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Market-driven automotive industry compliance with fuel economy and greenhouse gas standards: Analysis based on consumer choice[☆]

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ABSTRACT

This study explored factors that affect market-driven compliance with both Corporate Average Fuel Economy (CAFE) and greenhouse gas (GHG) standards (together called the National Program) in the United States for phase I 2012–2016 and phase II 2017–2025. We considered a consumer-choice-based simulation approach, using the MA3T model, to estimate the market acceptance of fuel efficiency (FE) technologies and alternative fuel technologies as reflected by new sales of light-duty vehicle (LDV). Because both full and extremely low FE valuations are common in the literature, we use a moderate assumption of a 10-year perceived vehicle lifetime at a 7% annual discount rate in the baseline and include both extreme views (5 years and 15 years) in the sensitivity analysis. The study focuses on market-driven compliance and therefore excludes manufacturers' cross-subsidization. The model results suggest that the LDV industry is able to comply with both standards even without cross-subsidization and with projected high technology cost, mainly thanks to the multiple credit programs and technology advancements. The compliance robustness, while encouraging, however is based on moderate market assumptions, such as Annual Energy Outlook 2016 Reference oil price projection and moderate FE consumer valuation. Sensitivity analysis results reveal two significant risk factors for compliance: low oil prices and consumers' FE undervaluation.

1. Introduction

With the increasing global concern over energy security and climate change, 10 nations and regions that represent 83% of the global automotive market have already adopted regulatory fuel economy/ greenhouse gas emissions (GHG) standards on light-duty vehicles (LDV) (GFEI, 2016). Understanding whether or not these standards will be successful is of great importance to projecting the sustainability of the global transportation energy sector. Among the 10 nations and regions, the United States was the world's largest transportation energy consumer in 2012 (EIA, 2016c), and its LDV fleet consumed 58% of U.S. transportation total energy use and emitted 60% of greenhouse gas (GHG) emissions in the transportation sector in 2013 (Davis et al., 2015). This study takes the U.S. LDV sector as a case study to evaluate compliance with U.S.-based fuel economy/GHG standards. Conclusions made in this study may not be applicable to other global fuel economy standards, which differ with respect to regulations, complementary policies, consumer segments, etc. However, the compliance analysis and its policy implications may provide insights that the international audience can use to analyze the standards in other nations and regions.

There are two highly correlated national standards for LDVs in the United States – one on fuel economy and the other on GHGs. These two standards together are termed the "National Program," designed, implemented, and overseen by the National Highway Traffic Safety Administration (NHTSA), on behalf of the Department of Transportation, and the Environmental Protection Agency (EPA) (EPA and NHTSA, 2012a). Within the National Program, NHTSA sets the National Corporate Average Fuel Economy (CAFE) standards to improve the fuel economy of LDVs, while EPA sets the GHG standards to reduce LDV GHG emissions. Both standards are harmonized to concurrently improve energy security and environmental quality. The National Program is divided into two phases; Phase I was in effect from 2012 to 2016, and Phase

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II is slated for 2017–2025. According to EPA (2016), the success of the National Program is projected to help the entire nation by (1) cutting 6 billion metric tons of GHG over the lifetimes (i.e., service life) of vehicles sold in 2012–2025, (2) saving consumers' fuel costs by $1.7 billion, and (3) reducing America's dependence on oil by 2 million barrels per day by 2025. In addition to these direct benefits, the harmonized National Program may also help to revive the domestic auto industry by encouraging original equipment manufacturers (OEMs) to produce fuel efficient vehicles, which are popular and competitive in Asia and Europe (The White House, 2012). Also, the standards are believed to contribute to a rapid transition to a greener automotive economy that will create new jobs in the United States (Carley et al., 2016).

With these remarkable potential impacts, the National Program has attracted great attention to conducting scientific analysis on possible impacts of the standards. Research efforts can be classified into three major categories: (1) economic impacts in terms of new vehicle sales (Center for Automotive Research, 2011; DOT, 2012; EPA, 2012; Wagner et al., 2012), (2) energy and environmental impacts (Karplus and Paltsev, 2012; NHTSA, 2012a), and (3) social impacts on employment (Baum and Luria, 2010; Busch et al., 2012). Interested readers can refer to the work of Carley et al. (2016) for a detailed literature review.

In addition to the impact analysis of the standards, the compliance analysis is another important and complex research topic that is relevant to the success of the National Program. The key questions are whether and under what conditions the automotive industry will meet the standards. There are two major approaches in evaluating compliance: (1) the optimization approach, by minimizing a system cost function or maximizing a profit function with real-world rules as constraints [examples are EPA's OMEGA model (EPA et al., 2010) and Liu and David (2014)'s Feebate model]; and (2) the simulation approach, where operations and behaviors are simulated on the basis of preset boundaries and rules for approximating the real-world conditions [an example is NHTSA's VOLPE model (DOT, 2012; National Research Council, 2015)]. Most of these compliance analyses focus on technology feasibility and cost-effectiveness, but clearly, compliance depends not only on OEMs' technological ability to design, produce, and price efficient vehicles, but also on consumer acceptance: whether or not consumers prefer fuel efficient vehicles with higher technology cost or less fuel efficient vehicles with lower technology cost (Carley et al., 2016). This study is a simulation-based compliance analysis with endogenous and explicit consumer choices. Specifically, we consider consumer heterogeneity (e.g., different driver types), technology competition (e.g., different fuel economies and alternative fuel vehicles), and policy mechanisms (e.g., credit banking), through an integrated market dynamics model called MA3T. We set up scenarios to analyze various factors that affect the compliance, aiming at answering three research questions: How likely will the industry comply with the CAFE and GHG standards when endogenous consumer acceptance is explicitly considered? What is the role or contribution of alternative fuel vehicles (AFVs), especially plug-in electric vehicles (PEVs), for industry compliance? And, how sensitive or robust will industry compliance be in response to uncertainty in fuel economy undervaluation, efficiency technology cost, and oil price? This study attempts to aid better understanding and prediction of potential compliance with the National Program and inform discussions of potential industry and government actions. Note that, the study focuses on market-driven compliance and therefore excludes manufacturers' cross-subsidization behavior for sake of simplicity.

In the rest of this paper, we will explain the methodologies and assumptions, show and discuss the compliance results under various scenarios, and draw some conclusions.

2. Methodology

This section explains key aspects of the modeling approach and assumptions.

2.1. Why consider consumer choices?

Consumer choice is relevant because both the CAFE and GHG standards utilize sales-weighted-average methods. Based on the National Program (EPA and NHTSA, 2012a), each new vehicle of a given model year is associated with a fuel economy target (in miles per gallon of gasoline equivalent, MPGGE) and a GHG target (in gCO_2/mile). Both targets are uniquely determined by the vehicle's footprint, model year, and class (passenger car or light truck). In general, the targets are more stringent with smaller footprint, over time, and for passenger cars. However, vehicle-level targets are not required, but only used to calculate the manufacturer's fleet-wide production-weighted average targets, with which the manufacturer shall comply. Thus, for each model year, a manufacturer needs to meet one fleet average target on fuel economy and one on GHG, with its actually achieved fleet-wide production-weighted average fuel economy and GHG emissions. Since "production" in the rule is clearly defined as "the number of units produced for sale in the United States" (EPA and NHTSA, 2012a, page 63,024), we assume all produced vehicles are sold in the United States and, for simplicity's sake, view the target and performance as sales-weighted. This leads to the need for consumer choice analysis of compliance, as the sales mix of different vehicle classes, efficiency technologies, and fuel types affect the fleet-wide average target and performance and ultimately the compliance outcome.

2.2. Simplification

The ideal model for compliance analysis should simulate consumer choices of technologies at the manufacturer level, but would then require explicit characterization of each manufacturer's current and future technological capabilities, advantages, and disadvantages as compared to competitors. This will involve confidential and controversial information and will be extremely difficult to accomplish. Fortunately, the rule allows trading of both fuel economy and GHG credits between manufacturers. This justifies, as adopted in this study, the simplification of analyzing compliance at the automotive industry level rather than the manufacturer level.

Another simplification we made is to capture the cross-subsidization behavior of manufacturers only at the vehicle class level. It is widely accepted that vehicle products differ in profitability. After calibrating the choice model (MA3T, to be explained later) with historical sales and price data and simulated production cost, we found that the price markup (the ratio of the manufacturer's suggested retail price to the production cost) is larger for light trucks than for passenger cars. With the varied markup factors, the industry's pricing behavior is only partially reflected. Since we do not model manufacturer-level compliance, we also ignore product-level pricing decisions. Technically, manufacturers could adjust prices of different vehicle products and even discontinue some less-efficient products to achieve compliance. This would in theory lead to loss of consumer or producer surplus. Sacrificing economic surplus for the policy compliance purpose is beyond the scope of this study, as we focus on analyzing market-driven compliance scenarios and identifying the risk factors. In other words, when an under-compliance scenario is presented in this study, readers should be reminded that, in reality, manufacturers can still achieve compliance with cross-subsidization decisions.