Fuel Economy and Safety:
A Reexamination under the U.S. Footprint-Based Fuel Economy Standards

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Introduction

Since 1975, the fuel economy targets were specified for new passenger cars and light trucks sold in the United States by the corporate average fuel economy (CAFE) standards. However, calls to increase fuel economy by the CAFE have been under fierce debate for several decades because one of the most direct ways available for firms to improve fuel efficiency is to reduce vehicle weight, and the opponents of increasing fuel economy standards observe that heavier vehicles provide a greater protection to their occupants in a crash than do lighter vehicles.

Responding to the criticisms that old CAFE standards forced people into lighter, smaller, and less safe vehicles, starting in 2011, the CAFE standards were amended and are newly expressed as mathematical functions depending on vehicle “footprint”. As a result, smaller vehicles have higher fuel economy targets and larger vehicles have lower targets.

According to this new CAFE, it is possible that a firm would modify its footprint choice and the changes in footprint choice could then have implications for both fuel economy goals and traffic safety. For example, the new CAFE could potentially create an incentive for firms to make ever-larger vehicles to avoid strict standards and hence diminish the policy’s goal of reduced fuel consumption. As for traffic safety, the changes in vehicle footprint could be an important factor that goes into insuring vehicle occupant safety on the road.

Together, this study considers vehicle footprint as one important link between fuel economy and automobile safety. Unlike most current literature that lumps size and weight together and constrains vehicle weight to be the sole link between fuel economy and automobile safety, this study separately deals with size and weight. Footprint and curb weight are used as the measures of vehicle size and vehicle weight, respectively. The different roles of footprint and curb weight in determining fuel economy and automobile safety, and how they link fuel
economy to automobile safety for those vehicles produced under the newly amended U.S. footprint-based CAFE standards are at the center of my concern in this paper.

Instead of using aggregated data or data on fatal crashes only, the database used in this paper is micro-level and covers crashes of all type, from minor to fatal, to dampen the effect of bias that occurred in sample selection. In addition, to my knowledge, this is the first empirical paper studying the new U.S. footprint-based CAFE and its implications for fuel economy goals and traffic safety.

Data

The primary basis for the vehicle accident dataset used in this paper is the General Estimates System (GES) data for the years 2010 to 2013, which is produced by the National Automotive Sampling System (NASS). The GES data come from a nationally representative sample of police-reported motor vehicle crashes of all types. GES records and classified injury severity by crash victim on an ordinal KABCO scale. This dataset also contains information on vehicle attributes, crash environments, and driver characteristics, which will be used to control for factors influencing risk and exposure in each vehicle crash. Since the population of interest is vehicles that were produced under the footprint-based CAFE standards that was introduced in 2011, the dataset was limited to single-vehicle crashes involving vehicles after the 2011 Model Year.

Using vehicle attribute information such as make, model, model year, and body type provided by the GES dataset, for each single-vehicle crash for which occupant injury severity was available, more detailed vehicle specifications were identified and recorded from www.thecarconnection.com. For accuracy, vehicle fuel economy data were directly obtained from www.fueleconomy.gov, the official U.S. government source for fuel economy information.

Methodology and Model Specification

To study the possible trade-off between fuel economy and vehicle safety, the model specification in this paper, however, does not require the framework to come out with any pre-specified relationship between these two; in formulating the model, the framework consists of two submodels: a fuel economy submodel and a vehicle safety submodel.
The Fuel Economy Submodel is designed to estimate the trade-offs faced when choosing between fuel economy, footprint \((fp_{it})\), weight \((w_{it})\), and other related vehicle attributes \((X_{it})\). The Cobb-Douglas assumption is made and vehicle fuel economy is modeled as

\[
\ln \text{mpg}_{it} = \beta_1 \ln fp_{it} + \beta_2 \ln w_{it} + X'_{it}B + \nu_{it}.
\]

Year fixed dummies are also included to control for and to estimate the possible fuel-efficiency technological progress in automobile industry during the sample period.

The severity of occupant injury reflects a combination of factors influencing risk and exposure and a vehicle safety submodel is used to explore what factors could possibly affect occupant injury risk in single-vehicle crashes. An ordered logistic regression model recognizes the indexed nature of, and is estimated for the response variables, saying the KABCO injury scales:

\[
Y_{it} = \begin{cases} 
0 & \text{if } -\infty \leq Y^*_{it} \leq \mu_1 \text{ (No Injury)}, \\
1 & \text{if } \mu_1 < Y^*_{it} \leq \mu_2 \text{ (Possible Injury)}, \\
2 & \text{if } \mu_2 < Y^*_{it} \leq \mu_3 \text{ (Nonincapacitating Evident Injury)}, \\
3 & \text{if } \mu_3 < Y^*_{it} \leq \mu_4 \text{ (Incapacitating Injury)}, \\
4 & \text{if } \mu_4 < Y^*_{it} \leq \infty \text{ (Fatal Injury)}. 
\end{cases}
\]

Underlying the indexing in such a model is a latent but continuous injury variable, \(Y^*_{it}\), and the following specifications were used here:

\[
Y^*_{it} = \alpha_1 fp_{it} + \alpha_2 w_{it} + \alpha'_V V_{it} + \alpha'_C C_{it} + \alpha'_D D_{it} + T_t + \epsilon_{it}
\]

where \(V_{it}\), \(C_{it}\), and \(D_{it}\) are three vectors of controlling variables describing vehicle attributes, crash environments, and driver characteristics for vehicle \(i\) in a crash occurred at year \(t\).

**Empirical Results**

Using micro-level data on vehicle attributes and on single-vehicle crashes as discussed above, this study shed some light on the relationship that exists between vehicle fuel economy and single-vehicle crash occupant injury severities under the newly amended footprint-based CAFE.

The empirical results suggest that, for passenger cars, increases in footprint do not adversely affect fuel economy but decrease the likelihood of more severe occupant injuries in single-vehicle crashes; while the weight variable has a negative impact on fuel economy but no significant effect in occupant protection. Specifically, a 10% increase in footprint is associated
with a 1.71% increase, rather than a decrease, in fuel economy or, equivalently, as footprint increases by 100 ft², the average fuel economy for passenger cars increases by 0.06 MPG; for this 100 ft² increase in footprint, the odds of fatal injury versus the combined incapacitating injury, non-incapacitating evident injury, possible injury, and no injury categories are 0.955 time lower. Meanwhile, a 10% increase in curb weight is associated with a 5.27% decrease in fuel economy, translating that a car that is 100-pound heavier is 0.39 MPG less fuel efficient than is its lighter counterpart; however this sacrifice in fuel efficiency does not have any statistically significant positive effect on its occupant protection, which is consistent with findings from recent U.S. and internationals studies on modern cars. Together, one can expect that increasing footprint, while using lighter materials in automobile manufacturing to reduce weight, makes it possible for society to increase both fuel economy and vehicle safety for passenger cars.

The fuel economy trade-off estimates for light trucks suggest that only weight but not footprint has an adverse effect on fuel economy. In addition, the ordered logistic regression results show that footprint does not have any significantly positive effect on vehicle safety, while curb weight help light trucks to protect their own occupants. Specifically, a light truck that is about 100 pounds heavier is only 0.23 MPG less fuel efficient when compared with its lighter counterpart; however for this 100-pound increase in curb weight, the odds of fatal injury versus the combined incapacitating injury, non-incapacitating evident injury, possible injury, and no injury categories are 0.87 time lower. That is to say, vehicle weight, instead of footprint, is the key variable that links fuel economy and safety for light trucks. Together, these empirical results also suggests that active and passive measures developed in recent years seem have largely improved light trucks’ safety performance without adding much to their curb weight.

In addition, the fuel-efficiency technology estimates in the Fuel Economy Submodel show that fuel economy has been constantly improving for passenger cars and light trucks during the sample period. And these technological progresses make it possible for automobile manufacturers to improve fuel economy without decreasing much to footprint or weight. To summarize, it seems that the much talked trade-off between safety and CAFE standards is not inexorable for modern passenger cars or light trucks.