Missing the Target: Fuel Economy, Power, and Safety

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Whether motivated by energy security or climate change, there are three pathways to reduce motor gasoline consumption: on-the-road energy intensity, vehicle miles traveled, and changing energy source (Figure 1). In 2009, the United States’ best-case scenario for 2020 will not reach the Kyoto Protocol target of 7% decrease from 1990 levels, given the current Reformed CAFE framework. Doing better than this requires two key tradeoffs to be resolved: fuel economy vs. horsepower, and fuel economy vs. safety.

Defining Tradeoffs

Vehicle features that compete with fuel economy (FE) take three general forms: technology tradeoffs, cost tradeoffs and what we call opportunity tradeoffs related to product development budget constraints. Technical tradeoffs include market-driven performance capabilities with power and energy usage implications, such as features that add mass or are energy-consuming [1]. Cost tradeoffs include the ability to add technology for fuel economy improvements independent of other attributes but add cost to the vehicle that the market cannot sustain. Opportunity tradeoffs occur in market segments where customers provide no incentive for fuel economy improvements but opt for other features, say, interior design appointments that manufacturers can provide within their target costs [2].

These tradeoffs highlight the fact that we will not be able to “have it all”, namely, maximize customer satisfaction and minimize social cost—except if the two are aligned [7/4]. Successful policy depends on ensuring technical and cost tradeoffs are well understood and opportunity tradeoffs are not mistaken for technical or cost tradeoffs.

In this article we focus on two tradeoffs that have prevented breakthroughs in FE: FE vs. performance, and FE vs. combined risk.

Fuel Economy versus Horsepower

Horsepower, and in turn acceleration (HP/mass), are technical tradeoffs with FE. Since the 1980s, manufacturers have directed powertrain technological advances towards increasing power or meeting FE requirements while increasing size and mass (Figure 2). Given this preference for acceleration and power in the market [10], breakthroughs in FE now have legitimate cost tradeoffs that wouldn’t have existed otherwise. Within the CAFE standards intended to rebalance FE-to-horsepower tradeoffs, producers could seek profits by satisfying customer demand for performance, size, and increased features. The average FE of offered cars and light trucks in the U.S. from 1984 to 2004 has stayed at 25 mpg. Japan’s FE in 2004 was 35 mpg. China’s 2010 FE standard is higher than required by the Reformed CAFE standard in 2020.

Figure 2. US 1984 and 2004 new vehicle design trade-offs for light-duty FE versus Power. The red arrow highlights that technical advances went into increasing the power capability of vehicle designs. FE versus Engine Size to Weight ratio illustrates design differences from 1984 to 2004 and US and Japan.
Fuel Economy versus Safety

Fuel economy and safety exhibit features of technical, cost and opportunity tradeoffs [6]. The Reformed CAFE structure adopted for light trucks (and proposed for cars), as defined by the National Highway Traffic Safety Administration (NHTSA), calculates fuel economy standards as a function of a vehicle’s footprint (track width multiplied by wheelbase) [5]. The purpose of employing a footprint-based fuel economy standard was to encourage manufacturers to reduce vehicle mass while maintaining vehicle size, motivated by the first-order understanding of safety where smaller size vehicles are more dangerous for their occupants [3, 11]. The second-order understanding of safety today illustrates that some of today’s smaller, lightweight cars are as safe for their occupants as larger and heavier light-duty trucks, but those cars tend to be more expensive (a cost tradeoff). The other side of the coin is clearer: relatively large, heavy pickups and SUVs put occupants of other vehicles at high risk in collisions, particularly side impacts [7, 9].

While NHTSA’s standards for light trucks may create an incentive to maintain or increase vehicle footprint, they may undermine the goal to reduce gasoline consumption. The relationship between fuel economy and safety is complex, and is often oversimplified when assessing the impact of CAFE [4, 12]. A comprehensive view of combined risk for both drivers, taking into account vehicle attributes in addition to weight, is imperative (Figure 3). Analysis of fatality rates by vehicle models demonstrates that smaller vehicles are not inherently less safe than larger vehicles in all types of crashes [9]. Indeed, new technologies and smarter design can at least partially decouple the relationship of mass and size in crash performance, allowing simultaneous gains in FE and safety. For example, extruded aluminum frames may improve occupant protection over traditional steel frames, while reducing mass [8]. Yet, high demand for aluminum would affect commodity pricing, and aluminum production is energy intensive, so other tradeoffs come into play. It could be more effective to regulate safety directly, rather than through fuel economy regulation.

The distribution of safety design burden on all vehicles imposed by the presence of pickups and truck-based SUVs currently on the road should be developed by taking combined risk into account. Our current system imposes a cost tradeoff on smaller vehicles, by giving them the onus to protect themselves from the largest vehicles.

Conclusions

The US has kept on-the-road energy intensity constant for decades, but gasoline consumption has continued to grow. This means that the US is not motivated fundamentally by energy security or greenhousegas emissions. Addressing these issues requires untangling the trade-offs between FE and performance. Now with FE and safety entangled through footprint vehicle attributes (instead of fuel source attributes, say), it seems the US will meet neither a 7% decrease in motor gasoline consumption nor create significant market penetration for electric or plug-in hybrid electric vehicles by 2020 [13]. We may disagree on what the right policy solution may be (including the authors themselves), but let’s at least agree on the fundamental issues requiring further discussion.

Figure 3. “Combined Risk” is driver deaths in a particular model (“risk in”) plus driver deaths in other vehicles that crash with that model (“risk by”), divided by million registered vehicles of that model per year [9]. Fuel intensity (and its reciprocal, fuel economy) correlates strongly with curb weight. Combined risk correlates poorly with weight, but correlates well with vehicle price. (See supplementary material).

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Fuel Intensity versus Weight

Safety versus Fuel Economy

Combined Risk vs Weight

Combined Risk vs Fuel Economy