model inputs are *not* "changes in CAFÉ/GHG policy." To produce a complete analysis of changes in CAFÉ/GHG policy requires the use of both the OMEGA model and the Greene and Liu model. In what follows, we may specifically refer to the Greene and Liu model by alternative names: "the Model," "the CVCM," or, "the NMNL model." To address broader issues related to the evaluation of CAFÉ/GHG policies we may refer to, e.g., "the OMEGA-NMNL system" (or other alternatives implied by the previous sentence). To analyze the impact of a change in CAFÉ/GHG policy, the OMEGA model must be used to "predict" the fuel economies and price changes that occur. These, in turn, are passed to the CVCM. Note that this requires some coordination between the two models. For example, both models must be set up to use the same new vehicle market definitions. The reference sales used by OMEGA must be passed along to the CVCM unchanged.

Briefly returning to Model outputs: note that the most general, disaggregated output produced by the Model will be sales and market shares for the individual vehicles, for both the reference and alternative scenarios. Other output measures (e.g., change in consumer surplus) can be computed based on these more fundamental outputs. The current implementation of the Model calculates various output measures, but could be easily modified to compute others.

Remarks on the role of OMEGA: One of the things that made this review difficult is that the model documentation did not provide helpful background information on the relationship between OMEGA and the CVCM. For example, the introductory material (in both the Charge and the Documentation) talks about OMEGA having "a 15 year planning horizon," and indicates that the CVCM "will be calibrated to baseline sales projection data provided by the EPA." This implies that policy analysis would involve establishing a 15-year baseline (reference) scenario under a reference policy, and then running OMEGA under alternative (15-year) policies. It is also the case that analyses of this type typically have a base year (not to be confused with a baseline). How this was handled was not specified.

After some investigation (which included reading OMEGA documentation, and getting responses to questions from EPA staff) we collected additional information that helped us to make more sense out of the model documentation. OMEGA has a provision for establishing a vehicle database in a *base year*. OMEGA assumes that vehicles can be redesigned at any time during a five-year planning cycle. For a given CAFÉ/GHG policy, OMEGA, in effect "simulates" manufacturers' decisions over a five-year planning cycle so as to meet regulation requirements for a given target year (which may correspond to the last year of the planning cycle). It appears as though OMEGA allows calculations for up to three "cycles" (so perhaps this corresponds to the 15-year planning horizon). Having said this, it appears as though OMEGA always starts from scratch for each cycle, and simulates redesign relative to the base year in every case. (In other words, the cycles are not cumulative, yielding an internally consistent 15-year forecast.) [Note: It is possible that the information contained in this paragraph is not entirely correct. I did the best I could in the time available.]

Depending on who the target audience is for the model documentation going forward, I would recommend making the documentation more "user friendly" by adding in this information (plus any other information that would be helpful).

2. Modeling Approach/Methodology

The Model uses methodology developed by Greene and co-authors over the years, which was used most recently in Bunch, et al. (2011). In this regard, the approach has appeared in multiple peer-reviewed publications during its evolution, so that it is well established with a solid history. (In other words, the model developed here does not represent a one-off exercise by researchers with little prior experience.) After providing some background, we review and comment on this methodology below.

2.1 Background on Discrete Choice Models

Discrete choice models based on solid economic theory are consistent with the notion of Random Utility Maximization (RUM). Consider a market with J vehicles indexed by $j = 1,..., J$. Consumer n's utility for vehicle j is given by:

$$U_{jn} = V_{jn} + \varepsilon_{jn} \quad (1)$$

where V_{jn} is a "fixed" portion of the utility that is in principle observable to the analyst, and ε_{jn} is an unobservable random disturbance. A consumer chooses the vehicle c that maximizes utility, and the choice probability is given by $P_{cn} = Prob[U_{cn} \geq U_{jn}, \text{ for all } j]$. Model development requires making assumptions about the functional form and explanatory variables in V_{jn}, and the probability distribution of ε_{jn}.

The Charge refers to a framework that identifies three "different approaches": unobserved product heterogeneity, taste variation (consumer heterogeneity) and choice set heterogeneity. These three notions are, in fact, not mutually exclusive and can co-exist within a single RUM framework. The Charge correctly points out that "choice set heterogeneity" is rarely assumed for vehicle choice models, i.e., all vehicle "types" are generally considered to be available to all consumers.[6] Virtually all discrete choice models assume "unobserved product heterogeneity."[7]

The most important distinctions among choice models are usually based on how they address consumer heterogeneity (taste heterogeneity). In this regard, there are two types of heterogeneity: observed and unobserved. "Observed" refers to models that explicitly include interactions between consumer characteristics (e.g., demographics) and product attributes in the fixed portion of the preference function that capture taste differences. "Unobserved" refers to, e.g., random coefficients.

Assuming a linear-in-parameters framework, some alternative utility forms are:

$$U_{jn} = V_j + \varepsilon_{jn} = \alpha_j + \sum_{k=1}^{K} f_k(X_j)\beta_k + \varepsilon_{jn} \quad (2)$$

$$U_{jn} = V_{jn} + \varepsilon_{jn} = \alpha_j + \sum_{k=1}^{K} f_k(X_j, D_n)\beta_k + \varepsilon_{jn} \quad (3)$$

---

[6] Note, however, that for future vehicle markets that include an initial rollout of advanced vehicle technologies, this may not be the case.

[7] This may actually be something of a misnomer, since some products may share the same unobserved attributes, and in this sense would not be heterogeneous. We would characterize this notion as "unobserved attributes." A related unobserved effect would be measurement error on attributes that are otherwise observable.

where X_j is a vector of attributes for vehicle j, D_n is a vector of characteristics for consumer n, f_k represents a mapping from the various input variables to the k^{th} of K explanatory variables, β_k is a preference parameter ("taste weight"), and α_j is an alternative-specific constant for vehicle j. If the ε_{jn}'s are independently and identically distributed (iid) with a Gumbel distribution, the result is a multinomial logit (MNL) model:

$$P_{cn} = \frac{e^{V_{cn}}}{\sum_{j=1}^{J} e^{V_{jn}}}, j = 1, \ldots, J \tag{4}$$

If V_{jn} is defined using equation (2) then the subscript n is lost, and the model can be considered a "representative consumer model," where V_j represents the average utility for vehicle j in a population of consumers (with preferences represented by the parameter $\boldsymbol{\beta}$), and ε_{jn} representing deviations from the average caused by all other effects (including unobserved product attributes, unobserved taste variation, etc.).

If V_{jn} is defined using equation (3), then the model incorporates (observable) taste variation by including the effect of consumer characteristics (typically, demographics such as income, household size, and number of workers). Note that simulating *total* market demand using a model based on equation (3) requires "integration" of choice probabilities over the probability distribution of demographic variables. (In practice, a finite number of demographic "segments" is identified, each with its own weight). If such a model were to be used for policy analysis, it would require forecasting future demographic distributions in addition to the more involved demand calculation (this is mentioned by the authors).

It is well known that the iid Gumbel assumption yields unrealistic behavior in the choice probabilities (Independence of Irrelevant Alternatives) with regard to product substitution. For example, if a small car were removed from the choice set, its demand would be expected to shift disproportionately to other small cars, and much less to, e.g., large SUVs. The MNL generally cannot capture this pattern of behavior. However, one way to address this deficiency is to develop models using equation (3) that include enough complexity in the f_k's to capture enough of the important effects, so that the remaining unobserved effects can be reasonably treated as independent. This would require detailed household-level data on vehicle purchase behavior.

Another way to address this issue is to introduce more complexity into the random disturbance terms. One type of complexity would be unobserved taste variation. For example, consider a group of consumers that have purchased the same small car. It is likely that these consumers have similar preferences in ways that are not captured by, e.g., equation (3), i.e., their disturbance terms are correlated. This can be captured as follows:

$$\begin{aligned} U_{jn} &= \alpha_j + \sum_{k=1}^{K} f_k(X_j, D_n)(\beta_k + \upsilon_{kn}) + \varepsilon_{jn} \\ &= \alpha_j + \sum_{k=1}^{K} f_k(X_j, D_n)\beta_k + \left[\sum_{k=1}^{K} f_k(X_j, D_n)\upsilon_{kn} + \varepsilon_{jn} \right] \\ &= V_{jn} + \tilde{\varepsilon}_{jn} \end{aligned} \tag{5}$$

where ν_{kn} is a random effect representing taste variation, so that in this model the disturbance terms ($\tilde{\varepsilon}_{jn}$'s) are correlated. If the ε_{jn}'s are still assumed to be iid Gumbel, then the choice probabilities *conditional* on a given set of ν_{kn}'s can be computed using equation (4). If many such probabilities are obtained by taking random draws on the ν_{kn}'s, and then averaging them to obtain simulated choice probabilities, then this is one version of a Mixed Logit model.

Another option is to use a nested multinomial logit model (NMNL). In this approach, the ε_{jn}'s are also no longer assumed to be independent. For example, unobserved attributes (and consumer preferences) for vehicles within a given vehicle class are assumed to be correlated. More generally, disturbance terms for vehicles in various classes are assumed to have a highly structured correlation pattern that can be represented by a tree. Alternatives within the same "nest" of the tree are assumed to have ε_{jn}'s that are more highly correlated than those in different nests of the tree. Choice probabilities for this type of model can be written using closed-form (albeit potentially complex) expressions, eliminating the need for simulation approaches such as those used with Mixed Logit. Analytical expressions for economic quantities such as elasticity can be obtained in a straightforward way. In particular, the literature provides a straightforward formula for computing consumer surplus for this particular model that is consistent with economic theory.

2.2 Evaluation of Methodology

2.2.1 Choice of Model Form

Greene and Liu have chosen to implement a Nested Multinomial Logit (NMNL) model based on equation (2) above. Specifically, they are using a "representative consumer" model that uses vehicle attributes as the only explanatory variables, so that a single set of choice probabilities can be computed to represent total market demand. Specifically, this is an *aggregate* demand model.[8] Based on the specification in their contract with EPA, they could have chosen to develop any "appropriate model," so all of the various options described above (plus others) were potentially on the table.

It is clear that most of the models described above make more detailed behavioral assumptions to explain consumers' vehicle choices than does the representative consumer NMNL (the only exception being the representative consumer MNL based on equation (2)). In this regard, they could be regarded as potentially superior in terms of more accurately capturing market reaction

[8] It would also be possible to develop a NMNL based equation (3), as alluded to below.

to changes in vehicle offerings. On the other hand, their model is extremely parsimonious while also capturing important market substitution effects across various types of vehicles, and Occam's razor could be said to apply.

The fact is that modeling future behavior of the new vehicle market is extraordinarily difficult. There is a relatively large literature on this subject, representing the efforts of many researchers using a variety of modeling approaches. As noted above, it could be argued on theoretical grounds that more complex models have the potential to be more accurate than an aggregate-level model. However, as shown in the review by Greene (2010), the results of more complex model estimation results vary over a wide range. Moreover, we are not aware of any studies that directly compare the accuracy of simpler models versus more complex models in any definitive way. Finally, it is well understood that modeling approaches are chosen based on a variety of factors, including the type of decision problem being addressed, availability of data to perform model estimation, data and computational requirements for using the model when performing scenario analysis, etc.

For this particular project, the ultimate goal is to use the OMEGA-NMNL system to analyze regulations. The most effective way to perform such analyses is by *comparison* of two scenarios (reference versus alternative) in response to specific types of *changes* (leaving all other factors constant). Specifically, the analysis is not predicated on requiring a model give the most accurate *forecast* of what will happen in the future (in an absolute sense). If this were the case, then it would be more important to include the effect of demographic variables over time (which would also require a demographic forecast), to predict structural changes in the vehicle market, and to simulate manufacturer decisions to add or delete various models (including the introduction of advanced technology vehicles).

The representative consumer NMNL form, and the inputs and outputs of the model, are an entirely appropriate choice of methodology for this problem. The OMEGA model itself is based on a specific model for manufacturer behavior whereby (1) the vehicle market definition does not change (2) the only changes to vehicles are the fuel economy and purchase price. Using this approach, this type of NMNL model could be readily integrated directly into the OMEGA model if necessary. In addition, this model could be viewed as only a starting point in an ongoing process of future model development. Additional complexity could be incrementally introduced into the model and evaluated.

2.2.2 Remarks on Model Notation and Equations

The specific NMNL form used by Greene and Liu has a tree structure that is much more complicated than most applications found in the literature. (Most have two or perhaps three levels, and exhibit a certain amount of symmetry.) In addition, they primarily use a notation developed over the years by Greene and co-authors that is not typically used by the rest of the field. The model parameters are one of two types: alternative-specific constants, and price slopes. The price slopes are the "structural parameters" of the model that relate to correlation among random disturbance terms in the RUM framework.

However, the use of the term "price slope" is potentially misleading, since one might infer that this is a model coefficient that exclusively applies to vehicle price.[9] Generally speaking, this parameter is a conversion factor that converts "generalized cost" (not just price) into "utility." In this approach, all of a choice alternative's attributes must be first expressed as costs (in dollars), and then added up. The resulting sum is then multiplied by a price slope to get "utiles." This works reasonably well for simple utility functions where the only entries are price and, e.g., present value of fuel costs. (It is also easier to digest when the model has only two levels.) However, in the future if other vehicle attributes are added (e.g., performance, vehicle size, etc.) this approach would be cumbersome. In discussing the implications of moving to lower levels of the tree, it is said that price slopes get larger (more negative), and that consumers are more "price sensitive." Again, this is potentially misleading, since consumers are actually becoming more "attribute sensitive."

The authors also include two other notational conventions in various locations in the paper. The other conventions are used more widely in the literature, with more conventional interpretations of the structural parameters as relating either to the scale or the variance of the (conditional) random disturbance term. The can also be used to express the degree of correlation between disturbance terms in the same nest. Overall, the way the notation, equations, and interpretation of parameters are used in the documentation could be said to be "sub-optimal". The authors are attempting to keep things simple (but still technically correct) in some places, but also more complete in other places. This is not an easy job, but depending on how EPA would like to use the documentation going forward, some attention may be required to these issues.

2.2.3 Approach to Determining Model Parameters

Greene and Liu take an approach that is a bit different from what is typical in most of the literature. Specifically, most researchers determine model parameters by obtaining data on vehicle choices (typically at the household level), and then using statistical estimation methods to obtain parameter estimates. In contrast, Greene and Liu use the parsimonious model form described above, and take a "calibration" approach. They make assumptions about the values of price elasticities, which are in turn related to the values of structural parameters (price slopes). The alternative-specific constants, on the other hand, are calibrated using actual sales data for a particular base year. (We say "calibrated" rather than "estimated" because there is a direct deterministic mapping between sales and the constants.) The assumptions on the elasticities are based on a review of the literature, combined with theoretical considerations related to the model. The values of the structural parameters are related to the elasticities, but there is not a deterministic relationship as in the case of the alternative-specific constants. The authors use an *ad hoc* approach to estimating price slopes based on elasticities. Although there could be a better way to do this, under the circumstances it seems reasonable. Finally, the only utility attribute currently required by their model is an estimate of the value of fuel savings from an improvement in fuel economy. This can be computed on the basis of additional assumptions.

[9] Potentially more confusing, the authors sometimes refer to "price coefficient" (e.g., on page 120.

Their approach avoids many of the pitfalls of the statistical estimation approach. First, the statistical approach requires access to good data sets (which are frequently not available) and a lot of difficult econometric analysis. When using this approach, revealed preference data are rife with multicollinearity, stated choice methods (which can overcome multicollinearity) are not universally accepted, and all aspects of such analyses are subject to debate and criticism that are a distraction from the main purpose of policy analysis. The literature review by Greene (2010) illustrates that the parameter estimates obtained via this approach are very context dependent, and can vary widely. In particular, there is very little agreement on a key issue: how consumers value fuel economy/fuel savings.

I support the decision by Greene and Liu to use a parsimonious NMNL model with a calibration approach. The assumptions can be debated separately from other parts of the analysis, and can always be changed to test their implications.

2.2.4 Chosen Values for Model Parameters

As already noted, there is a relationship between price elasticities and NMNL structural parameters (aka "price slopes"), and that the mapping is not one-to-one. The method used by the authors is described on page 29. Although there may be better methods, this one seems sufficient in practice. The other question is how to choose the elasticities. They do this based on values found in the literature, also recognizing that the NMNL requires the type of ordering found in equation (38). They provide a discussion (page 31) to support their selections, which seem reasonable. Having said this, one thing that is missing is an analysis of the distribution of price elasticities produced from actual runs of the Model itself. This would seem to be a useful validation exercise.

3. Summary of Responses to Charge Items

On page 2 of the Charge to Reviewers there is a list of nine items, plus some other requests for review and comment. The following is a summary of responses (and perhaps non-responses) to all items.

Section 1 of this review provides background on how the ORNL model relates to the overall purpose of evaluating regulations in conjunction with the OMEGA model. This addresses the types of information used an inputs to the Model (item 3), and the types of information the model produces (item 4). Section 2 provides a review of the overall approach used (item 1) as well as the appropriateness of the equations (item 5). Item 5 also asks for an evaluation of the "accuracy" of the equations. I am not quite sure what that means. The equations and derivations are generally correct (although see my concerns about notation in section 2.2.2).

Item 6 asks for a review of "the congruence between the … methodologies and the program execution" and item 7 asks about the "accuracy of the calculations made by the model." Similarly, item 8 asks for an "assessment of the accuracy of the model results." Depending on what is meant by "accuracy," I would either need to do a detailed analysis that includes checking the source code of the model (plus program my own version), or, I would need to have some specialized knowledge of what the "true" market shares and elasticities are. Either would not be workable. Having said this, I do recommend that additional test calculations be performed for validation purposes (section 2.2.4).

Item 9 asks for "caveats about the use of the model for regulatory analysis." Similarly, we are asked about the suitability of the model for analyzing regulatory programs, and for recommendations for clearly defined improvements, etc. As noted in the introduction and in Section 1, the suitability of the model for regulatory analysis hinges on how it is used in conjunction with the OMEGA model.

In terms of practical advice, I would offer the following observations: At this stage of development the ORNL model appears to be working in isolation and has not been "exercised" in conjunction with the OMEGA model. Based on what I can tell, the ORNL model has been developed and tested (in a limited way) using an augmented version of a CAFÉ data set. Based on e-mail exchanges, this may be from 2008. There needs to be some coordination and testing that involves both models, including common data for an agreed-upon base year. One concern is that, if the number and/or types of vehicles in the market definition were to change, it could affect how the ORNL model behaves. In particular, if the new market definition, e.g., reduced the number of configurations for each make/model combination to one, this could have implications for the elasticities at the bottom level of the tree.

More generally, it would seem important for regulatory analysis to establish some type of reference (baseline) scenario over the planning *period* (not to be confused with the base year). EIA produces forecasts of new vehicle sales as well as fuel price forecasts. There must be some working assumption about CAFÉ/GHG standards associated with these forecasts. What does EPA regard to be the reference assumptions for future CAFÉ/GHG standards?

One other concern: There seems to be some murkiness around the changes in vehicle cost/price associated with the technology packages. In at least one place these are called "retail price equivalents" (RPE). In other places they are simply identified as "costs" or perhaps "long-run average costs." More generally, it seems that manufacturers would be able to change vehicle prices as well as well as fuel economy in order to meet standards. Of course, the current version of OMEGA could not really deal with that because it does not incorporate sales shifts. However, one potential improvement to the ORNL model would be to identify price changes that would put manufacturers back into compliance. (Actually, the authors mention this on page 5.)

Other minor items:

The reference to Train 5 is incorrect. It should be 1986. (The third printing was in 1991, but that is not the same thing.)

In the middle of page 5, it is claimed that the nesting structure in CVCM is similar to those used in empirically estimated models. I don't think this is strictly true, but would welcome a reference. (NERA does a type of estimation, but assumes values for the structural parameters as is done here.)

On page 10 there are problems with equation (6), depending on the interpretation of the *U* values. The *U* values in equation (5) are random utilities, which are unknown and cannot be used in equation (6).

On page 11 it is claimed that the NMNL model is “also known as the Generalized Extreme Value (GEV) model.” This is incorrect. NMNL is a special case of the GEV.

On page 12, middle of page, it says “In equation (6) each nest has a different set of coefficients that map vehicle attributes into the utility index. In particular for this model, the price coefficients differ across nests.” This is generally not true for the form of the model they are attempting to use on this page, and represents the type of confusion that can arise based on the discussion in section 2.2.2 above.

To:

Gloria Helfand
US EPA, Assessment and Standards Division (OTAQ)
2000 Traverwood Drive
Ann Arbor, Michigan 48105

From:

Trudy Ann Cameron
1165 East 23rd Avenue
Eugene, OR 97403

October 14, 2011

Cover letter to accompany Review of Greene and Liu (August 2011) "Consumer Vehicle Choice Model Documentation" and accompanying software "CVCM_v1.5"

Greetings:

The documents that I received from SRA International included a memo containing the charge questions and the draft document by Greene and Liu (August 2011). I also received the installation program for the software.

I reviewed all of the documents that I received in developing my expert opinion as contained in the "Review of Greene and Liu (August 2011) 'Consumer Vehicle Choice Model Documentation' and accompanying software 'CVCM_v1.5'" submitted on October 14.

I declare that there are no real or perceived conflicts of interest concerning my involvement in this review for the EPA.

Best regards,

Trudy Ann Cameron

Review of:

Greene and Liu (August 2011) "Consumer Vehicle Choice Model Documentation" and accompanying software "CVCM_v1.5"

by Trudy Ann Cameron

Contents

Introduction

Let me say, first, that this model represents a truly heroic effort to pull together many disparate bits of evidence about the responsiveness of demand for particular types of automobiles to changes in purchase prices and fuel economies (via the effect of that fuel economy on the implied operating cost of the vehicle). This was a challenging assignment for the project team. Many of us can content ourselves with the very focused academic research that is needed to establish perhaps just one or two of the ingredients for an exercise in synthesis such as this one. We are excused from having to pull everything together across a motley collection of piecemeal efforts in an effort to build a comprehensive tool that makes it possible to work out what might happen to the overall market when mandated changes in fuel economy work their way through production costs and consumer responses.

Thus to a certain extent, I feel sheepish about complaining about the things that the current version of this tool does NOT do, since I'm very glad not to have to try to deliver something like this myself. But my role is to offer a critique of the tool, so I will point out the ways in which it could be improved and raise questions about omitted features that could make a difference to the implications of the simulations it is designed to process.

I would also like to be clear that I did not seek to get inside the C# code that implements the calculations described in the supporting document. I received the software as a user, not as a C# programmer, so I am only able to examine the inputs and the outputs for their apparent consistency with the model as presented in the Documentation. In any event, I do not program in this language myself, so I am not qualified to evaluate the underlying code. Thus I will limit my commentary on the software to the way in which the user interface is set up and the extent to which it seems to be "user friendly." I will suggest ways in which the user-friendliness could be improved.

Comments

Main Substantive Concern: Reflecting the uncertainty in the predictions

Spurious precision.—I am concerned that the calculations performed in the CVCM program are based upon rather arbitrary assumptions about the influence of changes in net annualized costs (capital and operating) on the market shares of different types of vehicles. The document is very clear that the empirical literature produces quite a range of possible estimates. It will be important to know just how much the arbitrariness of the input assumptions affects the output results.

Fixed parameters versus distributions on parameters.—I notice that the calculations can be executed very quickly, despite the degree of disaggregation. It would thus seem possible to embed the calculations within a loop that permits random draws from some assumed joint distributions of the input parameters. Instead of stipulating elasticities in column C of the "logit" sheet in the input .xlsx file, it would be beneficial if several additional columns could be specified. One of these extra columns could define the standard deviation of an assumed normal distribution for the parameter in question, and another pair of columns could contain the minimum and maximum values of a uniform distribution over that range. Of course, this assumes that the two most defensible distribution types for these parameters are either normal or uniform. An alternative might be to use "noisiness" estimates on each of the finite number of distinct elasticity estimates appearing in the literature, perhaps using an average of independent draws from these various distributions.

Honoring the bounds on elasticities across levels.—In any single iteration of the calculations, the program could make a random draw for the bounding elasticity values for Level 0 (lowest), which would define the limit of any acceptable elasticities drawn for each of the other levels. Draws could progress through levels 0 through 4. Any draw that violates the ordinal requirements imposed by the earlier level could be discarded and replacement draws could be made until that iteration produces a set of elasticities across levels 0 through 4 that conform to the a priori ranking requirement.

Allowing for some non-zero correlations between parameters.—Possible correlations among elasticity estimates within a group could also be imposed. It is likely intractable to specify the full N(N-1)/2 unique correlations between the elasticities, but perhaps the ability to specify that the correlations are something other than zero would be valuable. We are likely to be too high or too low simultaneously for subsets of vehicle types. Cholesky factorizations of the assumed elasticity variance-covariance matrix can certainly be used in the case of elasticities which are assumed to be multivariate joint normal in their (unobserved) distributions.

Build sampling distributions for output measures.—For each iteration (replication, "draw"), something like the existing program could be executed once to produce a vector(s) of results like those that are currently sent to the output file. Across a large number of iterations (1,000 or 10,000, for example), the program could build up a sort of a "sampling distribution" of outputs which could be summarized by their means and their variances (and covariances). This strategy of simulating the distribution of outputs would give users a better sense of how the implications of the model depend upon how precise we are able to be about the key input data on elasticities.

The InputValidation task could be adapted to help screen each draw from the assumed joint distribution of elasticities. The program could initially be run with just 100 random draws from the joint distribution of inputs, to see what range of results is generated, both for every result in the "Raw Output" table and all of the results in the "Aggregate Output" table.

Richer summaries of model results.—I would also like to see at least two more columns in the "Aggregate Output" file that show the percentage changes in each of the results, relative to baseline. A simulated distribution for each of these percentage changes, driven by the uncertainty about the elasticities used as inputs to the model, would leave the user with a much clearer idea about how sensitive these outputs are to the noise in the input information. I'm a big fan of standard errors. When the confidence bounds on a predicted change easily exclude zero as a potential result, I am much more impressed that something is going to change. If the "no change" outcome is well within the confidence bounds, despite the central tendency across simulations being positive or negative, this is much more informative than just the point estimates produced by the current model.

Needed software capabilities.—To implement this strategy for demonstrating the sensitivity of outputs to input amounts, the software being used to run the program would need access to a pseudo-random number generator, probably for both normal and uniform random variates. The information about standard errors and correlations would have to be harvested from the appropriate columns of the modified Logit sheet in the Input Excel file and assembled into a variance-covariance matrix for the complete set of elasticities. As elasticity draws are made for each level, the result would define acceptable draws based on the submatrix of variances and covariances at the next level, all the way to Level 4.

Other potentially stochastic variables.—Key assumptions such as the payback period and the discount rate should also be subjected to systematic sensitivity analysis. It may be simpler just to run one batch of simulations for each of a handful of different settings, but it would be possible to draw each of these important quantities from a specified distribution as well, to impart that uncertainty into the final outputs of the model. Perhaps users could be given the option to select fixed or randomized values for these global parameters.

To the extent that other inputs to the model are also not known with certainty, there could be an additional layer of simulations within each iteration. For example, if forecasts of the population or number of households come with standard errors, those could also be subjected to random draws.

Aspects of the Documentation

Section 3.2 (Equations)

In the Prelude section, in equation (15), a *vector* of vehicle attributes that is assumed to influence the utility of alternative *j* to individual *n* quietly turns into nothing more than a "sum" G_j that represents a “generalized cost” for alternative j. All other attributes of these vehicles besides their price become non-explicit and apparently get soaked up by the alternative-specific constant utility component α_j for that vehicle, which is therefore assumed not to vary with price. It would also seem that the individual and alternative-specific random utility component ε_{nj} must be assumed to be independent of the generalized cost variable if the coefficient β_p is to be unbiased. How does this work? What about the fact that there are reasons for some vehicles to be more expensive than others. The coefficient on price is intended to be a “ceteris paribus” effect of price on utility, holding all other features of the good constant. If vehicles have higher prices because they are more luxurious, more powerful, or more prestigious to own, how do you deal with the intuition that price is an indicator of quality to a large extent—in that it reflects many other things that differ across different types of vehicles? If these positive correlations among other attributes and price are present, but you fail to control for these other “hedonic” features of each vehicle, then a model with only price is likely to have a substantial upward bias in its price coefficient. The effect of a higher price is exaggerated by all of the other desirable features that accompany a higher price in the actual data. Too high a price coefficient will exaggerate the predicted response of demand to a change in generalized cost due to mandated improvements in fuel economy.

Where this matters, however, is not so much in the illustrative market share model developed in this document. Instead, it is crucial that the empirical research that produced the selection of price-responsiveness parameters for the calibration of this tool should have been careful to control for other vehicle attributes that are correlated with prices. This document could thus avoid setting off alarm bells for the reader by carrying along the other control variables in equation (15), or by explaining very clearly why other attributes can be ignored. The model assumes that increased fuel efficiency has no value to consumers other than through the reduced vehicle operating costs that it implies. (This may make it hard to explain demand for hybrid vehicles, especially in Los Angeles where they could get you into the carpool lane without a passenger.)

If all vehicle attributes, including price, are constant for a given make and model, then an empirical choice model specification might have nothing on the “right hand side” except a full set of alternative-specific constants (other than the one that is set to zero for normalization). The Documentation could spell out that you are merely partitioning the alternative-specific constants, in what would otherwise be a simple fitted market share model, by peeling off a component of each alternative-specific constant using some assumption about a universal “price coefficient” combined with some data on the “generalized cost” for every alternative currently on the market.

As someone who has mostly worked with choice models where the attributes differ both by alternative and by individual, I find it can be a bit of a difficult transition to think about random utility choice model specifications where attributes differ only by alternative, remaining constant across individuals. Pointing out this feature of the modeling framework at the beginning of the discussion could be helpful to other empirical choice modelers like me.

Incidental: I'm accustomed to the most disaggregated alternatives being called "elemental" alternatives, as in the Appendix. On page 26, however, they are called "elementary" alternatives. Please be consistent.

Section 3.3 (Value of Fuel Economy)

Allcott (2011) (a recent AER paper entitled "Consumers' Perceptions and Misperceptions of Energy Costs") would also be very relevant here. He uses a "nationally representative survey that elicits consumers' beliefs about gasoline prices and the relative energy costs of autos with different fuel economy ratings."

The "rebound" effect.—I am concerned that *M* in equation (35), annual VMT, is assumed to be exogenous. There seems to be a lot of literature concerned with the "rebound effect." For example, Barla et al. (2009), Eskeland and Mideksa (2008), Frondel et al. (2008; Greene et al. (1999; Greening et al. (2000; Hymel et al. (2010; Jones (1993; Kemel et al. (2011; Small and Van Dender (2007) all discuss this issue. Since Greene is one of these authors, we know he is aware of this. It would seem that *M* should be considered as endogenous, and should be specified as a function of the difference in fuel economy, rather than being treated as a constant that depends only on the age of the vehicle.

Capitalization of fuel economy into vehicle resale prices.—The parameter *L*, the "assumed payback period, in years," is presumably linked to planned duration of vehicle use (and is inherited from the OMEGA assumptions). However, it seems important to think about the extent to which fuel efficiency is capitalized into the resale value of used cars. If greater fuel efficiency enhances a vehicle's resale value, so that the capitalized value of fuel savings for used cars is fully reflected in their prices, the effective planning horizon is actually a lot longer—perhaps extending to the useful life of the vehicle. The current formulation is implemented with a value of 5 (years) in the GlobalParameter sheet for the CCM inputs. Allcott and Wozny (2010), for example, find that consumers are willing to pay \$0.61 to reduce expected discounted gas expenditures by \$1. This estimate undoubtedly hinges on their assumptions about individual discount rates. However, the fact that this WTP estimate is not zero suggests that a finite time horizon, with no "resale-value increment" factored into the model of expected fuel (cost) savings in equation (35), might need some re-thinking.

Heterogeneity in the OnRoad discount factor.—Is there evidence to suggest that the "Actual/Rated MPG" is constant across all types of vehicles? Surely this ratio has been established for almost all classes of vehicle. Consumer-contributed data by make/model/year seem to be available at www.fueleconomy.gov, for example, but the data are rather thin. It might be possible to do better here.

Section 3.4 (Calibration)

It would be helpful to first write the formula for a price elasticity of demand in a conventional Econ 101 format. If a demand equation is linear and additively separable in price, where the derivative of quantity demanded with respect to price is β_c, this formula in the single-equation case should be:

$$\eta_j = \left(\frac{\partial q_j}{\partial p_j}\right)\left(\frac{p_j}{q_j}\right) = \beta_c\left(\frac{p_j}{q_j}\right) = p_j\beta_c\left(\frac{1}{q_j}\right) \qquad (2)$$

To help the reader determine whether it is necessary to go find their copy of Train (2009), it would be helpful to explain how we get from $\left(1/q_j\right)$ to $\left(1-S_j\right)$. If this step is transparent, it can go right into the derivation in the text. If it is more complex, explain that the reader really needs to ponder an extended discussion in Train (and give a preview of what is involved there).

Emphasize in the discussion of equation (38) the strong assumption that the underlying β parameter (before normalization on the error dispersion for a given nest) is the same across all levels and branches of the model's correlation structure diagram. It is only the dispersion of the errors in each partitioning that leads to different normalized values of this parameter, B.

Appendix (Derivation of Nested Logit Model Equations…)

Include the additional assumption that the error terms ε_c and $\varepsilon_{j|c}$ are independent and hence uncorrelated (so that there is no covariance term in the variance of their sum).

Some notes on the current version of the software

The CVCM software is desperately in need of some more user-friendly instructions. When you first open the program, the Help button is inactive. (There is a "Contents" button and an "About…" button, but these have not yet been populated/activated.) Clicking on the File button offers two options: "Open" and "Output file to…" as well as an "Exit" option. Those are the only clues the user gets.

Fortunately, the "Open" button takes you to the input folder inside the CVCM_v1.5 folder where the program resides, and it is logical to try the one called "Baseline" first. This action fills the two small boxes in the program's window with just some of the information from the input file.

e.) It is irritating that you cannot drag the corner of the window to expand its size. With a whole widescreen monitor to work with, and with content that must currently have its headings truncated to fit, a re-sizeable window would be great. Right now, if you expand one column, all the others must shrink. A slider at the bottom of each window would be helpful, as in Excel, so that you can keep each column heading fully expanded and scroll to see those which are out of the current window.

f.) There is nothing in the user interface to suggest that there is vastly more information in the Excel spreadsheet in the Input folder than what seems to populate the limited number of boxes in the program window when you choose an Input file.

g.) Even inside the Input file, it took me a while to notice that there were multiple sheets in this spreadsheet. 1130 vehicles in the Vehicle sheet, 18 car companies in the Manufacturer sheet

h.) There is nothing to imply that the automobile icon in the upper right corner is the "execute" button. It just looked like a cute little graphic.

Responses to specific charge questions:

1. Overall approach, particular methodology chosen

From a broader social welfare perspective, the model is a bit narrow. Its goal is to explain the mix of vehicles sold and to predict how this mix might change when vehicle prices are affected by the costs of meeting more stringent fuel economy standards. However, this is not part of a full computable general equilibrium model. Instead, the OMEGA model apparently minimizes the costs of achieving a particular carbon dioxide goal across a variety of possible technology packages, and these higher costs are passed (in one direction) to the CVCM to predict the effects of higher vehicle prices on the demand for different vehicle types and therefore on the sales of each company and the resulting corporate average fuel economy effects, to a first approximation.

In reality, there would have to be a feedback. From an "Econ 101" perspective, higher production costs because of technology requirements will cause supply curves for almost all vehicles to shift upwards to varying extents. Depending upon the shapes of the corresponding demand curves for these vehicles, prices of some vehicles are likely to increase more than others. Changes in relative overall costs of vehicles and their operation (including discounted future fuel savings), in combination with different cross-price elasticities of substitution, will cause overall demand to be reallocated among manufacturers (or within each manufacturer, across product lines). This naturally raises the naïve question of why are there no estimates of *cross-price elasticities* of demand in the model. The demand curve shifts induced by changes in relative overall prices for different vehicles, in conjunction with supply elasticities, will have further effects on equilibrium prices of different vehicles, with further changes in consumer surplus across new vehicle buyers.

The market share model, as a function vehicle own-prices and incomes, with no feedback to the supply side, necessarily misses the effects of demand shifts in response to changes in relative prices as a result of the original supply shift. There are likely to be heterogeneous price changes and cross-price elasticities that are different from zero.

I worry about this model's narrow focus on how much vehicle prices go up due to standards and the resulting loss in consumer surplus in vehicle markets. We cannot conclude that vehicle buyers will be "hurt" to this extent without considering the potentially countervailing benefits from reduced carbon emissions and fewer emissions of conventional pollutants. This consideration needs to be mentioned explicitly somewhere in the story. I would like to see more emphasis that while some surplus will be lost by consumers of this product, society as a whole will avoid the negative increment to overall social surplus stemming from over-production (and over-consumption) in the presence of external costs (excessive carbon and other pollutants) currently borne by the everyone, rather than just the buyers and sellers of new vehicles.

2. The appropriateness of the model parameters and other inputs

As noted above, I am greatly concerned about the misleading impression of precision that is created by the use of arbitrary simple point estimates for price elasticities. These point estimates are selected from a sparsely populated range of empirical estimates of just a subset of the needed elasticities. These empirical estimates are typically for more-aggregated categories of vehicles as well. It seems imperative to implement a strategy for capturing the uncertainty about the true parameters that capture price responsiveness. The model cannot predict exact market shares, yet readers will be lulled into thinking that they can be confident in its predictions about changes in market shares and consumer surplus. Consumers of the model's results need to know how sensitive all of its predictions are with respect to the actual state of knowledge about the necessary input quantities.

The documentation for the model is very clear, on page 4, about the list of potential sources for prediction errors, including source number 4, "Errors in NML parameters." Just acknowledging these sources, however, does not reveal the potential sizes of these errors, relative to the predictions of the model. I think it is imperative to try to capture at least some of the noise that is actually in the model, so users are not left with zero information about the sensitivity of the results to at least some of the key subjective inputs. There is not much to be done about "model uncertainty," or "input variable uncertainty" (unless even more layers of randomization are added to the framework in which each single simulation is embedded), but at least some of the parameter uncertainty could be accommodated.

3. The types of information that can be inputs to the model

The assumption about individual discount rates is central to the choice model because it is necessary to express utility from each vehicle as a function of the present value of future fuel savings that accompanies the higher purchase price of a vehicle with improved fuel economy. Assuming one common discount rate for everyone, even if that discount rate can be adjusted, will miss the fact that individual subjective discount rates vary systematically with a number of individual characteristics. Furthermore, when it comes to capital-cost/operating-cost decisions like the ones made in the new automobile market, the fact that capital market constraints can sometime masquerade as higher individual discount rates may be very relevant. People who are heavily capital-market constrained may make very different choices in durable goods markets than people who are not. These vehicles will have different mixes of capital and operating costs at the baseline, and different fuel efficiency requirements will change the capital/operating cost mix as well.

The model is very flexible in terms of the different quantities that can be set by the user, although all of these quantities are entered as point values, rather than likely distributions. For example, the model seems to include gasoline and diesel prices for twenty years into the future, and these individual parameters lend the appearance of being amenable to being very precisely and independently specified. When I clicked on each cell to ascertain how it was being calculated, I expected to see each future cell computed as the starting value subjected to a growth rate, but this is not the case. It seems necessary for the user to propose a price per gallon for each type of fuel in each future year. It is not clear why these settings as flexible as they are (unless the programming merely anticipates that users will ask for such flexibility eventually). Would it be possible for users, alternatively, just to choose a rate of growth or a linear trajectory for these two fuel prices (with confidence bounds, of course)?

Among the global parameters, the user appears to be invited to provide individual independent estimates of the population and average household size from 2010 to 2030, although the note in line 6 suggests that these numbers come from the U.S. Census Bureau's projections of the U.S. population (not "polution") to 2050. It is not clear from this sheet what might be the Census Bureau's basis for such precise population estimates over a twenty-year horizon, or for the static value of projected average household sizes over the same period. What about how the baby boom is moving through the demographic landscape? Might it be reasonable to allow the user, alternatively, to commit only to an estimate of growth rates (with confidence bounds)? This could be based on the current actual population estimate in the starting year. Perhaps for flexibility into the future, these years could also be expressed relative to the current year, rather than as absolute time. In short order, the "starting" year of 2010 will definitely be obsolete.

Also among the global parameters, it might make sense to make the contents of "Market Size-CycleX" to be linked to the content of the relevant future population cells, both in this case, with one cycle specified, and when more than one cycle is specified. Perhaps "Input Validation" is a way to make sure that things line up in a foolproof way, but that is not transparent. It should also be made clearer in the column headings how the cycle length (six years, apparently) is related to assumptions about the length of the payback periods (if it is). If there is a relationship, functional relationships among the values for the fields could enforce these relationships.

To keep the program as self-contained as possible, please be clear, among the notes to this sheet, what are the definitions of a "cycle" and what is meant by the "OnRoad Discount" field. We know this is the fraction of advertised MPG that is actually achieved in regular driving, but it might be better to call it something else, unless there is a tradition in the literature of using this terminology. Perhaps "Actual/Rated MPG."

On the VehicleUse sheet, individual car and truck Survival (not Survial) Rates, by age, need to be specified. Again, I expected that each cell would be a function of the previous one, perhaps until a threshold was reached. Again, however, users are required to be specific about each cell, which probably overstates the precision that is feasible in forecasting these survival rates. Historical survival rates are not really relevant because of the substantial changes in materials and technology in recent decades. It might be preferable to allow users the options to specify a starting survival rate and a parameter according to which the survival rate changes over time (with confidence bounds) so that these cells can alternatively be populated automatically according to that function. The confidence bounds would allow for sensitivity analysis.

Without more information, the column headings in the Target sheet are just too cryptic. It is not clear what is meant by a "cycle," or what are the units for the "a" and "b" fields, or the "c" and "d" fields for cars and trucks, or why there are lower and higher constraints for both. These sheets could be rendered more self-contained and self-explanatory with more "Notes" as are offered on some other sheets. Since it is desirable to leave room for other "cycles" in this sheet, perhaps the headings could be expanded with "wrap text" invoked so that users could be confidence about what information was needed in each of these cells for each cycle.

The Logit sheet finally invokes the types of cross-sheet and cross-cell functions I expected to see elsewhere in the setup. The rank ordering of the degree of responsiveness of demand to full cost of a vehicle (I assume) is enforced at the level of the "Slope" variable, rather than among the "Elasticity" settings that the user is free to specify. Are there any values for the ingredients to this calculation for which a rank ordering of the elasticities will not produce an identical rank ordering of slopes? That would seem to be a possible problem. Users could specify elasticities that were admissibly rank-ordered, but the relationship among the slopes would then be rejected by the slope-ranking test.

Also in the Logit sheet, the counts of vehicle types at Level 4 (“Number of Members”) are linked directly to the Vehicle sheet where the full range of vehicles is inventoried. However, at level 3, the “Number of Members” seems to be set independently, without reference to the number of Vehicle Classes. Is there a way to make the software robust to the introduction of a user-specified new Vehicle Class? This might require the introduction of a “Type” column next to the “Class” column for Level 4 that shows the mapping from Classes to Types. I am comfortable that we can get along for quite a while before it would be necessary to introduce a new Category, but perhaps an extra column under Level 3 to make the corresponding Categories explicit for each Type would also be helpful. This information is contained in the (verbal) Parent Node, but it might be clearer to have the Parent Node relabeled as “Parent Type” for Level 4 and “Parent Category” for Level 3.

While we are at it, it would be more logical to have Level 1 at the top, progressing down to the most disaggregated levels at the bottom of the sheet. At least in my experience, correlation structure diagrams are not upward-growing “trees” but downward-expanding “root systems.” This could be just a matter of taste, but I had been visualizing the structure as expanding downward (perhaps in the order in which consumers narrow down their vehicle choice), so the reverse ordering of the Logit Sheet came with a bit of cognitive dissonance. Perhaps I was basing my expectations on Figure 1 on page 21 of the document.

4. The types of information that the model produces

Yet again, my concern in that the point estimates of consumer surplus and sales embody spurious precision. For example, it is hubris to predict industry revenue in hundreds of billions down to the exact dollar. At best, *the predictions of the model should be rounded to no more than two or perhaps three significant digits and confidence bounds of some kind should be provided*. The same goes for all of the other model outputs. The key elasticity settings must be so arbitrarily selected from the extant empirical estimates that it isn’t wise to imply so much accuracy in the results file. *The precision in the results can be no greater than the precision in the elasticity estimates that serve as inputs, since these inputs are the weakest ones.*

5. The accuracy and appropriateness of the model’s conceptual algorithms and equations

I am accustomed to seeing the qualification that the correlation structure in a nested logit model does not necessarily imply a sequential decision process. All it does is highlight subsets of choices within which there is an error component unique to the group and different from analogous components associated with other groups. My specific concerns about aspects of the conceptual approach are itemized above.

6. The congruence between the conceptual methodologies and the program execution

The software appears to do what is described in the Documentation.

7. Clarity, completeness and accuracy of the calculations made by the model

As explained above, I believe the calculations made by the model are too "accurate." They overstate the precision with which such forecasts can possibly be made. Some way to incorporate uncertainty is important, but it is also important to acknowledge that the user has to pick and choose between competing options for the point estimates of the elasticities for each level of the nests. Given the gaps in the empirical data, especially the differing vintages and contexts of the studies in which these sparse values have been quantified, the user just has to guess something reasonable for many of the settings, or use some kind of weighted average of the point estimates across different studies. If those studies were competently done, each estimate will come with confidence bounds and that uncertainty about these key ingredients to this program needs to be acknowledged somehow.

8. Accuracy of the model results, appropriateness of conclusions

Again, the model results leave the impression that these redistributions of consumer demand can be calculated, in many cases, to five or more significant figures, with certainty. Conditional on the "point" inputs and current market shares, precise estimates of the alternative-specific constants can be calculated for each Mfr/NamePlate/Model. However, this overstates the precision with which these constants are known because the point values that are inputs to the process are actually random variables which are not known with as much precision as is implied by the program. This sets aside any noise introduced by the various simplifications in the functional form of the model.

9. Any caveats about the use of the model for regulatory analysis

There should be heavy caveats that the error bounds on the calculated values are not presently being calculated. Thus it is not possible to know whether any *apparent* differences in the point estimates in the baseline versus the alternative scenarios are actually substantive (statistically significantly different from zero).

REFERENCES

Allcott, H., 2011. Consumers' Perceptions and Misperceptions of Energy Costs. *American Economic Review* 101, 98-104.

Allcott, H., Wozny, J.-N., 2010. Gasoline Prices, Fuel Economy, and the Energy Paradox, Working Papers. Massachusetts Institute of Technology, Center for Energy and Environmental Policy Research, , Massachusetts Institute of Technology, Center for Energy and Environmental Policy Research,.

Barla, P., Lamonde, B., Miranda-Moreno, L.F., Boucher, N., 2009. Traveled Distance, Stock and Fuel Efficiency of Private Vehicles in Canada: Price Elasticities and Rebound Effect. *Transportation* 36, 389-402.

Eskeland, G.S., Mideksa, T.K., 2008. Transportation fuel use, technology and standards: The role of credibility and expectations, Policy Research Working Paper Series, The World Bank.

Frondel, M., Peters, J., Vance, C., 2008. Identifying the Rebound: Evidence from a German Household Panel. *Energy Journal* 29, 145-163.

Greene, D.L., Kahn, J.R., Gibson, R.C., 1999. Fuel economy rebound effect for US household vehicles. *Energy Journal* 20, 1-31.

Greening, L.A., Greene, D.L., Difiglio, C., 2000. Energy efficiency and consumption - the rebound effect - a survey. *Energy Policy* 28, 389-401.

Hymel, K.M., Small, K.A., Van Dender, K., 2010. Induced demand and rebound effects in road transport. *Transportation Research Part B: Methodological* 44, 1220-1241.

Jones, C.T., 1993. Another Look at U.S. Passenger Vehicle Use and the 'Rebound' Effect from Improved Fuel Efficiency. *Energy Journal* 14, 99-110.

Kemel, E., Collet, R., Hivert, L., 2011. Evidence for an endogenous rebound effect impacting long-run car use elasticity to fuel price. *Economics Bulletin* 31, 2777-2786.

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

Inventory of other potentially relevant research (with abstracts) 2008-2011

I have taken the time to cull the literature from 2008 through 2011 to see whether there might be anything not cited in this document that could be relevant to the conceptualization of the problem or which could provide a "heads up" about other issues that could impinge on the ability of the model to forecast future market shares. The strong ceteris paribus assumptions embodied in the model at present are necessary in order to implement it, but that does not mean users should not be reminded of any concerns that might be on the horizon among practitioners or policymakers. It could be important to acknowledge anything that is lurking at the fringes of the literature that will need to be explicitly called out as being beyond the scope of the current implementation.

Some of the papers in this list are authored or co-authored by researchers involved with this project, but I include them for completeness when they are not cited in the current version of the documentation. I have cast a wide net. Where the listed paper may simply be an update of something similar that is mentioned in the documentation, I have erred on the side of including it here, just in case.

Allcott, H. (2011) "Consumers' Perceptions and Misperceptions of Energy Costs," *American Economic Review,* **101** (3), 98-104.

ABSTRACT: This paper presents three initial stylized facts from the Vehicle Ownership and Alternatives Survey (VOAS), a nationally representative survey that elicits consumers' beliefs about gasoline prices and the relative energy costs of autos with different fuel economy ratings. First, American consumers devote little attention to fuel costs when purchasing autos. Second, consistent with a cognitive bias called "MPG Illusion," consumers underestimate the fuel cost differences between low-MPG vehicles and overestimate the differences between high-MPG vehicles. Third, Americans' mean and median expected future gas prices were above current prices and predictions of the futures market at the time of the survey. Although it is often argued that misperceived energy costs justify policies to encourage the sale of energy efficient durable goods, these results show that misperceptions and expectations that differ from market information could either increase or decrease energy efficiency.

Anderson, S. T., I. W. H. Parry, J. M. Sallee, and C. Fischer (2011) "Automobile Fuel Economy Standards: Impacts, Efficiency, and Alternatives," *Review of Environmental Economics and Policy,* **5** (1), 89-108.

ABSTRACT: This article discusses automobile fuel economy standards in the United States and other countries. We first describe how these programs affect the automobile market, including impacts on fuel consumption and other dimensions of the vehicle fleet. We then review two different methodologies for assessing the costs of fuel economy programs—engineering and market-based approaches—and discuss what the results of these assessments imply for policy. Next we compare the welfare effects of fuel economy standards and fuel taxes and discuss whether these two types of policies can be complementary. Finally, we review arguments for transitioning away from fuel economy regulations and toward a "feebate" system, a policy approach that imposes fees on vehicles that are fuel inefficient and provides rebates to those that are fuel efficient.

Anderson, S. T., and J. M. Sallee (2011) "Using Loopholes to Reveal the Marginal Cost of Regulation: The Case of Fuel-Economy Standards," *American Economic Review,* **101** (4), 1375-1409.

ABSTRACT: Estimating the cost of regulation is difficult. Firms sometimes reveal costs indirectly, however, when they exploit loopholes to avoid regulation. We apply this insight to fuel economy standards for automobiles. These standards feature a loophole that gives automakers a bonus when they equip a vehicle with flexible-fuel capacity. Profit-maximizing automakers will equate the marginal cost of compliance using the loophole, which is observable, with the unobservable costs of strategies that genuinely improve fuel economy. Based on this insight, we estimate that tightening standards by one mile per gallon would have cost automakers just $9-$27 per vehicle in recent years. (JEL L51, L62, Q48)

Axsen, J., D. C. Mountain, and M. Jaccard (2009) "Combining stated and revealed choice research to simulate the neighbor effect: The case of hybrid-electric vehicles," *Resource and Energy Economics,* **31** (3), 221-238.

ABSTRACT: According to intuition and theories of diffusion, consumer preferences develop along with technological change. However, most economic models designed for policy simulation unrealistically assume static preferences. To improve the behavioral realism of an energy-economy policy model, this study investigates the "neighbor effect," where a new technology becomes more desirable as its adoption becomes more widespread in the market. We measure this effect as a change in aggregated willingness to pay under different levels of technology penetration. Focusing on hybrid-electric vehicles (HEVs), an online survey experiment collected stated preference (SP) data from 535 Canadian and 408 Californian vehicle owners under different hypothetical market conditions. Revealed preference (RP) data was collected from the same respondents by eliciting the year, make and model of recent vehicle purchases from regions with different degrees of HEV popularity: Canada with 0.17% new market share, and California with 3.0% new market share. We compare choice models estimated from RP data only with three joint SP-RP estimation techniques, each assigning a different weight to the influence of SP and RP data in coefficient estimates. Statistically, models allowing more RP influence outperform SP influenced models. However, results suggest that because the RP data in this study is afflicted by multicollinearity, techniques that allow more SP influence in the beta estimates while maintaining RP data for calibrating vehicle class constraints produce more realistic estimates of willingness to pay. Furthermore, SP influenced coefficient estimates also translate to more realistic behavioral parameters for CIMS, allowing more sensitivity to policy simulations. (C) 2009 Elsevier B.V. All rights reserved.

Baker, D., and M. Sherman (2008) "Oil Drilling and Automobile Fuel Economy: The Relative Impact on Oil Prices," CEPR Reports and Issue Briefs*,* Center for Economic and Policy Research (CEPR) (No. 2008-25).

ABSTRACT: This issue brief compares projected savings from drilling in presently restricted offshore zones, savings under the Energy Independence and Security Act of 2007, and the projected savings from the fuel efficiency schedule proposed by Senator Obama. The issue brief projects savings through 2027, the year in which offshore drilling would reach peak capacity.

Barla, P., B. Lamonde, L. F. Miranda-Moreno, and N. Boucher (2009) "Traveled Distance, Stock and Fuel Efficiency of Private Vehicles in Canada: Price Elasticities and Rebound Effect," *Transportation,* **36** (4), 389-402.

ABSTRACT: This paper presents estimates of the rebound effect and other elasticities for the Canadian light-duty vehicle fleet using panel data at the provincial level from 1990 to 2004. We estimate a simultaneous three-equation model of aggregate demand for vehicle kilometers traveled, vehicle stock and fuel efficiency. Price and income elasticities obtained are broadly consistent with those reported in the literature. Among other results, an increase in the fuel price of 10% would reduce driving by ~2% in the long term and by 1% the average fuel consumption rate. Estimates of the short- and long-term rebound effects are ~8 and 20%, respectively. We also find that an increase in the gross domestic product per capita of 10% would cause an increase in driving distance of 2-3% and an increase of up to 4% in vehicle stock per adult. In terms of policy implications, our results suggest that: (1) the effectiveness of new fuel efficiency standards will be somewhat mitigated by the rebound effect and (2) fuel price increases have limited impacts on gasoline demand.

Barla, P., and S. Proost (2008) "Automobile fuel efficiency policies with international innovation spillovers," Open Access publications*,* Katholieke Universiteit Leuven (No.

ABSTRACT: In this paper, we explore automobile fuel efficiency policies in the presence of two externalities i) a global environmental problem and ii) international innovation spillovers. Using a simple model with two regions, we show that both a fuel tax and a tax on vehicles based on their fuel economy rating are needed to decentralize the first best. We also show that if policies are not coordinated between regions, the resulting gas taxes will be set too low and each region will use the tax on fuel rating, to reduce the damage caused by foreign drivers. If standards are used instead of taxes, we find that spillovers may alleviate free-riding. Under some conditions, a strict standard in one region may favour the adoption of a strict standard in the other one.

Bassi, A. M., R. Powers, and W. Schoenberg (2010) "An Integrated Approach to Energy Prospects for North America and the Rest of the World," *Energy Economics,* **32** (1), 30-42.

ABSTRACT: Many international organizations and research institutions have released recently unequivocal scenarios on energy's future prospects. The peak in global oil production is likely to happen in the next ten to fifteen years, if it hasn't already happened, and decisions to be made in the near future are likely to have large impacts on our quality of life in the coming decades. This study presents an integrated tool for national energy planning customized to North America. The authors analyzed the impact of world oil production on economic, social, and environmental indicators. Two cases of global ultimate recoverable oil reserves are considered, a low and medium estimate within current research. Three sets of policy directions were chosen: business as usual (market based), maximum push for renewables, and low carbon emissions. Results of the simulations show that without restrictions on emissions coal becomes the dominant energy in the longer term. On the other hand, if US policymakers are able to effectively implement the necessary policies, such as a 20% RPS by 2020 and increased CAFE standards, along with increased energy conservation and efficiency, the medium to longer-term economic

impacts of a global peak in oil production can be mitigated, while a sustained reduction in emissions would require a larger effort.

Bento, A. M., S. Li, and K. Roth (2010) “Is There an Energy Paradox in Fuel Economy? A Note on the Role of Consumer Heterogeneity and Sorting Bias,” Resources For the Future, Discussion Papers, http://www.rff.org/documents/RFF-DP-10-56.pdf.

ABSTRACT: Previous literature finds that consumers tend to undervalue discounted future energy costs in their purchase decisions for energy-using durables. We argue that this finding could result from ignoring consumer heterogeneity in empirical analyses as opposed to true undervaluation. In the context of automobile demand, we show that, if not accounted for, consumer heterogeneity could lead to sorting, which in turn biases toward zero the estimate of marginal willingness to pay for discounted future fuel costs.

Bonilla, D. (2009) “Fuel demand on UK roads and dieselisation of fuel economy,” *Energy Policy,* **37** (10), 3769-3778.

ABSTRACT: Because of high oil prices, and climate change policy, governments are now seeking ways to improve new car fuel economy thus contributing to air quality and energy security. One strategy is to increase dieselisation rates of the vehicle fleet. Recent trends in fuel economy show improvement since 1995, however, efforts need to go further if the EU Voluntary Agreement targets on CO(2) (a greenhouse gas emission standard) are to be achieved. Trends show diesel car sales have accelerated rapidly and that the advantage of new car fuel economy of diesel cars over gasoline ones is narrowing posing a new challenge. We estimate the demand for new car fuel economy in the UK. In the long-run consumers buy fuel economy, but not in the short-run. We found that long-term income and price changes were the main drivers to achieve improvements particularly for diesel cars and that there is no break in the trend of fuel economy induced by the agreement adopted in the 1990s. Policy should target more closely both consumer choice of, and use of, diesel cars. (C) 2009 Elsevier Ltd. All rights reserved.

Bonilla, D., and T. Foxon (2009) “Demand for New Car Fuel Economy in the UK, 1970-2005,” *Journal of Transport Economics and Policy,* **43**, 55-83.

ABSTRACT: During the past thirty years, governments have sought to stimulate improvements in new car fuel economy to contribute to air quality, energy security. and climate change goals. We analysed the demand for new car fuel economy in the UK using a two-stage econometric model to investigate the drivers of this demand in the short and long terms over the period 1970-2004. We found that higher incomes and long-term price changes were the main drivers to achieve improvements in fuel economy, particularly for petrol cars, and that new car fuel economy changes were scarcely affected by the Voluntary Agreement on CO_2 emissions reductions adopted in the 1990s. We found, in agreement with other studies, that the demand for fuel economy was price inelastic for both fuels. Our calculated long-term income elasticity (petrol with -0.31 and diesel fuels with -0.20) values are above the range of international studies for petrol but within the range for diesel. An aggregate model of fuel economy gives a fuel price elasticity of -0.32 and an elasticity of -0.26 with respect to UK disposable income.

Brons, M., P. Nijkamp, E. Pels, and P. Rietveld (2008) “A Meta-analysis of the Price Elasticity of Gasoline Demand: A SUR Approach,” *Energy Economics,* **30** (5), 2105-2122.

ABSTRACT: Automobile gasoline demand can be expressed as a multiplicative function of fuel efficiency, mileage per car and car ownership. This implies a linear relationship between the price elasticity of total fuel demand and the price elasticities of fuel efficiency, mileage per car and car ownership. In this meta-analytical study, we aim to investigate and explain the variation in empirical estimates of the price elasticity of gasoline demand. A methodological novelty is that we use the linear relationship between the elasticities to develop a meta-analytical estimation approach based on a seemingly unrelated regression (SUR) model with cross equation restrictions. This approach enables us to combine observations of different elasticities and thus increase our sample size. Furthermore, it allows for a more detailed interpretation of our meta-regression results. The empirical results of the study demonstrate that the SUR approach leads to more precise results (i.e., lower standard errors) than a standard meta-analytical approach. We find that, with mean short run and long run price elasticities of -0.34 and -0.84, respectively, the demand for gasoline is not very price sensitive. Both in the short and the long run, the impact of a change in the gasoline price on demand is mainly driven by responses in fuel efficiency and mileage per car and to a slightly lesser degree by changes in car ownership. Furthermore, we find that study characteristics relating to the geographic area studied, the year of the study, the type of data used, the time horizon and the functional specification of the demand equation have a significant impact on the estimated value of the price elasticity of gasoline demand.

Brownstone, D., and T. F. Golob (2009) “The impact of residential density on vehicle usage and energy consumption,” *Journal of Urban Economics,* **65** (1), 91-98.

ABSTRACT: We specify and estimate a joint model of residential density, vehicle use, and fuel consumption that accounts for both self selection effects and missing data that are related to the endogenous variables. Our model is estimated on the California subsample of the 2001 U.S. National Household Travel Survey

(NHTS). Comparing two California households that are similar in all respects except residential density, a lower density of 1000 housing units per square mile (roughly 40% of the weighted sample average) implies an increase of 1200 miles driven per year (4.8%) and 65 more gallons of fuel used per household (5.5%). This total effect of residential density on fuel usage is decomposed into two paths of influence. Increased mileage leads to a difference of 45 gallons, but there is an additional direct effect of density through lower fleet fuel economy of 20 gallons per year, a result of vehicle type choice.

Chandra, A., S. Gulati, and M. Kandhkar (2010) "Green drivers or free riders? An analysis of tax rebates for hybrid vehicles," *Journal of Environmental Economics and Management,* **60** (2), 78-93.

ABSTRACT: We estimate the effect of tax rebates offered by Canadian Provinces on the sales of hybrid electric vehicles. We find that these rebates led to a large increase in the market share of hybrid vehicles. In particular, we estimate that 26% of the hybrid vehicles sold during the rebate programs can be attributed to the rebate, and that intermediate cars, intermediate SUVs and some high performance compact cars were crowded out as a result. However, this implies that the rebate programs also subsidized many consumers who would have bought either hybrid vehicles or other fuel-efficient vehicles in any case. Consequently, the average cost of reducing carbon emissions from these programs is estimated to be $195 per tonne. Crown Copyright (C) 2010 Published by Elsevier Inc. All rights reserved.

Cheah, L., and J. Heywood (2011) "Meeting U.S. passenger vehicle fuel economy standards in 2016 and beyond," *Energy Policy,* **39** (1), 454-466.

ABSTRACT: New fuel economy standards require new U.S. passenger vehicles to achieve at least 34.1 miles per gallon (MPG) on average by model year 2016, up from 28.8 MPG today. In this paper, the magnitude, combinations and timings of the changes required in U.S. vehicles that are necessary in order to meet the new standards, as well as a target of doubling the fuel economy within the next two decades are explored. Scenarios of future vehicle characteristics and sales mix indicate that the 2016 mandate is aggressive, requiring significant changes starting from today. New vehicles must forgo horsepower improvements, become lighter, and a greater number will use advanced, more fuel-efficient powertrains, such as smaller turbocharged engines, hybrid-electric drives. Achieving a factor-of-two increase in fuel economy by 2030 is also challenging, but more feasible since the auto industry will have more lead time to respond. A discussion on the feasibility of meeting the new fuel economy mandate is included, considering vehicle production planning realities and challenges in deploying new vehicle technologies into the market. (C) 2010 Elsevier Ltd. All rights reserved.

Chen, C., and Y. Ren (2010) "Exploring the Relationship between Vehicle Safety and Fuel Efficiency in Automotive Design," *Transportation Research: Part D: Transport and Environment,* **15** (2), 112-116.

ABSTRACT: Panel data analysis is used within a fixed effect model to examine the relationship between vehicle safety ratings and fuel efficiency of 45 new vehicle models sold in the US between 2002 and 2007. While conventional wisdom and most early literature suggest that lighter, more fuel efficient vehicles are less safe to their occupants, the tests show a positive relationship between vehicle safety ratings and fuel efficiencies not only within and across most size classes but also for vehicles produced by both the US and Asian automakers. We also explore the design initiatives by manufacturers to compensate for the reductions in weight/size of fuel-efficient vehicles.

Chen, C., and J. Zhang (2009) "The Inconvenient Truth about Improving Vehicle Fuel Efficiency: A Multi-attributes Analysis of the Technology Efficient Frontier of the US Automobile Industry," *Transportation Research: Part D: Transport and Environment,* **14** (1), 22-31.

ABSTRACT: Vehicle fuel efficiency has taken on more economic and environmental significance due to the rise in gasoline prices in 2007/2008. We examine adoption of fuel efficiency technologies by the US automobile industry between 1985 and 2002 and consider the environmental implications. The technology efficient frontier between vehicle weight and fuel efficiency of the US automobile fleet did not move outward significantly for an extended period in the 1980s and 1990s indicating a lack of company- or industry-wide adoption of new fuel efficiency technologies. While the firm with inferior technology capability did push its efficient frontier outward to close the technology gap, the two leading firms' efficient frontiers first showed signs of possible regression in the early 1990s, and did not move outward significantly until the mid 1990s. Several managerial and policy options are examined for improving vehicle fuel efficiency.

Chugh, R., M. L. Cropper, and U. Narain (2011) "The Cost of Fuel Economy in the Indian Passenger Vehicle Market," National Bureau of Economic Research, Inc, NBER Working Papers: 16987, http://www.nber.org/papers/w16987.pdf.

ABSTRACT: To investigate how fuel economy is valued in the Indian car market, we compute the cost to Indian consumers of purchasing a more fuel-efficient vehicle and compare it to the benefit of lower fuel costs over the life of the vehicle. We use hedonic price functions for four market segments (petrol hatchbacks, diesel hatchbacks, petrol sedans, and diesel sedans) to compute 95 percent confidence intervals for the marginal cost to the consumer of an increase in fuel economy. We find that the associated present value of fuel savings falls within the 95 percent confidence interval for some specifications, in all market segments, for the years

2002 through 2006. Thus, we fail to consistently reject the hypothesis that consumers appropriately value fuel economy. When we reject the null hypothesis, the marginal cost of additional fuel economy exceeds the present value of fuel savings, suggesting that consumers may, in fact, be overvaluing fuel economy.

Clerides, S., and T. Zachariadis (2008) "The effect of standards and fuel prices on automobile fuel economy: An international analysis," *Energy Economics,* **30** (5), 2657-2672.

ABSTRACT: There is an intense debate over whether fuel economy standards or fuel taxation is the more efficient policy instrument to raise fuel economy and reduce CO2 emissions of cars. The aim of this paper is to analyze the impact of standards and fuel prices on new-car fuel economy with the aid of cross-section time series analysis of data from 18 countries. We employ a dynamic specification of new-car fuel consumption as a function of fuel prices, standards and per capita income. It turns out that standards have induced considerable fuel savings throughout the world, although their welfare impact is not examined here. If standards are not further tightened then retail fuel prices would have to remain at high levels for more than a decade in order to attain similar fuel savings. Finally, without higher fuel prices or tighter standards, one should not expect any marked improvements in fuel economy under 'business as usual' conditions. (C) 2008 Elsevier B.V. All rights reserved.

Crabb, J. M., and D. K. N. Johnson (2010) "Fueling Innovation: The Impact of Oil Prices and CAFE Standards on Energy-Efficient Automotive Technology," *Energy Journal,* **31** (1), 199-216.

ABSTRACT: This paper tests the induced innovation hypothesis that higher oil prices will lead to increased innovation in energy-efficient automotive technology. Using a dynamic model of patenting, we find robust empirical support for the hypothesis, concluding that both the acquisition cost and retail markup portion of fuel prices are powerful in generating subsequent innovation. Our results include the effects of CAFE regulations, finding no evidence of their impact on innovation, even within a model that endogenizes them via fuel price expectations.

Crôtte, A., R. B. Noland, and D. J. Graham (2010) "An analysis of gasoline demand elasticities at the national and local levels in Mexico," *Energy Policy,* **38** (8), 4445-4456.

ABSTRACT: The majority of evidence on gasoline demand elasticities is derived from models based on national data. Since the largest growth in population is now taking place in cities in the developing world it is important that we understand whether this national evidence is applicable to demand conditions at the local level. The aim of this paper is to estimate and compare gasoline per vehicle demand elasticities at the national and local levels in Mexico. National elasticities with respect to price, income, vehicle stock and metro fares are estimated using both a time series cointegration model and a panel GMM model for Mexican states. Estimates for Mexico City are derived by modifying national estimates according to mode shares as suggested by Graham and Glaister (2006), and by estimating a panel Within Groups model with data aggregated by borough. Although all models agree on the sign of the elasticities the magnitudes differ greatly. Elasticities change over time and differ between the national and local levels, with smaller price responses in Mexico City. In general, price elasticities are smaller than those reported in the gasoline demand surveys, a pattern previously found in developing countries. The fact that income and vehicle stock elasticities increase over time may suggest that vehicles are being used more intensively in recent years and that Mexico City residents are purchasing larger vehicles. Elasticities with respect to metro fares are negligible, which suggests little substitution between modes. Finally, the fact that fuel efficiency elasticities are smaller than vehicle stock elasticities suggests that vehicle stock size, rather than its composition, has a larger impact on gasoline consumption in Mexico City.

Cuenot, F. (2009) "CO2 emissions from new cars and vehicle weight in Europe; How the EU regulation could have been avoided and how to reach it?," *Energy Policy.,* **37** (10), 3832-3842.

ABSTRACT: A segment- and fuel-disaggregated analysis of the production data of the new European vehicle market during the last decade helps to understand the sharp increase in average weight, and to introduce an indicator linking CO2 emissions to a vehicle's unit of weight. Using this indicator, simulations are made to calculate the average CO2 emissions if the average weight had stayed constant from 1995 to 2005. If the weight had remained constant, the 2008 target of 1998s voluntary agreement (VA) would have been met, and the recently approved regulation would probably have been unnecessary. Then, CO2 emissions are projected to 2015 using different vehicle characteristics and market penetration. Five scenarios have been introduced to study the different opportunities that could arise by 2015, including a backcasting scenario showing what is needed to reach the goal set by the recently approved EU climate package regulations. The analysis concludes that powertrain technologies alone are unlikely to bring the sufficient break in trends to reach set targets. Acting on average weight, through unitary vehicle weight or segment shifting, of new vehicles is key in reducing the average CO2 emissions in the short and medium term.

Eskeland, G. S., and T. K. Mideksa (2008) "Transportation fuel use, technology and standards: The role of credibility and expectations," Policy Research Working Paper Series, The World Bank (No. 4695).

ABSTRACT: There is a debate among policy analysts about whether fuel taxes alone are the most effective policy to reduce fuel use by motorists, or whether to also use mandatory standards for fuel efficiency. A problem with a policy mandating fuel economy standards is the "rebound effect, "whereby owners with more efficient vehicles increase vehicle usage. If an important part of negative externalities from transport are associated with vehicle kilometers (accidents, congestion, road wear) rather than fuel consumption, the rebound effect increases negative externalities. Taxes and standards should be mutually supportive because fuel taxes often meet political resistance. Over time, fuel efficiency standards can reduce political resistance to fuel taxes. Thus, by raising fuel efficiency standards now, politicians may be able to pursue higher fuel tax paths in the future. Another argument in support of fuel efficiency standards and similar policies is that standards to a greater extent than taxes can be announced in advance and still be credible and change the behavior of inventors, firms, and other agents in society. A further argument is that standards can be used with greater force and commitment through international coordination.

Fan, Q., and J. Rubin (2010) "Two-Stage Hedonic Price Model for Light-Duty Vehicles Consumer Valuations of Automotive Fuel Economy in Maine," *Transportation Research Record,* (2157), 119-128.

ABSTRACT: Consumers' marginal willingness to pay for a unit change of automotive fuel economy was estimated through development of a hedonic regression of new automobiles sales. The research combined national data on vehicle attributes with a unique data set that contains demographic information on all new vehicles registered in Maine in 2007. The research estimates the impact of demographic factors on consumer demands for fuel economy by generating a function for fuel economy demand in a second-stage hedonic model. Results show that consumers undervalue the long-run fuel savings of vehicle ownership, but they significantly value short-run fuel savings. Age and education are positively correlated with fuel economy demand, whereas income is statistically insignificant. Car consumers' net benefits from an increase in fuel economy from 25 to 35 mpg are computed from the fuel economy demand curve and are approximately $2,232. Strengthening corporate average fuel economy standards is reasonable because consumers can receive significant net benefits from increasing fuel economy.

Fang, H. A. (2008) "A Discrete-Continuous Model of Households' Vehicle Choice and Usage, with an Application to the Effects of Residential Density," *Transportation Research: Part B: Methodological,* **42** (9), 736-758.

ABSTRACT: This paper develops a new method to solve multivariate discrete-continuous problems and applies the model to measure the influence of residential density on households' vehicle fuel efficiency and usage choices. Traditional discrete-continuous modelling of vehicle holding choice and vehicle usage becomes unwieldy with large numbers of vehicles and vehicle categories. I propose a more flexible method of modelling vehicle holdings in terms of number of vehicles in each category, using a Bayesian multivariate ordinal response system. I also combine the multivariate ordered equations with Tobit equations to jointly estimate vehicle type/usage demand in a reduced form, offering a simpler alternative to the traditional discrete/continuous analysis. Using the 2001 National Household Travel Survey data, I find that increasing residential density reduces households' truck holdings and utilization in a statistically significant but economically insignificant way. The results are broadly consistent with those from a model derived from random utility maximization. The method developed above can be applied to other discrete-continuous problems.

Ferdous, N., A. R. Pinjari, C. R. Bhat, and R. M. Pendyala (2010) "A comprehensive analysis of household transportation expenditures relative to other goods and services: an application to United States consumer expenditure data," *Transportation,* **37** (3), 363-390.

ABSTRACT: This paper proposes a multiple discrete continuous nested extreme value (MDCNEV) model to analyze household expenditures for transportation-related items in relation to a host of other consumption categories. The model system presented in this paper is capable of providing a comprehensive assessment of how household consumption patterns (including savings) would be impacted by increases in fuel prices or any other household expense. The MDCNEV model presented in this paper is estimated on disaggregate consumption data from the 2002 Consumer Expenditure Survey data of the United States. Model estimation results show that a host of household and personal socio-economic, demographic, and location variables affect the proportion of monetary resources that households allocate to various consumption categories. Sensitivity analysis conducted using the model demonstrates the applicability of the model for quantifying consumption adjustment patterns in response to rising fuel prices. It is found that households adjust their food consumption, vehicular purchases, and savings rates in the short run. In the long term, adjustments are also made to housing choices (expenses), calling for the need to ensure that fuel price effects are adequately reflected in integrated microsimulation models of land use and travel.

Fischer, C. (2008) "Comparing flexibility mechanisms for fuel economy standards," *Energy Policy,* **36** (8), 3116-3124.

ABSTRACT: Since 1975, the Corporate Average Fuel Economy (CAFE) program has been the main policy tool in the US for coping with the problems of increasing fuel consumption and dependence on imported oil. The program mandates average fuel economy requirements for the new vehicle sales of each manufacturer's fleet, with separate standards for cars and light trucks. The fact that each manufacturer must on its own meet the standards means that the incentives to improve fuel economy are different across manufacturers and vehicle types, although the problems associated with fuel consumption do not make such distinctions. This paper evaluates different mechanisms to offer automakers the flexibility of joint compliance with nationwide fuel economy goals: tradable CAFE credits, feebates, output-rebated fees, and tradable credits with banking. The policies are compared according to the short- and long-run economic incentives, as well as to issues of transparency, implementation, administrative and transaction costs, and uncertainty. (C) 2008 Elsevier Ltd. All rights reserved.

Fischer, C. (2010) "Imperfect Competition, Consumer Behavior, and the Provision of Fuel Efficiency in Light-Duty Vehicles," Resources For the Future, Discussion Papers, http://www.rff.org/documents/RFF-DP-10-60.pdf.

ABSTRACT: This study explores the role of market power on the cost-effectiveness of policies to address fuel consumption. Market power gives manufacturers an incentive to under-(over-) provide fuel economy in classes whose consumers, on average, value it less (more) than in others. Adding a second market failure in consumer valuation of fuel economy, a policy trade-off emerges. Minimum standards can address distortions from price discrimination but, unlike average standards, do not provide broad-based incentives for improving fuel economy. Increasing fuel prices raises demand for fuel economy but exacerbates undervaluation and incentives for price discrimination. A combination policy may be preferred. For modelers of fuel economy policy, failure to capture consumer heterogeneity in preferences for fuel economy can lead to significant errors in predicting the distribution of effort in complying with regulation, as well as the calculation and distribution of the benefits.

Flood, L., N. Islam, and T. Sterner (2010) "Are demand elasticities affected by politically determined tax levels? Simultaneous estimates of gasoline demand and price," *Applied Economics Letters,* **17** (4), 325-328.

ABSTRACT: We introduce a simple method for detecting outliers in Data Envelopment Analysis. The method is based on two scalar measures. The first is the relative frequency with which an observation appears in the construction of the frontier when testing the efficiency of other observations, and the second is the cumulative weight of an observation in the construction of the frontier. We provide a link to computer programming code for implementing the procedure.

Frondel, M., J. Peters, and C. Vance (2008) "Identifying the Rebound: Evidence from a German Household Panel," *Energy Journal,* **29** (4), 145-163.

ABSTRACT: Using a panel of household travel diary data collected in Germany between 1997 and 2005, this study assesses the effectiveness of fuel efficiency improvements by estimating the rebound effect, which measures the extent to which higher efficiency causes additional travel. Following a theoretical discussion outlining three alternative definitions of the rebound effect, the econometric analysis generates corresponding estimates using panel methods to control for the effects of unobservables that could otherwise produce spurious results. Our results, which range between 57% and 67%, indicate a rebound that is substantially larger than obtained in other studies, calling into question the efficacy of policies targeted at reducing energy consumption via technological efficiency.

Fullerton, D. (2010) "Combinations of Instruments to Achieve Low-Carbon Vehicle-Miles," OECD/ITF Joint Transport Research Centre Discussion Papers*,* OECD Publishing (No. 2010/7).

ABSTRACT: Policymakers and economists have considered a number of different policies to reduce carbon emissions, including a carbon tax, a cap-and-trade permit system, a subsidy for the purchase or use of low-carbon vehicle technology, a renewable fuel standard, and mandates on manufacturers to increase the average fuel efficiency of the cars they sell. In this paper, we address issues in the use of these instruments separately or together. We consider the conditions under which policy makers should consider each such policy, and we show how the stringency of one such policy must depend upon the extent to which other such policies are already employed.

Fullerton, D., and S. E. West (2010) "Tax and Subsidy Combinations for the Control of Car Pollution," *B.E. Journal of Economic Analysis and Policy: Advances in Economic Analysis and Policy,* **10** (1).

ABSTRACT: Despite technological advances, an individual car's emissions still cannot be measured reliably enough to impose a Pigovian tax. This paper explores alternative market incentives that could be used instead. We solve for second-best combinations of uniform taxes on gasoline, engine size, and vehicle age. For 1,261 individuals and cars in the 1994 Consumer Expenditure Survey, we record the car's model, year, and number of cylinders. We then seek a corresponding car in data from the California Air Resources Board that shows the car's engine size, fuel efficiency, and emissions per mile. We calculate the welfare improvement from a zero-tax scenario to the ideal Pigovian tax, and we find that 71 percent of that gain can be achieved by the second-best combination of taxes on gas, size, and vintage. A gas tax alone attains 62 percent of that gain. These results are robust to variation in the elasticity of substitution among goods.

Gramlich, J. “Gas Prices and Fuel Efficiency in the U.S. Automobile Industry: Policy Implications of Endogenous Product Choice.” Yale University, 2009.

Greene, D. L. (2010) “Why the New Market for New Passenger Cars Generally Undervalues Fuel Economy,” OECD/ITF Joint Transport Research Centre Discussion Papers*,* OECD Publishing (No. 2010/6).

ABSTRACT: Passenger vehicles are a major source of greenhouse gas emissions and prodigious consumers of petroleum, making their fuel economy an important focus of energy policy. Whether or not the market for fuel economy functions efficiently has important implications for both the type and intensity of energy and environmental policies for motor vehicles. There are undoubtedly imperfections in the market for fuel economy but their consequences are difficult to quantify. The evidence from econometric studies, mostly from the US, is reviewed and shown to vary widely, providing evidence for both significant under- and over-valuation and everything in between. Market research is scarce, but indicates that the rational economic model, in general, does not appear to be used by consumers when comparing the fuel economy of new vehicles. Some recent studies have stressed the role of uncertainty and risk or loss aversion in consumers’ decision making. Uncertainty plus loss aversion appears to be a reasonable theoretical model of consumers’ evaluation of fuel economy, with profound implications for manufacturers’ technology and design decisions. The theory implies that markets will substantially undervalue fuel economy relative to its expected present value. It also has potentially important implications for welfare analysis of alternative policy instruments.

Helfand, G., and A. Wolverton (2009) “Evaluating the Consumer Response to Fuel Economy: A Review of the Literature,” NCEE Working Paper Series*,* National Center for Environmental Economics, U.S. Environmental Protection Agency (No. 200904).

ABSTRACT: In modeling how the U.S. market responds to changes in national fuel economy standards, the question of how consumers evaluate trade-offs between the cost of consuming more fuel economy than they would otherwise choose and the expected fuel savings that result is potentially quite important. Consumer vehicle choice models are a means to predict the change in vehicle purchase patterns, as well as the effects of these changes on compliance costs and consumer surplus. This paper surveys the literature on consumer choice models and finds a wide range in methods and results. A large puzzle raised is whether automakers build into their vehicles as much fuel economy as consumers are willing to purchase. This paper examines possible reasons why there may be a gap between the amount consumers are willing to pay for fuel economy and the amount that automakers provide.

Hennessy, H. J., and R. S. J. Tol (2010) “The Impact of Climate Policy on Private Car Ownership in Ireland,” Working Papers*,* Economic and Social Research Institute (ESRI) (No. WP342).

ABSTRACT: We construct a model of the stock of private cars in the Republic of Ireland. The model distinguishes cars by fuel, engine size and age. The modelled car stock is build up from a long history of data on sales, and calibrated to recent data on actual stock. We complement the data on the number of cars with data on fuel efficiency and distance driven ? which together give fuel use and emissions ? and the costs of purchase, ownership and use. We use the model to project the car stock from 2010 to 2025. The following results emerge. The 2009 reform of the vehicle registration and motor tax has lead to a dramatic shift from petrol to diesel cars. Fuel efficiency has improved and will improve further as a result, but because diesel cars are heavier, carbon dioxide emissions are reduced but not substantially so. The projected emissions in 2020 are roughly the same as in 2007. In a second set of simulations, we impose the government targets for electrification of transport. As all-electric vehicles are likely to displace small, efficient, and little-driven petrol cars, the effect on carbon dioxide emissions is minimal. We also consider the scrappage scheme, which has little effect as it applies to a small fraction of the car stock only.

Hensher, D. A., M. J. Beck, and J. M. Rose (2011) “Accounting for Preference and Scale Heterogeneity in Establishing Whether It Matters Who Is Interviewed to Reveal Household Automobile Purchase Preferences,” *Environmental and Resource Economics,* **49** (1), 1-22.

ABSTRACT: The choice of automobile purchases in households often involves participation of more than one household member, each of which exerts some degree of influence on the final choice outcome. The influence of more than one agent has been recognised for many years, and yet the majority of automobile choice studies develop choice models as if a single agent is involved in the preference revelation process. What is not clear is whether it makes any substantive difference in preference revelation according to who is interviewed in a household. Using a generalised mixed logit framework that accounts for preference and scale heterogeneity, we estimate a series of models to investigate whether there are significant differences between the preferences of each individual in a household when assessed in isolation from other household members, as well as their joint preferences when expressing their preferences through a group choice task. The context is choosing amongst petrol, diesel and hybrid fuelled vehicles (associated with specific levels of fuel efficiency and engine capacity) when faced with a mix of vehicle prices, fuel prices, fixed annual registration fees, annual emission surcharges and vehicle kilometre emission surcharges. Using a stated choice experiment, we find that sampling a single individual as a representative of the household's preferences is less appropriate than utilising preference information from the relevant group of decision makers in the household.

Hiramatsu, T. "The Impact of Anti-congestion Policies on Fuel Consumption, Carbon Dioxide Emissions and Urban Sprawl: Application of RELU-TRAN2, a CGE Model." University at Buffalo, 2010.

*ABSTRACT***:** RELU-TRAN (Regional Economy and Land Use and Transportation) is a numerically solvable general equilibrium model (Anas and Liu, 2007), which treats in a unified manner the regional economy, urban land use and urban personal transportation sectors. In this dissertation, the model is extended by adding the consumer-workers' choice of private vehicle type according to the vehicle's fuel economy, by treating congestion on local roads as well as on major roads and by introducing car fuel consumption as a function of congested vehicle speed. By making the extensions, the model becomes more suitable to analyze the fuel consumption and CO2 emission consequences of urban development. The model is calibrated and simulated for the Chicago metropolitan area. By adjusting the model to the longer time span gradually, the short- and long-run price elasticities of fuel consumption are examined. As the time span becomes longer, fuel consumption becomes more elastic with respect to gasoline price, but when technological improvements in car fuel economy over comparable time spans are introduced exogenously, then the elasticity of fuel with respect to gasoline price becomes similar to that estimated in the econometric literature. Comparative statics exercises show that, if travel by auto becomes relatively more attractive in terms of travel time or travel cost than travel by public transit, then the Chicago MSA becomes more sprawled in total developed land area, whereas if public transit travel becomes relatively more attractive, then the Chicago MSA becomes more centralized. To mitigate fuel consumption and CO2 emissions, relative effectiveness of quasi-Pigouvian congestion tolls, a fuel tax on gasoline, a cordon toll around the downtown and a downtown parking fee are tested. All of these policies successfully reduce the aggregate fuel consumption and CO2. The urban growth boundary (UGB) is an alternative policy tested by the model. The UGB directly makes the Chicago MSA more centralized by prohibiting the development into urban use of a part of the vacant land in the suburban areas. The UGB also reduces aggregate fuel and CO2 emissions, but the impact is much smaller than the quasi-Pigouvian toll. Although Chicago MSA is centralized by both the UGB and the quasi-Pigouvian toll, the auto travel is directly discouraged by quasi-Pigouvian toll and but not by the UGB.

Hymel, K. M., K. A. Small, and K. Van Dender (2010) "Induced demand and rebound effects in road transport," *Transportation Research Part B: Methodological,* **44** (10), 1220-1241.

*ABSTRACT***:** This paper analyzes aggregate personal motor-vehicle travel within a simultaneous model of aggregate vehicle travel, fleet size, fuel efficiency, and congestion formation. We measure the impacts of driving costs on congestion, and two other well-known feedback effects affecting motor-vehicle travel: its responses to aggregate road capacity ("induced demand") and to driving costs including those caused by fuel-economy improvements ("rebound effect"). We measure these effects using cross-sectional time series data at the level of US states for 1966 through 2004. Results show that congestion affects the demand for driving negatively, as expected, and more strongly when incomes are higher. We decompose induced demand into effects from increasing overall accessibility of destinations and those from increasing urban capacity, finding the two elasticities close in magnitude and totaling about 0.16, somewhat smaller than most previous estimates. We confirm previous findings that the magnitude of the rebound effect decreases with income and increases with fuel cost, and find also that it increases with the level of congestion.

Jacobsen, M. R. (2011) "Fuel Economy, Car Class Mix, and Safety," *American Economic Review,* **101** (3), 105-109.

Johnson, K. C. (2010) "Circumventing the Weight-versus-Footprint Tradeoffs in Vehicle Fuel Economy Regulation," *Transportation Research: Part D: Transport and Environment,* **15** (8), 503-506.

*ABSTRACT***:** China, Japan, and the European Union use weight-based fuel economy standards, whereas the US Department of Transportation favors footprint-based standards. In this paper we offer a way of reconciling these approaches. Weight-based standards tend to focus regulatory incentives on technology rather than downsizing, but they provide no incentive for weight reduction. Footprint-based standards, by contrast, motivate vehicle manufacturers to reduce weight without reducing footprint, but only to the extent that they are also motivated to increase footprint without increasing weight. Neither approach discriminates between beneficial and detrimental weight-changing strategies. However, the tradeoffs between weight and footprint can be circumvented by employing a weight-based standard, which does not create weight-changing incentives, in combination with complementary regulatory measures that would be focused specifically and exclusively on motivating beneficial weight reduction strategies.

Kagawa, S., Y. Kudoh, K. Nansai, and T. Tasaki (2008) "The Economic and Environmental Consequences of Automobile Lifetime Extension and Fuel Economy Improvement: Japan's Case," *Economic Systems Research,* **20** (1), 3-28.

*ABSTRACT***:** The present paper develops a structural decomposition analysis with cumulative product lifetime distributions to estimate the effects of both product lifetime shifts and energy efficiency changes on the embodied energy consumptions. The empirical analysis focuses on automobile use (ordinary passenger vehicles, small passenger vehicles, and light passenger vehicles) in Japan during the period 1990-2000. It reveals that the lifetime extension of existing old vehicles during the study period was more beneficial to the environment than purchasing new passenger vehicles with a relatively high fuel economy, because the lifetime extension empirically contributed to reducing the embodied energy consumption at the production and end-use stages. We also found that the energy-saving impact of a one-year lifetime extension was approximately 1.3 times larger than that of the most significant technological improvement in the electric power generation sector.

Karathodorou, N., D. J. Graham, and R. B. Noland (2010) "Estimating the effect of urban density on fuel demand," *Energy Economics,* **32** (1), 86-92.

*ABSTRACT***:** Much of the empirical literature on fuel demand presents estimates derived from national data which do not permit any explicit consideration of the spatial structure of the economy. Intuitively we would expect the degree of spatial concentration of activities to have a strong link with transport fuel consumption. The present paper addresses this theme by estimating a fuel demand model for urban areas to provide a direct estimate of the elasticity of demand with respect to urban density. Fuel demand per capita is decomposed into car stock per capita, fuel consumption per kilometre and annual distance driven per car per year. Urban density is found to affect fuel consumption, mostly through variations in the car stock and in the distances travelled, rather than through fuel consumption per kilometre. (C) 2009 Elsevier B.V. All rights reserved.

Kemel, E., R. Collet, and L. Hivert (2011) "Evidence for an endogenous rebound effect impacting long-run car use elasticity to fuel price," *Economics Bulletin,* **31** (4), 2777-2786.

*ABSTRACT***:** This paper presents a structural equation model of household fleet fuel efficiency and car use. It allows to weigh the contribution of car equipment changes and car use adjustments to the price elasticity of household demand for fuel. This model is implemented using a panel dataset of 322 households that were present in each annual wave of the French Car Fleet survey from 1999 to 2007. The longitudinal dimension of this dataset enables to assess the short and long-run adjustments at the household level over a period of fuel price increase. The estimated price elasticities of the demand for fuel are fully consistent with the literature: -0.30 in the short run and -0.76 in the long run. Regarding car use elasticities, accounting for an endogenous rebound effect allowed a striking finding: the sensitivity of household car use to fuel price changes is lower on the long run than on the short run. This paper thus not only provides the latest estimations of elasticities for France, in the early 2000's, it also shows that, on the long run, French households have managed to mitigate the impact of increasing fuel prices on their car mobility by using more fuel efficient cars.

Kleinbaum, R., and W. McManus (2009) "Fixing Detroit: how far, how fast, how fuel-efficient," MPRA Papers*,* University Library of Munich, Germany (No. 19607).

*ABSTRACT***:** The Automotive Industry Crisis of 2009 is the worst the industry has ever experienced. This paper helps resolve the debate on how much and fast it should change and how it should it respond to demands for increased fuel efficiency. Looking at the actions of successful corporate turnarounds, the lessons are very clear: implement broad, deep, fast change, replace the management team, and transform the culture. We modeled the impacts of different fuel economy standards on profitability and sales, using the most accepted estimates of all the key parameters, and conducted an extensive sensitivity analysis on the key parameters. The impact of higher fuel economy standards on industry profits is very clear: increasing fuel economy 30% to 50% (35 mpg to 40.5 mpg) would increase the Detroit 3's gross profits by roughly $3 billion per year, and increase sales by the equivalent of two large assembly plants. The sensitivity analysis showed our findings are very robust. The overall risk and reward profile is very positive, with only a small chance of losing and a very large probability of gain.

Klier, T., and J. Linn (2011) "Fuel Prices and New Vehicle Fuel Economy in Europe," Working papers*,* Massachusetts Institute of Technology, Center for Energy and Environmental Policy Research (No. 1117).

*ABSTRACT***:** This paper evaluates the effect of fuel prices on new vehicle fuel economy in the eight largest European markets. The analysis spans the years 2002–2007 and uses detailed vehicle registration and specification data to control for policies, consumer preferences, and other potentially confounding factors. Fuel prices have a statistically significant effect on new vehicle fuel economy in Europe, but this estimated effect is much smaller than that for the United States. Within Europe, fuel economy responds more in the United Kingdom and France than in the other large markets. Overall, substantial changes in fuel prices would have relatively small effects on the average fuel economy of new vehicles sold in Europe. We find no evidence that diesel fuel prices have a large effect on the market share of diesel vehicles.

Klier, T., and J. Linn (2010) "The Price of Gasoline and New Vehicle Fuel Economy: Evidence from Monthly Sales Data," *American Economic Journal: Economic Policy,* **2** (3), 134-153.

*ABSTRACT***:** This paper uses a unique dataset of monthly new vehicle sales by detailed model from 1978 to 2007, and implements a new identification strategy to estimate the effect of the price of gasoline on individual vehicle model sales. We control for unobserved vehicle and consumer characteristics by using within model year changes in the price of gasoline and sales. We find a significant sales response, suggesting that the gasoline price increase from 2002 to 2007 explains nearly half of the decline in market share of US manufacturers. On the other hand, an increase in the gasoline tax would only modestly raise average fuel economy.

Klier, T. H., and J. Linn (2011) "Corporate average fuel economy standards and the market for new vehicles," Federal Reserve Bank of Chicago, Working Paper Series: WP-2011-01, http://www.chicagofed.org/digital_assets/publications/working_papers/2011/wp2011_01.pdf.

ABSTRACT: This paper presents an overview of the economics literature on the effect of Corporate Average Fuel Economy (CAFE) standards on the new vehicle market. Since 1978, CAFE has imposed fuel economy standards for cars and light trucks sold in the U.S. market. This paper reviews the history of the standards, followed by a discussion of the major upcoming changes in implementation and stringency. It describes strategies that firms can use to meet the standards and reviews the CAFE literature as it applies to the new vehicle market. The paper concludes by highlighting areas for future research in light of the upcoming changes to CAFE.

Knittel, C. R. (2009) "Automobiles on Steroids: Product Attribute Trade-Offs and Technological Progress in the Automobile Sector," Working Paper Series, Institute of Transportation Studies, UC Davis (No. 1320892).

ABSTRACT: New car fleet fuel economy, weight and engine power have changed drastically since 1980. These changes represent both movements along and shifts in the "fuel economy/weight/engine power production possibilities frontier." This paper estimates the technological progress that has occurred since 1980 and the trade-offs that manufacturers and consumers face when choosing between fuel economy, weight and engine power characteristics. The results suggest that if weight, horsepower and torque were held at their 1980 levels, fuel economy for both passenger cars and light trucks could have increased by nearly 50 percent from 1980 to 2006; this is in stark contrast to the 15 percent by which fuel economy actually increased. I also find that once technological progress is considered, meeting the CAFE standards adopted in 2007 will require halting the observed increases in weight and engine power characteristics, but little more; in contrast, the standards recently announced by the new administration, while certainly attainable, require non-trivial "downsizing." I also investigate the relative efficiencies of manufacturers. I find that US manufacturers tend to be above the median in terms of their passenger vehicle fuel efficiency conditional on weight and engine power, and are among the top for light duty trucks; Honda is the most efficient manufacturer for both passenger cars, while Volvo is the most efficient manufacturer of light duty trucks. However, I also find that over time, U.S. manufacturers' relative efficiency in both passenger cars and light trucks has degraded. These results may provide insight into their current financial troubles.

Kverndokk, S., and K. E. Rosendahl (2010) "The effects of transport regulation on the oil market. Does market power matter?," Discussion Papers, Resources For the Future (No. dp-10-40).

ABSTRACT: Popular instruments to regulate consumption of oil in the transport sector include fuel taxes, biofuel requirements, and fuel efficiency. Their impacts on oil consumption and price vary. One important factor is the market setting. We show that if market power is present in the oil market, the directions of change in consumption and price may contrast those in a competitive market. As a result, the market setting impacts not only the effectiveness of the policy instruments to reduce oil consumption, but also terms of trade and carbon leakage. In particular, we show that under monopoly, reduced oil consumption due to increased fuel efficiency will unambiguously increase the price of oil.

Langer, A., and N. H. Miller (2008) "Automobile Prices, Gasoline Prices, and Consumer Demand for Fuel Economy," EAG Discussions Papers, Department of Justice, Antitrust Division (No. 200811).

ABSTRACT: The relationship between gasoline prices and the demand for vehicle fuel efficiency is important for environmental policy but poorly understood in the academic literature. We provide empirical evidence that automobile manufacturers price as if consumers respond to gasoline prices. We derive a reduced-form regression equation from theoretical micro-foundations and estimate the equation with nearly 300,000 vehicle-week-region observations over the period 2003-2006. We find that vehicle prices generally decline in the gasoline price. The decline is larger for inefficient vehicles, and the prices of particularly efficient vehicles actually rise. Structural estimation that ignores these effects underestimates consumer preferences for fuel efficiency.

Li, S., Y. Liu, and J. Zhang (2011) "Lose Some, Save Some: Obesity, Automobile Demand, and Gasoline Consumption," *Journal of Environmental Economics and Management,* **61** (1), 52-66.

ABSTRACT: This paper examines the unexplored link between the prevalence of overweight and obesity and vehicle demand in the United States. Exploring annual sales data of new passenger vehicles at the model level in 48 U.S. counties from 1999 to 2005, we find that new vehicles demanded by consumers are less fuel-efficient on average as a larger share of people become overweight or obese. The OLS results show that a 10 percentage point increase in obesity and overweight reduces the average MPG of new vehicles demanded by 1.4 percent, an effect requiring a 12 cent increase in gasoline prices to counteract. The 2SLS results after controlling for possible endogeneity in overweight and obesity prevalence put those two numbers at 5 percent and 54 cent, respectively. These findings, robust to a variety of specifications, suggest that policies to reduce overweight and obesity can have additional benefits for energy security and the environment.

Li, S., C. Timmins, and R. H. von Haefen (2009) "How Do Gasoline Prices Affect Fleet Fuel Economy?," *American Economic Journal: Economic Policy,* **1** (2), 113-137.

ABSTRACT: Exploiting a rich dataset of passenger vehicle registrations in 20 US MSAs from 1997 to 2005, we examine the effects of gasoline prices on the automotive fleet's composition. We find that high gasoline prices affect fleet fuel economy through two channels: shifting new auto purchases towards more fuel-efficient vehicles, and speeding the scrappage of older, less fuel-efficient used vehicles. Policy simulations suggest that a 10 percent increase in gasoline prices from 2005 levels will generate a 0.22 percent increase in fleet fuel economy in the short run and a 2.04 percent increase in the long run.

Liddle, B. (2009) "Long-run relationship among transport demand, income, and gasoline price for the US," *Transportation Research Part D-Transport and Environment,* **14** (2), 73-82.

ABSTRACT: Energy used in transport is a particularly important focus for environment-development studies because it is increasing in both developed and developing countries and is largely carbon-intensive. This paper examines whether a systemic, mutually causal, cointegrated relationship exists among mobility demand, gasoline price, income, and vehicle ownership using US data from 1946 to 2006. We find that those variables co-evolve in a transport system; and thus, they cannot be easily disentangled in the short-run. However, estimating a long-run relationship for motor fuel use per capita was difficult because of the efficacy of the CAFE standards to influence fleet fuel economy. The analysis shows that the fuel standards program was effective in improving the fuel economy of the US vehicle fleet and in temporarily lessening the impact on fuel use of increased mobility demand. Among the policy implications are a role for efficiency standards, a limited impact for fuel tax, and the necessity of using a number of levers simultaneously to influence transport systems. (C) 2008 Elsevier Ltd. All rights reserved.

Lindfeldt, E. G., M. Saxe, M. Magnusson, and F. Mohseni (2010) "Strategies for a road transport system based on renewable resources - The case of an import-independent Sweden in 2025," *Applied Energy,* **87** (6), 1836-1845.

ABSTRACT: When discussing how society can decrease greenhouse gas emissions, the transport sector is often seen as posing one of the most difficult problems. In addition, the transport sector faces problems related to security of supply. The aim of this paper is to present possible strategies for a road transport system based on renewable energy sources and to illustrate how such a system could be designed to avoid dependency on imports, using Sweden as an example. The demand-side strategies considered include measures for decreasing the demand for transport, as well as various technical and non-technical means of improving vehicle fuel economy. On the supply side, biofuels and synthetic fuels produced from renewable electricity are discussed. Calculations are performed to ascertain the possible impact of these measures on the future Swedish road transport sector. The results underline the importance of powerful demand-side measures and show that although biofuels can certainly contribute significantly to an import-independent road transport sector, they are far from enough even in a biomass-rich country like Sweden. Instead, according to this study, fuels based on renewable electricity will have to cover more than half of the road transport sector's energy demand.

Litman, T. (2009) "Evaluating Carbon Taxes as an Energy Conservation and Emission Reduction Strategy," *Transportation Research Record,* (2139), 125-132.

ABSTRACT: Carbon taxes are based on the carbon content of fossil fuel and therefore tax carbon dioxide emissions. In July 2008, British Columbia, Canada, introduced the first carbon tax in North America. This paper evaluates that tax. British Columbia's new tax reflects key carbon tax principles: it is broad, gradual, predictable, and structured to assist low-income people. It begins small and increases gradually, allowing consumers and businesses to respond with increased energy efficiency. Revenues are returned to residents and businesses in ways that protect the lowest-income households. Like most new taxes, the carbon tax has been widely criticized. Much of this criticism is technically incorrect or exaggerated. Consumers have many possible ways to conserve energy and therefore reduce their tax burden. Because lower-income households tend to consume less than the average amounts of fuel and receive targeted rebates, most low-income households will benefit overall. This tax supports economic development by encouraging energy conservation, which keeps money circulating within the regional economy. If other jurisdictions follow, its impacts and benefits will be huge.

Mahlia, T. M. I., R. Saidur, L. A. Memon, N. W. M. Zulkifli, and H. H. Masjuki (2010) "A review on fuel economy standard for motor vehicles with the implementation possibilities in Malaysia," *Renewable and Sustainable Energy Reviews,* **14** (9), 3092-3099.

ABSTRACT: This paper focused on a review of international experiences

on fuel economy standard based on technologies available. It also attempts to identify savings possibilities and greenhouse gas (GHG) emissions reductions. It is known that road transport, particularly private cars are responsible for large, and increasing share of transport fuel use and emissions. With the implementation of fuel economy standard and label for motor vehicles, it will reduce the risks of increasing dependency on petroleum-based fuel and will increase the profit to consumers. The GHG emissions, which causing global warming, air pollution, diseases, etc. can be reduced as well. In this regard, advanced technologies such as, engine, transmission, and vehicle technologies may brought significant consumers and social benefits. Studies in developed countries have shown that fuel economy standard is beneficial for the society, government as well as the environment.

Malaczynski, J. D., and T. P. Duane (2009) "Reducing Greenhouse Gas Emissions from Vehicle Miles Traveled: Integrating the California Environmental Quality Act with the California Global Warming Solutions Act," *Ecology Law Quarterly,* **36** (1), 71-135.

ABSTRACT: The California Global Warming Solutions Act of 2006 (AB 32) commits California to reduce its greenhouse gets (GHG) emissions to 1990 levels; by 2020. The transportation sector is the top GHG emitter in California, contributing roughly 40 percent of till California emissions. Poor fuel efficiency and high vehicle miles traveled (VMT) are primary contributors to transportation sector GHG emissions. Meeting California's GHG emissions reduction goals requires reductions in both per-mile emissions and vehicle miles traveled. Fuel efficiency has been addressed historically by federal Corporate Average Fuel Economy (CAFE) standards, and California has passed its own legislation regulating GHG emissions from vehicles. Vehicle miles traveled, however, have historically not received legislative attention, and have been growing at a much faster rate than population or the economy. There is consequently a "VMT gap" ill the current regulatory structure for GHG emissions reductions envisioned under AB 32. This Article addresses how AB 32's developing market-based GHG emissions reduction policy, allowing for carbon offsets, could interact with implementation of the California Environmental Quality Act (CEQA) to support emissions reductions from transportation-related land use projects. Allowing carbon offsets for CEQA land use projects requires the California Air Resources Board (CARB) to acknowledge that the degree of GHG mitigation required for transportation-related land use projects is discretionary under the CEQA process; otherwise, CARB would face the legal conundrum of allowing industry to claim offset credits for mitigation considered compulsory tinder a separate legal statute. Carbon offsets for CEQA mitigation should be recognized as being additional to emissions reductions that would otherwise take place without offset investment dollars. This is, because significant land use changes are necessary to meet California's long-term GHG reduction goals and it should be a legal priority to facilitate these changes. This outcome would be most consistent with the existing CEQA regime and would increase incentives and funding available to implement GHG emissions reductions from land use-related projects. Further, we recommend that a regional transportation authority (also known as a Metropolitan Planning Organization or MPO)-the same agency charged with modeling the impacts of future development plans on GHG emissions under recent legislation designed to address vehicle miles traveled (under SB 375)-facilitate quality offset projects and coordinate offset investment dollars for CEQA mitigation. We argue that such a carbon la offset program under AB 32 will prove to be more significant than SB 375 in addressing vehicle miles traveled by promoting increased investments in transportation-related land use projects.

Mandell, S. (2009) "Policies towards a more efficient car fleet," *Energy Policy,* **37** (12), 5184-5191.

ABSTRACT: Transportation within the EU, as in most of the industrialized world, shows an increasing trend in CO2 emissions. This calls for measures to decrease the amount of transportation but also to increase the efficiency in the vehicle fleet. To achieve this, numerous policy measures are available, all of which targets the agents in the economy in various ways. Policy makers thus face a highly complex task. The present paper aims at providing a simple and transparent analytical model that illustrates how different policy measures address different parts of an interlinked system, which determines the composition of the future car fleet. Apart from being simple, and thereby providing an intuitive framework, the model provides important lessons for policy design, e.g., through highlighting the difference between initial responses to policies and the outcome in equilibrium both in the short and the long run.

Martin, E. W. (2009) "New Vehicle Choice, Fuel Economy and Vehicle Incentives: An Analysis of Hybrid Tax Credits and the Gasoline Tax," University of California Transportation Center, Working Papers*,* University of California Transportation Center (No. 1330279).

ABSTRACT: Automobiles impose considerable public costs in the form of emissions and foreign oil dependence. Public policy has thus taken a considerable interest in influencing the technology and fuel economy associated with new vehicles brought to market. In spite of this interest, there is very limited information on the effectiveness of these policies in reducing greenhouse gas emissions or shifting vehicle demands. This is in part due to the fact that modeling the demand for automobiles is wrought with many challenges. These include large choice sets that change frequently over time and significant data collection obstacles. This work proposes a methodology for data development that simplifies many of the challenges associated with data collection in automotive modeling. The methodology explores a technique to merge data on aggregate sales with disaggregate vehicle holdings data

to synthesize a complete dataset that preserves the strengths of both. The merged dataset is used to estimate a logit choice model of automotive choice 2 that is applied in evaluating the effectiveness of hybrid tax credits and the gasoline tax in reducing greenhouse gas emissions. Policy simulations suggest that hybrid tax credits have saved an average 1.5 million metric tons of greenhouse gas emissions based on sales between 2006 and 2007. When considered in conjunction with the cost of the policies, the credits appear to have a cost effectiveness ranging between $1000 to $3000 per metric ton of greenhouse gas emissions reduced. Hybrid tax credits are also found to be more effective than a doubling of the gasoline tax in shifting the new vehicle stock towards more fuel efficient vehicles. Finally, the model evaluates the market willingness to pay for fuel cost reduction. The results suggest an average willingness to pay of $522 in purchase price per 1Â¢ reduction in fuel cost per mile. This means that reasonable circumstances exist in which some buyers will pay more for fuel economy than they save in fuel cost expenses over the life span of their automobiles.

Mau, P., J. Eyzaguirre, M. Jaccard, C. Collins-Dodd, and K. Tiedemann (2008) "The 'neighbor effect': Simulating dynamics in consumer preferences for new vehicle technologies," *Ecological Economics,* **68** (1-2), 504-516.

ABSTRACT: Understanding consumer behaviour is essential in designing policies that efficiently increase the uptake of clean technologies over the long-run. Expert opinion or qualitative market analyses have tended to be the sources of this information. However, greater scrutiny on governments increasingly demands the use of reliable and credible evidence to support policy decisions. While discrete choice research and modeling techniques have been applied to estimate consumer preferences for technologies, these methods often assume static preferences. This study builds on the application of discrete choice research and modeling to capture dynamics in consumer preferences. We estimate Canadians' preferences for new vehicle technologies under different market assumptions, using responses from two national surveys focused on hybrid gas-electric vehicles and hydrogen fuel cell vehicles. The results support the relevance of a range of vehicle attributes beyond the purchase price in shaping consumer preferences towards clean vehicle technologies. They also corroborate our hypothesis that the degree of market penetration of clean vehicle technologies is an influence on people's preferences ('the neighbor effect). Finally, our results provide behavioural. parameters for the energy-economy model CIMS, which we use here to show the importance of including consumer preference dynamics when setting policies to encourage the uptake of clean technologies. (C) 2008 Elsevier B.V. All rights reserved.

Mazraati, M., and H. Shelbi (2011) "Impact of Alternative Fuels and Advanced Technology Vehicles on Oil Demand in the United States up to 2030," *OPEC Energy Review,* **35** (1), 70-89.

ABSTRACT: The increasingly high oil consumption in US road transportation sector, coupled with its significant contribution to greenhouse gases emission, resulted in the implementation of many policies geared towards addressing both challenges. Aiming to enhance the US energy security, the Energy Policy Act encourages the use of alternative fuels and has set forth the requirements for the acquisition of alternative fuels vehicles (AFVs) by Federal Agencies. This paper applies a hybrid, top-down, two-stage model to forecast the share of AFVs in the United States until 2030 and the resulting impact on the US oil demand. In the first stage, a logistic model is being estimated by econometric techniques to forecast the stock of vehicles as a function of socio-economic variables, i.e. population, gross domestic product and saturation point. The second stage applies an S-shape function to forecast the annual share of AFVs based on a trend variable that encompasses inherently fuel cost, cost of AFVs, discount rate and consumer's choice and three different AFV saturation level scenarios (2 per cent, 3 per cent, 4 per cent). The impact of AFV and advanced technologies on oil demand was calculated based on average vehicle miles driven and corporate average fuel economy possible trends for both AFVs and total vehicle stock. The paper concludes that under the 4 per cent saturation level scenario for AFVs, the oil saving is forecasted at 196,000 b/d or 1.8 per cent of total transport fuel requirements in 2030. Furthermore, it was determined that marginal increase of 1 per cent in AFVs saturation level in 2030 results in oil saving of around 49,000 b/d which represents 0.5 per cent of total fuel requirement. Overall, it was concluded that unless stringent policy measures are introduced, or a sustainable level of high oil prices is reached, there is a limited impact of AFVs on the US oil demand.

Meyer, I., and S. Wessely (2009) "Fuel efficiency of the Austrian passenger vehicle fleet--Analysis of trends in the technological profile and related impacts on CO2 emissions," *Energy Policy,* **37** (10), 3779-3789.

ABSTRACT: This paper analyzes trends in the technological profile of the Austrian personnel vehicle fleet from 1990 to 2007. This includes the parameters of power, engine size and weight, which beyond the technological efficiency of the motor engine itself, are considered to be the main determinants of the fuel efficiency of the average car stock. Investigating the drivers of ever rising transport related greenhouse gas emissions is crucial in order to derive policies that strive towards more energy-efficient on-road passenger mobility. We focus on the efficacy of technological efficiency improvements in mitigating climate-relevant emissions from car use in light of shifting demand patterns towards bigger, heavier and more powerful cars. The analysis is descriptive in nature and based on a bottom-up database that was originally collated for the purpose of the present study. Technological data on car models, which includes tested fuel consumption, engine size, power and weight, is related to registered car stock and, in parts, to newly

registered cars. From this, we obtain an original database of the Austrian passenger car fleet, i.e. information on consumer choice of specific car models, segregated by gasoline and diesel fuelled engines. Conclusions are derived for policies aimed at reducing the fossil fuel consumption of the moving vehicle fleet in order to contribute to a low carbon society.

Mikler, J. (2008) "Sharing Sovereignty for Global Regulation: The Cases of Fuel Economy and Online Gambling," *Regulation and Governance,* **2** (4), 383-404.

ABSTRACT: Globalization is sometimes taken as a synonym for market liberalization, because it is claimed that power has flowed from states to markets. Whether happening as a result of undeniable "forces" or some hegemonic consensus, many on both the left and right of politics agree that this is a reality. However, this article argues that states which share sovereignty with market actors are able to influence outcomes beyond their borders. The cases of fuel economy and online gambling regulations are used to illustrate the point. In the former case, Japanese and European industry-driven regulations are being "exported" in the attributes of the products of their car industries. In the latter, UK market-friendly regulations are likely to be "exported" to the European region and beyond because of industry support, and market liberalization principles embodied in European Union institutions. Both cases indicate that sharing sovereignty in the process of making and implementing national regulations produces opportunities for global regulation.

Miravete, E. J., and M. J. Moral Rincon (2009) "Qualitative Effects of Cash-For-Clunkers Programs," C.E.P.R. Discussion Papers, CEPR Discussion Papers: 7517, http://www.cepr.org/pubs/dps/DP7517.asp.

ABSTRACT: We document how automobile scrappage incentives similar to the '2009 Car Allowance Rebate System' (cars) may influence drivers' tastes in favor of fuel-efficient automobiles. Between 1994 and 2000 the market share of diesel automobiles doubled after Spanish government sponsored two scrappage programs. We show that demand for diesel automobiles was not driven only by better mileage; that gasoline and diesel models became closer substitutes over time; and that automobile manufacturers reduced their markups on gasoline automobiles as their demand decreased. These programs simply accelerated a change of preference that was already on its way when they were implemented.

Moore, A. T., S. R. Staley, and R. W. Poole, Jr. (2010) "The Role of VMT Reduction in Meeting Climate Change Policy Goals," *Transportation Research: Part A: Policy and Practice,* **44** (8), 565-574.

ABSTRACT: This article evaluates the case for vehicle miles traveled (VMT) reduction as a core policy goal for reducing greenhouse gases (GHGs), concluding the economic impacts and social consequences would be too severe given the modest potential environmental benefits. Attempts to reduce VMT typically rely on very blunt policy instruments, such as increasing urban densities, and run the risk of reducing mobility, reducing access to jobs, and narrowing the range of housing choice. VMT reduction, in fact, is an inherently blunt policy instrument because it relies almost exclusively on changing human behavior and settlement patterns to increase transit use and reduce automobile travel rather than directly target GHGs. It also uses long-term strategies with highly uncertain effects on GHGs based on current research. Not surprisingly, VMT reduction strategies often rank among the most costly and least efficient options. In contrast, less intrusive policy approaches such as improved fuel efficiency and traffic signal optimization are more likely to directly reduce GHGs than behavioral approaches such as increasing urban densities to promote higher public transit usage. As a general principle, policymakers should begin addressing policy concerns using the least intrusive and costly approaches first. Climate change policy should focus on directly targeting greenhouse gas emissions (e.g., through a carbon tax) rather than using the blunt instrument of VMT reduction to preserve the economic and social benefits of mobility in modern, service-based economies. Targeted responses are also more cost effective, implying that the social welfare costs of climate change policy will be smaller than using broad-brushed approaches that directly attempt to influence living patterns and travel behavior.

Musti, S., and K. M. Kockelman (2011) "Evolution of the Household Vehicle Fleet: Anticipating Fleet Composition, PHEV Adoption and GHG Emissions in Austin, Texas," *Transportation Research: Part A: Policy and Practice,* **45** (8), 707-720.

ABSTRACT: In today's world of volatile fuel prices and climate concerns, there is little study on the relationship between vehicle ownership patterns and attitudes toward vehicle cost (including fuel prices and feebates) and vehicle technologies. This work provides new data on ownership decisions and owner preferences under various scenarios, coupled with calibrated models to microsimulate Austin's personal-fleet evolution. Opinion survey results suggest that most Austinites (63%, population-corrected share) support a feebate policy to favor more fuel efficient vehicles. Top purchase criteria are price, type/class, and fuel economy. Most (56%) respondents also indicated that they would consider purchasing a plug-in hybrid electric vehicle (PHEV) if it were to cost $6000 more than its conventional, gasoline-powered counterpart. And many respond strongly to signals on the external (health and climate) costs of a vehicle's emissions, more strongly than they respond to information on fuel cost savings. Twenty five-year simulations of Austin's household vehicle fleet suggest that, under all scenarios modeled, Austin's vehicle usage levels (measured in total vehicle miles traveled or VMT) are predicted to increase overall, along with average vehicle ownership levels (both per household and per capita). Under a feebate, HEVs, PHEVs and Smart Cars are estimated to represent 25% of the fleet's VMT by simulation year 25; this scenario is predicted to raise total regional VMT slightly (just 2.32%, by simulation year 25), relative to the trend scenario, while reducing CO2 emissions only slightly (by 5.62%, relative to trend). Doubling the trend-case gas price to $5/gallon is simulated to reduce the year-25 vehicle use levels by 24% and CO2 emissions by 30% (relative to trend). Two- and three-vehicle households are simulated to be the highest adopters of HEVs and PHEVs across all scenarios. The combined share of vans, pickup trucks, sport utility vehicles (SUVs), and cross-over utility vehicles (CUVs) is lowest under the feebate scenario, at 35% (versus 47% in Austin's current household fleet). Feebate-policy receipts are forecasted to exceed rebates in each simulation year. In the longer term, gas price dynamics, tax incentives, feebates and purchase prices along with new technologies, government-industry partnerships, and more accurate information on range and recharging times (which increase customer confidence in EV technologies) should have added effects on energy dependence and greenhouse gas emissions.

Musti, S., K. Kortum, and K. M. Kockelman (2011) "Household Energy Use and Travel: Opportunities for Behavioral Change," *Transportation Research: Part D: Transport and Environment,* **16** (1), 49-56.

ABSTRACT: This study examines personal travel decisions and residents' opinions on energy policy options in the Austin metropolitan area. The vast majority of respondents recognized global warming as a problem, and most agreed that lifestyle changes are needed to combat climate change. Many also believe that climate change can be combated by application of stricter policies in the areas of vehicle technology, fuel economy, and building design. Results of the study illuminate the importance of home-zone attributes on vehicle ownership, vehicle miles, and emissions. Most households agree that energy regulations should be pursued to curb global climate change, and most prefer caps on consumption over taxation. The results suggest that substantial US energy and greenhouse gas savings are likely to come from vehicle fuel-economy regulation, rebates on relatively fuel-efficient vehicle purchases, caps on maximum household energy use, and long-term behavioral shifts.

OECD (2010) "Stimulating Low-Carbon Vehicle Technologies: Summary and Conclusions," OECD/ITF Joint Transport Research Centre Discussion Papers, OECD Publishing (No.

ABSTRACT: If the transport sector is to make deep cuts to its carbon emissions, it is necessary to reduce the carbon-intensity of travel. Reducing travel itself, at some times and places, is sometimes justified but it is extremely unlikely that under expected global economic development patterns overall demand will decline. This holds true even if there is saturation in some markets and demand management policies are widely adopted. Technological change is therefore crucial. The emerging view is that the focus for decarbonising transport should be first to improve the fuel efficiency of conventional engines and then gradually introduce alternative technologies…

Oliver, H. H., K. S. Gallagher, D. Tian, and J. Zhang (2009) "China's fuel economy standards for passenger vehicles: Rationale, policy process, and impacts," *Energy Policy,* **37** (11), 4720-4729.

ABSTRACT: China issued its first Fuel Economy Standards (FES) for light-duty passenger vehicles (LDPV) in September 2004, and the first and second phases of the FES took effective in July 2005 and January 2008, respectively. The stringency of the Chinese FES ranks third globally, following the Japanese and European standards. In this paper, we first review the policy-making background, including the motivations, key players, and the process; and then explain the content and the features of the FES and why there was no compliance flexibility built into it. Next, we assess the various aspects of the standard's impact, including fuel economy improvement, technology changes, shift of market composition, and overall fuel savings. Lastly, we comment on the prospect of tightening the existing FES and summarize the complementary policies that have been adopted or may be considered by the Chinese government for further promoting efficient vehicles and reducing transport energy consumption. The Chinese experience is highly relevant for countries that are also experiencing or anticipating rapid growth in personal vehicles, those wishing to moderate an increase in oil demand, or those desirous of vehicle technology upgrades.

Peters, A., M. G. Mueller, P. de Haan, and R. W. Scholz (2008) "Feebates promoting energy-efficient cars: Design options to address more consumers and possible counteracting effects," *Energy Policy,* **36** (4), 1355-1365.

ABSTRACT: An increasing number of countries have implemented or are evaluating feebate systems in order to reduce energy consumption of new vehicle registrations. We distinguish between absolute feebates based strictly on a vehicle's energy consumption and relative feebates normalizing energy consumption by a given car utility. This paper analyzes whether absolute or relative feebates encourage more consumers to change to vehicles with lower energy consumption. We combine an analysis of all car models on sale at the end of 2005 with survey data from 326 potential new car buyers. Analysis of the car fleet with regard to behavioral changes assumed as realistic shows that relative systems succeed better in offering more consumer groups cars that are eligible for incentives. Survey results suggest that consumers show some, but limited, willingness to change behavior to obtain ail incentive. However, a relative system potentially allows people to switch to cars with higher relative efficiency without actually lowering absolute CO, emissions. We

discuss this inherent dilemma of simultaneously addressing more consumers and limiting counteracting effects. In order to find the optimal trade-off, we suggest assessing different parameters operationalizing vehicle utility by means of micro-simulation with detailed car fleet and differentiated consumer segments. (c) 2007 Elsevier Ltd. All rights reserved.

Pethig, R. (2009) "CO2 mitigation in road transport: Gasoline taxation and/or fuel-efficiency regulation?," Volkswirtschaftliche Diskussionsbeiträge*,* Universität Siegen, Fakultät Wirtschaftswissenschaften, Wirtschaftsinformatik und Wirtschaftsrecht (No. 133-09).

*ABSTRACT***:** Although gasoline taxes are widely used (nearly) efficient CO2 emission controls, additional fuel-efficiency regulation is applied e.g. in the USA and in Europe. In a simple analytical model, we specify the welfare implications of (i) gasoline taxes, (ii) of 'gas-guzzler taxes' (iii) of fuel-efficiency standards, and of combinations of the above. Both forms (ii) and (iii) of fuel-efficiency regulation turn out to produce the same suboptimally low emission rates. Combining (i) and (ii) is also distortionary, while efficiency can be secured by combining (i) and (iii). However, in the optimal mix of the latter two instruments the fuel-efficiency standard is redundant.

Plotkin, S. E. (2009) "Examining fuel economy and carbon standards for light vehicles," *Energy Policy,* **37** (10), 3843-3853.

*ABSTRACT***:** This paper examines fuel economy and carbon standards for light vehicles (passenger cars and light trucks), discussing the rationale for standards, appropriate degrees of stringency and timing, regulatory structure, and ways to deal with "real world" fuel economy issues that may not be dealt with by the standards. There is no optimum method of establishing the stringency of a standard, but policymakers can be informed by analyses of technology cost-effectiveness from the viewpoint of different actors (e.g., society, vehicle purchasers) and of "top runners"--vehicles in the current fleet, or projections of future leading vehicles, that can serve as models for average vehicles some years later. The focus of the paper is on the US light vehicle fleet, with some discussion of applications to the European Union. A "leading edge" midsize car for the 2020 timeframe is identified, and various types of attribute-based standards are discussed. For the US, a 12-15 year target for new vehicle fleet improvement of 30-50% seems a reasonable starting point for negotiations. For 2030 or so, doubling current fuel economy is possible. In both cases, adjustments must be made in response to changing economic circumstances and government and societal priorities.

Popp, M., L. Van de Velde, G. Vickery, G. Van Huylenbroeck, W. Verbeke, and B. Dixon (2009) "Determinants of consumer interest in fuel economy: Lessons for strengthening the conservation argument," *Biomass & Bioenergy,* **33** (5), 768-778.

*ABSTRACT***:** With an outlook for higher global energy prices and concomitant increase of agricultural resources for the pursuit of fuel, consumers are expected to seek more fuel-economic transportation alternatives. This paper examines factors that influence the importance consumers place on fuel economy, with attention given to differences between American and European consumers. In a survey conducted simultaneously in the United States (U.S.) and Belgium in the fall of 2006, respondents in both countries ranked fuel economy high among characteristics considered when purchasing a new vehicle. Overall, respondents in the U,S. placed greater emphasis on fuel economy as a new-vehicle characteristic. Respondents' budgetary concerns carried a large weight when purchasing a new vehicle as reflected in their consideration of a fuel's relative price (e.g. gasoline vs. diesel vs. biofuel) and associated car repair and maintenance costs. On the other hand, high-income Americans displayed a lack of concern over fuel economy. Concern over the environment also played a role since consumers who felt empowered to affect the environment with their purchasing decisions (buying low and clean emission technology and fuels) placed greater importance on fuel economy. No statistically significant effects on fuel economy rankings were found related to vehicle performance, socio-demographic parameters of age, gender or education. Importantly, the tradeoff between using agricultural inputs for energy rather than for food, feed and fiber had no impact on concerns over fuel economy. Finally, contrary to expectations, U.S. respondents who valued domestically produced renewable fuels did not tend to value fuel economy. Published by Elsevier Ltd.

Rakha, H. A., K. Ahn, K. Moran, B. Saerens, and E. Van den Bulck (2011) "Virginia Tech Comprehensive Power-Based Fuel Consumption Model: Model Development and Testing," *Transportation Research: Part D: Transport and Environment,* **16** (7), 492-503.

*ABSTRACT***:** Existing automobile fuel consumption and emission models suffer from two major drawbacks; they produce a bang-bang control through the use of a linear power model and the calibration of model parameters is not possible using publicly available data thus necessitating in-laboratory or field data collection. This paper develops two fuel consumption models that overcome these two limitations. Specifically, the models do not produce a bang-bang control and are calibrated using US Environmental Protection Agency city and highway fuel economy ratings in addition to publicly available vehicle and roadway pavement parameters. The models are demonstrated to estimate vehicle fuel consumption rates consistent with in-field measurements. In addition the models estimate CO2 emissions that are highly correlated with field measurements.

Richels, R. G., and G. J. Blanford (2008) “The value of technological advance in decarbonizing the US economy,” *Energy Economics,* **30** (6), 2930-2946.

ABSTRACT: This paper examines the role of technology in managing the costs of a carbon constraint on the U.S. economy. Two portfolios of technology are examined. One reflects modest investments in climate-friendly technologies, the other more aggressive development. The analysis indicates that the development of a broad range of low- to zero-carbon emitting technologies can substantially reduce (but not eliminate) the economic cost of decarbonization. By enabling large-scale emission reductions on the supply-side, costly reductions in demand are avoided. in particular, the emergence of electricity as a low-carbon fuel provides a powerful lever for achieving reductions in other sectors of the economy at lower cost. While the analysis suggests that there is no "free lunch," the bill, which may indeed be well worth paying, can be greatly reduced through an accelerated R&D program and successful diffusion of new technology throughout the economy. (c) 2008 Elsevier B.V. All rights reserved.

Roberts, M. C. (2008) “E85 and fuel efficiency: An empirical analysis of 2007 EPA test data,” *Energy Policy,* **36** (3), 1233-1235.

ABSTRACT: It is well known that ethanol has less energy per unit volume than gasoline. Differences in engine design and fuel characteristics affect the efficiency with which the chemical energy in gasoline and ethanol is converted into mechanical energy, so that the change in fuel economy may not be a linear function of energy content. This study analyzes the fuel economy tests performed by the US Environmental Protection Agency (EPA) on 2007 model year E85-compliant vehicles and finds that the difference in average fuel economy is not statistically different from the differential in energy content.

Rubin, J., P. N. Leiby, and D. L. Greene (2009) “Tradable fuel economy credits: Competition and oligopoly,” *Journal of Environmental Economics and Management,* **58** (3), 315-328.

ABSTRACT: Corporate average fuel economy (CAFE) regulations specify minimum standards for fuel efficiency that vehicle manufacturers must meet independently. We design a system of tradeable fuel economy credits that allows trading across vehicle classes and manufacturers with and without considering market power in the credit market. We perform numerical simulations to measure the potential cost savings from moving from the current CAFE system to one with stricter standards, but that allows vehicle manufacturers various levels of increased flexibility. We find that the ability for each manufacturer to average credits between its cars and trucks provides a large percentage of the potential savings. As expected, the greatest savings come from the greatest flexibility in the credit system. Market power lowers the potential cost savings to the industry as a whole, but only modestly. Loss in efficiency from market power does not eliminate the gains from credit trading. (C) 2009 Elsevier Inc. All rights reserved.

Sallee, J. (2010) “The Taxation of Fuel Economy,” National Bureau of Economic Research, Inc, NBER Working Papers: 16466, http://www.nber.org/papers/w16466.pdf.

ABSTRACT: Policy-makers have instituted a variety of fuel economy tax policies--polices that tax or subsidize new vehicle purchases on the basis of fuel economy performance--in the hopes of improving fleet fuel economy and reducing gasoline consumption. This article reviews existing policies and concludes that while they do work to improve vehicle fuel economy, the same goals could be achieved at a lower cost to society if policy-makers instead directly taxed fuel. Fuel economy taxation, as it is currently practiced, invites several forms of gaming that could be eliminated by policy changes. Thus, even if policy-makers prefer fuel economy taxation over fuel taxes for reasons other than efficiency, there are still potential efficiency gains from reform.

Sallee, J. M., and J. Slemrod (2010) “Car Notches: Strategic Automaker Responses to Fuel Economy Policy,” National Bureau of Economic Research, Inc, NBER Working Papers: 16604, http://www.nber.org/papers/w16604.pdf.

ABSTRACT: Notches--where small changes in behavior lead to large changes in a tax or subsidy--figure prominently in many policies, but have been rarely examined by economists. In this paper, we analyze a class of notches associated with policies aimed at improving vehicle fuel economy. We provide several pieces of evidence showing that automakers respond to notches in fuel economy policy by precisely manipulating fuel economy ratings so as to just qualify for more favorable treatment. We then describe the welfare consequences of this behavior and derive a welfare summary statistic applicable to many contexts.

Salvo, A., and C. Huse (2011) “Is Arbitrage Tying the Price of Ethanol to that of Gasoline? Evidence from the Uptake of Flexible-Fuel Technology,” *Energy Journal,* **32** (3), 119-148.

ABSTRACT: Brazil is the only sizable economy to date to have developed a home-grown ubiquitously-retailed alternative to fossil fuels in light road transportation: ethanol from sugar cane. Perhaps unsurprisingly, the uptake of flexible-fuel vehicles (FFVs) has been tremendous. Five years after their introduction, FFVs accounted for 90% of new car sales and 30% of the circulating car stock. We provide a stylized model of the sugar/ethanol industry which incorporates substitution by consumers, across ethanol and gasoline at the pump, and substitution by producers, across domestic regional and export markets for ethanol and sugar. We argue that the model stands up well to the empirical co-movement in prices at the pump in a panel of Brazilian states. The paper offers a case study of how agricultural and energy markets link up at the very micro level. doi: 10.5547/ISSN0195-6574-EJ-Vol32-No3-5

Schipper, L. (2008) "Automobile Fuel Economy and CO2 Emissions in Industrialized Countries: Troubling Trends through 2005/6," University of California Transportation Center, Working Papers*,* University of California Transportation Center (No. 1365936).

*ABSTRACT***:** A review of recently available data on both on-road fuel economy and new car test fuel economy shows that while US on-road fuel economy has been flat for almost 15 years, major European countries and Japan have shown modest improvements in response to â€œvoluntaryâ€ agreements on fuel economy, steadily rising fuel prices (since 2002), and to some extent shifts to smaller cars and 2nd family cars. At the same time the sales weighted average of new vehicles sold in the European Union, expressed in terms of their implied CO2 emissions, have fallen short of 2008 goals. That a significant part of the improvements in Japan are related to the growing share of mini-cars (displacement under 600 CC) suggest that technology is not the only factor that can or will yield significant and rapid energy savings and CO2 restraint in new cars. Fuel economy technology, while important, isn't the only factor that explains differenced sin tested or on-road fuel economy when comparing vehicle efficiency and transport emissions in different countries. Fuels, technology, and driver behavior also play significant roles in how much fuel is used. As long as the upward spiral of car weight and power offsets much of the impact of more efficient technology on fuel efficiency, fuel economy will not improve much in the future. And as long as the numbers of cars and the distances cars are driven keep creeping up, technology alone will have a difficult time offsetting all of these trends to lower fuel use and CO2 emissions from this important sector.

Schipper, L. (2011) "Automobile use, fuel economy and CO2 emissions in industrialized countries: Encouraging trends through 2008?," *Transport Policy,* **18** (2), 358-372.

*ABSTRACT***:** Car use and fuel economy are factors that determine oil demand and carbon dioxide (CO2) emissions. Recent data on automobile utilization and fuel economy reveal surprising trends that point to changes in oil demand and CO2 emissions. New vehicle and on-road fleet fuel economy have risen in Europe and Japan since the mid 1990s, and in the US since 2003. Combined with a plateau in per capita vehicle use in all countries analyzed, these trends indicate that per capita fuel use and resultant tail-pipe CO2 emissions have stagnated or even declined. Fuel economy technology, while important, is not the only factor that explains changes in tested and on-road fuel economy, vehicle efficiency and transport emissions across countries. Vehicle size and performance choices by car producers and buyers, and driving distances have also played significant roles in total fuel consumption, and explain most of the differences among countries. Technology applied to new vehicles managed to drive down the fuel use per unit of horsepower or weight by 50%, yet most of the potential fuel savings were negated by overall increased power and weight, particularly in the US. Similarly, the promise of savings from dieselization of the fleet has revealed itself as a minor element of the overall improvement in new vehicle or on-road fuel economy. And the fact that diesels are driven so much more than gasoline cars, a difference that has increased since 1990, argues that those savings are minimal. This latter point is a reminder that car use, not just efficiency or fuel choice, is an important determinant of total fuel use and CO2 emissions. We speculate that if the upward spiral of car weight and power slows or even reverses (as has been observed in Europe and Japan) and the now mandatory standards in many countries have the intended effect that fuel use will remain flat or only grow weakly for some time. If real fuel prices of 2008, which rivaled their peaks of the early 1980s, fell back somewhat but still remain well above their early 2000 values. If the prices remain high, this, combined with the strengthened fuel economy standards, may finally lead to new patterns of car ownership, use and fuel economy. However, if fuel prices continue their own stagnation or even decline after the peaks of 2008 and car use starts upward, fuel use will increase again, albeit more slowly.

Schipper, L. (2009) "Fuel economy, vehicle use and other factors affecting CO2 emissions from transport," *Energy Policy,* **37** (10), 3711-3713.

Schroeder, E. (2008) "A New Mandate for Federal CAFE Standards from the Ninth Circuit," *Ecology Law Quarterly,* **35** (3), 645-650.

Shiau, C.-S. N., J. J. Michalek, and C. T. Hendrickson (2009) "A Structural Analysis of Vehicle Design Responses to Corporate Average Fuel Economy Policy," *Transportation Research: Part A: Policy and Practice,* **43** (9-10), 814-828.

*ABSTRACT***:** The US Corporate Average Fuel Economy (CAFE) regulations are intended to influence automaker vehicle design and pricing choices. CAFE policy has been in effect for the past three decades, and new legislation has raised standards significantly. We present a structural analysis of automaker responses to generic CAFE policies. We depart from prior CAFE analyses by focusing on vehicle design responses in long-run oligopolistic equilibrium, and we view vehicles as differentiated products, taking demand as a general function of price and product attributes. We find that under general cost, demand, and performance functions, single-product profit maximizing firm responses to CAFE standards

follow a distinct pattern: firms ignore CAFE when the standard is low, treat CAFE as a vehicle design constraint for moderate standards, and violate CAFE when the standard is high. Further, the point and extent of first violation depends upon the penalty for violation, and the corresponding vehicle design is independent of further standard increases. Thus, increasing CAFE standards will eventually have no further impact on vehicle design if the penalty for violation is also not increased. We implement a case study by incorporating vehicle physics simulation, vehicle manufacturing and technology cost models, and a mixed logit demand model to examine equilibrium powertrain design and price decisions for a fixed vehicle body. Results indicate that equilibrium vehicle design is not bound by current CAFE standards, and vehicle design decisions are directly determined by market competition and consumer preferences. We find that with increased fuel economy standards, a higher violation penalty than the current stagnant penalty is needed to cause firms to increase their design fuel economy at equilibrium. However, the maximum attainable improvement can be modest even if the penalty is doubled. We also find that firms' design responses are more sensitive to variation in fuel prices than to CAFE standards, within the examined ranges.

Small, K. (2011) "Energy Policies for Passenger Motor Vehicles," Working Papers, University of California-Irvine, Department of Economics (No. 101108), 37 pages.

ABSTRACT: This paper assesses the costs and effectiveness of several energy policies for light-duty motor vehicles in the United States, using the National Energy Modeling System (NEMS). The policies addressed are higher fuel taxes, tighter vehicle efficiency standards, and financial subsidies and penalties for the purchase of high- and low-efficiency vehicles (feebates). I find that tightening fuel-efficiency standards beyond those currently mandated through 2016, or imposing feebates designed to accomplish similar changes, can achieve by 2030 reductions in energy use by all light-duty passenger vehicles of 7.1 to 8.4 percent. A stronger feebate policy has somewhat greater effects, but at a significantly higher unit cost. High fuel taxes, on the order of $2.00 per gallon (2007$), have somewhat greater effects, arguably more favorable cost-effectiveness ratios, and produce their effects much more quickly because they affect the usage rate of both new and used vehicles. Policy costs vary greatly with assumptions about the reason for the apparent myopia commonly observed in consumer demand for fuel efficiency, and with the inclusion or exclusion of ancillary costs of congestion, local air pollution, and accidents.

Thiel, C., A. Perujo, and A. Mercier (2010) "Cost and CO2 Aspects of Future Vehicle Options in Europe under New Energy Policy Scenarios," *Energy Policy,* **38** (11), 7142-7151.

ABSTRACT: New electrified vehicle concepts are about to enter the market in Europe. The expected gains in environmental performance for these new vehicle types are associated with higher technology costs. In parallel, the fuel efficiency of internal combustion engine vehicles and hybrids is continuously improved, which in turn advances their environmental performance but also leads to additional technology costs versus today's vehicles. The present study compares the well-to-wheel CO2 emissions, costs and CO2 abatement costs of generic European cars, including a gasoline vehicle, diesel vehicle, gasoline hybrid, diesel hybrid, plug in hybrid and battery electric vehicle. The predictive comparison is done for the snapshots 2010, 2020 and 2030 under a new energy policy scenario for Europe. The results of the study show clearly that the electrification of vehicles offer significant possibilities to reduce specific CO2 emissions in road transport, when supported by adequate policies to decarbonise the electricity generation. Additional technology costs for electrified vehicle types are an issue in the beginning, but can go down to enable payback periods of less than 5 years and very competitive CO2 abatement costs, provided that market barriers can be overcome through targeted policy support that mainly addresses their initial cost penalty.

Timilsina, G. R., and H. B. Dulal (2011) "Urban Road Transportation Externalities: Costs and Choice of Policy Instruments," *World Bank Research Observer,* **26** (1), 162-191.

ABSTRACT: Urban transportation externalities are a key development challenge. Based on the existing literature, the authors illustrate the magnitudes of various external costs, review response policies, and measure and discuss their selection, particularly focusing on the context of developing countries. They find that regulatory policy instruments aimed at reducing local air pollution have been introduced in most countries in the world. On the other hand, fiscal policy instruments aimed at reducing congestion or greenhouse gas emissions are limited mainly to industrialized economies. Although traditional fiscal instruments, such as fuel taxes and subsidies, are normally introduced for other purposes, they can also help to reduce externalities. Land-use or urban planning, and infrastructure investment, could also contribute to reducing externalities; but they are expensive and play a small role in already developed megacities. The main factors that influence the choice of policy instruments include economic efficiency, equity, country or city specific priority, and institutional capacity for implementation. Multiple policy options need to be used simultaneously to reduce effectively the different externalities arising from urban road transportation because most policy options are not mutually exclusive.

Tolouei, R., and H. Titheridge (2009) "Vehicle Mass as a Determinant of Fuel Consumption and Secondary Safety Performance," *Transportation Research: Part D: Transport and Environment,* **14** (6), 385-399.

ABSTRACT: One interaction between environmental and safety goals in transport is found within the vehicle fleet where fuel economy and secondary safety performance of individual vehicles impose conflicting requirements on vehicle mass from an individual's perspective. Fleet characteristics influence the relationship between the environmental and safety outcomes of the fleet; the topic of this paper. Cross-sectional analysis of mass within the British fleet is used to estimate the partial effects of mass on the fuel consumption and secondary safety performance of vehicles. The results confirmed that fuel consumption increases as mass increases and is different for different combinations of fuel and transmission types. Additionally, increasing vehicle mass generally decreases the risk of injury to the driver of a given vehicle in the event of a crash. However, this relationship depends on the characteristics of the vehicle fleet, and in particular, is affected by changes in mass distribution within the fleet. We confirm that there is generally a trade-off in vehicle design between fuel economy and secondary safety performance imposed by mass. Cross-comparison of makes and models by model-specific effects reveal cases where this trade-off exists in other aspects of design. Although it is shown that mass imposes a trade-off in vehicle design between safety and fuel use, this does not necessarily mean that it imposes a trade-off between safety and environmental goals in the vehicle fleet as a whole because the secondary safety performance of a vehicle depends on both its own mass and the mass of the other vehicles with which it collides.

Turrentine, T., K. S. Kurani, and R. R. Heffner (2008) "Fuel Economy: What Drives Consumer Choice?," Working Paper Series*,* Institute of Transportation Studies, UC Davis (No. 1344214).

ABSTRACT: When gasoline prices rise, it makes the news. Reporters mob gas stations to ask drivers how they are dealing with the higher prices. Many drivers say, "What can I do? I have to drive." Some drivers declare they will curtail their driving while others complain of price gouging and oil company conspiracies. We know that few drivers adjust their driving behavior much in response to gasoline price changes on the scale that occurred during our study, but we do see that sales of smaller vehicles have increased, and that hybrids are getting lots of attention. But how do consumers really think about and respond to gasoline prices? Do they know how much they spend on gasoline over the course of a year, or do they think only in terms of price per gallon? When they buy a car, do they think about fuel costs over time, are they just looking for high miles per gallon (MPG)?

Van Biesebroeck, J. (2010) "The Demand for and the Supply of Fuel Efficiency in Models of Industrial Organisation," OECD/ITF Joint Transport Research Centre Discussion Papers*,* OECD Publishing (No. 2010/9).

ABSTRACT: This report organizes and discusses empirical estimates of the effects of fuel prices and fuel emission standards on consumer and firm behaviour. I touch only briefly on model-free estimates. The focus is on results based on explicit models, taken mostly from the industrial organization literature. First, I review studies that identify the willingness to pay for fuel efficiency using static and dynamic models of vehicle demand. Next, I take explicitly into account that firms will adjust their product portfolios and the characteristics of the vehicles they offer. These decisions will have an impact on the choice set from which consumer demand is estimated and on the trade-off that consumers face between fuel efficiency and other desirable characteristics. Finally, I discuss models where firms choose to invest in innovations to achieve fuel efficiency gains without sacrificing characteristics.

van Dender, K., and P. Crist (2011) "What Does Improved Fuel Economy Cost Consumers and What Does it Cost Taxpayers?: Some illustrations," International Transport Forum Discussion Papers*,* OECD Publishing (No. 2011/16).

ABSTRACT: "Green growth" is an emerging paradigm that integrates several policy aspirations, including the durability of economic activity, reduced environmental impacts, and sustained growth in high-quality employment in such a way as to foster coherent, cross-sectoral policy design. Focusing on "green growth" highlights the need for governments to assess policies on their long-term economic, environmental and social impacts, recognizing that there can be synergies but also tradeoffs among the broad policy aims. As we hope to show in this paper, an examination of "green growth" policies in the transport sector provides an interesting case in point. Reducing emissions comes at a cost to consumers and taxpayers and if fuel tax revenues decline strongly it may be necessary to review the way the transport sector is taxed and contributes to aggregate tax revenue.

Wagner, D. V., F. An, and C. Wang (2009) "Structure and impacts of fuel economy standards for passenger cars in China," *Energy Policy,* **37** (10), 3803-3811.

ABSTRACT: By the end of 2006, there were about 24 million total passenger cars on the roads in China, nearly three times as many as in 2001. To slow the increase in energy consumption by these cars, China began implementing passenger car fuel economy standards in two phases beginning in 2005. Phase 1 fuel consumption limits resulted in a sales-weighted new passenger car average fuel consumption decrease of about 11%, from just over 9Â l/100Â km to approximately 8Â l/100Â km, from 2002 to 2006. However, we project that upon completion of Phase 2 limits in 2009, the average fuel consumption of new passenger cars in China may drop only by an additional 1%, to approximately 7.9Â l/100Â km. This is due to the fact that a majority of cars sold in 2006 already meets the stricter second phase fuel consumption limits. Simultaneously, other trends in the Chinese vehicle market, including increases in average curb weight and increases in standards-exempt imported vehicles, threaten to offset the efficiency gains achieved from 2002 to 2006. It is clear that additional efforts and policies beyond Phase 2 fuel consumption limits are required to slow and, ultimately, reverse the trend of rapidly rising energy consumption and greenhouse gases from China's transportation sector.

Wang, Z., Y. Jin, M. Wang, and W. Wei (2010) "New fuel consumption standards for Chinese passenger vehicles and their effects on reductions of oil use and CO2 emissions of the Chinese passenger vehicle fleet," *Energy Policy,* **38** (9), 5242-5250.

ABSTRACT: A new fuel consumption standard for passenger vehicles in China, the so-called Phase 3 standard, was approved technically in 2009 and will take effect in 2012. This standard aims to introduce advanced energy-saving technologies into passenger vehicles and to reduce the average fuel consumption rate of Chinese new passenger vehicle fleet in 2015 to 7Â L/100Â km. The Phase 3 standard follows the evaluating system by specifying fuel consumption targets for sixteen individual mass-based classes. Different from compliance with the Phases 1 and 2 fuel consumption standards, compliance of the Phase 3 standard is based on corporate average fuel consumption (CAFC) rates for individual automobile companies. A transition period from 2012 to 2014 is designed for manufacturers to gradually adjust their production plans and introduce fuel-efficient technologies. In this paper, we, the designers of the Phase 3 standard, present the design of the overall fuel consumption reduction target, technical feasibility, and policy implications of the Phase 3 standard. We also explore several enforcement approaches for the Phase 3 standard with financial penalties of non-compliance as a priority. Finally, we estimate the overall effect of the Phase 3 standard on oil savings and CO2 emission reductions.

Wayne, W. S., N. N. Clark, A. B. M. S. Khan, M. Gautam, G. J. Thompson, and D. W. Lyons (2008) "Regulated and Non-regulated Emissions and Fuel Economy from Conventional Diesel, Hybrid-Electric Diesel, and Natural Gas Transit Buses," *Journal of the Transportation Research Forum,* **47** (3), 105-125.

ABSTRACT: Distance-specific fuel economy (FE) and emissions of carbon monoxide (CO), hydrocarbons (HC), oxides of nitrogen (NOx), and particulate matter (PM) from transit buses representing diesel, retrofitted diesel, hybrid-electric diesel, and lean-burn natural gas technologies are presented in this paper. Emissions were collected from these buses at the Washington Metropolitan Area Transport Authority (WMATA) test site in Landover, Maryland. In this program, one bus each from diesel, retrofitted diesel, hybrid-electric diesel, and natural gas technologies was tested on 17 chassis cycles and the other buses were tested on a subset of these cycles. Data show that the test cycle has a profound effect on distance-specific emissions and FE, and relative emissions performance of technology is also cycle dependant. Lean-burn natural gas buses demonstrated their low PM output, diesel engines showed low HC output, benefit of exhaust filtration was evident, and the positive effect of hybrid-electric drive technology was most pronounced for low-speed transient cycles.

Xiao, J., and H. Ju (2011) "The impacts of air-pollution motivated automobile consumption tax adjustments of China," MPRA Paper*,* University Library of Munich, Germany (No. 27743).

ABSTRACT: A concomitant of the rapid development of the automobile industry in China is the serious air pollution and carbon dioxide emission. There are various regulation instruments to reduce the air pollution from automobile sources. China government chooses a small-displacement oriented consumption tax as well as fuel tax to alleviate the worse air pollution. This paper evaluates the effects of both policy instruments on fuel consumption and social welfare. Our empirical results show that fuel tax decreases the total sale of new cars, which leads to a decline of total consumption of fuel from the new cars, but does not change the sale distribution over various fuel efficiency models; while consumption tax adjustment results in a skewed sale distribution toward more efficient new cars but increases the total consumption of fuel due to an enlarged sale. The effects of these two taxes on pollution depend on our assumption about the average fuel efficiency of outside goods. On the other hand, consumption tax leads to less social welfare loss; in particular, consumer surplus decreases in an order of magnitude less than that caused by fuel tax. Fuel tax actually transfers more welfare from private sector to the government.

Yeh, S., A. E. Farrell, R. J. Plevin, A. Sanstad, and J. Weyant (2008) "Optimizing U.S. Mitigation Strategies for the Light-Duty Transportation Sector: What We Learn from a Bottom-Up Model," Working Paper Series*,* Institute of Transportation Studies, UC Davis (No. 1363866).

ABSTRACT: Few integrated analysis models examine significant U.S. transportation greenhouse gas emission reductions within an integrated energy system. Our analysis, using a bottom-up MARKet ALocation (MARKAL) model, found that stringent systemwide CO2 reduction targets will be required to achieve significant CO2 reductions from the transportation sector. Mitigating transportation emission reductions can result in significant changes in personal vehicle technologies, increases in vehicle fuel efficiency, and decreases in overall transportation fuel use. We analyze policy-oriented mitigation strategies and suggest that mitigation policies should be informed by the transitional nature of technology adoptions and the interactions between the mitigation strategies, and the robustness of mitigation strategies to long-term reduction goals, input assumptions, and policy and social factors. More research is needed to help identify robust policies that will achieve the best outcome in the face of uncertainties.

Zachariadis, T. (2008) "The Effect of Improved Safety on Fuel Economy of

European Cars," *Transportation Research: Part D: Transport and Environment,* **13** (2), 133-139.

Zhang, L., B. S. McMullen, D. Valluri, and K. Nakahara (2009) "Vehicle Mileage Fee on Income and Spatial Equity Short- and Long-Run Impacts," *Transportation Research Record,* (2115), 110-118.

ABSTRACT: Because of concern about the declining purchasing power of gas tax revenue due to inflation, public opposition to tax increases, and the improved fuel efficiency of new vehicles, the 2001 Oregon legislature created the Road User Fee Task Force (RUFTF) to make recommendations for a potential replacement for the gasoline tax. This paper estimates the distributional impact of the statewide vehicle miles traveled (VMT) fee policy proposed by the RUFTF on individuals with different incomes and residential locations. The methodology employs both vehicle ownership and type choice models and regression-based vehicle use models. This allows an examination of both short- and long-run responses from the affected households. The measures of the distributional impact of the proposed VMT fee include changes in consumers' surplus, fee-collection agency revenue totals, and overall welfare changes by income and location groups. The results show that the distributional effects of a $0.012/mi flat VMT fee are not significant in either the short or long run and suggest that distributional concerns should not be a hindering factor in the future implementation of the proposed VMT fees.

Zhang, Q., W. Tian, Y. Zheng, and L. Zhang (2010) "Fuel Consumption from Vehicles of China Until 2030 in Energy Scenarios," *Energy Policy,* **38** (11), 6860-6867.

ABSTRACT: Estimation of fuel (gasoline and diesel) consumption for vehicles in China under different long-term energy policy scenarios is presented here. The fuel economy of different vehicle types is subject to variation of government regulations; hence the fuel consumption of passenger cars (PCs), light trucks (Lts), heavy trucks (Hts), buses and motor cycles (MCs) are calculated with respect to (i) the number of vehicles, (ii) distance traveled, and (iii) fuel economy. On the other hand, the consumption rate of alternative energy sources (i.e. ethanol, methanol, biomass-diesel and CNG) is not evaluated here. The number of vehicles is evaluated using the economic elastic coefficient method, relating to per capita gross domestic product (GDP) from 1997 to 2007. The Long-Range Energy Alternatives Planning (LEAP) system software is employed to develop a simple model to project fuel consumption in China until 2030 under these scenarios. Three energy consumption decrease scenarios are designed to estimate the reduction of fuel consumption: (i) 'business as usual' (BAU); (ii) 'advanced fuel economy' (AFE); and (iii) 'alternative energy replacement' (AER). It is shown that fuel consumption is predicted to reach 992.28 Mtoe (million tons oil equivalent) with the BAU scenario by 2030. In the AFE and AER scenarios, fuel consumption is predicted to be 734.68 and 600.36 Mtoe, respectively, by 2030. In the AER scenario, fuel consumption in 2030 will be reduced by 391.92 (39.50%) and 134.29 (18.28%) Mtoe in comparison to the BAU and AFE scenarios, respectively. In conclusion, our models indicate that the energy conservation policies introduced by governmental institutions are potentially viable, as long as they are effectively implemented.

Review of ORNL's Consumer Choice Model

Walter McManus
McManus Analytics LLC

October 14, 2011

ORNL's Consumer Choice Model was developed for use in regulatory analysis by EPA-OTAQ. In the specifications to guide the model development, EPA-OTAQ requested a Nested Multinomial Logit (NMNL) or "other appropriate model." ORNL delivered a NMNL model as documented in Greene and Liu (2011).

EPA-OTAQ identified several necessary model capabilities. Most important, in my view, is the ability to estimate impacts of changes in greenhouse gas emissions standards on the mix of vehicles produced for sale in the U.S. To ensure that the industry actually attains the targeted reductions in greenhouse gas emissions, EPA must understand and be able to adjust standards for changes in vehicle mix. The model specifications also say that the model must be capable of estimating the impacts of changes in greenhouse gas emissions standards on consumer surplus. In my view, this is of secondary importance.

My review is based on materials provided to me. The model was contained in a computer program and described in a report documenting the model (Greene and Liu, 2011).

That the "appropriate" model would turn out to be a nested multinomial logit was probably inevitable. EPA-OTAQ explicitly mentioned the NMNL model, and by the words, "or other appropriate model," implicitly endorsed NMNL as an appropriate model. In addition, ORNL has long experience and solid expertise in NMNL models. Still, ORNL provides a reasonably balanced review of alternative appropriate models.

There are some items that ORNL could add to the review of alternative models that would enhance the usefulness of the review to EPA and practitioners.

Table 1 shows the elasticity matrix for vehicle classes as used by Kleit (2004). The text compares own-elasticities from this table to the NMNL's assumed own-elasticities. It would be useful to be able to compare the two approaches with respect to cross-elasticities. These could be simulated using the NMNL model, changing one class's price at a time, and presented in a table similar to table 1. There may be nonlinearities, so it would make sense to use a range of alternative starting points for the vector of prices and a range of percentage changes in each price. Cross-elasticities are indeed small, but the pattern has an intuitive economic interpretation. Are the cross-elasticities that are built into the NMNL similarly intuitive?
Bordley's elasticities are derived from second-choice information collected from new vehicle buyers. They were asked to specify the vehicle they would have bought, had the vehicle which they actually bought not been available. (Full disclosure: I was employed as an economist by

General Motors for nine years and became well-acquainted with the second-choice information.) A key insight from GM's consumer research is that the new vehicle buyer, in general, has a short shopping list. This means that each vehicle in the market is not considered by all buyers. Vehicles with novel technologies are likely to have low consideration when introduced. Therefore, the NMNL model would overstate their expected market share. There is no easy fix for this, but the issue should be mentioned as a limitation of the NMNL, especially for new advanced technologies.

Another way to look at the impact of willingness to consider on market share in a logit model can be shown mathematically in the two-product case. In the standard logit, the purchase probabilities are given by $\pi_0 = \frac{e^{u_0}}{e^{u_0}+e^{u_1}}$ and $\pi_1 = \frac{e^{u_1}}{e^{u_0}+e^{u_1}}$. Subscripts 0 and 1 refer to "conventional" vehicles and "advanced technology" vehicles respectively. Implicit in this frame is the assumption that the representative consumer considers every possible vehicle model, at least those models in the market. This is how the NMNL model frames things as well.

However, the formulas for purchase probability change if one of the vehicle types has lower consideration that the other. (See Struben and Sterman 2008) Suppose all consumers consider the conventional vehicle, but only fraction w consider the advanced technology vehicle. The probabilities need to be rewritten as $\pi_0 = \frac{e^{u_0}}{e^{u_0}+we^{u_1}}$ and $\pi_1 = \frac{we^{u_1}}{e^{u_0}+we^{u_1}}$. Thus, it should be possible to adjust for consideration.

The report points out that aggregate models or modeling NMNL at an aggregate level could miss some important shifts in vehicle mix within the aggregates. Thus the report advises using the most complete level of detail possible. However, the report's authors recognize that the forecast errors at this most complete level of detail possible are uncomfortable large, and that the impacts at this level are too imprecise to be reported. The authors do not put it as strongly as this, of course. They should provide some evidence, possibly from simulations, that aggregated NMNL models indeed miss mix shifts that the most complete level of detail possible captures accurately.

On page 4 sources of prediction errors should add "unexpected behavior by consumers over time."

Overall the model parameters are appropriate. The consumer value of fuel economy is, as the authors acknowledge, subject to conflicting views and assumptions. The ORNL model amounts to entering (price of fuel) / (fuel economy) in the demand function. This formulation forces the impact of fuel price and fuel economy to have effects that are equal but opposite in sign. Nearly all of the empirical estimates of the "value of fuel economy" also use this formulation, so these estimates might be "appropriate." However, most of the historically observed changes in (price of fuel) / (fuel economy), and almost all of the large changes, have come from variation in the price of fuel, not in fuel economy.

Modelers always demand more. More input options, more simulation options, and more output options. The ORNL strikes the right balance between too much and too little flexibility.

Large changes in fuel prices over a short period of time have caused significant movement by consumers between vehicle classes. Most recently, the fuel price spike in 2008 caused many buyers to trade in trucks and SUVs for cars. The danger is that we might be applying lessons from changes in behavior involving mix switching to the value of fuel economy at the level of a vehicle.

The authors have covered the salient caveats for regulatory analysis.

References

Greene, D. and C. Liu (2011), Consumer Vehicle Choice Model Documentation

Struben, J and J. Sterman (2008), Transition challenges for alternative fuel vehicle and transportation systems. Environment and planning bulletin 35(6): 1070-1097

II.

EPA's Response to Peer Review Comments

April 2012

<u>MEMORANDUM</u>

SUBJECT: EPA Response to Comments on the Peer Review of the Consumer Vehicle Choice Model and Associated Documentation Conducted by Drs. David Bunch, Trudy Cameron, and Walter McManus

FROM: Dr. Gloria Helfand, Assessment and Standards Division

The Consumer Choice Vehicle Model (CVCM) and associated documentation were reviewed by Drs. David Bunch (University of California, Davis), Trudy Cameron (University of Oregon), and Walter McManus (University of Michigan, Transportation Research Institute).

This memo includes a summary of comments prepared by SRA International and responses and actions in response to those comments from EPA. David Greene and Changzheng Liu, who developed the model and the documentation, provided EPA with responses to the comments from SRA; the following memo draws very heavily from those responses.

3.1 Overall Approach and Methodology of Model

Reviewers provide a range of opinion on the model's overall approach and methodology, with one providing detailed comment on the need to reflect the uncertainty in the predictions, and another concluding that the model is flexible enough.

Bunch: "The representative consumer NMNL [nested multinomial logit] form, and the inputs and outputs of the model, are an entirely appropriate choice of methodology for this problem. The OMEGA model itself is based on a specific model for manufacturer behavior whereby (1) the vehicle market definition does not change (2) the only changes to vehicles are the fuel economy and purchase price. Using this approach, this type of NMNL model could be readily integrated directly into the OMEGA model if necessary. In addition, this model could be viewed as only a starting point in an ongoing process of future model development. Additional complexity could be incrementally introduced into the model and evaluated."

Cameron: Provides extensive comment on her main substantive concern, which she terms "reflecting the uncertainty in the predictions". She cautions against "spurious precision"; discusses fixed parameters and distributions on parameters; and suggests "honoring the bounds" on elasticities across levels, allowing for some non-zero correlations between parameters, building sampling distributions for output measures, providing richer summaries of model results, enhancing the model to provide access to a pseudo-random number generator, and subjecting key assumptions to systematic sensitivity analysis.

"From a broader social welfare perspective, the model is a bit narrow. Its goal is to explain the mix of vehicles sold and to predict how this mix might change when vehicle prices are affected by the costs of meeting more stringent fuel economy standards. However, this is not part of a full computable general equilibrium model. Instead, the OMEGA model apparently minimizes the costs of achieving a particular carbon dioxide goal across a variety of possible technology packages, and these higher costs are passed (in one direction) to the CVCM to predict the effects of higher vehicle prices on the demand for different vehicle types and therefore on the sales of each company and the resulting corporate average fuel economy effects, to a first approximation." Cameron suggests that there should be a feedback, and she "raises the naïve question of why are there no estimates of *cross-price elasticities* of demand in the model. The market share model, as a function [of] vehicle own-prices and incomes, with no feedback to the supply side, necessarily misses the effects of demand shifts in response to changes in relative prices as a result of the original supply shift. There are likely to be heterogeneous price changes and cross-price elasticities that are different from zero." Cameron expresses worry about the model's "narrow focus on how much vehicle prices go up due to standards and the resulting loss in consumer surplus in vehicle markets." EPA should not conclude that "vehicle buyers will be "hurt" to this extent without considering the potentially countervailing benefits from reduced carbon emissions and fewer emissions of conventional pollutants," and should emphasize that although "some surplus will be lost by consumers of this product," society will benefit in general.

McManus: The model "strikes the right balance between too much and too little flexibility."

EPA Response: We appreciate the support for the general model framework provided by Drs. Bunch and McManus. We also agree, as Dr. Bunch points out, that the model is a starting point; as EPA develops experience and confidence in the basic model functions, we can add greater complexity.

We also appreciate Dr. Cameron's comments on how to portray the uncertainties involved in the predictions. Building a fully stochastic and dynamic model is beyond the scope of the current project, but EPA will keep it in consideration for future work. In the meantime, the sensitivity of the model's predictions to errors in the parameter estimates can be described by repeated sensitivity testing; ORNL added sensitivity analysis in the revised model documentation. Assume that the representative consumer NMNL model is parameterized by the following vector of n scalars: (β_1,β_2,…β_n). The parameters are italicized to indicate that they are mean or expected values. Since the true values of the β_i are not known, ORNL provides the results of running the model with our standard assumptions, then increasing and decreasing, the generalized cost coefficients by 25% and 50%. Of course, this does not completely describe all possibilities but does give a useful description of the sensitivity of model predictions to errors in parameters. These tests were done relative to a specific input data set. In addition, because of the importance of the sensitivity of consumer decisions to changes in fuel economy, ORNL examined the effects if consumers consider 2 or 15 years' worth of fuel savings when buying a vehicle, instead of the default value of 5 years' worth. ORNL finds that the estimated consumer surplus change is highly sensitive to how consumers are assumed to value fuel savings from fuel economy improvements relative to the baseline case. The greater the amount of fuel savings that consumers consider when buying their vehicles, the greater the increase in consumer surplus. Price elasticities have much smaller impacts on consumer surplus. Higher price elasticities lead to larger increases in consumer surplus, while lower elasticities reduce consumer surplus. The impacts on total sales follow the same pattern as consumer surplus changes. In future work with this model, EPA will consider building a structured way to incorporate uncertainty into the current framework.

Dr. Cameron's concerns about spurious accuracy are well taken. There is no reason to assume that the CVCM model can predict changes in market shares of individual vehicles to a high degree of precision. EPA does not plan to report detailed predictions; when final outputs are produced (e.g., total change in consumers' surplus, total change in vehicle sales, etc.), these numbers should be rounded to avoid conveying a spurious sense of precision. If the model is developed in the future to iterate sequentially with OMEGA, the detailed results will be passed from the CVCM to the OMEGA model and back again; in this context, there is nothing to be gained by rounding.

Concerning the issue of cross price elasticities of demand, the NMNL model does imply cross price elasticities. They are a consequence of the structure of the model, the data to which it is calibrated and the generalized cost parameters. In a simple MNL model, the own price elasticity of the market share of vehicle i is $\beta(1-s_i)P_i$, in which β is the generalized cost coefficient, s_i is the market share of vehicle i and P_i is its price. The cross-price elasticity of the market share of vehicle i with respect to the price of vehicle k is $-\beta s_k P_k$. Thus, the cross-price elasticities have a very specific structure dictated by the NMNL model form and the price and market share data. Because, in general, $s_i << 1$, cross price elasticities are much smaller than own price elasticities. In the CVCM, with about 1,000 vehicle types, there could be 500,000 cross price elasticities. Although the formulas for cross price elasticities in the NMNL model are a good deal more complicated, they too are determined once the generalized cost coefficients, the initial market shares, and the price and fuel economy changes are determined. Appendix B.2 now includes presentation of price elasticities at the vehicle class level. As can be seen there, most values are quite small, but some cross-price elasticities (such as between small and standard cargo pickup trucks) are large.

Dr. Cameron observes correctly that there is no feedback from demand shifts to the supply side of the market. Simultaneously estimating producer and consumer responses to regulations in the auto industry is a highly complex process that relatively few researchers have conducted, and the merits of these models for predicting changes due to regulations have not been tested. EPA at this stage seeks to develop experience with a relatively simple model and keeps open the possibility of further model development.

Dr. Cameron correctly points out that there is more to the value of fuel economy and CO_2 emissions standards than can be measured by consumers' surplus. In its rulemakings, EPA seeks to take all relevant costs and benefits into consideration and will not base its decision on the consumers' surplus impacts alone.

3.2 Appropriateness of Model Parameters and Inputs

Reviewers provide a range of opinion on the model parameters and inputs.

Bunch: "Greene and Liu take an approach that is a bit different from what is typical in most of the literature. Specifically, most researchers determine model parameters by obtaining data on vehicle choices (typically at the household level), and then using statistical estimation methods to obtain parameter estimates. In contrast, Greene and Liu use the parsimonious model form described above, and take a "calibration" approach. They make assumptions about the values of price elasticities, which are in turn related to the values of structural parameters (price slopes). The alternative-specific constants, on the other hand, are calibrated using actual sales data for a particular base year. (We say "calibrated" rather than "estimated" because there is a direct deterministic mapping between sales and the constants.) The assumptions on the elasticities are based on a review of the literature, combined with theoretical considerations related to the model. The values of the structural parameters are related to the elasticities, but there is not a deterministic relationship as in the case of the alternative-specific constants. The authors use an *ad hoc* approach to estimating price slopes based on elasticities. Although there could be a better way to do this, under the circumstances it seems reasonable. Finally, the only utility attribute currently required by their model is an estimate of the value of fuel savings from an improvement in fuel economy. This can be computed on the basis of additional assumptions.

Their approach avoids many of the pitfalls of the statistical estimation approach. First, the statistical approach requires access to good data sets (which are frequently not available) and a lot of difficult econometric analysis. When using this approach, revealed preference data are rife with multicollinearity, stated choice methods (which can overcome multicollinearity) are not universally accepted, and all aspects of such analyses are subject to debate and criticism that are a distraction from the main purpose of policy analysis. The literature review by Greene (2010) illustrates that the parameter estimates obtained via this approach are very context dependent, and can vary widely. In particular, there is very little agreement on a key issue: how consumers value fuel economy/fuel savings.

I support the decision by Greene and Liu to use a parsimonious NMNL model with a calibration approach. The assumptions can be debated separately from other parts of the analysis, and can always be changed to test their implications.

With regard to chosen values for model parameters, there is a relationship between price elasticities and NMNL structural parameters (aka "price slopes"), and that the mapping is not one-to-one. The method used by the authors is described on page 29. Although there may be better methods, this one seems sufficient in practice. The other question is how to choose the elasticities. They do this based on values found in the literature, also recognizing that the NMNL requires the type of ordering found in equation (38). They provide a discussion (page 31) to support their selections, which seem reasonable. Having said this, one thing that is missing is an analysis of the distribution of price elasticities produced from actual runs of the Model itself. This would seem to be a useful validation exercise. "

Cameron: "I am greatly concerned about the misleading impression of precision that is created by the use of arbitrary simple point estimates for price elasticities. These point estimates are selected from a sparsely populated range of empirical estimates of just a subset of the needed elasticities. These empirical estimates are typically for more-aggregated categories of vehicles as well. It seems imperative to implement a strategy for capturing the uncertainty about the true parameters that capture price responsiveness. The model cannot predict exact market shares, yet readers will be lulled into thinking that they can be confident in its predictions about changes in market shares and consumer surplus. Consumers of the model's results need to know how sensitive all of its predictions are with respect to the actual state of knowledge about the necessary input quantities.

The documentation for the model is very clear, on page 4, about the list of potential sources for prediction errors, including source number 4, "Errors in NML parameters." Just acknowledging these sources, however, does not reveal the potential sizes of these errors, relative to the predictions of the model. I think it is imperative to try to capture at least some of the noise that is actually in the model, so users are not left with zero information about the sensitivity of the results to at least some of the key subjective inputs. There is not much to be done about "model uncertainty," or "input variable uncertainty" (unless even more layers of randomization are added to the framework in which each single simulation is embedded), but at least some of the parameter uncertainty could be accommodated."

"Also, to the extent that other inputs to the model are also not known with certainty, there could be an additional layer of simulations within each iteration. For example, if forecasts of the population or number of households come with standard errors, those could also be subjected to random draws."

McManus: "Overall the model parameters are appropriate. The consumer value of fuel economy is, as the authors acknowledge, subject to conflicting views and assumptions. The ORNL model amounts to entering (price of fuel) / (fuel economy) in the demand function. This formulation forces the impact of fuel price and fuel economy to have effects that are equal but opposite in sign. Nearly all of the empirical estimates of the "value of fuel economy" also use this formulation, so these estimates might be "appropriate." However, most of the historically observed changes in (price of fuel) / (fuel economy), and almost all of the large changes, have come from variation in the price of fuel, not in fuel economy."

EPA Response: Dr. Bunch correctly points out that the calibration method is different from the approach taken by most academic researchers. However, this approach has been used before in studies of the impacts of feebates published in refereed journals (Greene et al., 2005; Greene, 2009) and in a major research project of the California Air Resources Board (Bunch and Greene, 2011). It combines a review of the available literature with a theoretical constraint on the relative magnitudes of generalized cost coefficients at different levels in the nesting structure. A similar method was used by NERA et al. (2007) to evaluate the impacts of California and Federal light-duty vehicle emissions regulations. The alternative is to statistically estimate parameters from data. This approach provides no guarantee that the resulting values would have been superior to those in the extant literature or that it would have solved the problems that statistical estimations in the literature have encountered. As Dr. Bunch noted, "Their approach avoids many of the pitfalls of the statistical estimation approach," which he enumerates. In practice, this method can generate a plausible, theoretically consistent set of generalized cost coefficient estimates in general agreement with the published literature, and it allows consideration of multiple estimates from the literature rather than one set of parameters from one dataset.

In addition, the model's generalized cost coefficients can be readily changed to conduct sensitivity analysis. As discussed above, a sensitivity analysis of the impacts of alternative assumptions about generalized cost coefficients has been added to the model documentation. The documentation also includes the distribution of price elasticities produced by the model, as requested by Dr. Bunch; both these additions are in the Appendix.

In general, three considerations strongly influenced the choice of modeling method:

1. That the only exogenous changes to be considered were changes in vehicle prices and fuel economies (apart from changes in public goods like CO_2 or criteria pollutant emissions).
2. That the scholarly literature on the value of fuel economy contained a wide range of estimates and no consensus on how consumers valued fuel economy in car buying decisions (Greene, 2010; Helfand and Wolverton, 2011).
3. That a relatively high level of detail was required in representing the makes and models of vehicles among which consumers might chose.

The first point implies that the model need not represent the myriad of factors that affect consumers' car buying decisions. The second point suggests that the model should allow alternative assumptions about the value consumers assign to fuel economy, and it does. Since the extant literature appears to be evenly divided between papers that indicate that consumers undervalue fuel economy and those that suggest that consumers value it at approximately its lifetime discounted present value, or more, a model with a fixed view could not reflect the current state of understanding of this issue. Points 1 and 2, taken together, imply that the model should allow a flexible method of translating changes in fuel economy to changes in present value dollars and should relate changes in the present value net cost of vehicles to changes in vehicle market shares. The third point requires a model that can be calibrated to a potentially large number of vehicle choices and used to predict changes in market shares at a relatively detailed level and yet be feasible to operate from the perspective of computational complexity. These three principles guided the decision to develop the NMNL model.

We agree with Dr. Cameron's concern that the accuracy of the model's predictions not be overstated by presenting results with a high degree of precision. As discussed above, to the extent that the outputs of the CVCM are to be passed back to the OMEGA model for iteration, there is no advantage to rounding numbers for that purpose. On the other hand, when final results are presented for consideration, Dr. Cameron makes an important point that false precision should be avoided. The sensitivity analyses suggest that outputs should be presented to no more than three digits, and perhaps only two. These sensitivity analyses also respond to her request that we attempt to quantify the potential impacts of "parameter uncertainty" on model predictions.

Dr. McManus judges the model parameters to be appropriate, overall. He notes the importance of consumers' evaluation of fuel economy and current uncertainty about that key aspect of the model. We fully agree with his point. He is correct that we calculate the value of a change in fuel economy by multiplying the price of fuel times the change in fuel consumption (gallons per mile). This does indeed make the effects of fuel price and fuel consumption equal and opposite in sign. We also agree that there is some statistical evidence favoring an asymmetrical relationship, in which fuel price has the larger impact. However, we think our formulation is reasonable for the intended use of the CVCM. In designing the CVCM, it was given that the price of fuel would not change during iterations between the CVCM and the OMEGA model. The CVCM will thus be calibrated to a given price forecast and only the fuel economies of vehicles will change, not the price of fuel. This again raises the question of doing sensitivity analysis or Monte Carlo simulation with combined OMEGA/CVCM runs, which we consider an interesting subject for future research and development.

3.3 Information that Can Be Input into the Model

One reviewer highlights the necessary linkage between the CVCM and OMEGA models in understanding inputs, while another provides a detailed review of specific inputs.

Bunch: "Note that the model inputs are *not* "changes in CAFÉ/GHG policy." To produce a complete analysis of changes in CAFÉ/GHG policy requires the use of both the OMEGA model and the Greene and Liu model. . . . To analyze the impact of a change in CAFÉ/GHG policy, the OMEGA model must be used to "predict" the fuel economies and price changes that occur. These, in turn, are passed to the CVCM. Note that this requires some coordination between the two models. For example, both models must be set up to use the same new vehicle market definitions. The reference sales used by OMEGA must be passed along to the CVCM unchanged. . . . There needs to be some coordination and testing that involves both models, including common data for an agreed-upon base year. One concern is that, if the number and/or types of vehicles in the market definition were to change, it could affect how the ORNL model behaves. In particular, if the new market definition, e.g., reduced the number of configurations for each make/model combination to one, this could have implications for the elasticities at the bottom level of the tree."

Cameron: "The assumption about individual discount rates is central to the choice model because it is necessary to express utility from each vehicle as a function of the present value of future fuel savings that accompanies the higher purchase price of a vehicle with improved fuel economy. Assuming one common discount rate for everyone, even if that discount rate can be adjusted, will miss the fact that individual subjective discount rates vary systematically with a number of individual characteristics. Furthermore, when it comes to capital-cost/operating-cost decisions like the ones made in the new automobile market, the fact that capital market constraints can sometime masquerade as higher individual discount rates may be very relevant. People who are heavily capital-market constrained may make very different choices in durable goods markets than people who are not. These vehicles will have different mixes of capital and operating costs at the baseline, and different fuel efficiency requirements will change the capital/operating cost mix as well.

The model is very flexible in terms of the different quantities that can be set by the user, although all of these quantities are entered as point values, rather than likely distributions. For example, the model seems to include gasoline and diesel prices for twenty years into the future, and these individual parameters lend the appearance of being amenable to being very precisely and independently specified. When I clicked on each cell to ascertain how it was being calculated, I expected to see each future cell computed as the starting value subjected to a growth rate, but this is not the case. It seems necessary for the user to propose a price per gallon for each type of fuel in each future year. It is not clear why these settings as flexible as they are (unless the programming merely anticipates that users will ask for such flexibility eventually). Would it be possible for users, alternatively, just to choose a rate of growth or a linear trajectory for these two fuel prices (with confidence bounds, of course)?

Among the global parameters, the user appears to be invited to provide individual independent estimates of the population and average household size from 2010 to 2030, although the note in line 6 suggests that these numbers come from the U.S. Census Bureau's projections of the U.S. population (not "polution") to 2050. It is not clear from this sheet what might be the Census Bureau's basis for such precise population estimates over a twenty-year horizon, or for the static value of projected average household sizes over the same period. What about how the baby boom is moving through the demographic landscape? Might it be reasonable to allow the user, alternatively, to commit only to an estimate of growth rates (with confidence bounds)? This could be based on the current actual population estimate in the starting year. Perhaps for flexibility into the future, these years could also be expressed relative to the current year, rather than as absolute time. In short order, the "starting" year of 2010 will definitely be obsolete.

Also among the global parameters, it might make sense to make the contents of "Market Size-CycleX" to be linked to the content of the relevant future population cells, both in this case, with one cycle specified, and when more than one cycle is specified. Perhaps "Input Validation" is a way to make sure that things line up in a foolproof way, but that is not transparent. It should also be made clearer in the column headings how the cycle length (six years, apparently) is related to assumptions about the length of the payback periods (if it is). If there is a relationship, functional relationships among the values for the fields could enforce these relationships.

To keep the program as self-contained as possible, please be clear, among the notes to this sheet, what are the definitions of a "cycle" and what is meant by the "OnRoad Discount" field. We know this is the fraction of advertised MPG that is actually achieved in regular driving, but it might be better to call it something else, unless there is a tradition in the literature of using this terminology. Perhaps "Actual/Rated MPG."

On the VehicleUse sheet, individual car and truck Survival (not Survial) Rates, by age, need to be specified. Again, I expected that each cell would be a function of the previous one, perhaps until a threshold was reached. Again, however, users are required to be specific about each cell, which probably overstates the precision that is feasible in forecasting these survival rates. Historical survival rates are not really relevant because of the substantial changes in materials and technology in recent decades. It might be preferable to allow users the options to specify a starting survival rate and a parameter according to which the survival rate changes over time (with confidence bounds) so that these cells can alternatively be populated automatically according to that function. The confidence bounds would allow for sensitivity analysis.

Without more information, the column headings in the Target sheet are just too cryptic. It is not clear what is meant by a "cycle," or what are the units for the "a" and "b" fields, or the "c" and "d" fields for cars and trucks, or why there are lower and higher constraints for both. These sheets could be rendered more self-contained and self-explanatory with more "Notes" as are offered on some other sheets. Since it is desirable to leave room for other "cycles" in this sheet, perhaps the headings could be expanded with "wrap text" invoked so that users could be confidence about what information was needed in each of these cells for each cycle.

The Logit sheet finally invokes the types of cross-sheet and cross-cell functions I expected to see elsewhere in the setup. The rank ordering of the degree of responsiveness of demand to full cost of a vehicle (I assume) is enforced at the level of the "Slope" variable, rather than among the "Elasticity" settings that the user is free to specify. Are there any values for the ingredients to this calculation for which a rank ordering of the elasticities will not produce an identical rank ordering of slopes? That would seem to be a possible problem. Users could specify elasticities that were admissibly rank-ordered, but the relationship among the slopes would then be rejected by the slope-ranking test.

Also in the Logit sheet, the counts of vehicle types at Level 4 ("Number of Members") are linked directly to the Vehicle sheet where the full range of vehicles is inventoried. However, at level 3, the "Number of Members" seems to be set independently, without reference to the number of Vehicle Classes. Is there a way to make the software robust to the introduction of a user-specified new Vehicle Class? This might require the introduction of a "Type" column next to the "Class" column for Level 4 that shows the mapping from Classes to Types. I am comfortable that we can get along for quite a while before it would be necessary to introduce a new Category, but perhaps an extra column under Level 3 to make the corresponding Categories explicit for each Type would also be helpful. This information is contained in the (verbal) Parent Node, but it might be clearer to have the Parent Node relabeled as "Parent Type" for Level 4 and "Parent Category" for Level 3.

It would be more logical to have Level 1 at the top, progressing down to the most disaggregated levels at the bottom of the sheet. At least in my experience, correlation structure diagrams are not upward-growing "trees" but downward-expanding "root systems." This could be just a matter of taste, but I had been visualizing the structure as expanding downward (perhaps in the order in which consumers narrow down their vehicle choice), so the reverse ordering of the Logit Sheet came with a bit of cognitive dissonance. Perhaps I was basing my expectations on Figure 1 on page 21 of the document."

McManus: Although modelers would like to have more input options, simulation options, and output options, the model "strikes the right balance between too much and too little flexibility."

<u>EPA Response</u>: Dr. Bunch notes that changes in emissions and fuel economy rules can only be fully evaluated by using the OMEGA and CVCM models together. As long as OMEGA is used as the representation, this statement is correct. (In principle, other sources could be used for input to the CVCM, but EPA expects to use OMEGA.) He also argues for testing of the two models in joint operation, which is a good idea but beyond the scope of the present project.

Dr. Cameron raises the issue of consumer heterogeneity with respect to discount rates and therefore valuation of fuel economy changes. There are also variations in vehicle usage rates across consumers, and these also can result in different valuations of changes in fuel economy. There is useful data on the distribution of annual vehicle miles across the U.S. population. Much less is known about the distribution of consumer discount rates and still less about the joint distribution of annual miles and discount rates. The main reasons for using a representative consumer model are the desire to keep the model simple, the lack of reliable data for calibration, and the added complexity of the calibration process. The key issue, however, is how much consumer heterogeneity might affect the *average* change in consumers' surplus or new vehicle *average* MPG. This could be tested by a sensitivity analysis repeatedly sampling from a distribution of annual miles of travel for new vehicles and running the CVCM. Such a simulation is beyond the scope of this project but is worth considering if more extensive model validation studies are undertaken.

Dr. Cameron notes that the data input requirements for factors such as population are individual numbers for each year and that the model does not allow short cuts, such as specifying growth rates. For EPA's regulatory analyses, detailed data either will be provided by OMEGA or will come from another source, such as the Energy Information Administration's Annual Energy Outlook, from which annual data can be readily obtained in electronic form. Thus, it is not necessary to set up the program to use growth rates.

Cryptic terminology makes the reviewer's job more difficult; the revised model and documentation have sought to improve the terminology and to correct typos.

Dr. Cameron is correct in noting that a user might specify a set of elasticities for nests that were suitably rank ordered but that this might result in a violation of the rank ordering of slopes, which is the critical theoretical requirement. The model input validation macro does flag such situations and provide error notification. At present, this phase of calibration requires expert judgment. It would be possible to implement different formulations. For example, one alternative to the present formulation would be to allow the user to specify the increase in relative price sensitivity at each stage. The spreadsheet could then calculate both the generalized cost coefficients and elasticities. The only requirement would be that the relative price sensitivities all be greater than one. The elasticities might be useful for comparison to published studies. We continue with the current format to incorporate the insights from existing literature on the magnitudes of the elasticities.

Dr. Cameron asks whether it might be made a simple matter to introduce a new vehicle class. This is not simple in a spreadsheet but could be done relatively easily in a high-level programming language. We opted for the spreadsheet format because it made the process more visible to the person calibrating the model. The key requirement would be to specify the mapping from individual vehicles (e.g., make, model, and configuration) to the new vehicle classes. This task is beyond the current project scope, but it will be considered for future model revisions.

The input sheet ordering has not been changed in this version, but the revised documentation seeks to be more consistent in terminology and description of levels to reduce confusion.

3.4 Types of Information the Model Produces

One reviewer compares various models and concludes that the chosen model produces sufficiently accurate information. Two reviewers express concerns about the types of information the model produces.

Bunch: Reviewer considers a number of possible models that might have been chosen and writes that most of them "make more detailed behavioral assumptions to explain consumers' vehicle choices than does the representative consumer NMNL (the only exception being the representative consumer MNL based on equation (2)). In this regard, they could be regarded as potentially superior in terms of more accurately capturing market reaction to changes in vehicle offerings. On the other hand, their model is extremely parsimonious while also capturing important market substitution effects across various types of vehicles, and Occam's razor could be said to apply.

The fact is that modeling future behavior of the new vehicle market is extraordinarily difficult. There is a relatively large literature on this subject, representing the efforts of many researchers using a variety of modeling approaches. As noted above, it could be argued on theoretical grounds that more complex models have the potential to be more accurate than an aggregate-level model. However, as shown in the review by Greene (2010), the results of more complex model estimation results vary over a wide range. Moreover, we are not aware of any studies that directly compare the accuracy of simpler models versus more complex models in any definitive way. Finally, it is well understood that modeling approaches are chosen based on a variety of factors, including the type of decision problem being addressed, availability of data to perform model estimation, data and computational requirements for using the model when performing scenario analysis, etc.

For this particular project, the ultimate goal is to use the OMEGA-NMNL system to analyze regulations. The most effective way to perform such analyses is by *comparison* of two scenarios (reference versus alternative) in response to specific types of *changes* (leaving all other factors constant). Specifically, the analysis is not predicated on requiring a model give the most accurate *forecast* of what will happen in the future (in an absolute sense). If this were the case, then it would be more important to include the effect of demographic variables over time (which would also require a demographic forecast), to predict structural changes in the vehicle market, and to simulate manufacturer decisions to add or delete various models (including the introduction of advanced technology vehicles).

Cameron: The point estimates of consumer surplus and sales embody spurious precision. "For example, it is hubris to predict industry revenue in hundreds of billions down to the exact dollar. At best, *the predictions of the model should be rounded to no more than two or perhaps three significant digits and confidence bounds of some kind should be provided*. The same goes for all of the other model outputs. The key elasticity settings must be so arbitrarily selected from the extant empirical estimates that it isn't wise to imply so much accuracy in the results file. *The precision in the results can be no greater than the precision in the elasticity estimates that serve as inputs, since these inputs are the weakest ones."*

McManus: "The report points out that aggregate models or modeling NMNL at an aggregate level could miss some important shifts in vehicle mix within the aggregates. Thus the report advises using the most complete level of detail possible. However, the report's authors recognize that the forecast errors at this most complete level of detail possible are uncomfortable large, and that the impacts at this level are too imprecise to be reported. The authors do not put it as strongly as this, of course. They should provide some evidence, possibly from simulations, that aggregated NMNL models indeed miss mix shifts that the most complete level of detail possible captures accurately."

EPA Response: We agree with Dr. Bunch's comment: "The fact is that modeling future behavior of the new vehicle market is extraordinarily difficult." As Dr. Bunch correctly notes, the function of the CVCM is not to accurately predict the evolution of the new vehicle market over time but only to predict the impacts of price and fuel economy changes, given the same set of vehicles. This is a much simpler task but still involves a good deal of uncertainty. Especially for an initial implementation of the concept, a simple but rigorous model is likely to be preferable to a more complicated one. Also as Dr. Bunch notes, EPA's use of the model will focus on comparing scenarios rather than on predicting specific impacts. Our hope is that errors in scenario modeling will roughly cancel out in the comparisons.

Dr. Cameron again notes the spurious precision of the model's raw outputs. As discussed above, EPA agrees with this concern and intends in rulemaking documents to round off the impacts. For intermediate exchanges between OMEGA and the CVCM we see no benefit to rounding at this point.

Dr. McManus asks for evidence that more aggregate modeling would miss mix shifts that a more detailed model can estimate. We maintain the disaggregated approach because a model that does not represent changes in sales at the disaggregated level could not possibly estimate the impacts of sales shifts at that level on MPG. A model that does not represent demand at the engine/transmission level, for example, could not calculate the impact on fleet MPG of a sales shift from the 6-cylinder to the 4-cylinder version of the same vehicle. Likewise, the consumers' surplus impacts of such a shift could not be estimated. It is also likely to be important that price sensitivity is greatest at the lowest level of the choice structure. Finally, given that the new standards are adjusted for vehicle footprint, one might also expect shifts among vehicle size classes to have a smaller impact than under the previous CAFE formulation, with most of the action occurring in sales shifts within size classes among makes, models, engines and transmissions. EPA notes that we do not expect to report results at the configuration level in our regulatory analyses; the results will be presented at more aggregated levels.

3.5 Accuracy and Appropriateness of Model's Algorithms and Equations

All three reviewers provide extensive and highly specific comment on the model's algorithms and equations.

Bunch: Although the equations and derivations are generally correct, there are concerns about the model notation. "The specific NMNL form used by Greene and Liu has a tree structure that is much more complicated than most applications found in the literature. (Most have two or perhaps three levels, and exhibit a certain amount of symmetry.) In addition, they primarily use a notation developed over the years by Greene and co-authors that is not typically used by the rest of the field. The model parameters are one of two types: alternative-specific constants, and price slopes. The price slopes are the “structural parameters” of the model that relate to correlation among random disturbance terms in the RUM framework.

However, the use of the term “price slope” is potentially misleading, since one might infer that this is a model coefficient that exclusively applies to vehicle price.[10] Generally speaking, this parameter is a conversion factor that converts “generalized cost” (not just price) into “utility.” In this approach, all of a choice alternative’s attributes must be first expressed as costs (in dollars), and then added up. The resulting sum is then multiplied by a price slope to get “utiles.” This works reasonably well for simple utility functions where the only entries are price and, e.g., present value of fuel costs. (It is also easier to digest when the model has only two levels.)

However, in the future if other vehicle attributes are added (e.g., performance, vehicle size, etc.) this approach would be cumbersome. In discussing the implications of moving to lower levels of the tree, it is said that price slopes get larger (more negative), and that consumers are more “price sensitive.” Again, this is potentially misleading, since consumers are actually becoming more “attribute sensitive.”

The authors also include two other notational conventions in various locations in the paper. The other conventions are used more widely in the literature, with more conventional interpretations of the structural parameters as relating either to the scale or the variance of the (conditional) random disturbance term. The can also be used to express the degree of correlation between disturbance terms in the same nest. Overall, the way the notation, equations, and interpretation of parameters are used in the documentation could be said to be “sub-optimal”. The authors are attempting to keep things simple (but still technically correct) in some places, but also more complete in other places. This is not an easy job, but depending on how EPA would like to use the documentation going forward, some attention may be required to these issues. “

Cameron: Expresses concern “that *M* in equation (35), annual VMT, is assumed to be exogenous. There seems to be a lot of literature concerned with the “rebound effect.” For example, Barla et al. (2009), Eskeland and Mideksa (2008), Frondel et al. (2008; Greene et al. (1999; Greening et al. (2000; Hymel et al. (2010; Jones (1993; Kemel et al. (2011; Small and Van Dender (2007) all discuss this issue. Since Greene is one of these authors, we know he is aware of this. It would seem that *M* should be considered as endogenous, and should be specified as a function of the difference in fuel economy, rather than being treated as a constant that depends only on the age of the vehicle.”

“I am accustomed to seeing the qualification that the correlation structure in a nested logit model does not necessarily imply a sequential decision process. All it does is highlight subsets of choices within which there is an error component unique to the group and different from analogous components associated with other groups.”

“In the Prelude section, in equation (15), a *vector* of vehicle attributes that is assumed to influence the utility of alternative *j* to individual *n* quietly turns into nothing more than a “sum” G_j that represents a “generalized cost” for alternative *j*. All other attributes of these vehicles besides their price become non-explicit and apparently get soaked up by the alternative-specific constant utility component α_j for that vehicle, which is therefore assumed not to vary with price. It would also seem that the individual

[10] Potentially more confusing, the authors sometimes refer to “price coefficient” (e.g., on page 120.

and alternative-specific random utility component ε_{nj} must be assumed to be independent of the generalized cost variable if the coefficient β_p is to be unbiased. How does this work? What about the fact that there are reasons for some vehicles to be more expensive than others."

"The parameter *L*, the "assumed payback period, in years," is presumably linked to planned duration of vehicle use (and is inherited from the OMEGA assumptions). However, it seems important to think about the extent to which fuel efficiency is capitalized into the resale value of used cars. If greater fuel efficiency enhances a vehicle's resale value, so that the capitalized value of fuel savings for used cars is fully reflected in their prices, the effective planning horizon is actually a lot longer—perhaps extending to the useful life of the vehicle. The current formulation is implemented with a value of 5 (years) in the GlobalParameter sheet for the CCM inputs. Allcott and Wozny (2010), for example, find that consumers are willing to pay $0.61 to reduce expected discounted gas expenditures by $1. This estimate undoubtedly hinges on their assumptions about individual discount rates. However, the fact that this WTP estimate is not zero suggests that a finite time horizon, with no "resale-value increment" factored into the model of expected fuel (cost) savings in equation (35), might need some re-thinking."

"Is there evidence to suggest that the "Actual/Rated MPG" is constant across all types of vehicles? Surely this ratio has been established for almost all classes of vehicle. Consumer-contributed data by make/model/year seem to be available at www.fueleconomy.gov, for example, but the data are rather thin. It might be possible to do better here."

It would be helpful to first write the formula for a price elasticity of demand in a conventional Econ 101 format. If a demand equation is linear and additively separable in price, where the derivative of quantity demanded with respect to price is β_c, this formula in the single-equation case should be:

$$\eta_j = \left(\frac{\partial q_j}{\partial p_j}\right)\left(\frac{p_j}{q_j}\right) = \beta_c\left(\frac{p_j}{q_j}\right) = p_j\beta_c\left(\frac{1}{q_j}\right) \quad (3)$$

To help the reader determine whether it is necessary to go find their copy of Train (2009), it would be helpful to explain how we get from $\left(1/q_j\right)$ to $\left(1-S_j\right)$. If this step is transparent, it can go right into the derivation in the text. If it is more complex, explain that the reader really needs to ponder an extended discussion in Train (and give a preview of what is involved there).

Emphasize in the discussion of equation (38) the strong assumption that the underlying β parameter (before normalization on the error dispersion for a given nest) is the same across all levels and branches of the model's correlation structure diagram. It is only the dispersion of the errors in each partitioning that leads to different normalized values of this parameter, B.

McManus: "Bordley's elasticities are derived from second-choice information collected from new vehicle buyers. They were asked to specify the vehicle they would have bought, had the vehicle which they actually bought not been available. (Full disclosure: I was employed as an economist by General Motors for nine years and became well-acquainted with the second-choice information.) A key insight from GM's consumer research is that the new vehicle buyer, in general, has a short shopping list. This means that each vehicle in the market is not considered by all buyers. Vehicles with novel technologies are likely to have low consideration when introduced. Therefore, the NMNL model would overstate their expected market share. There is no easy fix for this, but the issue should be mentioned as a limitation of the NMNL, especially for new advanced technologies.

Another way to look at the impact of willingness to consider on market share in a logit model can be shown mathematically in the two-product case. In the standard logit, the purchase probabilities are given by $\pi_0 = \frac{e^{u_0}}{e^{u_0}+e^{u_1}}$ and $\pi_1 = \frac{e^{u_1}}{e^{u_0}+e^{u_1}}$. Subscripts 0 and 1 refer to "conventional" vehicles and "advanced technology" vehicles respectively. Implicit in this frame is the assumption that the representative consumer considers every possible vehicle model, at least those models in the market. This is how the NMNL model frames things as well.

However, the formulas for purchase probability change if one of the vehicle types has lower consideration that the other. (See Struben and Sterman 2008) Suppose all consumers consider the conventional vehicle, but only fraction w consider the advanced technology vehicle. The probabilities need to be rewritten as $\pi_0 = \frac{e^{u_0}}{e^{u_0}+we^{u_1}}$ and $\pi_1 = \frac{we^{u_1}}{e^{u_0}+we^{u_1}}$. Thus, it should be possible to adjust for consideration. "

EPA Response: Dr. Bunch expresses concern about the notation and about the use of the term "price slope" instead of generalized cost coefficient. The difference between his view and that used in the draft on terminology and notation is a matter of preference. Since the notation is mathematically correct, it is not a problem that needs correcting. On the issue of generalized cost coefficient versus price slope, both are correct. It is possible to normalize the consumer utility function using the price slope as the normalization variable or using the coefficient of any other attribute. In general, there is a value to using the term "generalized cost" when many different attributes are included in the utility function and price may appear interacted with other variables. The utility function here is much simpler, however, consisting of only a constant, the change in price and the change in the present value of future fuel savings. Since both variables are measured in present value dollars, the application here normalizes on price and the "generalized cost" coefficient is the price slope. However, Dr. Bunch is correct in noting that, if other attributes were added, it might be clearer to refer to the coefficient used for normalization as the generalized cost coefficient. The terminology has been revised to generalized cost coefficient instead of price slope.

Dr. Cameron notes that the assumed annual miles per vehicle used in the calculation of the value of fuel savings is, in general, not constant but may depend on the fuel economy of the vehicle in question. There are two ways to interpret the assertion that vehicle use should be endogenous. The first is that, in choosing among vehicles prior to the implementation of new emissions/fuel economy standards, the representative consumer would drive more in a higher fuel economy vehicle than in a lower fuel economy vehicle. This would be true *ceteris paribus,* but vehicle use depends on other vehicle and household attributes as well. For example, historical data indicate that minivans and sport utility vehicles are driven about 10% to 20% more than passenger cars (EIA, 1997). From this perspective, the issue is once again the question of heterogeneity of parameters. The second is that, subsequent to an increase in fuel economy, consumers would drive their vehicles more, which would tend to increase the value of fuel savings. There is a good deal of evidence relating to the rebound effect, and Dr. Cameron is right that we are well aware of it. The effect is likely to be very small, however. EPA's assessment of the latest evidence finds that the rebound elasticity is approximately -0.1 (a 10% increase in fuel economy leads to a 1% increase in vehicle travel, *ceteris paribus*). But other things are not equal since vehicle prices have increased. Suppose, on average, that the increase in vehicle price offsets half of the fuel savings. In that case, the long-run cost of owning and operating a vehicle has decreased by only half as much; if so, the rebound effect would be only about -0.05. (This is arguable since a vehicle's capital value is used up not only by use but by aging, also.) Now suppose one is considering the impact of a 33% reduction in fuel consumption per mile (50% increase in fuel economy). Vehicle use would increase between one and two percent, considering the effect of reduced per mile fuel costs and increased vehicle capital costs. This induces a relatively small (1-2%) downward bias in the estimation of the consumers' surplus benefit of increased fuel economy. Given the uncertainties about how consumers value fuel economy, we think this is a negligible effect.

Dr. Cameron is correct that the nesting structure of the NMNL model does not imply a sequential decision process. This statement has been added to the documentation.

In the next paragraph Dr. Cameron raises the question of whether the calibrated constant terms for each vehicle might be related in some way to the price coefficient for their respective nests. The price (generalized cost) coefficient within a nest is assumed to be constant in the NMNL model. This also implies that the variance of the alternative-specific error terms is constant for all vehicles in the nest. This does not mean that the prices of vehicles are constant. Some vehicles do cost more than others. A vehicle with a high price relative to others in its group but with a large market share would have a large, positive constant term, reflecting the value of other attributes of the vehicle, some of which would presumably be responsible for its high price. A vehicle with a low price and a small market share would have a much smaller constant term, reflecting the fact that, despite its low price, its other attributes were not good enough to attract many buyers.

The next paragraph raises interesting questions about how best to represent how consumers value fuel economy. As noted above, this subject is both controversial and unresolved. EPA and NHTSA have used the assumption that consumers consider 5 years' worth of fuel savings in their vehicle purchases in previous rulemakings; it suggests that consumers do consider fuel economy, although imperfectly, in their purchase decision. This formulation should not be interpreted as necessarily implying that used car markets do not accurately capitalize the value of future fuel savings in the price of a used car (although it is possible, if not likely, that they do not). Rather, it is one way of representing the apparent undervaluing of fuel economy by new car buyers relative to its discounted expected present value.

There is evidence that Actual vs. Rated MPG values differ for certain types of vehicles based on a statistical analysis of the www.fueleconomy.gov data Dr. Cameron cites (see Lin and Greene, 2011). For example, it appears from that analysis that conventional gasoline internal combustion engine (ICE) vehicles do better in actual use relative to their EPA adjusted fuel economy estimates than hybrids, and that diesels do a little better (about 2%) than conventional gasoline ICE vehicles. It can be argued that the www.fueleconomy.gov data may be biased because they are a self-selected sample, although there are also reasons to believe that the data are representative. However, there is also evidence that different designs of hybrid vehicles perform differently, so it is not clear where future designs will wind up. This is a potentially important issue that needs more analysis before definitive adjustments can be made. As a result, we are using one value rather than differentiating for different vehicle types in the current version of the model.

The explanation of the derivation of the price elasticities in MNL models has been expanded, as requested.

With respect to the observation that "…the underlying β parameter…is the same across all levels and branches of the model's correlation structure diagram.", although this is one possible interpretation, it is also correct to say that every nest has its own generalized cost coefficient because the generalized cost coefficient within a nest is the inverse of the variance of the alternative-specific error terms in that nest. This is a matter of interpretation rather than a substantive difference. The generalized cost coefficients differ from nest to nest; it is a matter of to what one attributes the variation.

McManus points out that new vehicle buyers tend to have short shopping lists. That is, they do not "consider" all vehicles but only a few. This may be taken as a general criticism of the Random Utility Model (RUM) framework, which assumes all vehicles are in the consumer's choice set and that consumers trade off all vehicle attributes simultaneously. Clearly, this theory is not a precise description of consumers' actual cognitive processes. The question is whether the RUM framework provides a reasonable approximation in aggregate. One could argue that all vehicles are in the choice set, only some have been eliminated at an early stage in the decision-making process (i.e., most consumers do not "consider" buying a Rolls Royce, but if they were available at $20,000 they might well buy one). Another way of interpreting this comment is as another observation on the heterogeneity of consumers. There is no doubt that consumers are heterogeneous in their preferences and perhaps in their decision making algorithms, as well. We do not dispute this but consider it a subject for future research.

3.6 Congruence Between Conceptual Methodologies and Program Execution

Two reviewers provide comment on whether the model functions as suggested in the documentation.

Bunch: "Although it may seem nitpicky, the NMNL model produced by ORNL quite literally does *not* satisfy the specification quoted above (nor should it have). Specifically, the ORNL model we were asked to review *by itself* is not capable of "estimating … effects of greenhouse gas (GHG) emissions standards." Rather, it *is* capable of estimating the effects (consumer surplus impacts and sales mix effects) of changes in two specific vehicle characteristics: sales price, and fuel economy. This is what the software we were given actually does. So, reviewing the ORNL model should presumably address technical aspects of how it does what it actually does."

Cameron: Believes that the software does what it appears to suggest in the documentation.

<u>EPA Response:</u> Dr. Bunch is correct that the vehicle choice model is only one part of our analysis of the effects of GHG emissions standards. EPA plans to use the vehicle choice model in conjunction with OMEGA, our model for estimating the cost and effectiveness of GHG regulations for light-duty vehicles. OMEGA has previously been peer-reviewed. Before further development of the vehicle choice model, and its further integration into OMEGA, we conducted this peer review to get feedback specifically on this component.

We thank Dr. Cameron for her comment.

3.7 Clarity, Completeness, and Accuracy of Model's Calculations

One reviewer indicates that a more detailed analysis including a check of source code and knowledge of accurate data would be required to definitively assess the accuracy of the models calculations, while another states that the model's calculations are "too accurate" and "overstate the precision" of possible forecasts.

Bunch: "Depending on what is meant by "accuracy," I would either need to do a detailed analysis that includes checking the source code of the model (plus program my own version), or, I would need to have some specialized knowledge of what the "true" market shares and elasticities are. Either would not be workable. Having said this, I do recommend that additional test calculations be performed for validation purposes. . . . there is a relationship between price elasticities and NMNL structural parameters (aka "price slopes"), and that the mapping is not one-to-one. The method used by the authors is described on page 29. Although there may be better methods, this one seems sufficient in practice. The other question is how to choose the elasticities. They do this based on values found in the literature, also recognizing that the NMNL requires the type of ordering found in equation (38). They provide a discussion (page 31) to support their selections, which seem reasonable. Having said this, one thing that is missing is an analysis of the distribution of price elasticities produced from actual runs of the Model itself. This would seem to be a useful validation exercise."

Cameron: The model's calculations are too "accurate" and "overstate the precision with which such forecasts can possibly be made." It is important both to incorporate uncertainty and to acknowledge that "the user has to pick and choose between competing options for the point estimates of the elasticities for each level of the nests. Given the gaps in the empirical data, especially the differing vintages and contexts of the studies in which these sparse values have been quantified, the user just has to guess something reasonable for many of the settings, or use some kind of weighted average of the point estimates across different studies. If those studies were competently done, each estimate will come with confidence bounds and that uncertainty about these key ingredients to this program needs to be acknowledged somehow."

EPA Response: Dr. Bunch is correct to point out that, in principle, this issue seems to require a detailed checking of the model's code which it was not feasible for him to do. His recommended additional tests, including producing a distribution of price elasticities, have merit; additional tests are now reported in the model documentation.

Dr. Cameron reiterates her concern about spurious accuracy and adds that there is a need to describe the uncertainty of the model's predictions somehow. We think it is useful and responsive to this request to estimate the sensitivity of the model's fundamental predictions (fleet average fuel economy and the change in consumers' surplus) to: 1) assumed generalized cost coefficients and 2) how consumers value fuel economy. These analyses are now included the results in the model documentation. These results should not be used to describe the uncertainty in the model's predictions, since to do that would require knowing the probabilities of the different assumptions about 1) and 2). Furthermore, our results are specific to the OMEGA output used for this analysis. However, the results are indicative of the general sensitivities of the model's predictions to changes in the key model coefficients. In any future uses of the model, as noted above, EPA will refrain from reporting excessive significant digits and will seek to provide appropriate caveats for any results.

3.8 Accuracy of Model's Results and Appropriateness of Conclusions

One reviewer indicates that a more detailed analysis including a check of source code and knowledge of accurate data would be required to definitively assess the accuracy of the model's results. Another reviewer expresses concern about over stating the level of precision attainable.

Bunch: "Depending on what is meant by "accuracy," I would either need to do a detailed analysis that includes checking the source code of the model (plus program my own version), or, I would need to have some specialized knowledge of what the “true” market shares and elasticities are. Either would not be workable. Having said this, I do recommend that additional test calculations be performed for validation purposes. . . . there is a relationship between price elasticities and NMNL structural parameters (aka “price slopes”), and that the mapping is not one-to-one. The method used by the authors is described on page 29. Although there may be better methods, this one seems sufficient in practice. The other question is how to choose the elasticities. They do this based on values found in the literature, also recognizing that the NMNL requires the type of ordering found in equation (38). They provide a discussion (page 31) to support their selections, which seem reasonable. Having said this, one thing that is missing is an analysis of the distribution of price elasticities produced from actual runs of the Model itself. This would seem to be a useful validation exercise.”

Cameron: “The model results leave the impression that these redistributions of consumer demand can be calculated, in many cases, to five or more significant figures, with certainty. Conditional on the “point” inputs and current market shares, precise estimates of the alternative-specific constants can be calculated for each Mfr/NamePlate/Model. However, this overstates the precision with which these constants are known because the point values that are inputs to the process are actually random variables which are not known with as much precision as is implied by the program. This sets aside any noise introduced by the various simplifications in the functional form of the model.”

McManus: “Large changes in fuel prices over a short period of time have caused significant movement by consumers between vehicle classes. Most recently, the fuel price spike in 2008 caused many buyers to trade in trucks and SUVs for cars. The danger is that we might be applying lessons from changes in behavior involving mix switching to the value of fuel economy at the level of a vehicle.”

EPA Response: Dr. Bunch’s comments, about the infeasibility of assessing accuracy and the method of estimating price slopes (generalized cost coefficients), are addressed above.

Dr. Cameron’s comments reiterate her concerns about false precision, also addressed above. We consider this a useful area for future consideration.

Dr. McManus’s concern of whether the effects of price changes and fuel economy changes have a symmetrical effect on vehicle choices was addressed above, in Section 3.3.

3.9 Caveats About Using Model for Regulatory Analysis

Reviewers provide a range of opinion concerning use of the model for regulatory analysis.

Bunch: “The suitability of the model for regulatory analysis hinges on how it is used in conjunction with the OMEGA model. . . . The charge we were given also asks us to provide an opinion on the *suitability of the model for analyzing the effects of regulatory programs* on consumer vehicle choices.” It is clear that the larger purpose associated with this model is to allow EPA to perform policy analysis related to CAFÉ/GHG regulations. However, this can only be done in conjunction with the OMEGA model. Unfortunately, the materials provided to us were insufficient in describing the relationship between this model and the OMEGA model. . . . It would seem important for regulatory analysis to establish some type of reference (baseline) scenario over the planning *period* (not to be confused with the base year). EIA produces forecasts of new vehicle sales as well as fuel price forecasts. There must be some working assumption about CAFÉ/GHG standards associated with these forecasts. What does EPA regard to be the reference assumptions for future CAFÉ/GHG standards? “

"The introductory material (in both the Charge and the Documentation) talks about OMEGA having "a 15 year planning horizon," and indicates that the CVCM "will be calibrated to baseline sales projection data provided by the EPA." This implies that policy analysis would involve establishing a 15-year baseline (reference) scenario under a reference policy, and then running OMEGA under alternative (15-year) policies. It is also the case that analyses of this type typically have a base year (not to be confused with a baseline). How this was handled was not specified."

Cameron: "There should be heavy caveats that the error bounds on the calculated values are not presently being calculated. Thus it is not possible to know whether any *apparent* differences in the point estimates in the baseline versus the alternative scenarios are actually substantive (statistically significantly different from zero)."

McManus: The model's authors have covered the salient caveats for regulatory analysis.

EPA Response: Dr. Bunch again notes that the appropriateness of the CVCM for use in regulatory analysis is interdependent with the appropriateness of OMEGA and potentially of their interactions. As discussed previously, EPA believes that it is valuable to receive comments on the CVCM in its own rights, before further development of the model or its relationship with OMEGA. Our goal is to have a vehicle choice model that will provide reasonably robust estimates of the impacts of price and fuel economy changes on the average fuel economy of the new vehicle fleet. This model is expected to be successful in that goal because fleet average fuel economy is relatively insensitive to the price and fuel economy changes, and because the model produces reasonable estimates of these changes. The same cannot be said for changes in consumers' surplus because that is strongly affected by how consumers are assumed to value future fuel savings. Because of this, the model's estimations of changes in total vehicle sales are also strongly influenced by how consumers are assumed to value fuel economy.

Dr. Bunch raises the question of what the baseline projection of vehicle sales and fuel economy should be. This is an important question which EPA will address and document in working with the model.

Dr. Cameron requests that the model's predictions come with "heavy caveats" because error bounds have not been calculated. As noted above, we expect that the estimates of impacts on fleet average MPG are relatively robust. On the other hand, the estimates of consumers' surplus changes, dependent on assumptions about how consumers value fuel economy, are likely to be less robust because of the uncertainty around that parameter at the present time. EPA respects this concern and will seek to provide appropriate caveats about interpretation of the results in any uses of the model.

We thank Dr. McManus for his comments.

3.10 Recommendations and Specific Improvements

Reviewers note a variety of additions, corrections, and typographical errors that should be addressed in subsequent versions of the model and documentation.

Bunch: "There seems to be some murkiness around the changes in vehicle cost/price associated with the technology packages. In at least one place these are called "retail price equivalents" (RPE). In other places they are simply identified as "costs" or perhaps "long-run average costs." More generally, it seems that manufacturers would be able to change vehicle prices as well as well as fuel economy in order to meet standards. Of course, the current version of OMEGA could not really deal with that because it does not incorporate sales shifts. However, one potential improvement to the ORNL model would be to identify price changes that would put manufacturers back into compliance. (Actually, the authors mention this on page 5.)

EPA Response: The manuscript has been edited to insure consistency in the use of terminology about vehicle costs and prices. The model operates with the assumption that automakers are not changing prices strategically. Adding in the alternative assumption requires making assumptions about the form of oligopolistic behavior in the auto sector, as well as much more complex modeling. EPA has chosen for now to continue with its assumptions of full-cost pass-through for technology costs.

Bunch: The reference to Train 5 is incorrect. It should be 1986. (The third printing was in 1991, but that is not the same thing.)

EPA Response: The edition used said the third printing was 1993. That volume is cited in case there were some edits between printings.

Bunch: In the middle of page 5, it is claimed that the nesting structure in CVCM is similar to those used in empirically estimated models. I don't think this is strictly true, but would welcome a reference. (NERA does a type of estimation, but assumes values for the structural parameters as is done here.)

EPA Response: The text now says the nesting structure is similar to other constructed models and specifically cites the California feebates study and the NERA model.

Bunch: On page 10 there are problems with equation (6), depending on the interpretation of the *U* values. The *U* values in equation (5) are random utilities, which are unknown and cannot be used in equation (6).

EPA Response: A problem in the notation here was corrected by removing the k subscript from the error term and letting V be the component of U that does not include the error term.

Bunch: On page 11 it is claimed that the NMNL model is "also known as the Generalized Extreme Value (GEV) model." This is incorrect. NMNL is a special case of the GEV.

EPA Response: Agreed. This has been changed.

Bunch: On page 12, middle of page, it says "In equation (6) each nest has a different set of coefficients that map vehicle attributes into the utility index. In particular for this model, the price coefficients differ across nests." This is generally not true for the form of the model they are attempting to use on this page, and represents the type of confusion that can arise based on the discussion in section 2.2.2 of my review."

EPA Response: The terminology "price slope" has been changed to "generalized cost coefficient," to clarify this issue.

Cameron: "Among the global parameters, the user appears to be invited to provide individual independent estimates of the population and average household size from 2010 to 2030, although the note in line 6 suggests that these numbers come from the U.S. Census Bureau's projections of the U.S. population (not "polution") to 2050."

<u>EPA Response:</u> The data source of number of households has been changed to Annual Energy Outlook (AEO) 2011. EPA expects to use data from standard government projections rather than entering hypothetical values to create special scenarios.

Cameron: On the VehicleUse sheet, individual car and truck "Survial Rates, by age" should read "Survival".

<u>EPA Response:</u> Corrected.

Cameron: The most disaggregated alternatives are generally called "elemental" alternatives, as in the Appendix. On page 26, however, they are called "elementary" alternatives.
In the Appendix (Derivation of Nested Logit Model Equations…), include the additional assumption that the error terms ε_c and $\varepsilon_{j|c}$ are independent and hence uncorrelated (so that there is no covariance term in the variance of their sum).

<u>EPA Response:</u> We have edited the text to consistently use the term elemental. The word "independent" has been added to describe the two error components.

Cameron: The current version of the CVCM software is desperately in need of some more user-friendly instructions. When you first open the program, the Help button is inactive. (There is a "Contents" button and an "About…" button, but these have not yet been populated/activated.) Clicking on the File button offers two options: "Open" and "Output file to…" as well as an "Exit" option. Those are the only clues the user gets.
Fortunately, the "Open" button takes you to the input folder inside the CVCM_v1.5 folder where the program resides, and it is logical to try the one called "Baseline" first. This action fills the two small boxes in the program's window with just some of the information from the input file.
i.) It is irritating that you cannot drag the corner of the window to expand its size. With a whole widescreen monitor to work with, and with content that must currently have its headings truncated to fit, a re-sizeable window would be great. Right now, if you expand one column, all the others must shrink. A slider at the bottom of each window would be helpful, as in Excel, so that you can keep each column heading fully expanded and scroll to see those which are out of the current window.
j.) There is nothing in the user interface to suggest that there is vastly more information in the Excel spreadsheet in the Input folder than what seems to populate the limited number of boxes in the program window when you choose an Input file.
k.) Even inside the Input file, it took me a while to notice that there were multiple sheets in this spreadsheet. 1130 vehicles in the Vehicle sheet, 18 car companies in the Manufacturer sheet
l.) There is nothing to imply that the automobile icon in the upper right corner is the "execute" button. It just looked like a cute little graphic.

<u>EPA Response:</u> EPA agrees that the model in its current form is not as user-friendly as would be optimal. At this point, our emphasis was on getting a functional model more than it was on making it easy to use. Some revisions have been adopted, and the documentation should make clearer some of the input sheet and model operation features. We will consider this list and other features to make this model more friendly for future model revisions.

McManus: On page 4, sources of prediction errors should add “unexpected behavior by consumers over time.”

EPA Response: Since preferences and behavior are not the same, and behavior is more inclusive, we have modified the wording to read, “changes in consumers’ behavior over time”.

References

1. Greene, D.L., 2011. “Uncertainty, Loss Aversion and Markets for Energy Efficiency,” *Energy Economics*, vol. 33, pp. 608-616.
2. Greene, D.L., 2009. “Feebates, Footprints and Highway Safety,” *Transportation Research Part D*, vol. 14, pp. 375-384.
3. Greene, D.L., P.D. Patterson, M. Singh and J. Li, 2005. “Feebates, Rebates and Gas-Guzzler Taxes: A Study of Incentives for Increased Fuel Economy,” *Energy Policy*, vol. 33, no. 6, pp. 721-827.
4. Greene, D.L. 2010. *How Consumers Value Fuel Economy: A Literature Review*, EPA-420-R-10-008, U.S. Environmental Protection Agency, March.
5. Helfand, G. and A. Wolverton, 2011. "Evaluating the Consumer Response to Fuel Economy: A Review of the Literature", *International Review of Environmental and Resource Economics*: Vol. 5:No 2, pp 103-146. http:/dx.doi.org/10.1561/101.00000040
6. Bunch, D.S. and D.L. Greene, 2011. “Potential Design, Implementation, and Benefits of a Feebate Program for New Passenger Vehicles in California,” State of California Air Resources Board and the California Environmental Protection Agency, Sacramento, California, 2011, available at

   http://76.12.4.249/artman2/uploads/1/Feebate_Program_for_New_Passenger_Vehicles_in_California.pdf.
7. Z. Lin and D.L. Greene, 2011. *Predicting Individual On-road Fuel Economy Using Simple Consumer and Vehicle Attributes*, SAE Technical Paper Series No. 11SDP-0014, Society of Automotive Engineers, Warrendale, PA.
8. NERA Economic Consulting, Sierra Research, Inc. and Air Improvement Resource, Inc., 2007. “Effectiveness of the California Light Duty Vehicle Regulations As Compared to Federal Regulations, report prepared for the Alliance of Automobile Manufacturers, June 15, 2007.
9. U.S. Environmental Protection Agency, Peer Review for the Consumer Vehicle Choice Model and Documentation, Nov., 2011.