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AUTOMOBILE FUEL ECONOMY STANDARDS: IMPACTS, EFFICIENCY, AND ALTERNATIVES

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ABSTRACT

This paper discusses fuel economy regulations in the United States and other countries. We first describe how these programs affect the automobile market, including their impacts on fuel use and other dimensions of the vehicle fleet. We then review different methodologies for assessing the costs of fuel economy regulations and discuss what the results of these methodologies imply for policy. Following that, we compare the welfare effects of fuel economy regulations to those of fuel taxes and assess whether or not these two policies can be complements. Finally, we review arguments for transitioning away from fuel economy regulations towards a "feebate" system.

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Introduction

A number of countries now 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.

First, they require automakers to design more efficient vehicles or to shift sales toward more efficient models. This lowers CO_2 emissions, reduces dependence on oil markets subject to economic and political uncertainty, and mitigates other externalities associated with petroleum consumption. Note, however, that these regulations are limited to improving fuel economy in 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, they 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. 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).

Second, fuel economy standards might address a market failure due to consumers misperceiving the benefits of improved energy efficiency. This rationale is controversial, however, because information dissemination programs may be a more efficient way to deal with consumers misperceiving benefits. 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 is not a universal finding (e.g., Greene 2010, Helfand and Wolverton 2010). And even when consumers neglect apparently cost-effective opportunities, this behavior may only reflect unmeasured costs, rather than a market failure.

But whether or not there is a strong efficiency rationale for fuel economy standards, the fact that they are widely implemented suggests they may be more politically tractable than other instruments. This fact raises a number of important policy questions that are taken up in this paper.

We begin by discussing the structure of fuel economy standards in practice, their influence on fleet composition, driving, and other behaviors, and their historical and future effectiveness. We then review engineering and market-based approaches to measuring the costs of fuel economy programs. Next, we describe the overall welfare effects of fuel economy standards, comparing them to fuel taxes and assessing 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 also evaluate the case for replacing fuel economy regulations with “feebate” systems, which impose fees on inefficient vehicles and provide rebates for efficient vehicles according to their fuel consumption per mile. A final section summarizes our findings and concludes.

Given the predominance of U.S. studies in the literature, and given that most other countries have only recently begun to implement similar policies, our discussion focuses largely on the U.S., though we do draw comparisons with, and highlight broad implications for, other countries.

Fuel Economy Standards and their Effects

Policies in the U.S.

In the U.S., the Corporate Average Fuel Economy (CAFE) program was introduced in 1975 with the goal of reducing foreign oil dependence. 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 or SUVs), which rose from 16 mpg in 1980 to 22.5 mpg in 2008. The rationale for this lower standard was that trucks were primarily used by businesses and farmers, though this obviously is no longer the case.

Following the Energy Independence and Security Act (EISA) of 2007 and administrative action by the Obama Administration in 2009, 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 (NHTSA), and the other regulating CO_2 emissions per mile issued by the Environmental Protection Agency (EPA). The regulations 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. EPA’s standard would yield a combined average fuel economy for new passenger vehicles of 35.5 mpg (250g CO_2 per mile) in 2016, without the air conditioner credit, compared with a combined standard of about 25 mpg in 2008 (assuming no change in car vs.

truck sales shares). Automakers currently pay a fine of $55 per vehicle for every 1 mpg that their fleet average mpg falls short of the relevant standard, though presumably this fine will have to be increased to enforce the stricter 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.[1] There are separate mathematical functions for cars and light trucks, which map 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. We discuss the implications of flexibility provisions toward the end of the paper.

One looming issue (not pursued here) is how fuel economy standards might be adapted for electric and alternative-fuel vehicles, which promise to be growing parts of energy strategies around the world.[2] 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 feature 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.

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[1] 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).

[2] In part, these trends will be policy driven. For example, 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.

Policies in Other Countries

Figure 1 summarizes fuel economy standards in other countries with similar programs (for more details see An and Sauer 2004, Elmer and Fischer 2010 and IEA 2008). For example, in the E.U., average new vehicle fuel economy is set to reach 45 mpg in 2012 and continue rising thereafter, in response to regulations that set an ultimate target of 130g CO_2 per km. Tighter standards are easier to meet in Europe, because high fuel taxes and the predominance of small cars and more fuel-efficient diesel engines, implies a higher baseline fuel economy. Unlike the U.S., which has separate standards for cars and trucks, the E.U. has one set of regulations for the entire light-duty fleet, but a so-called "limit value curve" allows heavier cars higher emissions than lighter cars while preserving the overall fleet average. The E.U. penalties for noncompliance are applied on a sliding scale through 2018, as part of the phase-in of the new regulations, with low penalties of €5 for the first g/km in excess of the standard, rising up 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 fleetwide standards. Japan sets different fuel efficiency standards for diesel and gasoline vehicles, further differentiated by weight class. The future targets are based on the current "top runner" in each class (excluding niche products), but although the targets 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 U.S., although the regulation is voluntary.

Programs are also becoming more flexible in other countries. Examples are the movement toward weight-based standards in the E.U., Japan and China. The E.U. also allows pooling of targets across manufacturers to comply jointly with the standard and Japan allows manufacturers to accumulate credits in one weight category for use in another.

Understanding How the Programs Work

Predicting the effects of fuel economy programs is inherently difficult, given the complexity of new vehicle markets, which are best characterized as oligopolies.[3] Typically, firms offer a variety of models to the same consumer base. Thus, a firm that lowers the price on one of

[3] 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).

its models will reduce demand for its other models, while siphoning customers away from other firms. Besides price, automakers choose many physical attributes to bundle into a particular model. Market equilibrium is usually modeled as a Nash outcome, in which firms cannot profitably deviate by changing prices or vehicle attributes, given the choices of other firms (e.g., Austin and Dinan 2005, Bento et al. 2009, Jacobsen 2010a).

If fuel economy programs are binding, they constrain a firm's profit-maximizing choices by requiring that fleet average mpg exceed a minimum standard. Compliance strategies include altering vehicle characteristics—either by incorporating costly fuel-saving technologies or compromising other vehicle attributes, such as size and horsepower—or changing 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 2008).

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, creating a perverse incentive to re-design large cars as trucks (e.g., the Chevy HHR and Chrylser PT Cruiser).[4] 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 that perennially exceed U.S. standards. This means that tighter standards may harm the competitive position of domestic U.S. automakers, while perversely allowing unconstrained foreign automakers to produce the large vehicles that domestic firms would have produced otherwise.

Tighter fuel economy standards only affect new vehicles. Thus, when the standard increases, overall fuel economy improves gradually for about 15 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 this "rebound effect" is fairly modest, however,

[4] This increases an automaker's average fuel economy for both fleets, since a re-designed 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.

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 gradual turnover cause fuel taxation to be more efficient than fuel economy standards in conventional economic models (e.g., Austin and Dinan 2005).

Previous Experience

The U.S. has the longest history with fuel economy regulation. Although it is not possible to make precise statements about the historical effects of CAFE, given the complexities described above and the difficulty of decomposing the effects of regulation from changing fuel prices and preferences for vehicle size, a few stylized facts are still clear.

First, for most of its existence, CAFE has been binding. As indicated in Figure 2(a), actual fuel economy for new vehicles closely tracked the standard between 1978 and 2000, especially during the 1990s when the CAFE standards were unchanged.[5] Only during the run up in fuel prices in the 2000s were standards potentially non-binding.

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 2(b) 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 20 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 2(c)). A large part of this change was the advent of minivans, which replaced

[5] This is consistent with the claims of the "Big Three" US 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 non-compliance penalties.

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 preceded CAFE (Davis 1999). The standards likely contributed to this transition, however, by creating incentives to design car-like vehicles to qualify as trucks.

Less clear is the impact of fuel economy programs on road safety (e.g., Jacobsen 2010b). To the extent that it encouraged light truck sales, CAFE likely reduced traffic fatalities for the truck occupants that would have otherwise bought cars while increasing fatalities for everyone else (e.g., Li 2010, Gayer 2004). White (2004) finds that for each fatal crash that occupants of large vehicles avoid, over 4 additional fatal crashes involving others occur. 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. Based on available literature, it is difficult to draw definitive conclusions about the direction, let alone the magnitude, of the link between external accident costs and fuel economy regulations.

Going Forward

According to NHTSA (2010), automakers can meet future CAFE requirements with moderately costly technologies (e.g., cylinder deactivation, turbo-charging, engine down-sizing, conversion to dual-clutch transmissions, and start-stop engine 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 mpg 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 towards 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, gasoline use falls 23 percent below 2010 levels by 2030, despite a projected 33 percent increase in vehicle miles travelled over the period. However, at this point manufacturers are likely to run out of viable technologies and may prefer to pay fines in lieu of keeping in full compliance with CAFE, underscoring technological constraints on the potential for regulation to keep increasing fuel economy.

Costs of Fuel Economy Policies

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.

Engineering Analyses

In this approach (e.g., NRC 2002, Creyts et al. 2007, NHTSA 2010), upfront costs and per-mile fuel savings are assessed for a wide range of technologies. 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.[6] NHTSA (2010) 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.

[6] Pre-tax 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 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.

Controversies in the Engineering Approach

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

Skeptics of this "misperceptions" market failure see no reason why consumers should be systematically misinformed, not least because EPA fuel economy estimates must be prominently displayed on new vehicles. According to this view, 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-savings technologies. Were these unmeasured costs to be included, the argument goes, then the apparent net private benefit of tighter CAFE standards would disappear.

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 et al. 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.[7]

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 U.S. (e.g., Larrick and Soll 2008)—while qualitative surveys show that many consumers know little about the mpg of their current vehicles, their future mileage, and how to discount fuel savings (e.g., Turrentine and Kurani 2007). While these findings suggest that consumers inaccurately assess fuel economy benefits, the direction of any bias is unclear. Tests of market behavior provide a still 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

[7] 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).

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 very mixed (e.g., Kahn 1986, Kilian and Sims 2006, Allcott and Wozny 2009, Greene 2010, Helfand and Wolverton 2010).

Market Modeling Approach

Market modeling studies potentially address 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. Vehicle production costs typically depend on fuel economy, according to widely used technology cost assessments, such as NRC (2002), or possibly according to econometric estimates based on automaker behavior. Consumer demand functions for new vehicles are based either on detailed econometric models, in which household choices depend on prices and a range of vehicle attributes (e.g., Goldberg 1998, Gramlich 2009, Jacobsen 2010, Klier and Linn 2008), or on assumed own- and cross-price vehicle demand elasticities (e.g., Austin and Dinan 2005, Fischer et al. 2007, Goulder et al. 2009, Kleit 2004, 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.[8]

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

Given that studies differ considerably in their assumptions and methodologies, and that it is difficult to judge which models are the most reliable, we focus here on qualitative rather than quantitative results.

First, in contrast to NHTSA (2010), virtually all recent market-modeling studies find that CAFE standards impose non-negligible 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.[9]

Second, 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., Klier and Linn 2008, Jacobsen 2010a). 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 altering the sales mix.

Third, gasoline taxes are a far more cost effective policy because they exploit more margins of behavior for reducing gasoline use. Austin and Dinan (2005) and Jacobsen (2010a) estimate that CAFE standards are about 2-3 times more costly than a gasoline tax, for a given long-run reduction in fuel consumption. In Jacobsen's (2010a) study, 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 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 only permeate the vehicle fleet gradually.

Finally, 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 (without policy) which can change substantially over time. For example, rising oil prices in the future, or progress on fuel-saving technologies, could shift baseline demand towards more efficient vehicles, thereby reducing the effectiveness and costs of a given fuel economy standard.

[9] 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.

The Welfare Effects of Standards and Fuel Taxes

We now present a stylized model to assess the overall welfare effects of fuel taxes and fuel economy standards, accounting for externalities and possible "misperceptions" market failures. As we shall see, this model suggests that the efficiency basis for fuel economy standards is questionable, though we end our discussion with important caveats to this finding.

Externality Rationale for Policy Intervention

Suppose, for now, there are no misperceptions market failures. Consider Figure 3, which reproduces, based on the analysis developed by Parry et al. (2010), various marginal cost curves for reducing long-run gasoline use in the United States below a given baseline level.

The grey solid curves indicate marginal costs if there were no externalities or pre-existing fuel policies. For the fuel tax, the area under this curve corresponds to the Harberger 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 corresponding marginal cost for the fuel economy standard has a much steeper slope, given that this policy slightly increases (rather than reduces) vehicle use.

The dashed grey curves in Figure 3 take into account pre-existing fuel taxes, which are approximately 40 cents per gallon in the United States (combining state and federal taxes). 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 existing tax would already cause motorists to overinvest in fuel economy and drive too little.

The solid black curves in Figure 3 net out externality benefits. For the sake of argument, given the contentious nature of global warming damages, we assume an external damage of $20 per ton of CO_2, or 18 cents per gallon of gasoline (e.g., Aldy et al. 2010, Newbold et al. 2009, Tol 2009, IWG 2010). Accounting for this benefit shifts down the marginal cost curves in Figure 3, so they would now have intercepts of 22 cents per gallon.

Next, we net out the mileage-related externality effects. Parry et al. (2010) assume the following: 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 emissions damages are 1.0 cents per mile.[10] At current on-road fuel economy in the United States (about 22 miles per gallon), these combined externalities would be equivalent to about $2 per gallon.

However, mileage-related externalities do not fall in proportion to fuel use, because some of the tax-induced reduction comes from improved fuel economy. Assuming half the fuel reduction is from reduced driving implies an externality benefit amount of about $1 per gallon of fuel savings. Accounting for both fuel- and mileage-related externalities, the marginal cost for the fuel tax (the black curve) now has an intercept of about -80 cents per gallon. Marginal costs are negative up to a fuel reduction of about 10 percent, corresponding to the reduction implied by raising the fuel tax from its current level to its externality-correcting level (about $1.26 per gallon) at which point marginal costs intercept the horizontal axis.

Under the fuel economy standard, mileage-related externalities increase, albeit moderately, through the rebound effect implying an upward shift in the marginal cost curve—in Figure 3(b) this curve has an intercept of 43 cents per gallon. Thus, standards are welfare reducing under the above assumptions about market failures. This finding would likely apply even more strongly to countries with much higher fuel taxes, particularly western European countries, as higher pre-existing fuel taxes shift up the (solid black) marginal cost curves in Figure 3.

Misperceptions Rationale

There is, however, an additional source of welfare gain if lifetime fuel costs are not fully internalized by vehicle buyers. Parry et al. (2010) consider a bounding case for the potential magnitude of this market failure, where about two-thirds of the lifetime savings are not internalized—this corresponds to a case in which consumers take into account fuel savings over only the first three years of the life of a new vehicle.

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[10] 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.

The black dashed curves in Figure 3 show marginal costs, accounting for both externalities and this bounding case with misperceptions market failures. Under the fuel tax, the marginal cost is shifted downward even further to an intercept of approximately -\$1.80 per gallon, and the optimal fuel tax increases to \$3.25 per gallon. However, the downward shift in the marginal cost for the fuel economy standard is even greater, since all (rather than part) of a given fuel reduction under this policy comes from improved fuel economy.

However *in this model, the policy that maximizes economic efficiency does not include a fuel economy standard,* despite the large misperceptions market failure. For a given fuel reduction, tightening the standard implies that more of the reduction will come from better fuel economy and less from reductions in vehicle miles traveled. Thus, with fuel economy standards, we are trading off one source of welfare gain (addressing misperceptions failures) for another (addressing mileage-related externalities). In the neighborhood of the optimal fuel tax, the first source of welfare gain falls (just) short of the second source of welfare loss. Moreover, higher values for CO_2 (and any oil security benefit) is irrelevant to this finding, as this benefit is the same, regardless of how a given fuel reduction is achieved. That is, even with a high value for CO_2 and a large misperceptions failure, it is still preferable to raise the fuel tax in this model, without a complementary increase in fuel economy standards.

Accounting for fiscal considerations would seem to 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) swapping gasoline taxes for labor taxes (e.g., income and payroll taxes) will increase labor supply and generate additional welfare gains that are not possible under standards (West and Williams 2005, Parry 2007). Nonetheless, this presumes that the revenues from a gasoline tax are used efficiently, which is not guaranteed if revenues are instead earmarked for special interest projects rather than reducing distortionary taxes.

Further Arguments for Regulation

On further inspection however, the case for or against fuel economy regulation appears to be more nuanced.

If other policies (e.g., peak-period pricing) were introduced to address congestion and other mileage-related externalities, the marginal cost under the fuel tax would shift upward, raising the likelihood that fuel economy standards would be part of the efficient policy. In fact, if mileage-related externalities were fully internalized through other policies, it would then be optimal to address remaining market failures associated with fuel economy decisions through fuel economy policies rather than fuel taxes.

Moreover, standards may be more practical than taxes. There appears to be less opposition from motorists to standards, given that they do not transfer a large amount of revenue to the government. Fuel taxes are also thought to be regressive, albeit moderately, and prior to use of revenues (Bento et al. 2009, West 2004, West and Williams 2004). In contrast standards may actually be progressive, as their direct impact is on new vehicles which are disproportionately consumed by higher-income families, though the issue is complicated because of secondary effects on used car prices via substitution between new and used vehicles (Jacobsen 2010b).

A third potential reason for regulation may relate to the imperfectly competitive nature of vehicle markets, in which a few large manufacturers are managing sales of large fleets of vehicles. If fuel economy can be used as a means to segment consumers, price discrimination can be a motive for manufacturers to underprovide fuel economy to consumer types that value it less (e.g., large car buyers) and to overprovide it to those that value it more, in order to garner higher vehicle prices (Fischer 2005, 2010). However, while this kind of market failure can potentially motivate the use of 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.

For whatever reason, if the only practical option is standards, they can be welfare improving, with no misperceptions failure, under alternative CO_2 damage assumptions—though greenhouse gas emissions damages would have to be well above 65 cents per gallon, or $72 per ton of CO_2. Alternatively, the externality benefits from reducing oil dependence would need to be well above 22 cents per gallon. To the extent these externalities have been quantified, they appear to fall short of this threshold. For example, Brown and Huntington (2009) put the externality due to macroeconomic risks from exposure to oil price volatility at about 10 cents per gallon. More generally, there might be important national security or geo-political benefits from reducing reliance on imported oil from unstable regions, though these benefits are extremely difficult to quantify.

Alternatively, given the bounding case for the misperceptions market failure, the above model implies that to maximize economic efficiency it would be optimal to reduce long-run fuel use by 8.0 percent, given existing fuel taxes (Figure 3(b)). This would correspond, over the long run, to raising the average light-duty standard in the U.S. from about 25 mpg to about 27 mpg, well below the future standards now in law. As new fuel-saving technologies become available over time, however, baseline fuel economy would increase, thereby raising the appropriate stringency of the fuel economy standard.

Furthermore, the regulations themselves may help to create a stable environment for the development and adoption of fuel-saving technologies with high upfront costs and long-term payoffs, and the welfare gains from 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 innovators from fuel price volatility and more precisely targeting domestic and international spillovers associated with fuel-saving technologies (e.g., Barla and Stef Proost 2010). In fact, inducing innovation over the long haul may be one of the most important objectives of regulation from a policymaker's perspective.

Standards versus Feebates

There is growing interest in feebate policies that combine a fee for new vehicles with fuel economy below some specified "pivot point" with rebates for vehicles above the pivot point (e.g., Greene et al. 2005, Fischer 2008). Policymakers have been discussing feebates as an alternative to CAFE in the United States since the early 1990s, and feebates have already been implemented (in a modest form) in Ontario in 1991, and more recently in federal Canada and France. Like fuel economy regulations, feebates need not impose a politically unpopular tax burden on motorists. 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.

Under feebates, the tax or subsidy payment should be proportional to fuel consumption per mile (rather than fuel economy, in miles per gallon) to provide a constant incentive rate for each gallon of fuel saved, regardless of whether those improvements are in small or large vehicles. 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, so if the payment schedule were instead based on mpg it would give a disproportionately small subsidy to fuel savings in low-mpg vehicles (where the potential for fuel economy improvements is greatest).[11]

Here we compare the cost effectiveness of various fuel economy policies and discuss to what extent they are compatible with other policy instruments.

Cost Effectiveness

Within a given year, achieving an average fuel economy target for new vehicles at lowest industry-wide cost requires equating marginal compliance costs across automakers. Consider Figure 4 which 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, resulting in different marginal compliance costs. In terms of Figure 4, this would result in an efficiency loss 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 targets would fall by a significant (though not dramatic) 15 percent with this equalization of marginal compliance costs across firms. However, the least-cost outcome could also be achieved under the regulatory approach by allowing limitless trading of credits among firms. In fact, in the United States and elsewhere, inter-firm trading provisions are being extended, undermining one of the key arguments in favor

[11] 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 cut-off points in the tax system, resulting in some loss of efficiency compared with a single pivot point system.

of feebates. Nonetheless, with a relatively small number of firms, the trading market could be thin with the risk that limited arbitrage will not be sufficient to equalize marginal compliance costs.[12]

Another way to improve cost-effectiveness 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 that are potentially correlated with compliance costs. Still, 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 cuts off a potentially important option for improving fleet fuel economy.[13] 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. 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.

Again, fuel economy programs in their traditional form 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 the extent to which this lack of flexibility over time 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 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 that technological innovation brings down costs of complying with a fixed fuel

[12] 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, playing the same role as the fee and rebate. In the regulatory approach, the industry-wide standard plays the same role as the pivot point fuel economy in the feebate system.

[13] The potential importance of downsizing as a means of improving fuel economy is clear from a comparison of the United States and Europe, which enjoys a much higher fleet average due in large part to the prominence of smaller vehicles.

economy target, so marginal costs will not be equated over time unless the standard continually increases at an appropriate rate.

Feebate programs can easily accommodate 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.

Finally, while fuel economy standards naturally fall in the domain of the automakers, feebates could be applied either to automakers, dealers, or consumers. With efficient markets, the point of compliance should not matter, as the incentive should be passed along in the price of the vehicle regardless. Evidence in Busse et al. (2006) however, suggests that statutory incidence may matter: because of information asymmetries, the behavioral response to price incentives (such as feebates) may be stronger if they are levied at the consumer rather than producer level, with potential implications for cost effectiveness. This issue deserves further study.

Compatibility with Other Policy Instruments

While the gains from transitioning to feebates may not be that large on purely cost-effectiveness grounds, given recent reforms to fuel economy programs, an important drawback of standards is that they can undermine the performance of other, increasingly common, policy interventions in the transportation sector.

For example, the U.S. 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 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 therefore 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 other regions (Goulder et al. 2009). In fact, this concern recently motivated the federal government in the United States to set standards equivalent to more aggressive standards already being phased in under California law.

In contrast, 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 pre-existing 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.

Conclusion

The future effectiveness of fuel economy programs 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 the standards remains contentious, due in particular to uncertainty about how consumers value fuel-saving benefits. At first glance, fuel economy regulations seem difficult to justify on welfare grounds, given that fuel taxes—even in the U.S.—exceed most estimates for per-gallon climate damages. In contrast, 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 that are relatively large in magnitude. Even if there is a large market failure associated with consumers misperceiving 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, by revealed preference, standards seem to be more practicable than high fuel taxes for countries such as the U.S. Regulations 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. Whether fuel economy regulations are better or better or worse than other instruments (e.g., technology prizes, fuel taxes, and fuel price floors) along this dimension, however, is not well understood.

While the appropriate role of fuel economy regulations remains unsettled in the economics literature, recent structural reforms to 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 the standards. Their relative lack of compatibility with other interventions in the vehicle market and at different levels of government remain a concern, however, which is one reason that feebate systems deserve further consideration and research.

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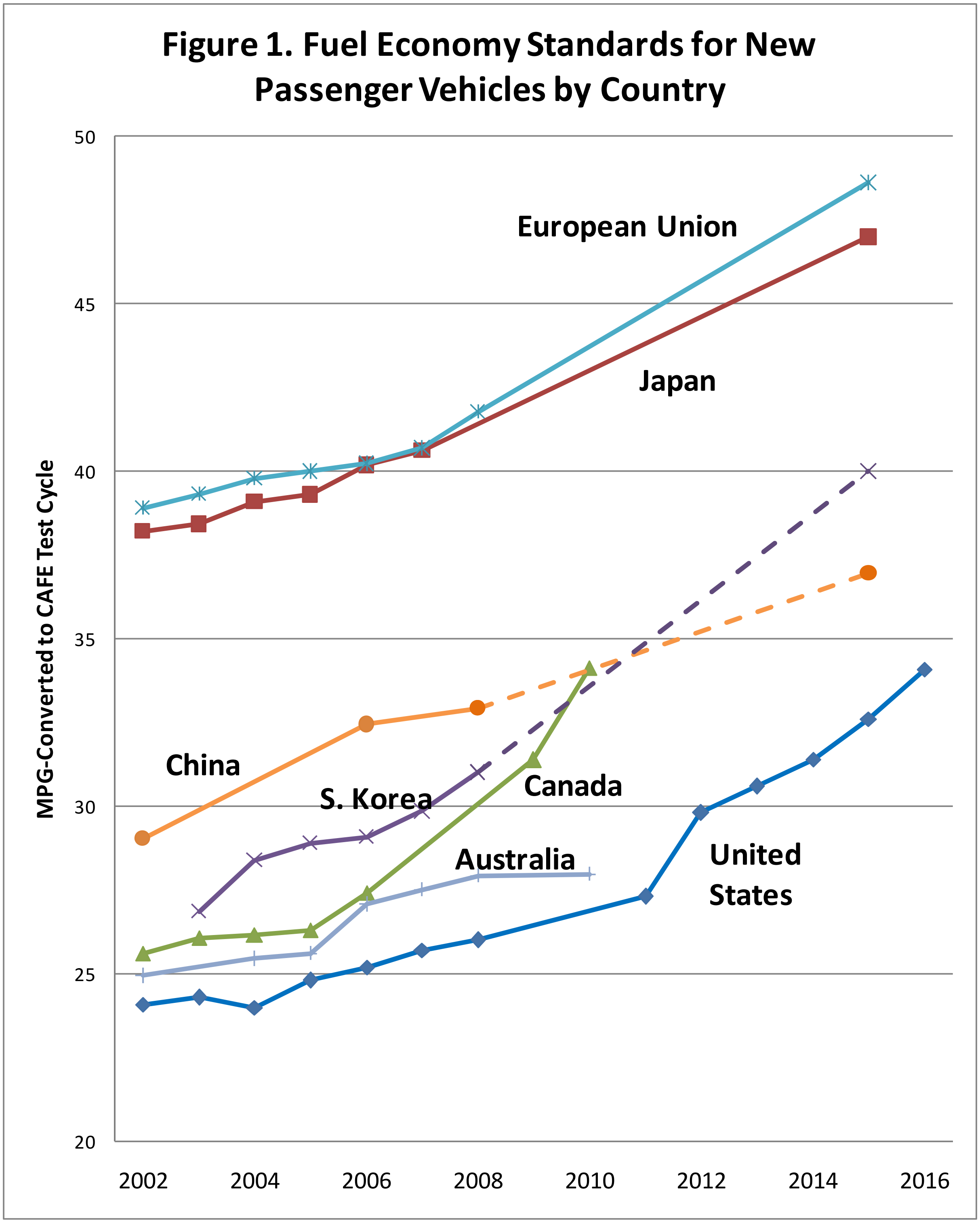
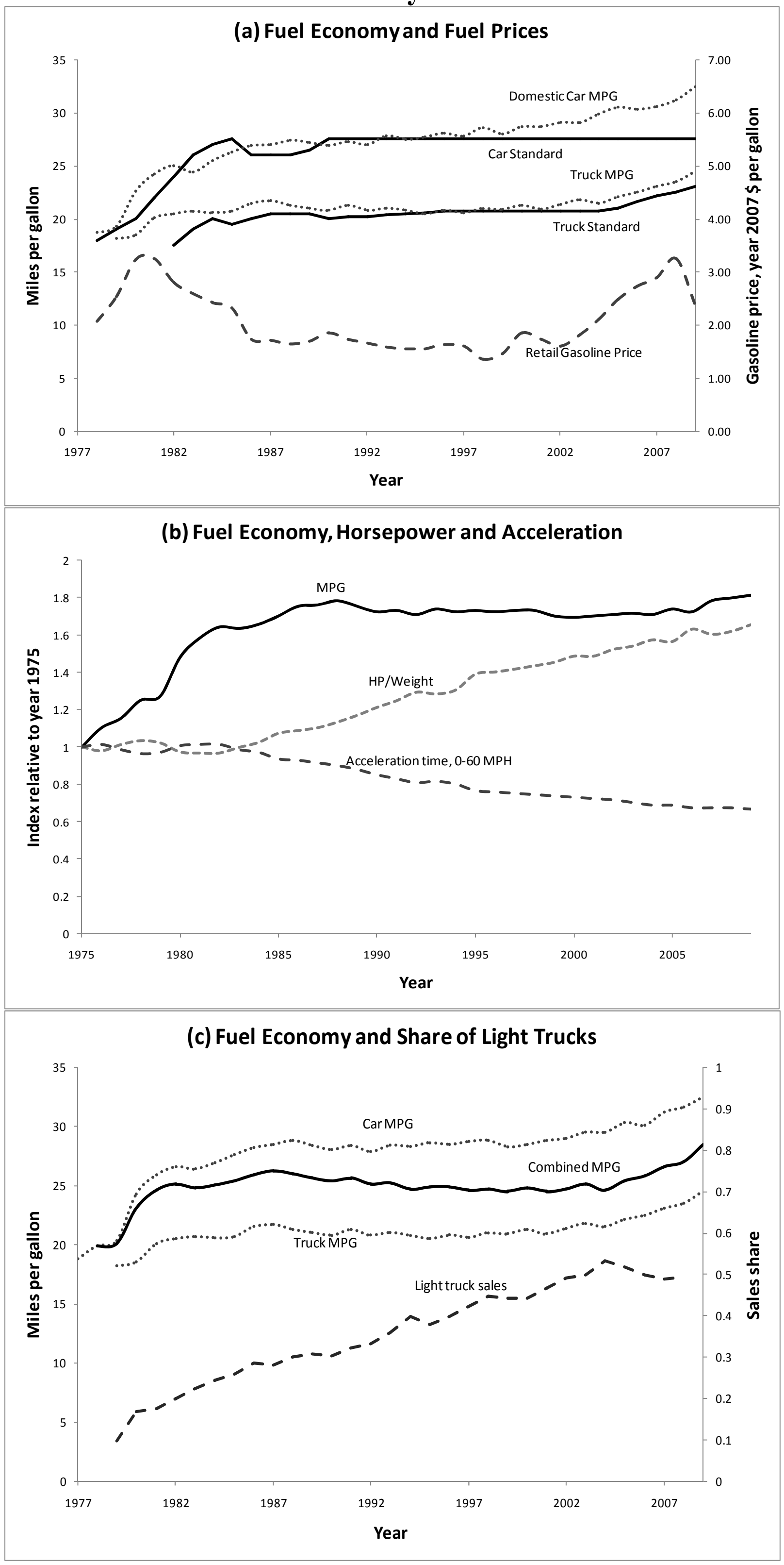


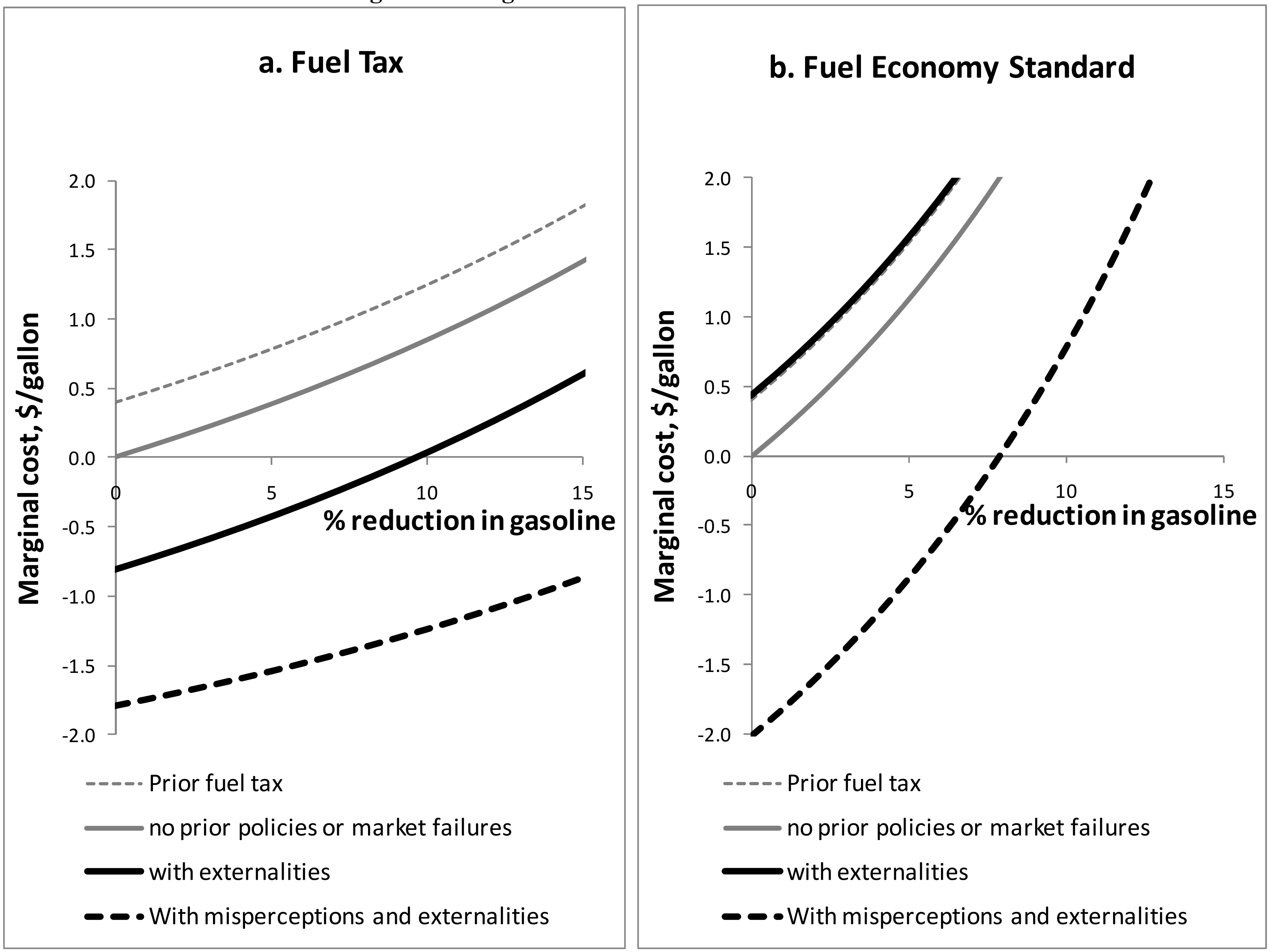
Source: ICCT (2009).
Notes. Dashed lines indicate proposed fuel economy targets not yet enacted. For Canada, the program includes in-use vehicles.

Figure 2. Trends in U.S. Fuel Economy and other Vehicle Characteristics



Sources. EPA (2009), NHTSA (2009).

Figure 3. Marginal Cost of Fuel Tax and Standards



Source. Parry et al. (2010).

Figure 4. Potential Static Cost Savings from Feebates or Credit Trading