Symposium:
Transportation and the Environment

Automobile Fuel Economy Standards: Impacts, Efficiency, and Alternatives

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Introduction

A number of countries regulate the fuel economy of new light-duty vehicles, while others regulate carbon dioxide (CO_2) emission rates per mile, which is almost equivalent. There are two main economic rationales for these regulations.

The first rationale is that fuel economy standards require automakers to design more efficient vehicles or to shift sales toward more efficient models. This lowers CO_2 emissions and reduces dependence on oil markets that are subject to economic and political uncertainty. However, these regulations are aimed only at improving the fuel economy of new automobiles; they do not encourage other forms of conservation or affect other sectors. In contrast, direct taxes on oil or on carbon raise fuel prices for everyone. Thus, such taxes promote fuel economy in new automobiles, discourage driving by owners of new and used vehicles alike, and reduce emissions and oil use beyond the automobile sector. This is important because other sectors play a key role in both CO_2 emissions and oil consumption. In fact, automobiles account for "only" about 20 percent of CO_2 emissions and 45 percent of oil use, both in the United States and worldwide (EIA 2009; IEA 2009).

The second rationale is that fuel economy standards may address a market failure that arises because consumers misperceive the benefits of improved energy efficiency. This rationale is controversial, however, because information dissemination programs may be more efficient than standards in dealing with this issue. Moreover, while a number of empirical studies find that consumers, in a variety of settings, appear not to pursue cost-effective opportunities to improve energy efficiency to the extent that they should, this finding is not universal (see, e.g., Helfand

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We are grateful to Gloria Helfand, Mark Jacobsen, Suzy Leonard, Joshua Linn, Kenneth Small, and a referee for very helpful comments on an earlier draft.

Review of Environmental Economics and Policy, volume 5, issue 1, winter 2011, pp. 89–108
doi:10.1093/reep/req021
Advance Access publication on May 24, 2011
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and Wolverton 2009; Greene 2010). In addition, even when consumers neglect apparently cost-effective opportunities, this behavior may reflect unmeasured costs rather than a market failure.

Whether or not there is a strong efficiency rationale for fuel economy standards, the fact that they are widely implemented suggests that they may be more politically tractable than other types of policy instruments. This fact raises a number of important policy questions. The purpose of this article, which is part of a symposium on Transportation and the Environment,[1] is to assess the impacts and efficiency of automobile fuel economy standards and compare them to alternative policy instruments such as fuel taxes and "feebate" systems, which impose fees on inefficient vehicles and provide rebates for efficient vehicles according to their fuel consumption per mile.

We begin by discussing the structure of fuel economy standards in practice; their influence on fleet composition, driving, and other behaviors; and their past and likely future effectiveness. We then review engineering and market-based approaches to measuring the costs of fuel economy programs. Next we compare the welfare effects of fuel economy standards and fuel taxes and assess whether these two policies can complement each other. Given that higher fuel taxes are widely believed to be politically infeasible in the United States, we next evaluate the case for replacing fuel economy regulations with feebate systems. The final section summarizes our findings and offers some conclusions.

Because U.S. studies dominate the literature and most other countries have only recently begun to implement similar policies, our discussion focuses largely on fuel economy regulations in the United States. However, whenever possible, we draw comparisons with, and highlight broad implications for, other countries.

Fuel Economy Standards in Practice

This section describes past and present fuel economy standards in the United States and other countries, examines how these regulations operate, and assesses their impacts.

Fuel Economy Standards in the United States

The Corporate Average Fuel Economy (CAFE) program was introduced in the United States in 1975 with the primary goal of reducing the country's dependence on foreign oil. Automakers were initially required to meet a sales-weighted average of 18 miles per gallon (mpg) for their car fleets, which increased steadily to 27.5 mpg by 1985. A lower standard was established for light trucks (pickups, minivans, and sport utility vehicles [SUVs]), which rose from 16 mpg in 1980 to 22.5 mpg in 2008. The rationale for this lower standard was that trucks were used primarily by businesses and farmers as part of their operations. However, this is obviously no longer the case.

As a result of the passage of the Energy Independence and Security Act (EISA) of 2007 and administrative action by the Obama Administration in 2009, fuel economy standards will be aggressively tightened between 2011 and 2016. In fact, there are now two separate regulations, one governing fuel economy, issued by the National Traffic Highway Safety Administration

[1]The other articles include Proost and Van Dender (2011), who review projections of road transport demand and assess long-term policy issues and options, and Anas and Lindsey (2011), who examine the use of road pricing as a tool for reducing congestion and other externalities related to urban road transportation.

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(NHTSA), and the other regulating CO_2 emissions per mile, issued by the Environmental Protection Agency (EPA). The standards are essentially equivalent, except that the slightly tighter EPA requirement allows automakers to earn compliance credits by modifying air conditioner refrigerants to reduce greenhouse gases. Without the air conditioner credit, EPA's standard would yield a combined average fuel economy for new passenger vehicles of 35.5 mpg (250 g CO_2 per mile) in 2016 (assuming no change in the shares of car versus truck sales). This compares to a combined standard of about 25 mpg in 2008. Automakers currently pay a fine of $55 per vehicle for every 1 mpg that their fleet average falls short of the relevant standard. Presumably this fine will be increased to enforce the stricter future standards.

The structure of the CAFE program is also being radically reformed, though some details are still being finalized. Each vehicle will face a separate fuel economy target based on its size or footprint.[2] There are separate mathematical formulas for cars and light trucks, which convert the footprints of individual models into fuel economy targets. These targets are then used to calculate sales-weighted standards for each automaker's car and light-truck fleet. Automakers specializing in smaller vehicles will face more stringent standards, reducing incentives for automakers to downsize vehicles to comply with regulation. Other pending changes to the CAFE program include expanding opportunities for automakers to bank and borrow fuel economy credits, allowing automakers to transfer credits between their car and light-truck fleets, and allowing credit trading across firms. The implications of such flexibility provisions are discussed below.

One looming issue (not addressed in detail here) is how fuel economy standards might be adapted for electric and alternative-fuel vehicles, which promise to play an increasingly important role in energy strategies throughout the world.[3] Accounting properly for vehicles that draw electricity from the grid, including plug-in hybrids and electric vehicles, is no easy task since it requires attributing some level of emissions to electricity. These emissions depend on the fuel used to generate extra electricity, which varies greatly by location and time of day. As regards alternative fuels, the CAFE standards include a loophole that treats flexible fuel vehicles capable of burning either gasoline or ethanol as though they run on ethanol 50 percent of the time even though, in practice, these vehicles rarely use ethanol (Anderson and Sallee 2010). Although this loophole is scheduled to phase out by 2020, regulators still need to establish a way of measuring the true gasoline consumption or CO_2 emissions of vehicles that use alternative fuels.

Fuel Economy Standards in Other Countries

Figure 1 summarizes the fuel economy standards in the United States and other countries that have similar programs.[4] In the European Union (EU), in response to regulations that set an ultimate target of 130 g CO_2 per kilometer, average new vehicle fuel economy is set to reach 45 mpg in 2012 and to continue rising thereafter. Tighter standards are easier to meet in Europe because high fuel taxes and the predominance of small cars and more fuel-efficient diesel

[2]A vehicle's footprint is its track width (distance between the centers of the left and right wheels) multiplied by its wheel base (distance between the front and rear axles).

[3]In part, this growth in the importance of electric and alternative-fuel vehicles will be policy driven. For example, the EISA strengthened the requirements for blending biofuels with gasoline. Low carbon fuel standards (recently introduced in California) will also encourage biofuels. There could be interesting interactions between these sorts of policies and fuel economy regulations that have yet to be explored in the literature.

[4]For more details on these programs, see An and Sauer (2004), Elmer and Fischer (2010), and IEA (2009).

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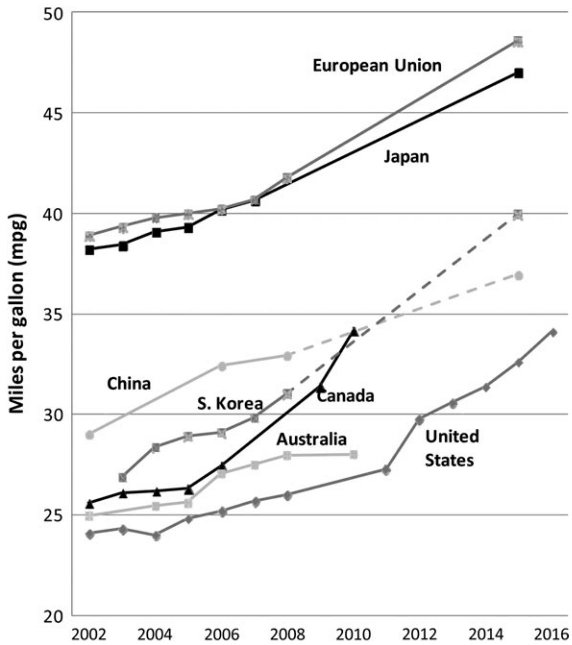

Figure 1 Fuel economy standards for new passenger vehicles by country
Source: ICCT (2009).
Notes: Dashed lines indicate proposed fuel economy targets not yet enacted. For Canada, the program includes in-use vehicles.

engines imply a higher baseline fuel economy. Unlike the United States, which has separate standards for cars and trucks, the EU has one set of regulations for the entire light-duty fleet, but a so-called "limit value curve" allows heavier cars to have higher emissions than lighter cars while preserving the overall fleet average. As part of the phase-in of the new regulations, the EU penalties for noncompliance are applied on a sliding scale through 2018, with low penalties of €5 for the first g/km in excess of the standard, which rise to €95 for the fourth g/km in excess and beyond.

China sets maximum fuel consumption standards for each vehicle, based on weight rather than average fleet-wide standards. Japan sets different fuel efficiency standards for diesel and gasoline vehicles, further differentiated by weight class. The future targets in Japan are based on the current "top performer" in each weight class (excluding niche products). Although the targets in Japan are mandatory, compliance seems to rely heavily on social pressures, as monetary penalties are low. Canada has modeled its fuel economy standards on those in the United States, but compliance is voluntary.

As in the United States, fuel economy programs in other countries are becoming more flexible. Examples include the movement toward weight-based standards in the EU, Japan, and China. The EU also allows pooling of targets across manufacturers to comply jointly with the standard. Japan allows manufacturers to accumulate credits in one weight category for use in another.

How Fuel Economy Standards Operate

Predicting the effects of fuel economy programs is inherently difficult, given the complexity of new vehicle markets, in which firms exercise market power, provide several differentiated

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products, and bundle many attributes into a single good. Firms may not behave as price takers because there is considerable market concentration, opening the door for strategic pricing that accounts for the behavior of competitors.[5] Typically, firms offer a variety of models to the same consumer base, which complicates strategic pricing—a firm that lowers the price on one of its models will not only siphon customers from its competitors but also lower demand for its other models. Besides price, automakers choose many physical attributes to bundle into a particular model. An equilibrium in this market, which is usually modeled as a Nash outcome in which firms cannot profitably deviate by changing prices or vehicle attributes given the choices made by other firms (e.g., Austin and Dinan 2005; Bento et al. 2009; Jacobsen 2010a), requires firms to choose attributes, fuel economy, and prices for multiple vehicles.

How do fuel economy standards influence these choices? When fuel economy standards are binding, firms must deviate from their profit-maximizing plan and raise their fleet average mpg to meet the minimum imposed by the standard. To do this, firms can alter vehicle characteristics—either by incorporating costly fuel-saving technologies or by compromising other vehicle attributes, such as size and horsepower—or change relative prices to increase the sales shares of more efficient models. Vehicle redesign is likely responsible for most improvements in fuel economy to date since studies find that compliance costs are substantially lower in the long run when automakers can redesign vehicles to be more efficient (e.g., Jacobsen 2010a; Klier and Linn 2010; Whitefoot, Fowlie, and Skerlos 2010).

Fuel economy regulations place an implicit tax on inefficient vehicles and changes in vehicle attributes that reduce fuel economy, while subsidizing efficient vehicles and changes that improve fuel economy. With separate standards for cars and light trucks, these taxes and subsidies operate separately *within* these two fleets, meaning that large cars are taxed while potentially less efficient small trucks are subsidized. This creates a perverse incentive to redesign large cars as trucks (e.g., the Chevy HHR and Chrysler PT Cruiser).[6] Moreover, in the absence of provisions that allow credit trading between firms, there are no implicit taxes or subsidies on firms like Honda and Toyota, which perennially exceed U.S. standards. This means that even if tighter standards cause low mpg manufacturers (e.g., Ford and General Motors) to improve fuel economy, their high mpg competitors (e.g., Honda and Toyota) may expand their offerings to capture the consumers who desire large vehicles. Whitefoot, Fowlie, and Skerlos (2010) estimate that this "leakage" is substantial.

Tighter fuel economy standards affect only new vehicles. Thus, when the standard increases, overall fuel economy improves gradually for about fifteen years as new vehicles replace the old. By lowering fuel costs per mile, fuel economy standards also encourage more driving. Recent evidence for the United States suggests that this "rebound effect" is fairly modest, however, offsetting just 10 percent of the fuel savings resulting from higher fuel economy (e.g., Small and Van Dender 2007). Both the rebound effect and the gradual turnover cause fuel taxation to be more efficient than fuel economy standards in conventional economic models (e.g., Austin and Dinan 2005).

[5]The seven largest firms in the U.S. market in 2009 (General Motors, Toyota, Ford, Honda, Chrysler, Nissan, and Hyundai) accounted for 87.5 percent of sales (Automotive News 2010).

[6]This increases an automaker's average fuel economy for both fleets since a redesigned vehicle would have fallen short of the car standard but exceeds the truck standard. Footprint-based standards will partially correct this perverse incentive, however, because small trucks will have fuel economy targets above the truck average.

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Impacts of Fuel Economy Standards

The United States has the longest history with fuel economy regulation, and thus our discussion focuses on U.S. experience. Given the complexities described above and the difficulty of distinguishing the effects of regulation from changing fuel prices and preferences for vehicle size, it is not possible to make precise statements about the historical impacts of CAFE. However, a few stylized facts are clear.

First, for most of its existence, CAFE has been binding. As a result, actual fuel economy for new vehicles closely tracked the standard between 1978 and 2000 (see Figure 2a), especially during the 1990s when the CAFE standards were unchanged.[7] Only during the run up in fuel prices in the 2000s were standards potentially nonbinding.

Second, while engine efficiency has improved during the last two decades, automakers have sacrificed potential improvements in fuel economy to make bigger, more powerful cars, presumably in response to perceived consumer preferences. Figure 2b shows the evolution of two key performance measures: (1) horsepower divided by weight; and (2) time to accelerate to 60 miles per hour. As fuel economy increased rapidly during the initial phase-in of CAFE standards, performance was flat. Then, for about twenty years, as CAFE standards and fuel economy both stabilized, automakers steadily improved performance. During that time, there were significant advances in *fuel efficiency* (in the sense of energy harnessed per gallon of fuel combustion), but the gains were allocated away from *fuel economy* (in the amount of fuel necessary to travel some distance), enabling bigger and faster vehicles to meet the CAFE requirements.

Third, the share of light trucks in new vehicle sales increased from 3 percent in 1978 to about 50 percent in 2003, causing overall fuel economy for new vehicles to fall slightly during the 1990s (Figure 2c). A large part of this change was due to the introduction of minivans, which replaced station wagons, and then the rise of SUVs as family cars. Changes in consumer preferences are at least part of the explanation for the growth in light-truck sales, which began before implementation of CAFE (Davis 1999). However, the CAFE standards likely contributed to this transition by creating incentives to design car-like vehicles to qualify as trucks (Sallee 2010; Sallee and Slemrod 2010).

The impact of fuel economy standards on road safety is less clear (e.g., Jacobsen 2010b). To the extent that it encouraged light-truck sales, CAFE likely reduced traffic fatalities for those truck occupants who would have otherwise bought cars but increased fatalities for everyone else (e.g., Gayer 2004; Li 2010). White (2004) finds that for each fatal crash that occupants of large vehicles avoid, more than four additional fatal crashes occur that involve others. On the other hand, for a given fleet mix, fuel economy regulations probably lead to smaller and lighter vehicles overall, which are less safe in single-vehicle collisions but can reduce injury risks to others in multi-vehicle collisions. Moreover, from an economic efficiency perspective, what matters are the overall *external* costs of traffic accidents, rather than highway fatalities. External costs exclude the risk of injuring oneself in an accident but include injuries to others and third-party property damage, medical costs, and productivity losses. However, based on the available literature, it is difficult to draw definitive conclusions about the direction,

[7]This is consistent with the claims of the “big three” U.S. automakers, who have argued that CAFE is binding and costly for them. Broadly, the Asian automakers have historically been well above the standard, while European luxury-car makers have frequently paid noncompliance penalties.

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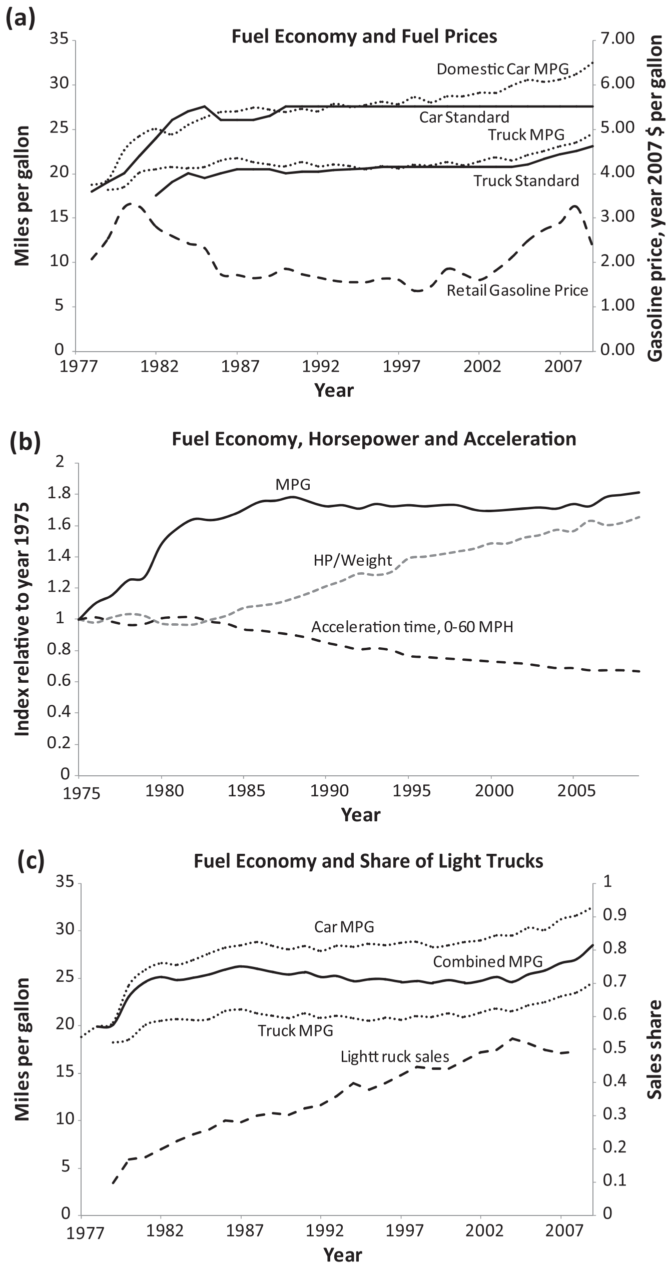

Figure 2 Trends in U.S. fuel economy and other vehicle characteristics
Source: EPA (2009), NHTSA (2009).

let alone the magnitude, of the link between external accident costs and fuel economy regulations.

Likely Future Impacts

Looking to the future, according to NHTSA (2010), automakers can meet future CAFE requirements with moderately costly technologies (e.g., cylinder deactivation, turbo charging, engine downsizing, conversion to dual-clutch transmissions, and start–stop engine

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technology) and other modifications (e.g., weight reductions), without causing a deterioration in power, acceleration, or other attributes.

All else equal, raising average new vehicle fuel economy from 25 to 35 mpg would reduce long-run fuel consumption by about 30 percent. Disentangling the actual future effect of tighter standards is difficult, however, given that future fuel use would likely fall anyway (reducing the effect of the standards) with rising fuel prices, biofuel mandates, and a shift in sales back toward cars. Small (2010) considers a continued tightening of fuel economy regulations beyond 2016 that ultimately raises average new vehicle fuel economy to 46 mpg by 2030. In this scenario, by 2030 gasoline use falls 23 percent below 2010 levels, despite a projected 33-percent increase in vehicle miles traveled over the period. However, at this point, Small (2010) finds that manufacturers are likely to run out of viable technologies and may prefer to pay fines in lieu of maintaining full compliance with CAFE. This underscores the technological constraints on the ability of standards to continue to increase fuel economy.

Assessing the Costs of Fuel Economy Standards

There are two broad methodological approaches to assessing the costs of fuel economy standards (excluding their impacts on externalities). The engineering approach envisions automakers adding fuel-saving technologies to existing models, taking as given other vehicle attributes, such as power, and the size and composition of the new vehicle fleet. In contrast, the market-modeling approach accounts for broader behavioral responses, including altering the sales mix of new vehicles and improving fuel economy at the expense of other attributes.

The Engineering Approach and Its Limitations

Under this approach, upfront costs and per-mile fuel savings are assessed for a wide range of technologies (see, e.g., NRC 2002; Creyts et al. 2007; NHTSA 2010). Automakers are assumed to progressively adopt the most cost-effective technologies to meet fuel economy requirements. Estimates of lifetime fuel savings are then subtracted from the technology adoption costs.[8] NHTSA (2010) has estimated that its new standard would add about $900 in incremental technology costs for the average new vehicle in 2016 but generate about $3,200 in fuel savings and other private benefits (e.g., reduced refueling time), implying a *negative* net private cost of about $2,300 per vehicle. Although NHTSA (2010) uses a relatively low social discount rate of 3 percent, private costs are still negative even under a 7-percent rate. Note that we have defined benefits here to exclude externalities.

These estimates of negative costs beg the question of why automakers have not already incorporated these seemingly profitable technologies. One possibility, put forward by NHTSA, is that consumers undervalue fuel economy benefits because of myopia, unreasonably short planning horizons, imperfect information, bounded rationality, limited importance of fuel costs in vehicle purchases, or simply an inability to calculate the financial benefits of energy efficiency properly.

[8]Pretax fuel prices should be used here, as savings in tax payments to motorists are offset by a revenue loss to the government. To the extent that the rebound effect is included, it plays a relatively minor role (leaving aside externalities), as smaller savings in lifetime fuel costs are approximately offset by increased driving benefits.

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Skeptics of this "misperceptions" market failure see no reason why consumers should be systematically misinformed, not least because EPA fuel economy estimates are required to be prominently displayed on new vehicles. According to these skeptics, various "unmeasured" costs (i.e., costs that are unobserved or ignored in engineering studies) account for any difference between the present discounted value of fuel savings and the cost of fuel-saving technologies. Unmeasured costs might include costs associated with actually implementing new technologies, such as marketing, maintenance, and retraining mechanics. They also might include the opportunity costs of using emerging engine technologies to enhance fuel economy at the expense of competing vehicle attributes (such as horsepower or additional energy-using devices) that consumers value more highly (e.g., Austin and Dinan 2005; Fischer, Harrington, and Parry 2007; Knittel 2009). A further unmeasured cost may arise if risk-averse consumers discount fuel economy benefits because they are uncertain about future fuel prices or actual fuel savings.[9] If such unmeasured costs were included in the analysis, the argument goes, then the apparent net private benefit of tighter CAFE standards would disappear.

Research on the misperceptions market failure hypothesis remains inconclusive. Lab experiments suggest that consumers are confused by the fact that cost savings are linear in gallons per mile—not miles per gallon, which is the standard way of reporting vehicle efficiency in the United States (e.g., Larrick and Soll 2008)—while qualitative surveys show that many consumers know little about the mpg of their current vehicles, their future driving pattern, and how to discount fuel savings (e.g., Turrentine and Kurani 2007). While these findings suggest that consumers may inaccurately assess fuel economy benefits, the direction of any bias is unclear. Tests of market behavior provide an even murkier picture. For example, Dreyfus and Viscusi (1995) estimate implicit discount rates for new vehicle fuel economy of up to about 20 percent, which is broadly consistent with estimated implicit discount rates for other energy durables (e.g., Hausman 1979; Dubin and McFadden 1984). However, the rate of a private automobile loan was around 10–15 percent during their sample period, suggesting that high implicit discount rates may largely reflect borrowing costs. Given that credit markets for automobile loans are extensive and competitive, these high rates may simply reflect default risks, rather than any market failure. Another branch of the literature uses fuel price variation to test whether vehicle prices adjust by as much as predicted when consumers fully value fuel economy, but again the findings are mixed (e.g., Kahn 1986; Kilian and Sims 2006; Allcott and Wozny 2009; Helfand and Wolverton 2009; Sallee, West, and Fan 2009; Greene 2010).

Market-Modeling Approach

Market-modeling studies may address some of the limitations of engineering approaches, which ignore the impact of fuel economy standards on fleet size and composition and on other vehicle attributes, such as weight and power.

Market-modeling studies simulate the effects of CAFE regulations on gasoline consumption, automaker profits, and consumer welfare using explicit models of the new vehicle market. In these studies, vehicle production costs typically depend on fuel economy and are based on widely used technology cost assessments such as NRC (2002) or possibly

[9]Fuel economy ratings are inexact—a factor highlighted by the EPA's recent overhaul of the rating system; individual fuel economy performance varies significantly depending on driving behavior (Sallee 2010).

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econometric estimates that are based on automaker behavior. Consumer demand functions for new vehicles are based on either detailed econometric models, in which household choices depend on prices and a range of vehicle attributes (e.g., Goldberg 1998; Gramlich 2008; Jacobsen 2010a; Klier and Linn 2010), or assumed own- and cross-price vehicle demand elasticities (e.g., Kleit 2004; Austin and Dinan 2005; Fischer, Harrington, and Parry 2007; Goulder, Jacobsen, and van Benthem 2009; Small 2010). Fuel economy improvements affect vehicle demand via the pass-through of technology adoption costs into prices and through consumer preferences for fuel economy and other attributes. For tractability, most studies assume that automakers compete on prices in a Nash–Bertrand setting and that profits are maximized on a year-by-year basis. Most studies also model the rebound effect.[10] Because market-modeling studies differ considerably in their assumptions and methodologies and it is difficult to judge which models are the most reliable, we focus here on qualitative rather than quantitative findings concerning the costs of fuel economy standards.

First, in contrast to NHTSA (2010), virtually all recent market-modeling studies find that CAFE standards impose nonnegligible costs on automakers and consumers. However, these studies rule out the consumer misperceptions hypothesis by *assuming* that the private market for fuel economy operates efficiently in the absence of CAFE standards.[11]

Second, market-modeling studies find that the short-run cost estimates for a small increase in the CAFE standard typically exceed long-run cost estimates by a factor of 2–3 (e.g., Jacobsen 2010a; Klier and Linn 2010; Whitefoot, Fowlie, and Skerlos 2010). This reflects the fact that in the longer run, automakers have greater scope for altering vehicle characteristics to meet a given standard, while in the very short run their only compliance option is to alter the sales mix.

Third, market-modeling studies indicate that gasoline taxes are a far more cost-effective policy than CAFE standards because they exploit more options for reducing gasoline use. Austin and Dinan (2005) and Jacobsen (2010a) estimate that for a given long-run reduction in fuel consumption, CAFE standards are about two to three times more costly than a gasoline tax. Jacobsen (2010a) finds that total welfare costs average about $2 per gallon of fuel saved for a 1 mpg increase in the CAFE standard, while a gasoline tax that saves the same amount of fuel imposes welfare costs of about $0.80 per gallon. The apparent cost disadvantage of fuel economy standards is even more pronounced in the short run, as fuel taxes give all motorists an immediate incentive to save fuel by driving less, while new vehicle standards permeate the vehicle fleet gradually.

Finally, it appears that market-modeling studies based on historical data may not provide reliable estimates of the future costs of fuel economy regulations. Cost estimates are sensitive to assumptions about baseline fuel economy (i.e., without policy changes), which can change substantially over time. For example, rising oil prices in the future, or progress on developing fuel-saving technologies, could shift baseline demand toward more efficient vehicles, thereby reducing both the effectiveness and the costs of a given fuel economy standard.

[10] Anderson and Sallee (2010) do not model consumer and automaker behavior explicitly but instead observe that automakers have often failed to take full advantage of low-cost flexible fuel credits in recent years, which provides an indirect estimate of automaker compliance costs.

[11] For example, Kleit (2004) and Austin and Dinan (2005) scale up the marginal cost of adding fuel-saving technologies (to proxy for hidden costs) until, in the observed baseline (i.e., prior to the CAFE policy), there are no fuel-saving technologies that could be profitably adopted.

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Comparing the Welfare Effects of Fuel Economy Standards and Fuel Taxes

This section presents a stylized model, which accounts for externalities and possible misperceptions market failures, to compare the overall welfare effects of fuel taxes and fuel economy standards.

Conceptual Framework

Consider Figure 3, reproduced from Parry, Evans, and Oates (2010), which shows various marginal cost curves for reducing long-run gasoline use in the United States below a given baseline level through fuel taxes and fuel economy standards. The solid gray curves indicate marginal costs if there were no market failures or preexisting fuel policies. For the fuel tax, the area under this curve corresponds to the deadweight loss triangle created by the tax in the gasoline market. With a perfectly elastic fuel supply curve, the slope of the marginal cost depends on the long-run gasoline demand elasticity, taken to be −0.4 (see, e.g., Small and Van Dender 2007). The marginal cost for the fuel economy standard has a much steeper slope than the curve for the fuel tax. This is because the policy places the entire burden of the fuel reduction on fuel economy improvements and fails to exploit any fuel savings through reduced vehicle mileage.

The dashed gray curves in Figure 3 take into account preexisting fuel taxes, which are approximately 40 cents per gallon in the United States (with state and federal taxes combined). For both policies, marginal costs now have an intercept equal to this prior tax, which reflects the initial wedge between demand and supply prices in the fuel market. That is, with no market failures, the preexisting tax would cause motorists to overinvest in fuel economy and drive too little.

Next, we subtract from these costs estimates of fuel- and mileage-related externality benefits. Although highly contentious, a plausible value for global warming damages is $20 per ton of CO_2, which amounts to 18 cents per gallon of gasoline (see, e.g., Newbold et al. 2009; Tol 2009; Aldy et al. 2010; IWG 2010). Netting out this benefit, the marginal cost curves in Figure 3 shift down, but they would still have positive intercepts of 22 cents per gallon. Thus, under this assumption, global warming by itself is not sufficient to warrant raising the existing fuel tax or imposing fuel economy standards on top of the fuel tax.

As for mileage-related externalities, Parry, Evans, and Oates (2010) assume that the marginal costs of traffic congestion (averaged across region and time of day) are 4.5 cents per mile, the external costs of traffic accidents are 3.5 cents per mile, and local pollution damages are 1.0 cents per mile.[12] Given current on-road fuel economy levels in the United States (about 22 miles per gallon), these combined externalities would be equivalent to about $2 per gallon. However, because only about half of the fuel reduction under fuel taxes comes from reduced mileage (the remainder comes from fuel economy improvements that do not affect these externalities), the externality benefit per gallon of fuel savings amounts to about $1 per gallon.

[12]Roughly speaking, local emissions vary with vehicle miles driven rather than total fuel use. That is, they are independent of vehicle fuel economy. This is because all new vehicles have to satisfy the same grams-per-mile standards, regardless of fuel economy, and these standards are approximately maintained throughout a vehicle's life through emissions inspection and maintenance programs.

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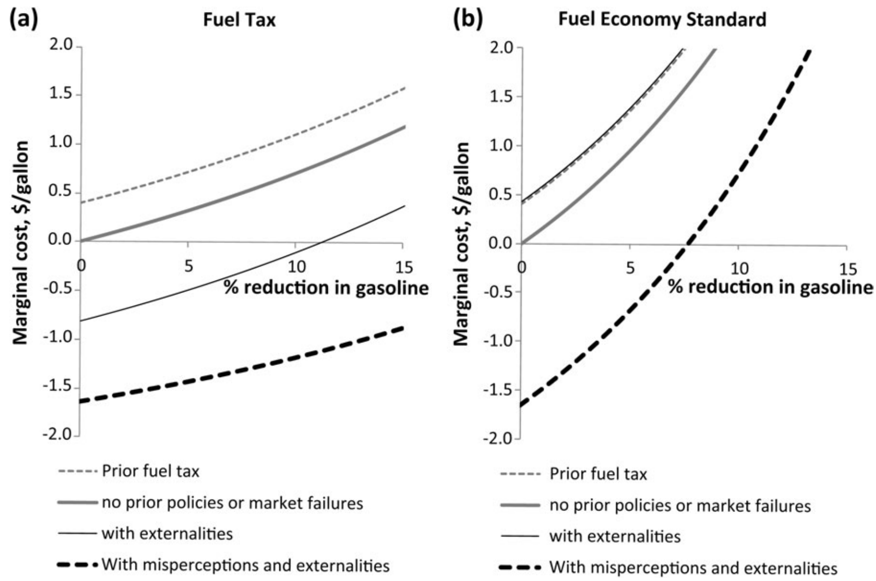

Figure 3 Marginal costs of a fuel tax versus a fuel economy standard
Source: Parry, Evans, and Oates (2010).

Overall, the marginal cost curve for the fuel tax (the solid black curve) now has an intercept of about −80 cents per gallon and marginal costs are negative up to a fuel reduction of about 11 percent. This corresponds to the reduction implied by raising the fuel tax from its current level to its externality-correcting level (about $1.26 per gallon). Under the fuel economy standard, however, mileage-related externalities increase (albeit moderately) due to the rebound effect. The (solid black) marginal cost for this policy now has an intercept of 43 cents per gallon, implying that fuel economy standards are still welfare reducing.

However, there is an additional source of welfare gain if consumers undervalue fuel economy improvements. Parry, Evans, and Oates (2010) consider a plausible upper bound for the potential magnitude of this misperceptions market failure where about two-thirds of the lifetime fuel savings are not internalized (this corresponds to a case in which consumers consider fuel savings only over the first three years of the life of a new vehicle). Under the fuel tax, the marginal cost curve (now indicated by the dashed black line in Figure 3) is shifted down further to the extent it increases fuel economy and addresses the market failure. However, the downward shift in the marginal cost for the fuel economy standard is even greater since all (rather than part) of the fuel reduction under this policy comes from improved fuel economy. Nonetheless, the marginal cost for this policy does not fall below that for the fuel tax.

This last finding implies that fuel taxes and fuel economy standards are not complementary instruments, despite the large misperceptions market failure. That is, reducing gasoline use through fuel taxes is more efficient than reducing it through some combination of fuel taxes and fuel economy standards. For any given fuel reduction, tightening the standard (and reducing the tax) implies that more of the reduction will come from better fuel economy and less from reductions in vehicle miles traveled. In Parry, Evans, and Oates (2010), any

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efficiency benefits from improving fuel economy are offset by efficiency losses, as less is done to reduce traffic congestion, accidents, and local pollution.[13]

Some Caveats

One caveat here is that fuel taxes are an inefficient way to reduce the mileage-related externalities. For example, traffic congestion is highly specific to region and time of day and is much better addressed through peak-period pricing. If mileage-related externalities were comprehensively internalized through other policies, it would then be optimal to address any remaining market failures associated with fuel economy misperceptions through standards rather than through fuel taxes.

Furthermore, standards may be more politically practical than taxes. Motorists appear to be less opposed to standards because they do not transfer a large amount of revenue to the government. Fuel taxes are also thought to be regressive, at least prior to the use of revenues (West 2004; West and Williams 2004; Bento et al. 2009). In contrast, standards may actually be progressive, as their direct impact is on new vehicles, which are disproportionately consumed by higher-income families (though, as discussed in Jacobsen 2010b, distributional effects are complicated because of secondary effects on used-car prices).[14]

Suppose fuel economy standards are the only practical option—do they do more good than harm? Unfortunately, it is difficult to answer this question definitively. If there are large climate and energy security benefits from cutting fuel use, and a significant market failure associated with fuel economy decisions, then standards can be welfare improving. On the other hand, if any benefits from improved energy security, and addressing fuel economy market failures, are modest, the costs of standards can easily outweigh the benefits.[15]

Finally, the standards themselves may help create a stable environment for the development and adoption of fuel-saving technologies with high up front costs and long-term payoffs. It is important to note that the welfare gains from such induced innovation are not included in Figure 3. While a higher fuel tax would also provide incentives for innovation, the standard could provide more direct incentives by eliminating the downside risks to

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[13]Accounting for fiscal considerations may further strengthen the welfare basis for fuel taxes over standards. Gasoline appears to be a relatively weak substitute for leisure, which implies that (up to a point) replacing labor taxes (e.g., income and payroll taxes) with gasoline taxes will increase labor supply and generate additional welfare gains that are not possible under standards (West and Williams 2005; Parry 2007).

[14]Another potential rationale for using standards rather than taxes is related to the imperfectly competitive nature of vehicle markets, in which a few large manufacturers manage sales of large fleets of vehicles. If fuel economy can be used as a means to segment consumers, manufacturers may engage in price discrimination in order to garner higher vehicle prices by underproviding fuel economy to consumer types that value it less (e.g., large car buyers) and overproviding it to those that value it more (Fischer 2005, 2010). However, while this kind of market failure can potentially be a motivation for using minimum standards as a means of limiting the availability of price discrimination mechanisms, average fuel economy standards like CAFE do little to address problems of excessive differentiation.

[15]For example, without a consumer misperceptions market failure, and the above CO_2 externality benefit (i.e., $20 per ton), energy security benefits would need to be well above 22 cents per gallon for standards to be welfare enhancing. One security benefit is the reduced vulnerability of the macroeconomy to oil price shocks. However, Brown and Huntington (2010) put the benefit at only about 5 cents per gallon. More generally, there might be important foreign policy or national security benefits from reducing dependence on imported oil from the Middle East, though these sorts of benefits are extremely difficult to quantify.

innovators from fuel price volatility and more precisely targeting domestic and international spillovers associated with fuel-saving technologies (e.g., Barla and Proost 2010). In fact, from a policymaker's perspective, inducing innovation over the long term may actually be one of the most important objectives of regulation.

Standards versus Feebates

There has been growing interest in feebates. Such policies combine a fee for new vehicles that have fuel economy below some specified "pivot point" with rebates for vehicles that have fuel economy above the pivot point, where these fees/rebates could be levied at either the consumer or the manufacturer level (e.g., Greene et al. 2005; Fischer 2008). Policymakers in the United States have been discussing feebates as an alternative to CAFE standards since the early 1990s, and feebates have already been implemented (in a modest form) in Ontario in 1991 and, more recently, on a national basis in Canada and France. Like fuel economy standards, feebates need not impose a politically unpopular tax burden on motorists. This is because they can be made revenue neutral by setting the pivot point in one year slightly above the average fuel economy for new vehicles in the previous year.

To provide a constant incentive rate for each gallon of fuel saved, the fee or rebate under a feebate system should be proportional to fuel consumption per mile (rather than fuel economy, in mpg) regardless of whether those improvements are in small or large vehicles. Because an increase of 1 mpg starting at a lower fuel economy rating has a larger impact on gasoline consumption than a 1 mpg increase starting at a higher mpg, a payment schedule based on mpg would give a disproportionately small rebate (or subsidy) for fuel savings in low-mpg vehicles (where the potential for fuel economy improvements is greatest).

This section compares the cost-effectiveness of fuel economy standards and feebates and discusses their compatibility with other policy instruments.

Comparison of Cost-Effectiveness

Within a given year, to achieve an average fuel economy target for new vehicles at the lowest industry-wide cost requires equating marginal compliance costs across automakers. Figure 4 shows marginal compliance costs (net of consumer willingness to pay for fuel economy improvements) for reducing fuel consumption per mile for representative high-cost and low-cost firms—for example, firms that specialize in large cars and small cars. The industry-wide costs of meeting an average standard of $\bar{f}$ gallons per mile are minimized when the high-cost and low-cost firms reduce fuel consumption per mile to f_H and f_L, respectively (assuming firms have the same fleet size).

Under a traditional fuel economy (or vehicle CO_2) standard, all firms are required to meet the same industry-wide standard. This results in different marginal compliance costs across firms. As shown in Figure 4, this causes an efficiency loss, which is indicated by the difference between the taller and shorter shaded trapezoids. Feebates automatically achieve the cost-minimizing outcome, in which high-cost firms pay a fee of τ on each unit between their actual fuel consumption per mile and the target level, while low-cost firms receive a subsidy of τ for each unit that their actual fuel consumption per mile exceeds the target level. Austin and Dinan (2005), for example, estimate that the total costs of complying with fuel economy

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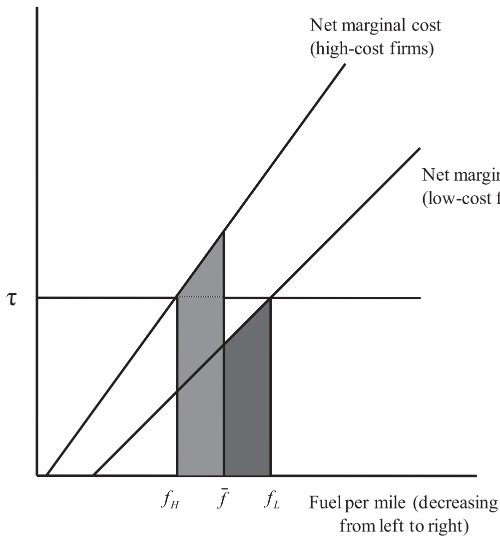

Figure 4 Potential savings in compliance costs from feebates and flexible regulations
Notes: This figure indicates cost savings from equating marginal compliance costs across firms rather than forcing firms to meet the same fuel per-mile standard. Cost savings are indicated by the shaded trapezoid under the higher marginal cost curve less the shaded trapezoid under the lower marginal cost curve.

targets would fall by a significant (though not dramatic) 15 percent with this equalization of marginal compliance costs across firms.

The least-cost outcome could also be achieved using fuel economy standards by allowing limitless trading of credits among firms. In principle, feebates and standards with credit trading are equivalent instruments. The (uniform) price on fuel economy credits ensures that all vehicles face the same marginal incentive to improve fuel economy, thus playing the same role as the fee and rebate. Under the regulatory approach, the industry-wide standard plays the same role as the pivot-point fuel economy in the feebate system. In fact, in the United States and elsewhere, inter-firm trading provisions are being implemented, which undermines one of the key arguments in favor of feebates. However, because there is a relatively small number of firms in the automobile market, the trading market could be thin, which raises the risk that limited arbitrage would not be sufficient to equalize marginal compliance costs.

Another way to improve the cost-effectiveness of standards in the absence of credit trading is to set standards based on vehicle size or other attributes, which introduces variation in fuel economy requirements across firms (e.g., firms specializing in relatively large vehicles receive a less stringent fleet-wide target). However, in the absence of credit trading, the full equalization of marginal abatement costs will not be realized. Moreover, size-based standards blunt incentives for reducing vehicle size, which eliminates a potentially important option for improving fleet fuel economy.[16] Elmer and Fischer (2010) discuss how this problem could be avoided by allowing for automaker-specific targets based on historical (rather than current) fleet attributes.

In a multi-period context, cost minimization also requires equating the marginal costs of compliance in one year with the (discounted) marginal costs of compliance in another.

[16]The potential importance of downsizing as a means of improving fuel economy is clear if one compares the United States with Europe, which enjoys a much higher fleet average due in large part to the predominance of smaller vehicles.

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From a broader welfare perspective, this requirement presumes that the marginal external benefits of fuel reductions are the same over time, which is a fairly reasonable assumption, at least for CO_2. In their traditional form, fuel economy standards violate this condition, as the marginal costs of complying with a fixed fuel economy standard will vary from year to year with volatility in fuel prices, which affect consumer willingness to pay for more efficient vehicles, and other factors. There is little evidence, however, on how this lack of dynamic flexibility might increase costs. Furthermore, recent provisions in the CAFE program are helping to deal with cost uncertainty, at least in part. Automakers are now allowed to bank CAFE credits for up to five years when they exceed the fuel economy standard in a given year, and they may borrow credits if they fall short of the standard, so long as credits are paid back within three years. Perhaps more important is the fact that technological innovation brings down the costs of complying with a fixed fuel economy target, which means that marginal costs will not be equated over time unless the standard continually increases at an appropriate rate.

Feebate programs can easily accommodate both cost uncertainty and technical change. In periods of high compliance costs, automakers can choose to pay more in fees, or forgo subsidies, enabling them to sell a greater share of vehicles with low fuel economy, and vice versa in periods of low compliance costs. Feebates also provide ongoing incentives for improvement, as the value of fuel economy stays constant and does not diminish with technical advancements.

In practice, feebate systems have featured multiple pivot points as a way of lowering the tax burden paid, or subsidies received, by individual manufacturers. This system results in "tax notches," where a marginal change in fuel economy can create a large discrete change in tax treatment. Sallee and Slemrod (2010) find evidence that manufacturers respond to these incentives by slightly modifying vehicles close to cutoff points in the tax system, resulting in some loss of efficiency compared to both a smooth schedule and fuel economy standards.

Finally, while fuel economy standards are applied only to automakers, feebates could be applied to automakers, dealers, or consumers. Economic theory suggests that with efficient markets, the point of compliance should not matter, as the incentive will be passed along through the price of the vehicle. Evidence in Busse, Silva-Risso, and Zettelmeyer (2006), however, suggests that the point of compliance may be relevant. They find that because of information asymmetries, the behavioral response to price incentives (such as feebates) may be stronger if the incentives are levied at the consumer rather than the producer level, which has potential implications for cost-effectiveness. Politicians appear to believe in this asymmetry, as fuel economy taxes have historically been levied on manufacturers while rebates have been given directly to consumers (Sallee 2010). This is an issue that requires further study.

Compatibility with Other Policy Instruments

The gains from transitioning from standards to feebates may not appear to be very significant on purely cost-effectiveness grounds. However, recent reforms to fuel economy programs have highlighted an important drawback of standards—that they can undermine the performance of other, increasingly common, policy interventions in the transportation sector.

For example, the United States provides generous tax credits for the purchase of hybrid vehicles. One of the primary objectives of these subsidies is to reduce CO_2 emissions and

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dependence on oil. In the presence of binding fuel economy regulations, however, greater penetration of hybrid vehicles will simply allow automakers to cut back on fuel-saving technologies for conventional gasoline vehicles (McConnell and Turrentine 2010). Similarly, taxes on vehicles with low fuel economy or high CO_2 emissions may increase demand for smaller, more efficient vehicles, but this will allow automakers to install fewer fuel-saving technologies than would otherwise be needed to meet the standard. To take another example, under a binding nationwide fuel economy program, a state or regional program that increases fuel economy in one area may be offset by reductions in fuel economy in other regions (Goulder, Jacobsen, and van Benthem 2009). In fact, this concern recently motivated the federal government in the United States to set standards that are equivalent to the more aggressive standards already being phased in under California law.

In contrast to fuel economy standards, pricing instruments tend to be additive. That is, hybrid vehicle subsidies and gas guzzler taxes will improve fuel economy and reduce gasoline use, regardless of any preexisting fuel taxes or the presence of feebates. Similarly, feebates at the national level would not undermine the effects of regional environmental or fuel economy initiatives.

Conclusions

The future effectiveness of fuel economy standards is difficult to gauge, given that the baseline fuel economy (in the absence of policy) is sensitive to oil prices, technology costs, and other factors. In addition, the cost-effectiveness of standards remains contentious, due in particular to uncertainty about how consumers value fuel-saving benefits. At first glance, fuel economy standards appear to be difficult to justify on welfare grounds, given that fuel taxes—even in the United States—exceed most estimates for per-gallon climate damages. In fact, our stylized model suggests that high levels of fuel taxation can be defended—up to a point—on economic efficiency grounds since they reduce congestion and other externalities that vary with miles driven and are relatively large in magnitude. Even if there is a large market failure associated with consumer misperceptions about the benefits of fuel economy, and even if the social costs of global warming or oil dependence are high, this need not imply a role for fuel economy regulations if fuel taxes can be adjusted.

On the other hand, in countries such as the United States, standards appear to be more acceptable to the public, and hence more practicable, than high fuel taxes. Standards may also help create a more stable environment for the development of clean technology by removing some of the downside risks to innovators in a world of uncertain fuel prices. However, it is not well understood whether fuel economy standards are better or worse than other instruments, such as technology prizes, fuel taxes, and fuel price floors, in encouraging such innovation.

While the appropriate role of fuel economy standards remains an unresolved issue in the economics literature, recent structural reforms of existing programs, particularly provisions that expand opportunities for credit trading across firms, vehicle types, and over time, have helped to improve the cost-effectiveness of standards. However, their relative incompatibility with other interventions in the vehicle market and at different levels of government remains a concern. This is one important reason why feebate systems deserve further consideration and research.

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