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A benefit-cost assessment of new vehicle technologies and fuel economy in the U.S. market ☆

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HIGHLIGHTS

- Engine, vehicle & hybrid technologies increase fleet fuel economy 10% from 2011 to 2014.
- Benefit-cost analyses show consumer incentives are lacking for higher fuel economy.
- Increases in miles driven or fuel price improve economic viability of technologies.
- Downsized turbocharged engines, new transmissions and hybrids most promising.
- High costs for fuel economy technologies may stall growth, delay compliance.

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ABSTRACT

Increasingly stringent fuel economy and emissions regulations alongside efforts to reduce oil dependence have accelerated the global deployment of advanced vehicle technologies. In recent years, original equipment manufacturers (OEMs) and consumers have generally been successful in mutually deploying cleaner vehicle options with little sacrifice in cost, performance or overall utility. Projections regarding the challenges and impacts associated with compliance with mid- and long-term targets in the U.S., however, incur much greater uncertainty. The share of existing new vehicles that is expected to comply with future regulations, for example, falls below 10% by 2020. This article explores advanced technologies that result in reduced fuel consumption and emissions that are commercially available in 2014 Model Year compact and midsize passenger cars. A review of the recent research literature and publicly available cost and technical specification data addressing correlations between incremental cost and fuel economy is presented. This analysis reveals that a 10% improvement in the sales-weighted average fuel economy of passenger cars has been achieved between 2011 and 2014 at costs that are at or below levels anticipated by the regulations by means of reductions in weight, friction, and drag; advancements in internal combustion efficiency; turbocharging combined with engine downsizing; transmission upgrades; and the growth of hybrids. Benefit-cost analyses performed on best-selling models in the selected classifications reveal that consumers thus far are not substantially incentivized to purchase fuel economy. Under baseline conditions, benefit-cost ratios are above a breakeven value of unity for only 6 of 28 models employing improved fuel-economy technologies. Sales-weighted data indicate that the "average" consumer that elected to invest in greater fuel economy spent $1490 to realize a 17.3% improvement in fuel economy, equating to estimated savings of $1070. Thus savings were, on average, insufficient to cover technology costs in the baseline scenario. However, a sensitivity analysis reveals that a majority of new technologies become financially attractive to consumers when average fuel prices exceed $5.60/gallon, or when annual miles traveled exceed 16,400. The article concludes with techno-economic implications of the research on future fuel economy regulations for stakeholders. In general, the additional cost consumers incur in exchange for a given level of fuel economy improvement in the coming years will need to be steadily reduced compared to current levels to ensure that the expected benefits of fuel savings are financially warranted.

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1. Introduction

A combination of evolutionary and transformational technologies have substantially increased fuel economy levels for light duty vehicles in the U.S., representing a tremendous achievement for consumers, automakers and policymakers alike. With the promulgation of the revised Corporate Average Fuel Economy (CAFE) standards in 2011 for the period 2012–2016 [1], technological innovations bundled into a variety of existing and new vehicle models are increasingly meeting both consumer and regulatory demands. From the 2011 through the 2014 model years, the passenger car fleet has improved from 33.1 to 36.5 miles per gallon (mpg, EPA combined) on a sales weighted basis, outperforming the Federal standard by 8.0% in 2012, 7.8% in 2013, and 7.0% in 2014 [2]. In a similar fashion, sales-weighted CAFE performance for the entire light duty fleet, which includes all cars and light trucks, increased at a rate of 4.3% in 2011, 3.1% in 2012 and 3.0% in 2013 [3].

Leading the U.S. government efforts to shape CAFE, the Department of Transportation's National Highway and Traffic Safety Administration (NHTSA) and the Environmental Protection Agency (EPA) aimed to develop a robust policy in hopes of carefully balancing consumer utility and choice against aggressive goals to reduce the national consumption of petroleum fuels and related emissions. Automakers, herein referred to as Original Equipment Manufacturers (or OEMs), have thus far been able to meet and exceed the more stringent requirements by pulling ahead existing fuel-saving technologies and by adjusting business strategies and sales portfolios. A great deal of investigation, consultation, and modeling based upon then current information provided the framework for the rule regulating 2012–2016 model year vehicles. The lead agencies issued the Draft Joint Technical Support Document (TSD) specifically to document relevant technology performance and cost data available prior to rule issuance [4]. Such processes are admittedly uncertain, in part because subject estimates of technology, costs and fleet evolution are based upon projections drawn from 2008 and 2010 model year information [1], yet implementation of the regulations extends more than a decade into the future. Technologies are assumed to penetrate the market based upon a cost-effectiveness algorithm that compares the technology cost to the discounted stream of fuel savings and the value of performance to the consumer [5]. Though the source data detailed technology specificity [6] and delineated assumptions about fuel prices and discount rates, projections of fleet-wide impacts and vehicle sales by technology type were aggregated, making it difficult to explicitly determine the relative performance and cost-effectiveness of fuel savings technologies. Now nearing the mid-term of the first phase of the CAFE regulations for the 2012–2016 model years [1] (a second phase will be implemented between 2017 and 2025 [7]), the timing is appropriate to assess the progress made thus far, the constituent technologies underpinning the improved fuel economy performance, the consumer benefits and costs associated with the trends, as well as some implications for the coming years. This study looks at the empirical record, drawing from vehicle and technology specifications, published selling prices, and established conventions for financial decision-making by consumers and the economy as a whole. To ensure consistency, it uses accepted terms, definitions and concepts while drawing from many of the same literature sources that were used to formalize the standards.

This study seeks to ascertain how closely costs, fuel economy improvements and the recently promulgated regulatory standards align, as well as to quantify the extent to which novel fuel saving technologies are financially attractive to consumers and how their value proposition may evolve in the future. Such an assessment may prove valuable to a wide range of stakeholders, including researchers in transportation and energy, economics and policy as well as consumers and OEMs.

2. Fuel economy overview of the U.S. market: background and resources

2.1. Current CAFE standards

As noted, Federal fuel economy policies are designed to simultaneously address key challenges and deliver tangible benefits to consumers, the economy, and the country as a whole. Positive aspects of the regulation include: (1) the potential to reduce fuel consumption and preserve consumer choice; (2) the potential to meaningfully reduce emissions and improve air quality; and (3) the promise of a single, consistent national policy for all stakeholders [8]. Sustainably achieving these goals over a period of a decade or more, whether in the United States or elsewhere, requires that regulations be based upon the most current scientific and market-based data available, and appropriately address sources of uncertainty over time. While numerous studies quantify the benefits of fuel economy standards and project the composition of future vehicle fleets in 2035 or 2050 [9–13], researchers have suggested that the market for fuel economy does not function efficiently [14–18], with consumers often undervaluing its benefits. Given the sales-weighted emphasis of most policies, Greene suggested that "policy analysis must be based upon how real world markets actually function," noting that costs and benefits may vary accordingly [18].

Recent trends indicate that OEM compliance is largely being attained, the policy has thus far been successful, and progress is on track [19]. In fact, and as shown in Fig. 1, OEMs began to increase internal CAFE metrics beyond the required level, even before the issuance of the 2012–2016 rule. Specifically, this is illustrated in Fig. 1 by the substantial gap between the "Actual fleet" and "Avg Fed Std" fuel economy levels in the year 2010. One reason they have continued to exceed the minimum requirements is that they can generate credits for over-compliance within the current policy, and have the option of carrying them forward or backward, or trading them with other OEMs [7].

A December 2013 EPA report indicates that 28% of MY2013 vehicles meet the 2016 standard [19], which varies slightly among the two regulatory agencies due to the regulation of CAFE vs. CO_2 emissions (34.1 mpg is NHTSA's CAFE goal for passenger cars, whereas 35.5 mpg is EPA's "CO_2 equivalent" goal) [1]. It should be noted that the exact regulatory standard is variable within annual limits due to the unknown sales mix and the footprint-specific approach, and also because the authority of NHTSA and EPA requires them to regulate fuel economy and GHG emissions respectively [1,7,20]. However, the standards on passenger cars roughly follow a 4.3% increase through 2016, and then a 4–5% annual increase beginning in 2017 and extending until 2025. With this steady increase in requirements through 2025, the share of 2014 models that will be able to comply in that terminal year without further modification falls precipitously toward the end of the decade. Only 5% of all light duty MY 2013 vehicles appear to be compliant with the 2025 standards (which include CO_2 equivalent emission targets as well as fuel economy targets) [19]. Aside from today's hybrids, a portion of those that do are currently low volume, partially or fully-electrified platforms such as plug-in

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