Transport Policy 53 (2017) 146–160

Contents lists available at ScienceDirect

Transport Policy

journal homepage: www.elsevier.com/locate/tranpol

What is the evidence concerning the gap between on-road and Environmental Protection Agency fuel economy ratings?

David L. Greene[a], Asad J. Khattak[a,*], Jun Liu[b], Xin Wang[c], Janet L. Hopson[d], Richard Goeltz[e]

[a] Department of Civil and Environmental Engineering, University of Tennessee, Knoxville, TN 37996, United States
[b] Center for Transportation Research, The University of Texas at Austin, United States
[c] Virginia Department of Transportation, Transportation & Mobility Planning Division, United States
[d] Department of Earth and Planetary Sciences, University of Tennessee, Knoxville, TN 37996, United States
[e] Center for Transportation Analysis, Oak Ridge National Laboratory, United States

ARTICLE INFO

Keywords:
Test cycle
On-road
Fuel economy
Gap
My MPG

ABSTRACT

U.S. government fuel economy tests are used for two primary purposes: 1) to monitor automobile manufacturers' compliance with fuel economy and greenhouse gas emissions standards and 2) to inform consumers about the fuel economy of passenger cars and light trucks. This study analyzes a unique database of 75,000 fuel economy estimates self-reported by customers of the U.S. government website www.fueleconomy.gov to evaluate the effectiveness of the government's estimates for these two purposes. The analysis shows great variability in individuals' own fuel economy estimates relative to the official government estimates with a small bias relative to the sample average. For consumers, the primary limitation of government fuel economy estimates is imprecision for a given individual rather than bias relative to the average individual. The analysis also examines correlations between individuals' fuel economy estimates and specific technologies, vehicle class, driving style, method used to calculate fuel economy, manufacturer, and state. Gasoline, hybrid and diesel vehicles were separately evaluated. There is some evidence that the shortfall between test cycle fuel economy estimates (used to measure compliance with regulations) and in-use fuel economy estimates (such as those provided by customers of www.fueleconomy.gov) has been increasing since 2005. If this trend continues, it could affect the benefits realized by fuel economy and greenhouse gas emissions standards. A scientifically designed survey of in-use fuel economy is needed to insure that an unbiased sample is collected and that fuel economy is rigorously and consistently measured for all vehicles. The potential for information technology to enable more precise prediction of individual fuel economy should be explored.

1. Introduction

The window sticker of every new passenger car or light truck sold in the U.S. bears a label with a prominently displayed government fuel economy rating. The intent is to provide consumers with consistent and reliable information they can use when comparing vehicles. Each label also contains the following caveat: "Actual results will vary for many reasons, including driving conditions and how you drive and maintain your vehicle". Differences between consumers' experiences with fuel economy and label values have been a source of discussion and dissatisfaction with the official government ratings since shortly after they were first introduced in 1975 (McNutt et al., 1978).

The U.S. Environmental Protection Agency (EPA) provides two sets of fuel economy estimates ("test cycle" and "label") for every make, model, engine and transmission configuration of passenger car and light truck sold in the U.S. In fact, most vehicle testing is done by the vehicle manufacturers, who certify to the EPA that the tests have been done in accordance with government procedures. The EPA tests 15–20% of vehicles each year to verify compliance (EPA, 2014). These estimates are important for two main reasons: (1) to enforce the Corporate Average Fuel Economy (CAFE) and greenhouse gas (GHG) emissions regulations for light-duty vehicles (EPA, 2012) the government needs test cycle estimates that are proportional to real world experience and (2) consumers need precise and unbiased fuel economy estimates to make informed choices when buying vehicles.

In statistics, the terms accurate, precise and unbiased have specific, mathematical definitions. Accuracy measures the closeness of agreement between repeated measures of a given quantity and its true value.

* Corresponding author.
E-mail addresses: dlgreene@utk.edu (D.L. Greene), akhattak@utk.edu (A.J. Khattak), jun.liu@utexas.edu (J. Liu), xin.wang@vdot.virginia.gov (X. Wang), jhopson@utk.edu (J.L. Hopson), goeltzrt@ornl.gov (R. Goeltz).

http://dx.doi.org/10.1016/j.tranpol.2016.10.002
Received 2 March 2016; Received in revised form 15 August 2016; Accepted 12 October 2016
Available online 01 November 2016
0967-070X/

Precision measures the closeness of agreement between repeated measures of a given quantity and the mean of those measures. Bias measures the difference between the mean of a series of measurements or predictions and the true value of a quantity or the true mean of a population. The situation is somewhat different for government fuel economy estimates. A single number (e.g., a car's fuel economy label number) is proposed as a reasonable estimate of the actual fuel economies of all motorists using the same vehicle. In this case, there is no "true value" but rather a distribution of values for individual drivers. Assuming that the government fuel economy estimate is intended to correspond to the average fuel economy of all drivers of a given vehicle, bias can be defined as the difference between the official estimate and the mean of the population. Because there are not repeated measurements for an actual or even hypothetical true value of fuel economy, how to define accuracy and precision is less clear. In this paper we will quantitatively describe the deviations of individual motorists' estimates from their vehicle's fuel economy rating as *variance*. At the same time, we recognize that from an individual motorist's perspective, the official rating may be perceived as both biased and inaccurate.

The government is well aware of the issue of the variance of individual fuel economy results. Every fuel economy label contains the following caveat: "Actual results will vary for many reasons, including driving conditions and how you drive and maintain your vehicle".

It is quite possible for fuel economy ratings to be unbiased (reasonably predict the average fuel economy of all motorists) but poor predictors of the experiences of individuals. For the purposes of testing compliance with fuel economy standards, unbiased fuel economy estimates would be sufficient. If the expected fuel economy improvements are realized on average, the expected benefits in petroleum and greenhouse gas (GHG) reductions will be achieved. In fact, all that is necessary for the expected benefits to be realized is that a given percent increase in miles per gallon (MPG) on the test cycle produce the same percentage increase in on-road fuel economy. On the other hand, for the fuel economy label estimates to be of greatest value to consumers' car purchase decisions, they should precisely predict the fuel economy an individual will experience on the road. This is clearly not achievable with a single-number rating for each vehicle. However, modern information technology might possibly enable relatively accurate prediction of individuals' fuel economy.

The test cycle fuel economy estimates used to determine manufacturers' compliance with regulations are based on laboratory testing of vehicles over two (city and highway) driving cycles as required by statute. These drive cycles have been in use since the Corporate Average Fuel Economy (CAFE) standards were enacted in 1975. The label fuel economy estimates provided on the window stickers of new vehicles and used in advertising and the media are based on five drive cycles, adjusted in an attempt to reflect average U.S. on-road experience. The five cycles include the "city" and "highway" cycles used to determine compliance with fuel economy and greenhouse gas emission standards plus additional cycles that reflect, (1) more aggressive driving behavior, (2) the impact of operating under colder ambient conditions and, (3) the impact of air conditioner use.

This study addresses how well the EPA estimates serve their intended purposes though a statistical analysis of approximately 75,000 individual fuel economy estimates voluntarily submitted to the "My MPG" section of the government website www.fueleconomy.gov (Greene et al., 2015). The relationship between individuals' own fuel economy estimates (My MPG) and the EPA label estimates is analyzed to determine whether the adjusted EPA estimates are unbiased and to measure the variability of consumers' experiences relative to the label numbers. The relationship between individuals' My MPG estimates and EPA test cycle estimates is examined to shed light on whether the ratio of test cycle to on-road MPG has been changing with succeeding model years. A continually increasing gap would imply that the government's fuel economy standards might not achieve as much reduction in oil use and GHG emissions as intended. The need to monitor on-road fuel economy was recognized by the Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA) in their fuel economy and greenhouse gas rule for light-duty vehicles. The agencies recognize the potential for future changes in driver behavior or vehicle technology to change the on-road gap to be either larger or smaller. The agencies assumed that a gap of 20%, which is consistent with fuel economy labeling, would continue through 2025, with minor adjustments for fuel energy content (EPA, 2012).

The impacts of fuel efficient technologies such as turbo-charging and transmissions with higher gear counts are estimated to see if they perform better or worse on the road in comparison to the test cycles. The analysis also attempts to take into account driving conditions that vary from state to state and other factors that might influence on-road fuel economy (Wang et al., 2015; Liu et al., 2016a).

Although both www.fueleconomy.gov and the new fuel economy labels present ratings in gallons per hundred miles as well as MPG, they both emphasize the MPG numbers because U.S. consumers still overwhelmingly compare vehicles in terms of MPG. However, when assessing the potential gap between certification test cycle fuel economy and real world fuel economy we conduct the analysis in terms of the logarithm of MPG. Estimating coefficients for log-transformed MPG is equivalent to estimating coefficients for log-transformed gallons per mile except that the coefficients' signs are reversed.

The scope of this study is limited to light-duty vehicles with conventional gasoline (gasoline), gasoline-electric hybrid (hybrid), and diesel powertrains due to the nature of the data available from www.fueleconomy.gov. The analyses are carried out separately for conventional gasoline, diesel and hybrid vehicles.

The MyMPG data is a self-selected sample. In that sense it best reflects what individuals believe their fuel economy is. Nevertheless, all but one published study in this area is based either on a self-selected or a convenience sample. We present evidence below that self-selection bias may not be a serious problem. However, the only way to definitively answer the questions posed in this study is to carry out an on-going, scientifically designed survey of in-use fuel economy. Until that time, the choice is between imperfect information and no information.

2. Previous research

When the EPA fuel economy estimates were first introduced in 1975, they were not adjusted in any way for real-world driving conditions. Concern about the ability of the test cycle estimates to measure on-road fuel economy motivated assessments by government, industry and consumer groups. In the first year the CAFE Standards took effect (1978), researchers at the U.S. Department of Energy (DOE) published an analysis of over 5000 fuel economy records for model year 1974–1977 vehicles, obtained from a variety of sources. The average shortfall had increased from 4% in model year 1974 to about 20% for model year 1977 (McNutt et al., 1978).

Studies by General Motors (Schneider et al., 1982) and Ford (McKenna and South, 1982) found shortfalls ranging from 14% to 20% across model years of 1978–1981. The GM survey also found that front-wheel drive vehicles averaged a 6.4% smaller shortfall than rear-wheel drive vehicles, diesels had a 6.5% smaller shortfall than gasoline vehicles, and manual transmissions had 7.2% higher on-road fuel economy than automatic transmissions (Schneider et al., 1982). The Ford study found that the shortfall for winter driving was 10% greater than for summer driving (McKenna and South, 1982). Analyzing a much larger data base of 56,395 vehicles amassed from a variety of sources, McNutt et al. (1982) found large variations in the fuel economy shortfall by model year but no consistent trend over time. Their data showed a strong tendency for the percent shortfall to